

Realtime and Embedded Specification for Java

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The Realtime Specification for Java (RTSJ) is under development within the Java Community Process (JCP) by the members of the JSR-282 Expert Group (EG). This group, was lead by TimeSys Inc. Corporation, but has been taken over by aicas GmbH.

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Chapter 1

Introduction

The goal of the *Real-Time Specification for Java* (RTSJ) is to support the use of Java technology in embedded and realtime systems. It provides a specification for refining the *Java Language Specification* and the *Java Virtual Machine Specification* and of providing an extended Application Programming Interface that facilitates the creation, verification, analysis, execution, and management of realtime Java programs such as control and sensor applications.

The Java Virtual Machine and the Java Language were conceived as a portable environment for desktop and server applications. The emphasis has been on throughput and responsiveness. These are characteristics obtainable with time-sharing systems. For this conventional Java environment, it is more important that each task makes progress, than that a particular task completes within a predefined time slot.

In a realtime system, the system tries to schedule the most critical task that is ready to run first. This task runs either until it is finished, or it needs to wait for some event or data, or a more critical task is released or a more critical task becomes schedulable after waiting for its event or data.

Realtime scheduling is commonly done with a priority preemptive scheduler, where tasks that have short deadlines are given higher priority than tasks that have longer deadlines. The programmer is responsible for encoding some notion of task importance to priorities. The goal is to see that all tasks finish within their deadlines. Scheduling analysis, such as Rate Monotonic Analysis, can be used to help determine this.

Many realtime systems have nonrealtime components, so it is desirable to be able to combine realtime and nonrealtime tasks in a single system. Realtime tasks are then given preference over nonrealtime tasks. For Java, this means that realtime tasks must be scheduled before threads with conventional Java priorities (1–10). Being able to synchronize between tasks, both realtime and conventional Java threads, adds additional requirements.

Providing realtime semantics and the additional programming interfaces required

is a core part of this specification. So much so that the original specification provided special memory areas to avoid the use of garbage collection. The availability of various techniques for realtime garbage collection has changed the state of practice since RTSJ Version 1.0. Though still part of the specification, these special memory areas are no longer central to it. Realtime scheduling and priority inversion avoidance for synchronization are the core of providing realtime response. These are provided through refinements to the base Java semantics and additional classes.

Realtime tasks can be modeled both with realtime threads and with event handlers. Realtime threads are much the same as conventional Java threads except for how they are scheduled. Event handlers encapsulate a bit of work that is done every time some event occurs. Events are referred to as asynchronous because they generally occur independent of program flow. Thus, a periodic timed event is considered to be an asynchronous event, but scheduled periodically. Event handling provides a less resource intensive means of writing control applications because the underlying thread mechanism can be shared between event handlers. Deadline analysis is also somewhat simpler because the end of the work to be done is well bounded. Event handling is ideal for periodic tasks and responding to external impulses. The specification provides both paradigms.

Though realtime is necessary for many control tasks, it is not sufficient. A significant part of the RTSJ API addresses communication with the outside world through devices and signals. This makes it possible to write control applications without resorting to JNI, thereby maintaining the integrity and safety that Java offers.

Since not all applications need all aspects of the specification, there are now modules to suite the major application scenarios. This should make it easier for conventional JVM providers to include basic specification facilities without negatively impacting their core application domains, but still be compatible with hard realtime implementations. The goal is to make the transition between conventional JVMs and realtime JVMs easier.

1.1 Guiding Principles

Providing a coherent semantics and set of programming interfaces requires some guiding principles around which to organize the RTSJ. These principles delimit the scope of the RTSJ and its compatibility requirements with conventional Java.

1.1.1 Applicability to Particular Java Environments

The RTSJ shall not include specifications that restrict its use to a particular Java environment, such as a particular versions of the Java Development Kit, an Embedded

Java Application Environment, or a Java Edition, beyond the natural development of the Java language.

1.1.2 Backward Compatibility

The RTSJ shall not prevent existing, properly written, conventional Java programs from executing on implementations of the RTSJ.

1.1.3 Write Once, Run Anywhere

The RTSJ should recognize the importance of “Write Once, Run Anywhere”, but it should also recognize the difficulty of achieving WORA for realtime programs and not attempt to increase or maintain binary portability at the expense of predictability. Hence, the goal should be “Write Once Carefully, Run Anywhere Conditionally”.

1.1.4 Current Practice vs. Advanced Features

The RTSJ should address current realtime system practice as well as allow future implementations to include advanced features.

1.1.5 Predictable Execution

The RTSJ shall hold predictable execution as first priority in all trade-offs; this may sometimes be at the expense of typical general-purpose computing performance measures.

1.1.6 No Syntactic Extension

In order to facilitate the job of tool developers, and thus to increase the likelihood of timely implementations, the RTSJ shall not introduce new keywords or make other syntactic extensions to the Java language.

1.1.7 Allow Variation in Implementation Decisions

Implementations of the RTSJ may vary in a number of implementation decisions, such as the use of efficient or inefficient algorithms, trade-offs between time and space efficiency, inclusion of scheduling algorithms not required in the minimum implementation, and variation in code path length for the execution of byte codes. The RTSJ should not mandate algorithms or specific time constants for such, but require that the semantics of the implementation be met and where necessary put

limits on execution time complexity. The RTSJ offers implementers the flexibility to create implementations suited to meet the requirements of their customers.

1.1.8 Interoperability

It should be possible to implement all aspects of the RTSJ on a conventional JVM with the exception that realtime response and pointer assignment rules would not necessarily be guaranteed. This should ease the transition between conventional and realtime programming and aid functional testing on a conventional JVM. The API should support modules for this as well.

1.2 Areas of Enhancement

Each guiding principle has had a direct effect on the development of the specification. There are eight aspects of these refinements and additions in the specification. Their enumeration should aid the understanding of the rest of the specification.

1.2.1 Thread Scheduling and Dispatching

Portability dictates the specification of at least one standard realtime scheduler, but in light of the significant diversity in scheduling and dispatching models and the recognition that each model has wide applicability in the diverse realtime systems industry, the specification provides an underlying scheduling infrastructure that can be extended to use other scheduling algorithms for scheduling realtime Java threads and event handlers.

To accommodate current practice, the RTSJ shall require a base scheduler in all implementations. The required base scheduler will be familiar to realtime system programmers. It is a priority preemptive, first-in-first-out, scheduler. Since most realtime systems also support round-robin scheduling, a round-robin scheduler shall also be supplied. For compatibility with conventional Java implementations, both schedulers shall use priorities above the conventional Java priorities (1–10).

The specification is constructed to allow implementations to provide unanticipated scheduling algorithms. Implementations will enable the programmatic assignment of parameters appropriate for the underlying scheduling mechanism as well as provide any necessary methods for the creation, management and termination of realtime Java threads. In the current specification, any other thread, scheduling, and dispatching mechanism may be bound to an implementation; however, there should be enough flexibility in the thread scheduling framework to enable future versions of the specification to build on this release.

1.2.2 Memory Management

Automatic memory management is a particularly important feature of the Java programming environment. The specification enables, as far as possible, the job of memory management to be implemented automatically by the underlying system and not intrude on the programming task. Many automatic memory management algorithms, also known as garbage collection (GC), exist, and many of those apply to certain classes of realtime programming styles and systems. In an attempt to accommodate a diverse set of GC algorithms, the specification defines a memory allocation and reclamation paradigm that

- is independent of any particular GC algorithm,
- requires the VM to precisely characterize its GC algorithm's effect on the preemption of realtime Java tasks, and
- enables the allocation and reclamation of objects outside of any interference by any GC algorithm.

1.2.3 Synchronization and Resource Sharing

Logic often requires serial access to resources, and realtime systems introduce an additional complexity: the need to minimize priority inversion and hence the excessive delay of more critical tasks. The least intrusive specification for enabling realtime safe synchronization is to require that implementations of the Java keyword `synchronized` implement one or more algorithms that prevent priority inversion among realtime Java tasks that share the serialized resource. In addition, the specification provides other data passing mechanisms to minimize the need for synchronization.

1.2.4 Asynchronous Event Handling

Realtime systems typically interact closely with the real world. With respect to the execution of logic, the real world is asynchronous; therefore, the specification includes efficient mechanisms for programming disciplines that would accommodate this inherent asynchrony. The RTSJ has a general mechanism for asynchronous event handling. This specification provides classes that represent things that can happen and logic that executes when those things happen. The execution of the logic is scheduled and dispatched by the RTSJ runtime.

1.2.5 Task Interruption

Sometimes, the real world changes so drastically (and asynchronously) that the current point of logic execution should be immediately, efficiently, and safely ended and control transferred to another point of execution. The RTSJ provides a mechanism which

extends Java's interrupt and exception handling mechanisms to enable applications to programmatically change the locus of control of another Java task. This mechanism may restrict this asynchronous transfer of control to logic specifically written with the assumption that its locus of control may asynchronously change. Due to the inherent susceptibility to deadlock, the `Thread.stop` method cannot be used for this.

1.2.6 Raw Memory Access

Accessing device memory is not in and of itself a realtime issue; however, many realtime systems require it for providing realtime control of a system. This requires an API providing programmers with byte-level access to physical device registers, whether in main memory or in some I/O space. This API must be as efficient as possible, since such access is often under tight time constraints.

1.2.7 Physical Memory Access

Some systems provide memory areas that differ in important aspects, such as time to read or write data and its persistence. Being able to take advantage of these areas can have an impact on performance. This specification enables their efficient use.

1.2.8 Modularization

Not all applications require all aspects of the specification. In fact, having a core set of the APIs presented is useful for conventional Java programming and aids overall interoperability. To this end, the specification provides a core set of APIs and a few optional modules as well as semantics for use in conventional JVMs that do not offer realtime guarantees. This should enable implementations to be optimized for particular use cases and enable conventional Java environments to be used to help develop code that can be more easily shared between realtime and conventional systems.

Chapter 2

Overview

The RTSJ comprises several areas of extended semantics. These areas are discussed in approximate order of their relevance to realtime programming. The semantics and mechanisms of each of threads and scheduling, synchronization, asynchrony, clocks and timers, memory management, device access and raw memory, system options, and exceptions are all crucial to the acceptance of the RTSJ as a viable realtime development platform. Further details, exact requirements, class documentation, and rationale for these extensions are given in subsequent chapters.

2.1 Threads and Scheduling

One of the concerns of realtime programming is to ensure the timely and predictable execution of sequences of machine instructions. Various scheduling schemes name these sequences of instructions differently, for example, thread, task, module, or block. In Java, this computation is executed in the context of a thread. Since Java threads were designed for fair execution¹ rather than predictable execution, the RTSJ introduces the concept of a *schedulable*. These are the objects managed by the base scheduler: `RealtimeThread` and its subclasses and `AsyncBaseEventHandler` and its subclasses. `RealtimeThread` is a specialization of Java's `Thread`.

Timely execution of schedulables means that the programmer can determine, by analysis of the program, testing the program on particular implementations, or both, whether particular threads will always complete execution before a given timeliness constraint. This is the essence of realtime programming: the addition of temporal constraints to the correctness conditions for computation. For example, for a program to compute the sum of two numbers, it may no longer be acceptable to

¹Actually, neither the Java Virtual Machine Specification[6] nor the Java Language Specification[5] defines how Java threads should be scheduled, but most implementations, including the reference implementations, use some sort of fair scheduling.

compute only the correct arithmetic answer but the answer must be computed within a particular time interval. Typically, temporal constraints are deadlines expressed in either relative or absolute time.

The term *scheduling* (or *scheduling algorithm*) refers to the production of a sequence (or ordering) for the execution of a set of schedulables (a *schedule*). This schedule attempts to optimize a particular metric (a metric that measures how well the system is meeting the temporal constraints). A *feasibility analysis* determines if a schedule has an acceptable value for the metric. For example in hard realtime systems, the typical metric is “number of missed deadlines” and the only acceptable value for that metric is zero. So called soft realtime systems use other metrics (such as mean tardiness) and may accept various values for the metric in use.

Many systems, including most conventional Java implementations, use thread priority to guide the determination of a schedule. Priority is typically an integer associated with a thread; these integers convey to the system the order in which the threads should execute. The generalization of the concept of priority is *execution eligibility*. The term *dispatching* refers to that portion of the system which selects the thread with the highest execution eligibility from the pool of threads that are ready to run.

In current realtime system practice, the assignment of priorities is typically under programmer control as opposed to under system control. As a base scheduler for realtime tasks, the RTSJ provides preemptive priority-based first-in-first-out (FIFO) scheduler, which also leaves the assignment of priorities to programmer control. It also provides a priority-based round-robin (RR) scheduler. Most realtime operating systems (RTOS) are also based on priority preemptive scheduling and support both FIFO and RR scheduling.

The RTSJ defines a number of classes with names of the format `<string>Parameters` such as `ReleaseParameters`, which provide parameters for resource management. An instance of one of these parameter classes holds a particular resource-demand characteristic for one or more schedulables. For example, the `PriorityParameters` subclass of `SchedulingParameters` contains the execution eligibility metric of the base scheduler, i.e., a priority. At some time (construction-time or later when the parameters are replaced using setter methods), instances of parameter classes are bound to a schedulable. The schedulable then assumes the characteristics of the values in the parameter object. For example, a `PriorityParameters` instance with its priority set to the value representing the highest priority available on a system is bound to a schedulable, then that schedulable will assume the characteristic that it will execute whenever it is ready in preference to all other schedulables (except, of course, those also with the same priority).

The RTSJ provides implementers with the flexibility to install arbitrary scheduling algorithms in an implementation of the specification. This is to support the widely

varying requirements of the realtime systems industry with respect to scheduling. Use of the Java platform may help produce code written once but able to be executed on many different computing platforms. The RTSJ contributes to this goal, but the rigors of realtime systems detract from it. The RTSJ's rigorous specification of the required priority scheduler is critical for portability of time-critical code, but the RTSJ permits and supports platform-specific schedulers which are not necessarily portable.

2.2 Synchronization

If the computation in each thread were independent of the computation in all other threads, scheduling alone would be enough to ensure timeliness; however, this is usually not the case. Threads often need to communicate with one another or share data. Resources must be shared as well. Two threads cannot read different data from the disk at the same time nor write data to a disk at the same time. They cannot send a message to another machine at the same time. They cannot update the same in-memory data at the same time. One thread may have to wait for another thread to get the data it needs. Just as in a normal system, synchronization is required. In a realtime system, this synchronization must not prevent other threads from completing their tasks on time.

2.2.1 Priority Inversion

The additional concern for synchronization in a realtime system, as opposed to a conventional system, is that blocking can cause the wrong thread to run first. A high priority thread can be blocked by a low priority thread that is vying for the same resource. A priority queue can be used to ensure that a highest priority thread goes first, when more than one thread is waiting to enter a synchronized block, but this is not always sufficient.

Consider a single processor system with three threads, t_1 , t_2 , and t_3 , where t_1 has the highest priority and t_3 has the lowest priority. It is possible that t_2 can prevent t_1 from running by preempting t_3 . This is called priority inversion. It occurs when t_1 is blocked by attempting to acquire a lock that is held by thread t_3 and t_3 is preempted by t_2 . When t_2 does run, it may prevent t_3 from running indefinitely, thereby keeping t_1 blocked past its deadline.

What is needed is a mechanism to ensure that, while t_1 is waiting on a resource in use by t_3 , thread t_3 runs before all threads with a priority less than that of t_1 .

2.2.2 Priority Inversion Avoidance

Two of the most common mechanisms for avoiding priority inversion are priority inheritance and priority ceiling emulation (a.k.a. highest locker protocol). Both of these boost the priority of a thread holding the lock in order to prevent a noncontending thread from transitively blocking a higher priority thread which is waiting for the same lock. The difference is how high the priority is raised and when. Both take effect when a thread is in a **synchronized** section of code.

The first is the default behavior for **synchronized** blocks and methods. It applies to all code running within the implementation, not just to **schedulables**. The priority inheritance protocol is a well-known algorithm in the realtime scheduling literature and it has the following effect. If thread t_1 attempts to acquire a lock that is held by a lower-priority thread t_3 , then t_3 's priority is raised to that of t_1 as long as t_3 holds the lock (and recursively if t_3 is itself waiting to acquire a lock held by an even lower-priority thread).

The specification also provides a mechanism by which the programmer can override the default system-wide policy, or control the policy to be used for a particular monitor, provided that policy is supported by the implementation. The second policy, priority ceiling emulation protocol, can be set using this mechanism. It is also a well-known algorithm in the literature. The following three points provide a somewhat simplified description of its effect.

1. A monitor is given a “priority ceiling” when it is created; the programmer should choose at least the highest priority of any thread that could attempt to enter the monitor.
2. As soon as a thread enters synchronized code, its (active) priority is raised to the monitor's ceiling priority. If, through programming error, a thread has a higher base priority than the ceiling of the monitor it is attempting to enter, then an exception is thrown.
3. On leaving the monitor, the thread has its active priority reset. In simple cases it will set be to the thread's previous active priority, but under some circumstances (e.g. a dynamic change to the thread's base priority while it was in the monitor) a different value is possible.

In addition, threads and asynchronous event handlers waiting to acquire a resource must be released from highest to lowest priority (in priority order). This applies to processors as well as to synchronized blocks. If schedulables with the same priority are possible under the active scheduling policy, such schedulables are awakened in FIFO order. This is exemplified in the following scenarios.

1. Threads waiting to enter synchronized blocks are granted access to the synchronized block in priority order.
2. A blocked thread that becomes ready to run is given access to a processor in priority order.

3. A thread whose priority is explicitly set by itself or another thread is given access to a processor in priority order.
4. A thread that performs a yield will be given access to the processor after waiting for threads of the same priority to be given a processor.
5. Threads that are preempted in favor of a thread with higher priority may be given access to a processor at any time as determined by a particular implementation. The implementation is required to provide documentation stating exactly the algorithm used for granting such access.

In any case, there needs to be a fixed upper bound on the time required to enter a synchronized block for an unlocked monitor.

2.2.3 Execution Eligibility

Since an implementation of the RTSJ may provide schedulers other than priority-based schedulers, the notion of priority can be generalized to execution eligibility. Execution eligibility defines a partial ordering over all tasks for determining which task should run before which other tasks. Execution eligibility may be determined dynamically. For example, earliest deadline first (EDF) scheduling determines execution eligibility ordering by the order of the next deadlines for each of its tasks. The notion of priority, as described above, can be generalized to execution eligibility to integrate other schedulers into an RTSJ implementation.

2.2.4 Wait-Free Queues

While the RTSJ requires that the execution of schedulables which do not access the heap must not be delayed by garbage collection on behalf of lower-priority schedulables, an application can cause such a schedulable to wait for garbage collection by synchronizing using an object shared with a heap-using thread or schedulable. The RTSJ provides wait-free queue classes to provide protected, non-blocking, shared access to objects accessed by both regular Java threads and schedulables, which do not access the heap.

2.3 Asynchrony

Since a realtime system must be able to react to the outside world, the system needs to be able to change its execution flow asynchronously to the current execution. All external signals, whether interrupts, messages, or timed events, are asynchronous with respect to ongoing computation. This means that computation must be both startable and stoppable based on external stimuli.

2.3.1 Asynchronous Events

Asynchronous events provide a means of starting computation based on external stimuli. The asynchronous event facility is based on two classes: `AsyncBaseEvent` and `AsyncBaseEventHandler`. An `AsyncBaseEvent` object represents something that can happen, like a POSIX signal, a hardware interrupt, or a computed event like an airplane entering a specified region. When one of these events occurs, which is indicated by the `fire()` method being called, the associated instances of `AsyncBaseEventHandler` are scheduled and the `handleAsyncEvent()` methods are invoked, thus the required logic is performed. Also, methods on `AsyncBaseEvent` are provided to manage the set of instances of `AsyncBaseEventHandler` associated with the instance of `AsyncBaseEvent`.

An instance of an `AsyncBaseEventHandler` can be thought of as something similar to a thread. When an event fires, the associated handlers are scheduled and the `handleAsyncEvent()` methods are invoked. What distinguishes an `AsyncBaseEventHandler` from a simple `Runnable` is that an `AsyncBaseEventHandler` has associated instances of `ReleaseParameters`, `SchedulingParameters` and `MemoryParameters` that control the actual execution of the handler once the associated `AsyncBaseEvent` is fired. When an event is fired, the handlers are executed asynchronously, scheduled according to the associated `ReleaseParameters` and `SchedulingParameters` objects, in a manner that looks like the handler has just been assigned to its own thread. It is intended that the system can cope well with situations where there are large numbers of instances of `AsyncBaseEvent` and `AsyncBaseEventHandler` (tens of thousands), since the number of fired (in progress) handlers is expected to be much smaller.

There are specialized forms of `AsyncBaseEvent`: `AsyncEvent`, `AsyncLongEvent`, and `AsyncObjectEvent` for events that are stateless, carry a long payload, and carry an `Object` payload, respectively. They are matched by specialized forms of `AsyncBaseEventHandler`: `AsyncEventHandler`, `AsyncLongEventHandler`, and `AsyncObjectEventHandler`. Most external events are stateless, but sometimes it is helpful to be able to receive some information about the event or pass some data with the event. The `Long` and `Object` variants enable this and the `POSIXRealtimeSignal` takes advantage of it.

Another specialized form of an `AsyncEvent` is the `Timer` class, which represents an event whose occurrence is driven by time. There are two forms of Timers: the `OneShotTimer` and the `PeriodicTimer`. Instances of `OneShotTimer` fire once, at the specified time. Periodic timers fire initially at the specified time, and then periodically according to a specified interval.

Timers are driven by `Clock` objects. There is a special `Clock` object, `Clock.getRealtimeClock()`, that represents the realtime clock. The `Clock` class may be extended to represent other clocks, which the underlying system might make available

(such as an execution-time clock of some granularity).

2.3.2 Asynchronous Transfer of Control

Many event-driven computer systems that tightly interact with external physical systems (e.g., humans, machines, control processes, etc.) may require mode changes in their computational behavior as a result of significant changes in the non-computer real-world system. It simplifies the architecture of a system when a task can be programmatically terminated when an external physical system change causes its computation to be superfluous. Without this facility, a thread or set of threads have to be coded so that their computational behavior anticipates all of the possible transitions among possible states of the external system. When the external system makes a state transition, the changes in computation behavior can be managed by an oracle that terminates a set of threads required for the old state of the external system, and invokes a new set of threads appropriate for the new state of the external system. Since the possible state transitions of the external system are encoded in only the oracle and not in each thread, the overall system design is simpler.

There is a second requirement for a mechanism to terminate some computation, where a potentially unbounded computation needs to be done in a bounded period of time. In this case, if that computation can be executed with an algorithm that is iterative, and produces successively refined results, the system could abandon the computation early and still have usable results. The RTSJ supports aborting a computation by signalling from another thread, or the passage of time, with a feature termed Asynchronous Transfer of Control (ATC).

An example of the second case is processing compressed video for a human controller. The system knows that a new frame must be produced at a constant update frequency. The cost of each iteration is highly variable and the minimum required latency to terminate the computation and receive the last consistent result is much less than the mean iteration cost and bound. Therefore, using ATC for interrupting a computation to capture an intermediate result at the expiration of a known time bound is a convenient programming style. Of course, there are other kinds of programming tasks that may also benefit from ATC.

2.3.3 Principles

The RTSJ's approach to ATC uses asynchronous interruptions and exceptions, and is based on several guiding principles covering methodology, expressiveness, semantics, and pragmatic concerns.

2.3.3.1 Methodological Principles

1. A method must explicitly indicate its susceptibility to ATC, i.e., it is asynchronously interruptible. Since legacy code or library methods might have been written assuming no ATC, by default ATC must be turned off (more precisely, must be deferred as long as control is in such code).
2. Even if a method allows ATC, some code sections must be executed to completion and thus ATC is deferred in such sections. These ATC-deferred sections are synchronized methods, static initializers, and synchronized statements.
3. Code that responds to an ATC does not return to the point in the schedulable where the ATC was triggered; that is, an ATC is an unconditional transfer of control. Resumptive semantics, which returns control from the handler to the point of interruption, are not needed since they can be achieved through other mechanisms (in particular, an `AsyncEventHandler`).

2.3.3.2 Expressibility Principles

1. A mechanism is needed through which an ATC can be explicitly triggered in a target schedulable. This triggering may be direct (from a source thread or schedulable) or indirect (through an asynchronously interrupted exception).
2. It must be possible to trigger an ATC based on any asynchronous event including an external happening or an explicit event firing from another thread or schedulable. In particular, it must be possible to base an ATC on a timer going off.
3. Through ATC it must be possible to abort a realtime thread but in a manner that does not carry the dangers of the `Thread` class's `stop()` and `destroy()` methods.

2.3.3.3 Semantic Principles

1. If ATC is modeled by exception handling, there must be some way to ensure that an asynchronous exception is only caught by the intended handler and not, for example, by an all-purpose handler that happens to be on the propagation path.
2. Nested ATCs must work properly. For example, consider two, nested ATC-based timers and assume that the outer timer has a shorter time-out than the nested, inner timer. If the outer timer times out while control is in the nested code of the inner timer, then the nested code must be aborted (as soon as it is outside an ATC-deferred section), and control must then transfer to the appropriate `catch` clause for the outer timer. An implementation that either handles the outer time-out in the nested code, or that waits for the longer (nested) timer, is incorrect.

2.3.3.4 Pragmatic Principles

1. There should be straightforward idioms for common cases such as timer handlers and realtime thread termination.
2. If code with a time-out completes before the timer's expiration, the timer needs to be automatically stopped and its resources returned to the system.

2.3.4 Asynchronous Realtime Thread Termination

A special case of stopping a particular computation is stopping a thread. Earlier versions of the Java language supplied mechanisms for achieving these effects: in particular the methods `stop()` and `destroy()` in class `Thread`. However, since `stop()` could leave shared objects in an inconsistent state, `stop()` has been deprecated. The use of `destroy()` can lead to deadlock (if a thread is destroyed while it is holding a lock) and although it was not deprecated until version 1.5 of the Java specification, its usage has long been discouraged. A goal of the RTSJ was to meet the requirements of asynchronous thread termination without introducing the dangers of the `stop()` or `destroy()` methods.

The RTSJ accommodates safe asynchronous realtime thread termination through a combination of the asynchronous event handling and the asynchronous transfer of control mechanisms. To create such a set of realtime threads consider the following steps:

1. make all of the application methods of the realtime thread asynchronously interruptible;
2. create an oracle which monitors the external world by setting up an asynchronous event with a number of asynchronous event handlers, which is fired when an appropriate mode change;
3. have the handlers call `interrupt()` on each of the realtime threads affected by the change; then
4. after the handlers call `interrupt()`, have them create a new set of realtime threads appropriate to the current state of the external world.

The effect of the event is to cause each interruptible method to abort abnormally by transferring control to the appropriate catch clause. Ultimately the `run()` method of the realtime thread will complete normally.

This idiom provides a quick (if coded to be so) but orderly clean up and termination of the realtime thread. Note that the oracle can comprise as many or as few asynchronous event handlers as appropriate.

2.4 Clocks, Time, and Timers

Realtime systems require a high resolution notion of time. Both very small units and very long periods of time must be uniformly representable, a range that is not even representable with a `long` value. Furthermore, a time can represent an absolute value, usually represented as some absolute fixed point in time plus an offset, or it can represent an interval of time. The time classes defined in Chapter 9 support a `long` worth of seconds and another integer for nanoseconds.

2.5 Memory Management

The Java language is designed around automatic memory management, in particular garbage collection. Unfortunately, though garbage collection is a functional safety and security feature, conventional garbage collectors interrupt the normal flow of control in a program. Therefore, garbage-collected memory heaps had been considered an obstacle to realtime programming due to the potential for unpredictable latencies introduced by the garbage collector. Though convention collectors still have these drawbacks, there are now realtime collectors that can be used for hard realtime application. Still, the RTSJ provides an alternative to garbage collection for systems which require it, either because they do not have a garbage collector or deterministic garbage collector, or require heap partitioning for some other reason. Extensions to the memory model, which support memory management in a manner that does not interfere with the ability of realtime code to provide deterministic behavior, are provided to support these alternatives. This goal is accomplished by providing memory areas for the allocation of objects outside of the garbage-collected heap for both short-lived and long-lived objects. In order to provide additional separation between the garbage collector and schedulables which do not require its services, a schedulable can be marked to indicate that it never accesses the heap.

2.5.1 Memory Areas

The RTSJ introduces the concept of a memory area. A memory area represents an area of memory that may be used for allocating objects. Some memory areas exist outside of the heap and place restrictions on what the system and garbage collector may do with objects allocated within. Objects in some memory areas are never garbage collected; however, the garbage collector must be capable of scanning these memory areas for references to any object within the heap to preserve the integrity of the heap.

There are four basic types of memory areas:

1. Heap memory represents an area of memory that is the heap. The RTSJ does not change the determinant of lifetime of objects on the heap. The lifetime is still determined by visibility.
2. Immortal memory represents an area of memory containing objects that may be referenced without exception or garbage collection delay by any schedulable, specifically including realtime threads and asynchronous event handlers configured to not have access to the heap.
3. Scoped memory provides a mechanism for managing objects that have a lifetime defined by their scope. It is akin to, but more general than, allocating objects on the thread stack.
4. Physical memory allows objects to be created within specific physical memory regions that have particular important characteristics, such as memory that has substantially faster access.

2.5.2 Heap Memory

Heap memory is the memory area used by Java by default. It is garbage collected and the access time to objects in this area are not guaranteed unless the implementation supports realtime garbage collection. The RTSJ, as with conventional Java, supports only one Heap in a system. Multiple heaps are only practical in one of two configurations: the heaps are completely independent of one another or there are subsidiary heaps from which a program may not store references in the main heap. In other words, the subsidiary heaps can reference the main heap but not vice versa. Currently, the RTSJ does not address these cases.

2.5.3 Immortal Memory

`ImmortalMemory` is a memory resource shared among all schedulable objects and threads in an application. Objects allocated in `ImmortalMemory` are always available to non-heap threads and asynchronous event handlers without the possibility of a delay for garbage collection.

2.5.4 Scoped Memory

The RTSJ introduces the concept of scoped memory. A memory scope is used to give bounds to the lifetime of any objects allocated within it. When a scope is entered, every use of `new` causes the memory to be allocated from the active memory scope. A scope may be entered explicitly, or it can be attached to a schedulable which will effectively enter the scope before it executes the object's `run()` method.

The contents of a scoped memory are discarded when no object in the scope can be accessed. This is done by a technique similar to reference counting the scope.

A conforming implementation might maintain a count of the number of external references to each memory area. The reference count for a **ScopedMemory** area would be increased by entering a new scope through the **enter()** method of **MemoryArea**, by the creation of a schedulable using the particular **ScopedMemory** area, or by the opening of an inner scope. The reference count for a **ScopedMemory** area would be decreased when returning from the **enter()** method, when the schedulable using the **ScopedMemory** terminates, or when an inner scope returns from its **enter()** method. When the count drops to zero, the finalize method for each object in the memory would be executed to completion. Reuse of the scope is blocked until finalization is complete.

Scopes may be nested. When a nested scope is entered, all subsequent allocations are taken from the memory associated with the new scope. When the nested scope is exited, the previous scope is restored and subsequent allocations are again taken from that scope.

Because of the lifetimes of scoped objects, it is necessary to limit the references to scoped objects, by means of a restricted set of assignment rules. A reference to a scoped object cannot be assigned to a variable from an outer scope, or to a field of an object in either the heap or the immortal area. A reference to a scoped object may only be assigned into the same scope or into an inner scope. The virtual machine must detect illegal assignment attempts and must throw an appropriate exception when they occur.

For cases where the usage of memory does not follow a stack discipline, in particular code that uses the producer-consumer pattern, a special variant of scoped memory is provided. This variant **PinnableMemory** has the same semantics as **LTMemory** except that a task can “pin” the memory, thereby keeping it open, even when no task is in the area. One task can fill the memory, put a reference in its portal, and then pass it on to another task to consume the data therein. Thus one does not have to have a dummy task to hold a pinned area open while it is passed from producer to consumer.

The flexibility provided in choice of scoped memory types enables the application to use a memory area that has characteristics that are appropriate to a particular syntactically defined region of the code.

2.5.5 Physical Memory Areas

In many cases, systems needing the predictable execution of the RTSJ will also need to access various kinds of memory at particular addresses for performance or other reasons. Consider a system in which very fast static RAM was programmatically available. A design that could optimize performance might wish to place various frequently used Java objects in the fast static RAM. The **PhysicalMemoryRegion** and **PhysicalMemoryFactory** classes provide the programmer this flexibility. The

programmer would construct a physical memory object on the memory addresses occupied by the fast RAM.

2.5.6 Budgeted Allocation

The RTSJ also provides limited support for providing memory allocation budgets for schedulables using memory areas. Maximum memory area consumption and maximum allocation rates for individual schedulable objects may be specified when they are created.

2.6 Device Access and Raw Memory

The RTSJ defines classes for programmers wishing to directly access physical memory from code written in the Java language. The `RawMemory<Size>` types, where `<Size>` is one of `Byte`, `Short`, `Long`, `Float`, or `Double`, define methods that enable the programmer to construct an object that represents a vector of consecutive positions in memory where the `Size` represents a primitive numerical data type, i.e., byte, short, int, long, float, and double respectively. Access to the physical memory is then accomplished through `get<Size>()` and `set<Size>()` methods of that object. No semantics other than the `set<Size>()` and `get<Size>()` methods are implied. On the other hand, the `PhysicalMemoryRegion` and `PhysicalMemoryFactory` classes enable programmers to construct an object that represents a range of physical memory addresses. When this object is used as a `MemoryArea` other objects can be constructed in the physical memory using the `new` keyword as appropriate. Factories can be used to create the desired type of both physical and raw memory.

2.6.1 Raw Memory Access

An instance of `RawMemory` models a range of physical memory locations as a fixed sequence of elements of a given size. The elements correspond to Java primitive types. For objects that access more than a single physical address, elements can be accessed through offsets from the base, where the offset is measured in multiples of the element size, not necessarily the byte offset in memory.

The `RawMemory` interface enables a realtime program to implement device drivers, memory-mapped registers, I/O space mapped registers, flash memory, battery-backed RAM, and similar low-level hardware.

A raw memory area cannot contain references to Java objects. Such a capability would be unsafe (since it could be used to defeat Java's type checking) and error prone (since it is sensitive to the specific representational choices made by the Java compiler).

2.7 System Options

POSIX defines some convenient interfaces for interacting with the system. These interactions include catching keyboard interrupts, user-to-process signaling, and interprocess signaling. Many realtime operating systems support this POSIX signal interface. For this reason, the RTSJ provides a POSIX signal interface. Though many of the features POSIX signals provide are also available on most other operating systems, the specification does not require the POSIX signal interface to be emulated on these other platforms. Thus they are optional in the sense that they are only required on systems that directly support POSIX signals.

2.8 Exceptions

Aside from several new exceptions, the RTSJ provides a new interface for using exceptions without creating ephemeral objects and some new treatment of exceptions surrounding asynchronous transfer of control.

Using exceptions is resource intensive, since a new exception is allocated for each throw. This is particularly a problem for scoped memory, since scopes may need to be sized much larger than otherwise necessary to hold exceptions and their stack traces. Additionally, the information they contain cannot be propagated beyond the scope in which they are allocated. To better support scoped, immortal, and physical memory, a new class of throwable has been included: `PreallocatedThrowable`. Exceptions and Errors which implement this interface are not thrown in the usual manner, but with a style that does not require memory to be allocated at all.

Asynchronous transfer of control can cause the exception that triggered it to be propagated even when it is caught but the underlying interrupt is not cleared. The system rethrows the exception once the catch is finished. This is necessary since the exception hierarchy is poorly designed. There is a base class neither for all checked exceptions nor for all errors. There is no common base class for checked exceptions, so application code often contains a catch for `Exception` when only checked exceptions need to be caught. Even the JVM specification wording is awkward on this point, where a checked exception is an exception that is not a subclass of `RuntimeException` and an error is a throwable that is not a subclass of `Exception`.

2.9 Summary

The RTSJ refines the semantics of threads, scheduling, synchronization, memory management, and exceptions and adds features to support realtime threads, realtime scheduling, configuring synchronization, asynchrony, representing time, clocks and

timers, additional methods for memory management, device access and raw memory, system options. These features and semantic refinements to the Java language and virtual machine have been outlined above, but the description does not constitute a definition for them. In other words, it is not normative. The normative chapters follow.

Chapter 3

General Requirements

3.1 Overview

The RTSJ is both an Application Programmer Interface (API) and a refinement of the semantics of the Java virtual machine. Both aspects are necessary to produce a programming environment conducive to programming realtime systems. Most realtime systems require features that go beyond simply being able to react within a defined time bounds, they must also respond to something and take action thereon. Therefore, the ability to interact with the external environment is a necessary part of a realtime specification.

There are many applications that can benefit from the API and semantic refinements of the Java runtime environment that have been described above. Not every application requires all parts, so some flexibility of implementation is necessary. Therefore the RTSJ is divided into a core package and three optional packages. Furthermore, it also provides for different usage modes to support both development and deployment.

Finally, the vast majority of realtime systems are also embedded systems. The constraints of such system must also be considered. The specification begins with the overall requirements of these concerns.

3.2 Definitions

Code — program text written in the Java programming language.

Java Language — a programming language defined through the Java Community Process.

Heap — an area of memory for allocating data structures (objects) defined by the Java Language.

Thread — An instance of the `java.lang.Thread` class.

- Realtime Thread** — an instance of the `javax.realtime.RealtimeThread` class.
- Java Thread** — an instance of `java.lang.Thread` class, but does not extend the `javax.realtime.RealtimeThread` class.
- Heapless Realtime Thread** — is an instance of the `javax.realtime.RealtimeThread` class that must not access the heap.
- Event Handler** — is an instance of the `javax.realtime.AbstractAsyncEventHandler` class.
- Schedulable** — any object that is of type **Schedulable**, and is recognized as a dispatchable entity by the required schedulers. The required schedulers' set of schedulables comprises instances of **RealtimeThread** and **AbstractAsyncEventHandler**. Other schedulers may support a different set of schedulables, but this specification only defines the behavior of the required schedulers so the term schedulable should be understood as “schedulable by the base scheduler.”
- Task** — any thread or schedulable, including Java threads.
- Garbage Collection** — is a processes that reclaims memory on the heap that is no longer reachable by the application program. It may be accomplished through a dedicated set of threads or be distributed throughout the application.

3.3 Semantics

This specification is a contract between the specification implementer and the user who writes a program to run on an implementation. To be able to support both implementation and use, many chapters provide additional rationale to help both the implementer and the user understand the intention behind the normative text. The remainder of this specification, including this chapter, is normative, except for the introductory text in each chapter and the sections named Rationale.

3.3.1 Base Requirements

The base requirements of this specification are as follows.

1. Except as specifically required by this specification, any implementation shall fully conform to a Java platform configuration.
2. Any implementation of this specification shall implement all classes and methods in the base module of this specification.
3. Except as noted in this chapter, all classes and methods in an implemented module shall be implemented.
4. The `javax.realtime` package and its subpackages shall contain no public or protected classes or methods not included in this specification.
5. A realtime JVM implementation shall not be implemented in a way that permits unbounded priority inversion in any scheduling interaction it implements.

6. All methods defined under `javafx.realtime` can safely be used concurrently by multiple threads unless otherwise documented.
7. Static final values, as found in `AperiodicParameters`, `SporadicParameters`, `RealtimeSystem`, and `PriorityScheduler`, shall be implemented such that their values cannot be resolved by a conformant Java compiler (Java source to byte code).

Many aspects of this specification set a minimum requirement, but permit the implementation latitude in its implementation. For instance, the required priority scheduler requires at least 28 consecutively numbered realtime priorities. It does not, however, specify the numeric values of the maximum and minimum realtime priorities. Implementations are encouraged to offer as many realtime priority levels immediately above the conventional Java priorities as they can support.

Except where otherwise specified, when this specification requires object creation, the object is created in the current allocation context.

3.3.2 Modules

The original RTSJ specification was conceived, with the exception of some optional features, as a monolith specification. This has inhibited the adoption of the RTSJ beyond the hard realtime community, because some of the features were considered to have an overly negative impact on overall JVM performance. Version 2.0 addresses this by breaking the specification into modules.

Modules provide a means of grouping like functionality together in a way that promotes maximal adoption for various implementation classes. A conventional JVM may simply implement the Base Module API, without providing any realtime guarantees at all, thereby providing programmers with the benefits of features such as asynchronous event programming as an alternative to conventional threading. A hard realtime implementation could implement all modules to provide the maximal flexibility and functionality to the realtime programmer. Both would benefit from easier migration of code to realtime systems.

Every RTSJ implementation shall provide the Base Module functionality, but all other modules are optional. The optional modules are the Device Module, the Alternative Memory Areas Module and the POSIX Module. In addition, there are a couple of optional features as well. This give the implementation some choice over which modules and features to include and which not.

3.3.2.1 Base Module

The Base Module adds the concepts of processor affinity, threads with realtime scheduling, and asynchronous event handling. This includes the notion of executing code at a given time interval, providing a much more stable response than using

`sleep` in a loop. These features should have no impact on the overall performance of a system that implements them, but enrich the programming modules available to the programmer. The classes and interfaces required in this module are all in package `javafx.realtime` and are listed below.

- `AbsoluteTime` (Section 9.4.1.1)
- `ActiveEvent` (Section 8.4.1.1)
- `ActiveEventDispatcher` (Section 8.4.3.1)
- `Affinity` (Section 6.4.3.1)
- `AperiodicParameters` (Section 6.4.3.2)
- `AsyncBaseEvent` (Section 8.4.3.2)
- `AsyncBaseEventHandler` (Section 8.4.3.3)
- `AsyncEvent` (Section 8.4.3.4)
- `AsyncEventHandler` (Section 8.4.3.5)
- `AsyncLongEvent` (Section 8.4.3.6)
- `AsyncLongEventHandler` (Section 8.4.3.7)
- `AsyncObjectEvent` (Section 8.4.3.8)
- `AsyncTimable` (Section 10.4.1.1)
- `AsyncObjectEventHandler` (Section 8.4.3.9)
- `BoundAsyncBaseEventHandler` (Section 8.4.1.2)
- `BoundAsyncEventHandler` (Section 8.4.3.10)
- `BoundAsyncLongEventHandler` (Section 8.4.3.11)
- `BoundAsyncObjectEventHandler` (Section 8.4.3.12)
- `Clock` (Section 10.4.2.1)
- `Chronograph` (Section 10.4.1.2)
- `ConfigurationParameters` (Section 5.4.2.1)
- `FirstInFirstOutScheduler` (Section 6.4.3.3)
- `GarbageCollector` (Section 14.3.2.1)
- `HeapMemory` (Section 11.4.2.1)
- `HighResolutionTime` (Section 9.4.1.2)
- `ImmortalMemory` (Section 11.4.2.2)
- `ImportanceParameters` (Section 6.4.3.4)
- `Interruptible` (Section 8.4.1.3)
- `MemoryArea` (Section 11.4.2.3)
- `MemoryAreaVisitor` (Section 11.4.1.1)
- `MemoryParameters` (Section 11.4.2.4)¹
- `MonitorControl` (Section 7.4.1.1)
- `OneShotTimer` (Section 10.4.2.2)
- `PeriodicParameters` (Section 6.4.3.6)
- `PeriodicTimer` (Section 10.4.2.3)

¹The `mayUseHeap` flag is present, but can only be set if the Memory Module is supported.

- `PhasingPolicy` (Section 5.4.1.1)
- `PriorityCeilingEmulation` (Section 7.4.1.2)
- `PriorityInheritance` (Section 7.4.1.3)
- `PriorityParameters` (Section 6.4.3.7)
- `PriorityScheduler` (Section 6.4.3.8)
- `ProcessingGroup` (Section 6.4.3.9)
- `QueueOverflowPolicy` (Section 6.4.2.2)
- `RealtimeExecutionContext` (Section 6.4.1.2)
- `RealtimeSecurity` (Section 14.3.2.2)
- `RealtimeSystem` (Section 14.3.2.3)
- `RealtimeThread` (Section 5.4.2.2)
- `RelativeTime` (Section 9.4.1.3)
- `Releasable` (Section 8.4.1.4)
- `ReleaseParameters` (Section 6.4.3.10)
- `RoundRobinScheduler` (Section 6.4.3.11)
- `RTSJModule` (Section 14.3.1.1)
- `Schedulable` (Section 6.4.1.3)
- `Scheduler` (Section 6.4.3.12)
- `SchedulingParameters` (Section 6.4.3.14)
- `SizeEstimator` (Section 11.4.2.5)
- `SporadicParameters` (Section 6.4.3.15)
- `Timable` (Section 10.4.1.3)
- `Timed` (Section 8.4.2.2)
- `TimeDispatcher` (Section 10.4.2.4)
- `Timer` (Section 10.4.2.6)
- `WaitFreeReadQueue` (Section 7.4.1.4)
- `WaitFreeWriteQueue` (Section 7.4.1.5)

All throwables defined in the RTSJ are also in the `javax.realtime` package:

- `AlignmentError` (Section 15.3.3.1)
- `ArrivalTimeQueueOverflowException` (Section 15.3.2.1)
- `CeilingViolationException` (Section 15.3.2.2)
- `DeregistrationException` (Section 15.3.2.3)
- `IllegalAssignmentError` (Section 15.3.3.2)
- `InaccessibleAreaException` (Section 15.3.2.4)
- `LateStartException` (Section 15.3.2.5)
- `MemoryAccessError` (Section 15.3.3.3)
- `MemoryInUseException` (Section 15.3.2.7)
- `MemoryScopeException` (Section 15.3.2.8)
- `MemoryTypeConflictException` (Section 15.3.2.9)
- `MITViolationException` (Section 15.3.2.6)

- `OffsetOutOfBoundsException` (Section 15.3.2.10)
- `POSIXException` (Section 15.3.2.11)
- `POSIXInvalidSignalException` (Section 15.3.2.12)
- `POSIXInvalidTargetException` (Section 15.3.2.13)
- `POSIXSignalPermissionException` (Section 15.3.2.14)
- `ProcessorAffinityException` (Section 15.3.2.15)
- `RangeOutOfBoundsException` (Section 15.3.2.16)
- `RegistrationException` (Section 15.3.2.17)
- `ResourceLimitError` (Section 15.3.3.4)
- `ScopedCycleException` (Section 15.3.2.18)
- `StaticCheckedException` (Section 15.3.2.20)
- `StaticError` (Section 15.3.3.5)
- `StaticOutOfMemoryError` (Section 15.3.3.6)
- `StaticRuntimeException` (Section 15.3.2.21)
- `StaticThrowable` (Section 15.3.1.1)
- `StaticThrowableStorage` (Section 15.3.3.7)
- `SizeOutOfBoundsException` (Section 15.3.2.19)
- `ThrowBoundaryError` (Section 15.3.3.8)
- `UnsupportedPhysicalMemoryException` (Section 15.3.2.22)
- `UnsupportedRawMemoryRegionException` (Section 15.3.2.23)

3.3.2.2 Device Module

The Device Module provides a low level interface for interacting with the real world. Though realtime control systems need this kind of interaction, other systems can benefit from it as well. Data collection, that is not time critical is a good example. For instance, monitoring the temperature or humidity in a room could be done easily with off-the-shelf hardware using this module. The classes required in this module are all in the package `javax.realtime.device` and are listed below.

- `Happening` (Section 12.4.2.3)
- `HappeningDispatcher` (Section 12.4.2.4)
- `InterruptServiceRoutine` (Section 12.4.2.5)
- `DMABufferFactory` (Section 12.4.2.1)
- `RawMemory` (Section 12.4.1.16)
- `RawMemoryFactory` (Section 12.4.2.6)
- `RawMemoryRegion` (Section 12.4.2.7)
- `RawMemoryRegionFactory` (Section 12.4.1.17)
- `RawByte` (Section 12.4.1.1)
- `RawByteReader` (Section 12.4.1.2)
- `RawByteWriter` (Section 12.4.1.3)
- `RawDouble` (Section 12.4.1.4)

- [RawDoubleReader](#) (Section 12.4.1.5)
- [RawDoubleWriter](#) (Section 12.4.1.6)
- [RawFloat](#) (Section 12.4.1.7)
- [RawFloatReader](#) (Section 12.4.1.8)
- [RawFloatWriter](#) (Section 12.4.1.9)
- [RawInt](#) (Section 12.4.1.10)
- [RawIntReader](#) (Section 12.4.1.11)
- [RawIntWriter](#) (Section 12.4.1.12)
- [RawLong](#) (Section 12.4.1.13)
- [RawLongReader](#) (Section 12.4.1.14)
- [RawLongWriter](#) (Section 12.4.1.15)
- [RawShort](#) (Section 12.4.1.18)
- [RawShortReader](#) (Section 12.4.1.19)
- [RawShortWriter](#) (Section 12.4.1.20)

3.3.2.3 Alternative Memory Area Module

The Alternative Memory Areas Module provides an alternative to a single heap with garbage collection model for memory management. Most of the facilities are centered around providing an alternative to garbage collection, but facilities for providing what memory to use for Java objects is also addressed. The classes required in this module are all in package `javax.realtime.memory` and are listed below.

- [LTMemory](#) (Section 11.5.3.1)
- [PhysicalMemoryCharacteristic](#) (Section 11.5.1.1)
- [PhysicalMemoryFactory](#) (Section 11.5.3.2)
- [PhysicalMemoryRegion](#) (Section 11.5.3.3)
- [PhysicalMemorySelector](#) (Section 11.5.3.4)
- [PinnableMemory](#) (Section 11.5.3.5)
- [ScopedMemory](#) (Section 11.5.3.6)
- [StackedMemory](#) (Section 11.5.3.7)
- [VirtualMemoryCharacteristic](#) (Section 11.5.1.2)

3.3.3 POSIX module

The POSIX module provides access to functionality particular to POSIX systems. In particular, it addresses POSIX signals and POSIX realtime signals. This module is optional, but it an implementation of this standard on a POSIX platform should provide it. Implementations on non-POSIX platforms may provide it. The classes in this module are in the package `javax.realtime.posix` and are listed below.

- [RealtimeSignal](#) (Section 13.4.1.1)
- [RealtimeSignalDispatcher](#) (Section 13.4.1.2)

- **Signal** (Section 13.4.1.3)
- **SignalDispatcher** (Section 13.4.1.4)

3.3.4 Optional Features

Even with modules, it is difficult to eliminate all optional features. These features are either not easy to implement on all platforms or have the potential to cause a significant performance overhead. Therefore, an application cannot depend on them to be present in every implementation. However, if an optional facility is implemented, the application may rely on it to behave as specified here. Those extensions are illustrated in Table 3.1.

Table 3.1: RTSJ Options

Hard cost enforcement	Provides an automatic means of controlling the processor usage of a task or group of tasks.
Processing Group deadline less than period	Enables the application to specify a processing group deadline less than the processing group period
Allocation-rate enforcement on heap allocation	Enables the application to limit the rate at which a schedulable creates objects in the heap.
Interrupt Service Routine	Provides first level interrupt processing in Java.

The **ProcessingGroup** class only intervenes in scheduling on systems that support the hard cost enforcement option. The precision of intervention is limited by the precision of the clock being used to measure time times the number of CPUs involved in the enforcement. When cost enforcement is supported, the precision of enforcement is the drive precision of the clock being used. In any event, cost and deadline overrun handlers are fired with the resolution specified for hard cost enforcement.

In implementations where processing group deadline less than period is not supported, values passed to the constructor for **ProcessingGroup** and its **setDeadline** method are constrained to be equal to the period. If the option is supported, processing group deadlines less than the period shall be supported and function as specified.

In implementations where heap allocation rate enforcement is supported, it shall be implemented as specified. If heap allocation rate enforcement is not supported, the allocation rate attribute of **MemoryParameters** shall be checked for validity but otherwise ignored by the implementation.

First level interrupt handling can only be supported in certain contexts, such as in kernel space and in a device driver context in user space on systems that

support this feature. Normally user space programs cannot handle interrupts directly. The class should be present in every system that implements the device module, but in implementations that do not support first level interrupt handling, the `InterruptServiceRoutine.register` should always throw an `UnsupportedOperationException`.

Extensions to this specification are allowed, but shall not require changes to the public interfaces defined in the `javax.realtime` package tree in particular and the `java` and `javax` package trees in general.

3.3.5 Deprecated Classes

Classes and methods that have been deprecated as of this specification are not part of any module, but may be implemented by a full RTSJ implementation. The following classes are deprecated:

- `DuplicateFilterException` (Section A.3.2.1)
- `ImmortalPhysicalMemory` (Section A.3.3.1)
- `LTMemory` (Section A.3.3.2)
- `LTPhysicalMemory` (Section A.3.3.3)
- `NoHeapRealtimeThread` (Section A.3.3.4)
- `PhysicalMemoryManager` (Section A.3.3.6)
- `PhysicalMemoryTypeFilter` (Section A.3.1.1)
- `ProcessingGroupParameters` (Section A.3.3.7)
- `POSIXSignalHandler` (Section A.3.3.5)
- `RationalTime` (Section A.3.3.8)
- `RawMemoryAccess` (Section A.3.3.9)
- `RawMemoryFloatAccess` (Section A.3.3.10)
- `ScopedMemory` (Section A.3.3.11)
- `UnknownHappeningException` (Section A.3.2.2)
- `VTMemory` (Section A.3.3.12)
- `VTPhysicalMemory` (Section A.3.3.13)
- `WaitFreeDequeue` (Section A.3.3.14)

They are documented fully in Chapter A.

3.3.6 Implementation types Allowed

As described in Section 3.3.2, the RTSJ now has modules. Every implementation, except one supporting **Safety Critical Java**, must implement the Core module. Each module provided by an implementation must be provided in full. None of the classes of an unimplemented module should be present. Only an implementation of this specification for **Safety Critical Java**, may subset classes and packages herein, but must implement the methods and classes defined in that specification.

3.3.6.1 Realtime Deployment Implementation

A realtime deployment implementation must support all semantics described herein necessary for deterministic programming. In addition to implementing the core module, a realtime deployment implementation must have a realtime garbage collector or implement the alternate memory area module. All other modules are optional.

The minimum scheduling semantics that must be supported in all implementations of the RTSJ are fixed-priority preemptive scheduling and at least 28 unique priority levels. Fixed priority means that the system does not change the priority of any `Schedulable` except, temporarily, for priority inversion avoidance. Priority change is under control of the application.

What the RTSJ precludes by this statement is scheduling algorithms for realtime priorities which change thread priorities according to policies for optimizing throughput. An implementation may not increase the priority of a thread that has been receiving few processor cycles because of higher priority threads (aging) or other so-called fair scheduling algorithms. Fair scheduling operations are also prohibited. These types of algorithms are reserved for conventional Java thread priorities. This does not prohibit an application from implementing other realtime schedulers, such as earliest deadline first, which use underlying OS priorities to support an application meeting its deadlines.

The 28 unique priority levels are required to be unique to preclude implementations from using fewer priority levels of underlying systems to implement the required 28 by simplistic algorithms (such as lumping four RTSJ priorities into seven buckets for an underlying system that only supports seven priority levels). It is sufficient for systems with fewer than 28 priority levels to use more sophisticated algorithms to implement the required 28 unique levels as long as `Schedulable` behave as though there were at least 28 unique levels. (e.g. if there were 28 `RealtimeThreads` (t_1, \dots, t_{28}) with priorities (p_1, \dots, p_{28}), respectively, where the value of p_1 was the highest priority and the value of p_2 the next highest priority, etc., then for all executions of threads t_1 through t_{28} thread t_1 would *always* execute in preference to threads t_2, \dots, t_{28} and thread t_2 would *always* execute in preference to threads t_3, \dots, t_{28} , etc.)

The minimum synchronization semantics that must be supported in all deployment implementations of the RTSJ are detailed in the section on synchronization below and repeated here. All deployment implementations of the RTSJ must provide an implementation of the synchronized primitive with default behavior that ensures that there is no unbounded priority inversion. Furthermore, this must apply to code if it is run within the implementation as well as to schedulables. Both the priority inheritance and the priority ceiling emulation protocols must be implemented, but priority inheritance is the default.

All schedulable waiting to acquire a resource must be queued in priority order. This applies to the processor as well as to synchronized blocks. When schedula-

bles with the same exact priority are possible under the active scheduling policy, schedulables with the same priority are queued in FIFO order. Note that these requirements apply only to the required scheduling policy and hence use the specific term "priority". In particular,

1. schedulables waiting to enter synchronized blocks are granted access to the synchronized block in priority order;
2. a blocked schedulable that becomes ready to run is given access to the processor in priority order;
3. a schedulables whose execution eligibility is explicitly set by itself or another schedulable is given access to the processor in priority order;
4. a schedulable that performs a `yield()` will be given access to the processor after waiting schedulables of the same priority;
5. however, schedulables that are preempted in favor of a schedulable with higher priority may be given access to the processor at any time as determined by a particular implementation. The implementation is required to provide documentation stating exactly the algorithm used for granting such access.

Other realtime schedulers must provide and document similar algorithms to expedited schedulables with higher execution eligibility over those with lower execution eligibility.

The RTSJ does not require any particular garbage collection algorithm; however, every deployment implementation must either implement the alternate memory area module or have a realtime garbage collection. In the later case, the realtime limitations must be documented. All implementations of the RTSJ must support the class `GarbageCollector` and implement all of its methods.

Notwithstanding the above, a program that uses the RTSJ and is deployed as an executable, so that it does not provide general access to the virtual machine, but solely runs that program code, need only include the RTSJ methods and classes needed by the application.

3.3.6.2 Simulation Implementation

An implementation that chooses not to provide realtime guarantees, is termed a simulation implementation. Such an implementation does not need to provide the realtime characteristic described above, but does need to at least provide all the APIs of the core module. A simulation implementation can be a production system, but not for realtime applications. This enables a conventional JVM to make the base APIs available to a wider audience without changing its performance characteristics.

The following semantics are optional for an RTSJ implementation designed and licensed exclusively as a development tool.

1. The priority scheduler need not support fixed-priority preemptive scheduling or the priority inversion avoidance algorithms. This does not excuse an implemen-

tation from fully supporting the relevant APIs. It only reduces the required behavior of the underlying scheduler to the level of the scheduler in the Java specification extended to at least 28 priorities.

2. No semantics constraining timing beyond the requirements of the Java specifications need be supported. Specifically, garbage collection may delay any thread without bound and any delay in delivering asynchronously interrupted exceptions is permissible including never delivering the exception. Note, however, that if any AIE other than the generic AIE is delivered, it shall meet the AIE semantics, and all heap-memory-related semantics other than preemption remain fully in effect. Further, relaxed timing does not imply relaxed sequencing. For instance, semantics for scoped memory shall be fully implemented.
3. The RTSJ semantics that alter standard Java method behavior, such as the modified semantics for `Thread.setPriority` and `Thread.interrupt`, are not required for a development tool, but such deviations from the RTSJ shall be documented, and the implementation shall be able to generate a runtime warning each time one of these methods deviates from standard RTSJ behavior.

These relaxed requirements set a floor for RTSJ development system tool implementations. A development tool may choose to implement semantics that are not required.

3.4 Required Documentation

In order to properly engineer a realtime system, an understanding of the cost associated with any arbitrary code segment is required. This is especially important for operations that are performed by the runtime system, largely hidden from the programmer. An example of this is the maximum expected latency before the garbage collector can be interrupted.

The RTSJ does not require specific performance or latency numbers to be matched. Rather, to be conformant to this specification, an implementation must provide documentation regarding the expected behavior of particular mechanisms. The mechanisms requiring such documentation, and the specific data to be provided, will be detailed in the class and method definitions.

Each implementation of the RTSJ is required to provide documentation for several behaviors.

1. If schedulers other than the required first-in-first-out (FIFO) and round robin (RR) schedulers are available to applications, the behavior of these schedulers and their interaction with each other and the required schedulers as detailed in Chapter 6, Scheduling, shall be documented.
 - (a) The documentation must define how its order of execution eligibility relates to that of the priority schedulers, where the order of execution

- eligibility of a priority scheduler is the priority order.
- (b) The list of classes whose instances constitute schedulables for the scheduler, unless that list is the same as the list of schedulables for the required schedulers, shall be included.
 - (c) If there are restrictions on use of the scheduler from a nonheap context, such restrictions shall be documented as well.
2. A scheduler that cannot place a schedulable at the front of the queue for its active priority when it is preempted by a higher-priority schedulable must document such a deviation from the specification.
 3. An implementation is required to document the granularity at which the current CPU consumption is updated for cost monitoring and cost enforcement, when the later is implemented.
 4. The implementation shall fully document the behavior of any subclasses of **GarbageCollector**.
 5. An implementation that provides any **MonitorControl** subclasses not detailed in this specification shall document their effects, particularly with respect to priority inversion control and which (if any) schedulers fail to support the new policy.
 6. If on losing “boosted” priority due to a priority inversion avoidance algorithm, the schedulable is not placed at the front of its new queue, the implementation shall document the queuing behavior.
 7. For any available scheduler other than the required schedulers, an implementation shall document how, if at all, the semantics of synchronization differ from the rules defined for the default **PriorityInheritance** monitor control policy.
 - (a) It shall supply documentation for the behavior of the new scheduler with priority inheritance (and, if it is supported, priority ceiling emulation protocol) equivalent to the semantics for the base priority scheduler found in the Synchronization chapter.
 - (b) If there are restrictions on use of the scheduler from an extraheap context, the documentation shall detail the effect of these restrictions for each RTSJ API.
 8. The worst-case response interval between firing an **AsyncEvent** because of a bound happening to releasing an associated **AsyncEventHandler** (assuming no higher-priority schedulables are runnable) shall be documented for some reference architecture.
 9. The interval between firing an **AsynchronouslyInterruptedException** at an ATC-enabled thread and first delivery of that exception (assuming no higher-priority schedulables are runnable) shall be documented for some reference architecture.
 10. If cost enforcement is supported and the implementation assigns the cost of

running finalizers for objects in scoped memory to any schedulable other than the one that caused the scope's reference count to drop to zero by leaving the scope, the rules for assigning the cost shall be documented.

11. If hard cost enforcement is supported and enforcement (blocked-by-cost-overflow) can be delayed beyond the enforcement time granularity, the maximum such delay shall be documented.
12. If the implementation of `RealtimeSecurity` is more restrictive than the required implementation, or has run-time configuration options, those features shall be documented.
13. For each supported clock, the documentation shall specify whether the resolution is settable, and if it is settable the documentation shall indicate the supported values.
14. If an implementation includes any clocks other than the required realtime clock, their documentation shall indicate in what contexts those clocks can be used. If they cannot be used in extraheap context, the documentation shall detail the consequences of passing the clock, or a time that uses the clock to a heapless schedulable.

3.5 Rationale

The embedded market, especially for safety critical applications, is quite sensitive to including code that is not needed by an application. Furthermore, different application domains have differing needs on API. Flexibility is needed to ensure that these diverse domains and requirements are met. Still, it is important to ensure that when a given function is needed, it is included as defined herein. It is also important that an open virtual machine deployment has a well-defined API set. The above modules and deployment rules provide both this flexibility and standardization.

Chapter 4

Conventional Java Classes and Language

4.1 Overview

Though compatibility with conventional Java, i.e., any Java runtime environments that implement the Java Virtual Machine Specification and the Java Language Specification but not the RTSJ, is the first concern of this specification, there are several cases where being able to meet realtime constraints requires a tightening of the semantics of the virtual machine and some subtle changes to the semantics of two key classes: `java.lang.Thread` and `java.lang.ThreadGroup`. These constraints and changes place additional requirements on scheduling, the memory model, and memory management. Finally, the specification defines both an extension to thread for realtime scheduling and a new type of concurrent activity called an event handler; hence, the meaning of current thread has a different interpretation than in conventional java. In fact, the term task is used when referring to any of these three types: conventional Java thread, realtime thread, and event handler.

4.2 Definitions

Conventional Java — the language and runtime as defined by the “Java Language Specification[]” and “Java Virtual Machine Specification[],” without any realtime extensions.

4.3 Semantics

The refinements and changes to the semantics of the Java runtime environment and classes shall not affect the functional correctness of Java code written for a conventional Java implementation when running on a Java runtime environment which implements this specification. There may be changes in the relative timing of threads, but these should not violate the conventional Java specifications. The use of some RTSJ features with code written for a conventional Java implementation may, however, be surprising. This is particularly true when using alternate memory areas, asynchronous transfer of control, and thread local memory in conjunction with unbound asynchronous event handlers.

4.3.1 Scheduling

How tasks are scheduled in a realtime system is quite different from what one expects in a conventional Java virtual machine. For compatibility, this means that there must be a domain where conventional Java threads are scheduled in a familiar way and another domain that supports realtime scheduling. This separation is done in part via task priority.

Tasks running with the conventional ten priorities defined in Java should be scheduled as expected. Unfortunately, in order to ease the porting of Java to different environments, the scheduling of conventional Java threads is underspecified. This has been resolved in practice to avoid surprising the programmer by providing some sort of fair scheduling for these threads, i.e, scheduling that at least prevents task starvation, but may also try to balance CPU availability across threads. For tasks running in these priorities an implementation of this specification should provide some notion of fair scheduling between tasks with priority between one and ten inclusive. Realtime threads and event handlers need a stronger notion of prioritization than conventional Java threads, so this specification requires the implementation of two priority-preemptive schedulers, one with run to completion (or next suspension point) and one with round-robin semantics. Priorities above the conventional ten priorities are used for these schedulers, and the interactions of the two schedulers are well-defined. Multithreaded code that runs with the priority-preemptive scheduler (or any other realtime scheduler) is more prone to deadlock or starvation than code run with fair scheduling. The changes to **Thread** and **ThreadGroup** are to support this realtime scheduling.

1. The semantics of set and get methods for priority in **Thread** differ for realtime threads.
2. The **ThreadGroup** class's behavior differs with respect to realtime threads.
3. The behavior of the **ThreadGroup**-related methods in **Thread** differ when they are applied to realtime threads.

Code running at realtime priorities can also block tasks scheduled on the conventional Java scheduler, possibly indefinitely.

4.3.1.1 Priority

The methods `setPriority` and `getPriority` in `java.lang.Thread` are `final`. The realtime thread classes are consequently not able to override them and modify their behavior to suit the requirements of the RTSJ scheduler. To bring the `java.lang.Thread` class in line with its realtime subclasses, the semantics of the `getPriority` and `setPriority` methods must be modified.

4.3.1.1.1 Setting Priority

The `setPriority` method has the following additional requirements.

1. Use of `Thread.setPriority()` shall not affect the correctness of the priority inversion avoidance algorithms controlled by `PriorityCeilingEmulation` and `PriorityInheritance`. Changes to the base priority of a realtime thread as a result of invoking `Thread.setPriority()` are governed by semantics from Chapter 7 on *Synchronization*.
2. Threads may not use `setPriority` to apply the expanded range of priorities defined by this specification.
3. When `setPriority` is called on a realtime thread, that thread's `SchedulingParameters` are set to `null` and the thread is scheduled as if it were a Java thread.

4.3.1.1.2 Getting Priority

The `getPriority` method has the following additional requirements.

1. When called on a conventional Java thread, its priority is returned even if it has a higher priority than what would be allowed by conventional Java.
2. When called on a realtime thread with `null SchedulingParameters` a value in the conventional Java priority range is returned.
3. When used on a realtime thread with `PriorityParameters`, `getPriority` behaves effectively as if it included the following code snippet:

```
1 (PriorityParameters)t.getSchedulingParameters().getPriority();
```

4. When the scheduling parameters are of a type other than `PriorityParameters`, a `ClassCastException` is thrown.

All supported monitor control policies must apply to Java threads as well as to all schedulables.

4.3.1.2 Thread Groups

The RTSJ provides a subclass of `ThreadGroup` called `SchedulingGroup` which provides services similar to `ThreadGroup` for instance of `Schedulable`. In an RTSJ implementation, thread groups are rooted at a base `SchedulingGroup` object which may be created in heap or immortal memory. All thread group objects hold references to all their member threads, and subgroups, and a reference to their parent group. Since heap and immortal memory can not hold references to scoped memory, it follows that a thread group can never be allocated in scoped memory. It also follows that no thread allocated in scoped memory may be referenced from any thread group. `Schedulable` groups are extended to be able to reference threads, schedulables, and other schedulable groups, even when they are in scoped memory. Consequently conventional java threads, schedulables, and schedulable groups are not part of any thread group and will hold a schedule group reference for as their thread group. This also requires that the thread group of the main thread is also a schedulable group, so that schedulables and schedule groups can be created from the main thread.

1. Realtime threads with `null` thread groups are not included in any operation on any thread group. This applies to enumeration and interruption, as well as the deprecated actions `stop`, `resume`, and `suspend`. However, when the current thread is a realtime thread with a `null` thread group:
 - (a) The `Thread.enumerate` class method returns the integer 1, and populates its array argument with the current realtime thread.
 - (b) `Thread.activeCount` returns 1.
 - (c) `Thread.getThreadGroup` returns `null` in all cases, not only when the thread has terminated.
2. A Java thread (not a realtime thread) that is created from a realtime thread without an explicit thread group and is not assigned a thread group by the security manager inherits the thread group of the realtime thread, when it has one; otherwise an attempt is made to add it to the application root thread group. The constructor shall throw a `SecurityException` when the Java thread is not permitted to use the application root thread group.
3. The thread group of a Java thread created by an asynchronous event handler is assigned as if it was created by a realtime thread without a thread group (as described in 2. above)
4. A thread group cannot be created in scoped memory. The constructor shall throw an `IllegalAssignmentError`.
5. Setting a maximum priority on a thread group, either explicitly or via its parent, has no influence on the realtime threads in that group.
6. Except as specified previously, realtime threads have the same `ThreadGroup` membership rules as the parent `Thread` class.

4.3.1.3 Current Thread

In Java, the currently executing thread can always be determined by calling the static method `Thread.currentThread()`. In the RTSJ, there are two types of schedulable entities: threads and asynchronous event handlers. The latter may be mapped dynamically by the realtime Java virtual machine onto the underlying thread model. The method `Thread.currentThread()` when called from an unbound asynchronous event handler will return the thread that is being used as the current execution engine for that event handler. The program should not rely on this being constant for the lifetime of the program. It can rely on it being constant for the current *release* of the handler (see 6.2 for the definition of a *release*). It is not recommended that the program perform any operations on this underlying thread as it may have an impact beyond that of the current event handler. This also means that thread local memory cannot be relied on in unbound event handlers, because data saved in one release may not be available in the next release.

4.3.2 InterruptedException

The specification extends the use of the `InterruptedException` to support asynchronous transfer of control.

The interruptible methods in the standard libraries (such as `Object.wait`, `Thread.sleep`, and `Thread.join`) have their contract expanded slightly such that they will respond to interruption not only when the interrupt method is invoked on the current thread, but also, for schedulables, when executing within a call to `AIE.doInterruptible` and that AIE is fired. See Chapter 8 on Asynchrony.

4.3.3 Java Memory Model

Some aspects of the Java Memory Model must be tightened for this specification, in particular with regards to interactions with native code or when using the Device Module. A conforming implementation must ensure that volatile loads and stores, raw memory operations (see 12.3.1), and `DMABufferFactory` fence methods are all ordered in a way that is consistent with respect to native code or hardware devices using platform-native memory coherence protocols to access raw memory or raw byte buffers shared with the virtual machine. In particular, all code in a JNI call happens after the Java code that proceeds it and happens before all Java code that follows it. Though not specified for conventional Java, most implementations provide explicit fencing for JNI calls.

4.3.4 Memory Management

The specification provides for two means of managing memory: garbage collection and special memory areas. The latter are not collected by the garbage collector. Since memory allocated in Java is always in the heap, or at least appears to be, the initial allocation area is the heap. Furthermore, the allocation area can only be changed either by entering another memory area or by calling a method that explicitly causes allocation in another area. When this alternate memory management module is not present, the conventional java semantics for allocation prevails.

4.3.4.1 Memory Areas

Using a conventional class in a memory area other than a heap can result in unexpected behavior. This is particularly the case when a method of a class is called in a different area than the object was created, which can lead to exceptions. In general, memory areas other than the heap may become full much faster than expected, because objects that are no longer referenced will not be collected automatically.

A method that allocates an object or takes an object that was created in a different memory area and tries to assign it to a field of its associated object can fail. For example, creating a `List` on the heap and adding to it from a scoped memory will most likely cause an exception. Although using other memory areas such as scoped memory is useful for helping to improving determinism, its use complicates the logic of application and library code.

On systems that support memory areas other than heap and do not support realtime garbage collection, some global resources must be put in immortal memory. System properties and their `String` values allocated during system initialization shall be allocated in immortal memory. For such a system, class objects should also be stored there. Though this avoids priority inversion with the garbage collector, it can cause higher memory use than expected.

4.3.4.2 Garbage Collection

Garbage collection is an important safety feature of the Java language and runtime environment. Unfortunately, the garbage collection process can interfere with a realtime program's ability to always meet its timing deadlines. This specification provides two main means of circumventing this problem: using a realtime garbage collector or using the memory area module as an alternative to garbage collection for realtime code. Additionally, an implementation may ignore the problem for an implementation meant as a development system or for systems that choose not to provide realtime guarantees. In any case, an implementation must document what realtime guarantees it gives and which method it uses to do so.

4.3.4.3 Realtime Garbage Collections

Industrial realtime garbage collectors are available with varying approaches to providing realtime response. Though new collectors will undoubtedly be developed, all current ones use a variant of the mark-and-sweep algorithm. In all cases, the collectors are incremental: realtime response is obtained by limiting how much of a collection cycle is done each time the collector runs. Even on a multicore machine, the garbage collector must be incremental, because it must tolerate changes to the heap during garbage collection. Then CPU use is limited by tying the collector to one or more cores.

4.3.4.3.1 Thread-Based Collectors

A realtime thread-based collector is an incremental garbage collector that has its own thread of control and runs at intervals. In this case, the garbage collector needs to be scheduled to ensure that it runs often enough and long enough at each interval to recycle discarded objects fast enough to keep up with allocations. There should also be some maximum time after which the garbage collector can be interrupted.

4.3.4.3.2 Allocation-Based Collectors

A realtime allocation-based garbage collector does not have its own thread of control. Instead, some interval of garbage collection work is done at each allocation. This work is generally a function of the size of the object being allocated. This work becomes part of the execution time of the program. Again, there should be some maximum time after which the garbage collector can be interrupted.

4.3.4.3.3 Alternatives to Garbage Collection

This specification provides an Alternative Memory Areas Module for managing memory without garbage collection. An implementation of this specification may provide realtime response by requiring applications to use that module instead of providing a realtime garbage collector. This means that all realtime threads would have to run above the priority of the garbage collector and all communication with conventional threads would have to use some nonblocking protocol.

4.3.4.3.4 Developer Implementation

An implementation that simply provides all the API but no realtime guarantee is also permitted. This is useful as a development environment. Also, many of the APIs are useful even in a conventional Java implementation.

4.4 Rationale

The treading model of conventional Java was never meant for realtime programming. Refinements to the virtual machine and new APIs are necessary to support the additional requirements of applications, which have tasks that must complete in a fixed amount of time. However, to ensure that any conventional Java program can run on a virtual machine or runtime that implements this specification requires careful consideration of each refinement to the Java programming model. Therefore conventional Java APIs and semantics have been extended, rather than replaced, to facilitate compatibility with conventional Java runtime implementations.

Chapter 5

Realtime Threads

5.1 Overview

Conventional Java provides a thread class for its tasking model. Tasks can be run simultaneously by creating multiple threads, but they do not provide realtime scheduling semantics. For this, the specification provides a realtime thread class, that does. This class provides for the creation of

- realtime threads that have more precise scheduling semantics than `java.lang.Thread`, and
- realtime threads that have no dependency on the heap.

The `RealtimeThread` class extends `java.lang.Thread`. The `ReleaseParameters`, `SchedulingParameters`, and `MemoryParameters` objects that can be passed to the `RealtimeThread` constructor provide the temporal and processor configuration of the thread to be communicated to the *scheduler*. `ProcessingGroup`, a class derived from `ThreadGroup` provides cost enforcement on groups of threads. The `ConfigurationParameters` class defines, amongst other things, the size of Java thread stack; it also indicates whether the `RealtimeThread` is allowed to allocate or even reference objects from the Java heap (and can thus safely execute in preference to the garbage collector). The `PhasingPolicy` class defines the relationship between the threads start time and its first release time when the start time is in the past.

The RTSJ provides two types of objects which implement the `Schedulable` interface: realtime threads and asynchronous event handlers. This chapter defines the facilities that are available to realtime threads. In many cases these facilities are also available to asynchronous event handlers. In particular:

- the default scheduler must support the scheduling of both realtime threads and asynchronous event handlers;
- realtime threads and asynchronous event handlers are allowed to enter into memory areas and consequently they have associated scope stacks;

- the flow of control of realtime threads and asynchronous event handlers are affected by the RTSJ asynchronous transfer of control facilities;

Where the semantics apply to both realtime threads and asynchronous event handlers, the term *schedulable* will be used.

5.2 Definitions

Exception — both a mechanism of nonlocal transfer of control and a Java object which carried information about the cause of the control transfer.

Scheduler — a module that manages the execution of tasks, as well as detecting deadline misses and monitoring costs.

5.3 Semantics

Instances of `RealtimeThread` have the same semantics as conventional Java threads except as noted below.

1. Garbage collection executing in the context of a Java thread must not in itself block execution of a realtime thread with a higher execution eligibility that may not access the heap; however application locks work as specified even when the lock causes synchronization between a heap-using thread and a realtime thread that may not use the heap.
2. Each realtime thread has an attribute which indicates whether an `AsynchronouslyInterruptedException` is pending. This attribute is set when a call to `RealtimeThread.interrupt()` is made on the associated realtime thread, and when an asynchronously interrupted exception's `fire` method is invoked between the time the realtime thread has entered that exception's `doInterruptible` method, and before it has return from `doInterruptible`. (See Chapter 8 on *Asynchrony*.)
3. A call to `RealtimeThread.interrupt()` generates the system's generic `AsynchronouslyInterruptedException`. (See Chapter 8 on *Asynchrony*.)
4. The `RealtimeThread.waitForNextRelease` method is for use by realtime threads that have periodic or aperiodic release parameters. In the absence of any deadline miss or cost overrun, or an interrupt, the method returns when the realtime thread's next period is due or the next release happens.
5. In the presence of a cost overrun or a deadline miss, the behavior of `waitForNextRelease` is governed by the thread's scheduler.
6. The first release time of a realtime thread is governed by the value of any `start` time in its associated `ReleaseParameter` object and the time at which the `RealtimeThread.start` method is called and the value of any `PhasingPolicy`

parameter passed to it.

7. Instances of **RealtimeThread** may not be created with a thread group which is not an instance of **SchedulingGroup**.
8. System-related termination activity (such as execution of finalizers for scoped objects in scoped memory areas that become unreferenced) triggered by termination of a realtime thread is not subject to cost enforcement or deadline miss detection.
9. The scheduling of a realtime thread is governed by its **SchedulingParameters** and **Scheduler** unless set explicitly with `java.lang.Thread.setPriority(int)`, which causes it to be treated as a conventional java thread until a new **SchedulingParameters** object is set.

5.4 Package javax.realtime

5.4.1 Enumerations

5.4.1.1 PhasingPolicy

Inheritance

```
java.lang.Object
  java.lang.Enum
    javax.realtime.PhasingPolicy
```

Description

This class defines a set of constants that specify the supported policies for starting a periodic thread or periodic timer, when it is started later than the assigned absolute time. The following table specifies the effective start time (that is, the first release time of a periodic realtime thread). The effective start time of a periodic timer is similar; where the first firing is equivalent to the first release.

Available since RTSJ 2.0

5.4.1.1.1 Enumeration Constants

ADJUST_IMMEDIATE

```
public static final ADJUST_IMMEDIATE
```

Description

Indicates that a periodic thread started after the absolute time given for its start time should be released immediately with the next release one period later.

ADJUST_FORWARD

```
public static final ADJUST_FORWARD
```

Description

Indicates that a periodic thread started after the absolute time given for its start time should be released at the next multiple of its period from its start time.

Table 5.1: Effect of PhasingPolicy on the First Release of a RealtimeThread with PeriodicParameters

	ADJUST IM-MEDIATE	ADJUST FORWARD	ADJUST BACKWARD	STRICT PHASING
Relative Time	The time of start method invocation plus start time.	The time of start method invocation plus start time.	The time of start method invocation plus start time.	The time of start method invocation plus start time.
Absolute Time, earlier than call to start	Release immediately and set next release time to be at the time the start method was invoked plus period .	All releases before the time start is called are ignored. The first release is at the start time plus the smallest multiple of period whose time is after the time start was called.	The first release occurs immediately and the next release is at the start time plus the smallest multiple of period whose time is after the time start was called.	The start method throws an exception.
Absolute Time, later than call to start	First release is at time passed to start .	First release is at time passed to start .	First release is at time passed to start .	First release is at time passed to start .
Without Time	First release is at time of start method invocation	First release is at time of start method invocation	First release is at time of start method invocation	First release is at time of start method invocation

ADJUST_BACKWARD

```
public static final ADJUST_BACKWARD
```

Description

Indicates that a periodic thread started after the absolute time given for its start time show be released immediately with the next release at the next multiple of its period from its start time.

STRICT_PHASING

```
public static final STRICT_PHASING
```

Description

Indicates that a periodic thread started after the absolute time given for its start time show throw an exception instead of being released.

5.4.1.1.2 Methods

values

Signature

```
public static  
    javax.realtime.PhasingPolicy[] values()
```

Description

valueOf(String)

Signature

```
public static  
    javax.realtime.PhasingPolicy valueOf(String name)
```

Description

5.4.2 Classes

5.4.2.1 ConfigurationParameters

Inheritance

java.lang.Object
 javafx.runtime.ConfigurationParameters

Description

Configuration parameters provide a way to specify various implementation-dependent parameters such as the Java stack and native stack sizes, and to configure the statically allocated [ThrowBoundaryError](#)¹ associated with a [Schedulable](#)².

Note that these parameters are immutable.

Available since RTSJ 2.0

5.4.2.1.1 Constructors

ConfigurationParameters(int, int, long)

Signature

```
public  
ConfigurationParameters(int messageLength,  
                        int stackTraceLength,  
                        long[] sizes)  
throws IllegalStateException
```

Description

Creates a parameter object for initializing the state of a [Schedulable](#)³. The parameters provide the data for this initialization. For [RealtimeThread](#)⁴ and bound versions of [AsyncBaseEventHandler](#)⁵, the stack and message buffers can

¹Section [15.3.3.8](#)

²Section [6.4.1.3](#)

³Section [6.4.1.3](#)

⁴Section [5.4.2.2](#)

⁵Section [8.4.3.3](#)

be set exactly, but for the unbound event handlers, the system cannot give any guarantees to allow thread sharing.

Parameters

messageLength Memory space in bytes dedicated to the message associated with **Schedulable**⁶ objects created with these parameters' preallocated exceptions, plus references to the method names/identifiers in the stack trace. The value 0 indicates that no message should be stored. The value of -1 uses the system default and is the default when an instance of this class is not provided.

stackTraceLength Length of the stack trace buffer dedicated to **Schedulable**⁷ objects created with these parameters' preallocated exceptions, in frames. The amount of space this requires is implementation-specific. The value 0 indicates that no stack trace should be stored. The value of -1 uses the system default and is the default when an instance of this class is not provided.

sizes An array of implementation-specific values dictating memory parameters for **Schedulable** objects created with these parameters, such as maximum Java and native stack sizes. The **sizes** array will not be stored in the constructed object. The default is system dependent when set to **null** or an instance of this class is not provided.

ConfigurationParameters(long)

Signature

```
public
ConfigurationParameters(long[] sizes)
```

Description

Same as **ConfigurationParameters(int,int,long[])**⁸ with arguments -1, -1, **sizes**.

5.4.2.1.2 Methods

⁶Section 6.4.1.3

⁷Section 6.4.1.3

⁸Section 5.4.2.1.1

getMessageLength

Signature

```
public  
int getMessageLength()
```

Description

Gets the memory space in bytes dedicated to the message associated with [Schedulable](#)⁹ objects created with these parameters' preallocated exceptions, plus references to the method names/identifiers in the stack trace. The value 0 indicates that no message will be stored.

Returns

Reserved memory size in bytes.

getStackTraceLength

Signature

```
public  
int getStackTraceLength()
```

Description

Gets the length of the stack trace buffer dedicated to [Schedulable](#)¹⁰ objects created with these parameters' preallocated exceptions, in frames. The amount of space this requires is implementation-specific. The value 0 indicates that no stack trace will be stored.

Returns

Reserved memory size in implementation-dependent stack frames.

getSizes

Signature

```
public  
long[] getSizes()
```

Description

⁹Section [6.4.1.3](#)

¹⁰Section [6.4.1.3](#)

Gets the array of implementation-specific sizes associated with `Schedulable`¹¹ objects created with these parameters. *This method may allocate memory.*

Returns

Array of implementation-specific sizes.

5.4.2.2 RealtimeThread

Inheritance

java.lang.Object
 java.lang.Thread
 javax.realtime.RealtimeThread

Interfaces

javax.realtime.BoundSchedulable
javax.realtime.AsyncTimable

Description

Class `RealtimeThread` extends `Thread` and adds access to realtime services such as asynchronous transfer of control, nonheap memory, and advanced scheduler services.

As with `java.lang.Thread`, there are two ways to create a usable `RealtimeThread`.

- Create a new class that extends `RealtimeThread` and override the `run()` method with the logic for the thread.
- Create an instance of `RealtimeThread` using one of the constructors with a `logic` parameter. Pass a `Runnable` object whose `run()` method implements the logic of the thread.

5.4.2.2.1 Constructors

RealtimeThread(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, ConfigurationParameters, TimeDispatcher, SchedulingGroup, Runnable)

Signature

¹¹Section 6.4.1.3


```
public
RealtimeThread(SchedulingParameters scheduling,
               ReleaseParameters release,
               MemoryParameters memory,
               MemoryArea area,
               ConfigurationParameters config,
               TimeDispatcher dispatcher,
               SchedulingGroup group,
               Runnable logic)
```

Description

Create a realtime thread with the given characteristics and a specified `Runnable`. The scheduling group of the new thread is inherited from its creator unless `group` is set. The newly-created realtime thread is associated with the scheduler in effect during execution of the constructor.

Available since RTSJ 2.0

Parameters

scheduling The `SchedulingParameters`¹² associated with `this` (And possibly other instances of `Schedulable`¹³). When `scheduling` is `null` and the creator is a schedulable, `SchedulingParameters`¹⁴ is a clone of the creator's value created in the same memory area as `this`. When `scheduling` is `null` and the creator is a Java thread, the contents and type of the new `SchedulingParameters` object is governed by the associated scheduler.

release The `ReleaseParameters`¹⁵ associated with `this` (and possibly other instances of `Schedulable`¹⁶). When `release` is `null` the new `RealtimeThread` will use a clone of the default `ReleaseParameters` for the associated scheduler created in the memory area that contains the `RealtimeThread` object.

memory The `MemoryParameters`¹⁷ associated with `this` (and possibly other instances of `Schedulable`¹⁸). When `memory` is `null`, the new `RealtimeThread` receives `null` value for its memory parameters, and the amount or rate of memory allocation for the new thread is unrestricted, and it may access the heap.

¹²Section 6.4.3.14

¹³Section 6.4.1.3

¹⁴Section 6.4.3.14

¹⁵Section 6.4.3.10

¹⁶Section 6.4.1.3

¹⁷Section 11.4.2.4

¹⁸Section 6.4.1.3

area the initial memory area of this handler.

config The [ConfigurationParameters](#)¹⁹ associated with **this** (and possibly other instances of [Schedulable](#)²⁰). When **config** is **null**, this **RealtimeThread** will reserve no space for preallocated exceptions and implementation-specific values will be set to their implementation-defined defaults.

dispatcher The [TimeDispatcher](#)²¹ to use for realtime sleep and determining the period of a periodic thread.

group The **SchedulingGroup** of the newly created realtime thread or the parent's scheduling group when **null**.

logic The **Runnable** object whose **run()** method will serve as the logic for the new **RealtimeThread**. When **logic** is **null**, the **run()** method in the new object will serve as its logic.

Throws

IllegalArgumentException when the parameters are not compatible with the associated scheduler or the current thread group is not a **SchedulingGroup** and **group** is **null**.

IllegalAssignmentError when the new **RealtimeThread** instance cannot hold a reference to any of the values of **scheduling**, **release**, **memory**, or **group**, when those parameters cannot hold a reference to the new **RealtimeThread**, when the new **RealtimeThread** instance cannot hold a reference to the values of **area** or **logic**, when the initial memory area is not specified and the new **RealtimeThread** instance cannot hold a reference to the default initial memory area, and when the thread may not use the heap, as specified by its memory parameters, and any of the following is true:

- the initial memory area is not specified,
- the initial memory is heap memory,
- the initial memory area, scheduling, release, memory, or group is allocated in heap memory.
- when this is in heap memory, or
- logic is in heap memory.

RealtimeThread(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, ConfigurationParameters, Runnable)

¹⁹Section [5.4.2.1](#)

²⁰Section [6.4.1.3](#)

²¹Section [10.4.2.4](#)

Signature

```
public
RealtimeThread(SchedulingParameters scheduling,
                ReleaseParameters release,
                MemoryParameters memory,
                MemoryArea area,
                ConfigurationParameters config,
                Runnable logic)
```

Description

Create a realtime thread with the given [SchedulingParameters](#)²², [ReleaseParameters](#)²³, [MemoryParameters](#)²⁴, [ConfigurationParameters](#)²⁵, a specified `Runnable`, and default values for all other parameters.

This constructor is equivalent to `RealtimeThread(scheduling, release, memory, area, config, null, null, logic)`.

Available since RTSJ 2.0

RealtimeThread(SchedulingParameters, ReleaseParameters, ConfigurationParameters, Runnable)

Signature

```
public
RealtimeThread(SchedulingParameters scheduling,
                ReleaseParameters release,
                ConfigurationParameters config,
                Runnable logic)
```

Description

Create a realtime thread with the given [SchedulingParameters](#)²⁶, [ReleaseParameters](#)²⁷, [MemoryArea](#)²⁸ and a specified `Runnable` and default values for all other parameters.

²²Section 6.4.3.14

²³Section 6.4.3.10

²⁴Section 11.4.2.4

²⁵Section 5.4.2.1

²⁶Section 6.4.3.14

²⁷Section 6.4.3.10

²⁸Section 11.4.2.3

This constructor is equivalent to `RealtimeThread(scheduling, release, config, null, null, null, logic)`.

Available since RTSJ 2.0

RealtimeThread(SchedulingParameters, ReleaseParameters, ConfigurationParameters)

Signature

```
public
RealtimeThread(SchedulingParameters scheduling,
                ReleaseParameters release,
                ConfigurationParameters config)
```

Description

Create a realtime thread with the given [SchedulingParameters](#)²⁹, [ReleaseParameters](#)³⁰ and [MemoryArea](#)³¹ and default values for all other parameters.

This constructor is equivalent to `RealtimeThread(scheduling, release, null, null, config, null, null, null)`.

Available since RTSJ 2.0

RealtimeThread(SchedulingParameters, ReleaseParameters, Runnable)

Signature

```
public
RealtimeThread(SchedulingParameters scheduling,
                ReleaseParameters release,
                Runnable logic)
```

Description

²⁹Section [6.4.3.14](#)

³⁰Section [6.4.3.10](#)

³¹Section [11.4.2.3](#)

Create a realtime thread with the given [SchedulingParameters](#)³², [ReleaseParameters](#)³³ and a specified `Runnable` and default values for all other parameters.

This constructor is equivalent to `RealtimeThread(scheduling, release, null, null, null, null, null, logic)`.

Available since RTSJ 2.0

RealtimeThread(SchedulingParameters, ReleaseParameters)

Signature

```
public  
RealtimeThread(SchedulingParameters scheduling,  
                ReleaseParameters release)
```

Description

Create a realtime thread with the given [SchedulingParameters](#)³⁴ and [ReleaseParameters](#)³⁵ and default values for all other parameters.

This constructor is equivalent to `RealtimeThread(scheduling, release, null, null, null, null, null)`.

RealtimeThread(SchedulingParameters, TimeDispatcher)

Signature

```
public  
RealtimeThread(SchedulingParameters scheduling,  
                TimeDispatcher dispatcher)
```

Description

Create a realtime thread with the given [SchedulingParameters](#)³⁶ and [TimeDispatcher](#)³⁷ and default values for all other parameters. This constructor is

³²Section 6.4.3.14

³³Section 6.4.3.10

³⁴Section 6.4.3.14

³⁵Section 6.4.3.10

³⁶Section 6.4.3.14

³⁷Section 10.4.2.4

equivalent to `RealtimeThread(scheduling, null, null, null, null, dispatcher, null, null)`.

Available since RTSJ 2.0

RealtimeThread(SchedulingParameters)

Signature

```
public  
RealtimeThread(SchedulingParameters scheduling)
```

Description

Create a realtime thread with the given [SchedulingParameters](#)³⁸ and default values for all other parameters. This constructor is equivalent to `RealtimeThread(scheduling, null, null, null, null, null, null, null)`.

RealtimeThread

Signature

```
public  
RealtimeThread()
```

Description

Create a realtime thread with default values for all parameters. This constructor is equivalent to `RealtimeThread(null, null, null, null, null, null, null, null)`.

5.4.2.2.2 Methods

currentRealtimeThread

Signature

³⁸Section [6.4.3.14](#)

```
public static  
    javax.realtime.RealtimeThread currentRealtimeThread()  
    throws ClassCastException
```

Description

Gets a reference to the current instance of `RealtimeThread`.

It is permissible to call `currentRealtimeThread` when control is in an `Async-EventHandler`³⁹. The method will return a reference to the `RealtimeThread` supporting that release of the async event handler.

Throws

`ClassCastException` when the current execution context is that of a Java thread.

Returns

A reference to the current instance of `RealtimeThread`.

getCurrentMemoryArea

Signature

```
public static  
    javax.realtime.MemoryArea getCurrentMemoryArea()
```

Description

Return a reference to the `MemoryArea`⁴⁰ object representing the current allocation context.

When this method is invoked from a Java thread it will return that thread's current memory area (heap or immortal memory).

Returns

A reference to the `MemoryArea`⁴¹ object representing the current allocation context.

getInitialMemoryAreaIndex

Signature

³⁹Section 8.4.3.5

⁴⁰Section 11.4.2.3

⁴¹Section 11.4.2.3

```
public static
int getInitialMemoryAreaIndex()
throws IllegalStateException,
    ClassCastException
```

Description

Gets the position of the initial memory area for the current [Schedulable](#)⁴² in the memory area stack. Memory area stacks may include inherited stacks from parent threads. The initial memory area of a [RealtimeThread](#)⁴³ or an [AsyncBaseEventHandler](#)⁴⁴ is the memory area specified in its constructor. The index of the initial memory area in the initial memory area stack is a fixed property of a [Schedulable](#).

When the current memory area stack of the current realtime thread is not the original stack and the memory area at the initial memory area index is not the initial memory area, then `IllegalStateException` is thrown.

Throws

`IllegalThreadStateException` when the memory area stack of the current `RealtimeThread` has changed from its initial configuration and the memory area at the originally specified initial memory area index is not the initial memory area.

`ClassCastException` when the current execution context is that of a Java thread.

Returns

The index into the initial memory area stack of the initial memory area of the current `RealtimeThread`.

getMemoryAreaStackDepth

Signature

```
public static
int getMemoryAreaStackDepth()
throws ClassCastException
```

Description

⁴²Section [6.4.1.3](#)

⁴³Section [5.4.2.2](#)

⁴⁴Section [8.4.3.3](#)

Gets the size of the stack of `MemoryArea`⁴⁵ instances to which the current schedulable has access.

Note: The current memory area (`getCurrentMemoryArea()`⁴⁶) is found at memory area stack index of `getMemoryAreaStackDepth() - 1`.

Throws

`ClassCastException` when the current execution context is that of a Java thread.

Returns

The size of the stack of `MemoryArea`⁴⁷ instances.

`getOuterMemoryArea(int)`

Signature

```
public static
    javax.realtime.MemoryArea getOuterMemoryArea(int index)
    throws ClassCastException,
           MemoryAccessError
```

Description

Gets the instance of `MemoryArea`⁴⁸ in the memory area stack at the index given. When the given index does not exist in the memory area scope stack then `null` is returned.

Note: The current memory area (`getCurrentMemoryArea()`⁴⁹) is found at memory area stack index `getMemoryAreaStackDepth() - 1`, so `getCurrentMemoryArea() == getOuterMemoryArea(getMemoryAreaStackDepth() - 1)`.

Parameters

`index` The offset into the memory area stack.

Throws

`ClassCastException` when the current execution context is that of a Java thread.

`MemoryAccessError` when the memory area is allocate in heap memory and the caller is a schedulable that may not use the heap.

Returns

⁴⁵Section 11.4.2.3

⁴⁶Section 5.4.2.2.2

⁴⁷Section 11.4.2.3

⁴⁸Section 11.4.2.3

⁴⁹Section 5.4.2.2.2

The instance of `MemoryArea`⁵⁰ at index or `null` when the given value does not correspond to a position in the stack.

`sleep(HighResolutionTime)`

Signature

```
public static
void sleep(javax.realtime.HighResolutionTime<?> time)
throws InterruptedException,
      ClassCastException,
      IllegalArgumentException
```

Description

A sleep method that is controlled by a generalized clock. Since the time is expressed as a `HighResolutionTime`⁵¹, this method is an accurate timer with nanosecond granularity. The actual resolution available for the clock and even the quantity it measures depends on `clock`. The time base is the given `Clock`⁵². The sleep time may be relative or absolute. When relative, then the calling thread is blocked for the amount of time given by `time`, and measured by `clock`. When absolute, then the calling thread is blocked until the indicated value is reached by `clock`. When the given absolute time is less than or equal to the current value of `clock`, the call to sleep returns immediately.

It is permissible to call `sleep` when control is in an `AsyncEventHandler`⁵³. The method cause the handler to sleep.

This method must not throw `IllegalAssignmentError`. It must tolerate `time` instances that may not be stored in `this`.

Parameters

`time` The amount of time to sleep or the point in time at which to awaken.

Throws

`InterruptedException` when the thread is interrupted by `interrupt()`⁵⁴ or `AsynchronouslyInterruptedException.fire()`⁵⁵ during the time between calling this method and returning from it.

`ClassCastException` when the current execution context is that of a Java thread.

⁵⁰Section 11.4.2.3

⁵¹Section 9.4.1.2

⁵²Section 10.4.2.1

⁵³Section 8.4.3.5

⁵⁴Section 5.4.1

⁵⁵Section 8.4.2.1.2

`IllegalArgumentException` when `time` is null, when `time` is a relative time less than zero, or when the `Chronograph`⁵⁶ of `time` is not a `Clock`⁵⁷.

suspend(HighResolutionTime)

Signature

```
public static
void suspend(javax.realtime.HighResolutionTime<?> time)
throws ClassCastException,
       IllegalArgumentException
```

Description

The same as `sleep(HighResolutionTime)`⁵⁸ except that it is not interruptible.

Parameters

`time` an absolute or relative time until which to suspend.

Throws

`ClassCastException` when the current execution context is that of a Java thread.

`IllegalArgumentException` when `time` is null, when `time` is a relative time less than zero, or when the `Chronograph`⁵⁹ of `time` is not a `Clock`⁶⁰.

Available since RTSJ 2.0

spin(HighResolutionTime)

Signature

```
public static
void spin(javax.realtime.HighResolutionTime<?> time)
throws InterruptedException,
       ClassCastException,
       IllegalArgumentException
```

Description

Similar to `sleep(HighResolutionTime)`⁶¹ except it performs a busy wait by

⁵⁶Section 10.4.1.2

⁵⁷Section 10.4.2.1

⁵⁸Section 5.4.2.2.2

⁵⁹Section 10.4.1.2

⁶⁰Section 10.4.2.1

⁶¹Section 5.4.2.2.2

polling on the `Chronograph`⁶² associated with `time` until `time` has been reached. Note that the implementation is permitted to use delay loops or other tactics to reduce the frequency of polling for long delays, so an application cannot assume that the associated `Chronograph` will be polled as fast as possible.

Parameters

`time` an absolute or relative time at which to stop spinning.

Throws

`InterruptedException` when the thread is interrupted by `interrupt()`⁶³ or `AsynchronouslyInterruptedException.fire()`⁶⁴ during the time between calling this method and returning from it.

`ClassCastException` when the current execution context is that of a Java thread.

`IllegalArgumentException` when `time` is null, or when `time` is a relative time less than zero.

Open issue 5.4.1

I wanted to allow for calculated delay loops where feasible, but do we need to say something about timing implications thereof? Is that a deal-breaker? –elb

End of issue 5.4.1

Available since RTSJ 2.0

spin(int)

Signature

```
public static
void spin(int nanos)
throws InterruptedException,
        ClassCastException,
        IllegalArgumentException
```

Description

The same as calling `spin(HighResolutionTime)`⁶⁵ with a relative time to the default realtime clock, zero milliseconds, and `nanos` nanoseconds, except no relative time object is necessary.

Parameters

⁶²Section 10.4.1.2

⁶³Section 5.4.1

⁶⁴Section 8.4.2.1.2

⁶⁵Section 5.4.2.2.2

`nanos` a relative number of nanoseconds to wait.

Throws

`InterruptedException` when the thread is interrupted by `interrupt()`⁶⁶ or `AsynchronouslyInterruptedException.fire()`⁶⁷ during the time between calling this method and returning from it.

`ClassCastException` when the current execution context is that of a Java thread.

`IllegalArgumentException` when `nanos` is less than zero.

Available since RTSJ 2.0

waitForNextRelease

Signature

```
public static
boolean waitForNextRelease()
throws AsynchronouslyInterruptedException,
       IllegalStateException,
       ClassCastException
```

Description

Causes the current realtime thread to delay until the next release. (See `release()`⁶⁸.) Used by threads that have a reference to either periodic or aperiodic `ReleaseParameters`⁶⁹. The first release starts when `this` thread is released as a consequence of the action of one of the `start()`⁷⁰ family of methods. Each time this method is called it will block until the next release unless the thread is in a deadline miss condition. In that case, the operation of `waitForNextRelease` is controlled by this thread's scheduler. (See `PriorityScheduler`⁷¹.)

Throws

`AsynchronouslyInterruptedException` when the thread is interrupted by `interrupt()`⁷² or `AsynchronouslyInterruptedException.fire()`⁷³ during

⁶⁶Section 5.4.1

⁶⁷Section 8.4.2.1.2

⁶⁸Section 5.4.1

⁶⁹Section 6.4.3.10

⁷⁰Section 5.4.1

⁷¹Section 6.4.3.8

⁷²Section 5.4.1

⁷³Section 8.4.2.1.2

the time between calling this method and returning from it and the `ReleaseParameters.isRousable()`⁷⁴ on its release parameters returns `true`.

An interrupt during `waitForNextPeriodInterruptible` is treated as a release for purposes of scheduling. This is likely to disrupt proper operation of the periodic thread. The timing behavior of the thread is unspecified until the state is reset by altering the thread's release parameters or the thread is no longer in a deadline miss state.

`IllegalStateException` when `this` does not have a reference to a `ReleaseParameters`⁷⁵ type of either `PeriodicParameters`⁷⁶ or `AperiodicParameters`⁷⁷.

`ClassCastException` when the current thread is not an instance of `RealtimeThread`.

Returns

Either `false` when the thread is in a deadline miss condition or `true` otherwise. When a deadline miss condition occurs is defined by its thread's scheduler.

Available since RTSJ 2.0

release

Signature

```
public  
void release()
```

Description

Generate a release for this `RealtimeThread`. The action of this release is governed by the scheduler. It may, for instance, act immediately, or be queued, delayed, or discarded.

Throws

`IllegalStateException` when `this` does not have a reference to a `ReleaseParameters`⁷⁸ type of `AperiodicParameters`⁷⁹.

Available since RTSJ 2.0

⁷⁴Section 6.4.3.10.2

⁷⁵Section 6.4.3.10

⁷⁶Section 6.4.3.6

⁷⁷Section 6.4.3.2

⁷⁸Section 6.4.3.10

⁷⁹Section 6.4.3.2

deschedule

Signature

```
public  
void deschedule()
```

Description

When the `ReleaseParameters`⁸⁰ object associated with `this RealtimeThread` is an instance of `AperiodicParameters`⁸¹, perform any *deschedule* actions specified by this thread's scheduler. When the type of the associated instance of `ReleaseParameters`⁸² is not `AperiodicParameters`⁸³ nothing happens.

Available since RTSJ 2.0

getMemoryArea

Signature

```
public  
javax.realtime.MemoryArea getMemoryArea()
```

Description

Return the initial memory area for this `RealtimeThread`. When not specified through the constructor, the default is a *reference* to the current allocation context when `this` was constructed.

Returns

A reference to the initial memory area for this thread.

Available since RTSJ 1.0.1

getMemoryParameters

Signature

```
public  
javax.realtime.MemoryParameters getMemoryParameters()
```

⁸⁰Section 6.4.3.10

⁸¹Section 6.4.3.2

⁸²Section 6.4.3.10

⁸³Section 6.4.3.2

Description

Gets a reference to the [MemoryParameters](#)⁸⁴ object for this schedulable.

Returns

A reference to the current [MemoryParameters](#)⁸⁵ object.

getSchedulingGroup

Signature

```
public  
    javax.realtime.SchedulingGroup getSchedulingGroup()
```

Description

Gets a reference to the [SchedulingGroup](#)⁸⁶ instance of this schedulable.

Returns

A reference to the current [SchedulingGroup](#)⁸⁷ object.

Available since since RTSJ 2.0

getConfigurationParameters

Signature

```
public  
    javax.realtime.ConfigurationParameters getConfigurationParameters()
```

Description

Gets a reference to the [ConfigurationParameters](#)⁸⁸ object for this schedulable.

Returns

A reference to the associated [ConfigurationParameters](#)⁸⁹ object.

Available since RTSJ 2.0

⁸⁴Section [11.4.2.4](#)

⁸⁵Section [11.4.2.4](#)

⁸⁶Section [6.4.3.13](#)

⁸⁷Section [6.4.3.13](#)

⁸⁸Section [5.4.2.1](#)

⁸⁹Section [5.4.2.1](#)

getReleaseParameters

Signature

```
public  
javafx.realtime.ReleaseParameters getReleaseParameters()
```

Description

Gets a reference to the [ReleaseParameters](#)⁹⁰ object for this schedulable.

Returns

A reference to the current [ReleaseParameters](#)⁹¹ object.

getScheduler

Signature

```
public  
javafx.realtime.Scheduler getScheduler()
```

Description

Gets a reference to the [Scheduler](#)⁹² object for this schedulable.

Returns

A reference to the associated [Scheduler](#)⁹³ object.

getSchedulingParameters

Signature

```
public  
javafx.realtime.SchedulingParameters getSchedulingParameters()
```

Description

Gets a reference to the [SchedulingParameters](#)⁹⁴ object for this schedulable.

Returns

A reference to the current [SchedulingParameters](#)⁹⁵ object.

⁹⁰Section [6.4.3.10](#)

⁹¹Section [6.4.3.10](#)

⁹²Section [6.4.3.12](#)

⁹³Section [6.4.3.12](#)

⁹⁴Section [6.4.3.14](#)

⁹⁵Section [6.4.3.14](#)

interrupt

Signature

```
public  
void interrupt()
```

Description

Extends the function of `Thread.interrupt()`, generates the generic `AsynchronouslyInterruptedException`⁹⁶ and targets it at this, and sets the interrupted state to pending. The semantics of `Thread.interrupt()` are also preserved.

reschedule

Signature

```
public  
void reschedule()  
throws InterruptedException
```

Description

Begin unblocking `RealtimeThread.waitForNextRelease`⁹⁷ for an periodic thread. When deadline miss detection is disabled, enable it. Typically used when an aperiodic schedulable is in a deadline miss condition.

The details of the interaction of this method with `deschedule`⁹⁸, `waitForNextRelease`⁹⁹ and `release`¹⁰⁰ are dictated by this thread's scheduler. When this `RealtimeThread` does not have a type of `AperiodicParameters`¹⁰¹ as its `ReleaseParameters`¹⁰² nothing happens.

Throws

`IllegalStateException` when the configured `Scheduler` and `SchedulingParameters` for this `RealtimeThread` are not compatible.

Available since RTSJ 2.0

⁹⁶Section 8.4.2.1

⁹⁷Section 5.4.1

⁹⁸Section 5.4.1

⁹⁹Section 5.4.1

¹⁰⁰Section 5.4.1

¹⁰¹Section 6.4.3.2

¹⁰²Section 6.4.3.10

setMemoryParameters(MemoryParameters)

Signature

```
public  
void setMemoryParameters(MemoryParameters memory)
```

Description

Sets the memory parameters associated with this instance of **Schedulable**.

This change becomes effective under conditions determined by the scheduler controlling the schedulable. For instance, the change may be immediate or it may be delayed until the next release of the schedulable object. See the documentation for the scheduler for details.

Parameters

memory memory A **MemoryParameters**¹⁰³ object which will become the memory parameters associated with **this** after the method call. When **null**, the default value is governed by the associated scheduler (a new object is created when the default value is not null). (See **PriorityScheduler**¹⁰⁴.)

Throws

IllegalArgumentException **IllegalArgumentException** when **memory** is not compatible with the schedulable's scheduler. Also when this schedulable may not use the heap and **memory** is located in heap memory.

IllegalAssignmentError **IllegalAssignmentError** when the schedulable cannot hold a reference to **memory**, or when **memory** cannot hold a reference to this schedulable instance.

IllegalStateException **IllegalStateException** when the schedulable's scheduler prohibits this parameter change at this time due to the state of the schedulable.

setReleaseParameters(ReleaseParameters)

Signature

```
public  
void setReleaseParameters(ReleaseParameters release)
```

Description

Sets the release parameters associated with this instance of **Schedulable**.

¹⁰³Section 11.4.2.4

¹⁰⁴Section 6.4.3.8

This change becomes effective under conditions determined by the scheduler controlling the schedulable. For instance, the change may be immediate or it may be delayed until the next release of the schedulable. The different properties of the release parameters may take effect at different times. See the documentation for the scheduler for details.

Parameters

release A `ReleaseParameters`¹⁰⁵ object which will become the release parameters associated with this after the method call, and take effect as determined by the associated scheduler. When `null`, the default value is governed by the associated scheduler (a new object is created when the default value is not `null`). (See `PriorityScheduler`¹⁰⁶.)

Throws

`IllegalArgumentException` Thrown when **release** is not compatible with the associated scheduler. Also when this schedulable may not use the heap and **release** is located in heap memory.

`IllegalAssignmentError` when **this** object cannot hold a reference to **release** or **release** cannot hold a reference to **this**.

`IllegalThreadStateException` when the schedulable's scheduler prohibits the changing of the release parameter at this time due to the state of the schedulable.

setScheduler(Scheduler)

Signature

```
public
void setScheduler(Scheduler scheduler)
```

Description

Sets the reference to the Scheduler object. The timing of the change must be agreed between the scheduler currently associated with this schedulable, and **scheduler**. If the `Schedulable` is running, its associated `SchedulingParameters` (if any) must be compatible with **scheduler**.

For an instance of `RealtimeThread`, the `Schedulable` is *running* when `RealtimeThread.start()`¹⁰⁷ has been called on it and `RealtimeThread.join()` would block.

¹⁰⁵Section 6.4.3.10

¹⁰⁶Section 6.4.3.8

¹⁰⁷Section 5.4.1

Parameters

scheduler scheduler A reference to the scheduler that will manage execution of this schedulable. `Null` is not a permissible value.

Throws

IllegalArgumentException `IllegalArgumentException` Thrown when **scheduler** is `null`, or the schedulable's existing parameter values are not compatible with **scheduler**. Also when this schedulable may not use the heap and **scheduler** is located in heap memory.

IllegalAssignmentError `IllegalAssignmentError` when the schedulable cannot hold a reference to **scheduler** or the current `Schedulable` is running and its associated `SchedulingParameters` are incompatible with **scheduler**.

SecurityException `SecurityException` when the caller is not permitted to set the scheduler for this schedulable.

IllegalThreadStateException `IllegalThreadStateException` when **scheduler** refuses to accept this schedulable at this time due to the state of the schedulable.

setScheduler(Scheduler, SchedulingParameters, ReleaseParameters, MemoryParameters)

Signature

```
public
void setScheduler(Scheduler scheduler,
                  SchedulingParameters scheduling,
                  ReleaseParameters release,
                  MemoryParameters memoryParameters)
```

Description

Sets the scheduler and associated parameter objects. The timing of the change must be agreed between the scheduler currently associated with this schedulable, and **scheduler**.

Parameters

scheduler A reference to the scheduler that will manage the execution of this schedulable. `Null` is not a permissible value.

scheduling A reference to the `SchedulingParameters`¹⁰⁸ which will be associated with **this**. When `null`, the default value is governed by **scheduler** (a new object is created when the default value is not `null`). (See `PriorityScheduler`¹⁰⁹.)

¹⁰⁸Section 6.4.3.14

¹⁰⁹Section 6.4.3.8

release A reference to the [ReleaseParameters](#)¹¹⁰ which will be associated with **this**. When **null**, the default value is governed by **scheduler** (a new object is created when the default value is not **null**). (See [PriorityScheduler](#)¹¹¹.)

memoryParameters A reference to the [MemoryParameters](#)¹¹² which will be associated with **this**. When **null**, the default value is governed by **scheduler** (a new object is created when the default value is not **null**). (See [PriorityScheduler](#)¹¹³.)

Throws

IllegalArgumentException Thrown when **scheduler** is **null** or the parameter values are not compatible with **scheduler**. Also thrown when this schedulable may not use the heap and **scheduler**, **scheduling release**, **memoryParameters**, or **group** is located in heap memory.

IllegalAssignmentError when **this** object cannot hold references to all the parameter objects or the parameters cannot hold references to **this**.

IllegalThreadStateException when **scheduler** prohibits the changing of the scheduler or a parameter at this time due to the state of the schedulable.

SecurityException when the caller is not permitted to set the scheduler for this schedulable.

setSchedulingParameters(SchedulingParameters)

Signature

```
public
void setSchedulingParameters(SchedulingParameters scheduling)
```

Description

Sets the scheduling parameters associated with this instance of **Schedulable**.

This change becomes effective under conditions determined by the scheduler controlling the schedulable. For instance, the change may be immediate or it may be delayed until the next release of the schedulable. See the documentation for the scheduler for details.

Parameters

¹¹⁰Section [6.4.3.10](#)

¹¹¹Section [6.4.3.8](#)

¹¹²Section [11.4.2.4](#)

¹¹³Section [6.4.3.8](#)

scheduling A reference to the [SchedulingParameters](#)¹¹⁴ object. When `null`, the default value is governed by the associated scheduler (a new object is created when the default value is not `null`). (See [PriorityScheduler](#)¹¹⁵.)

Throws

`IllegalArgumentException` Thrown when **scheduling** is not compatible with the associated scheduler. Also when this schedulable may not use the heap and **scheduling** is located in heap memory.

`IllegalAssignmentError` when **this** object cannot hold a reference to **scheduling** or **scheduling** cannot hold a reference to **this**.

`IllegalThreadStateException` when the schedulable's scheduler prohibits the changing of the scheduling parameter at this time due to the state of the schedulable object.

startPeriodic(PhasingPolicy)

Signature

```
public
void startPeriodic(PhasingPolicy phasingPolicy)
throws LateStartException
```

Description

Start the thread with the specified phasing policy.

Parameters

phasingPolicy The phasing policy to be applied when the start time given in the realtime thread's associated [PeriodicParameters](#)¹¹⁶ is in the past.

Throws

`javax.realtime.LateStartException` when the actual start time is after the assigned start time and the phasing policy is [PhasingPolicy.STRICT_PHASING](#)¹¹⁷.

`IllegalArgumentException` when the thread is not periodic, or when its start time is not absolute.

`IllegalThreadStateException` when the configured `Scheduler` and `SchedulingParameters` for this `RealtimeThread` are not compatible.

Available since RTSJ 2.0

¹¹⁴Section 6.4.3.14

¹¹⁵Section 6.4.3.8

¹¹⁶Section 6.4.3.6

¹¹⁷Section 5.4.1.1.1

start

Signature

```
public  
void start()
```

Description

Set up the realtime thread's environment and start it. The set up might include delaying it until the assigned start time and initializing the thread's scope stack. (See [ScopedMemory](#)¹¹⁸.)

Throws

`IllegalStateException` when the configured `Scheduler` and `SchedulingParameters` for this `RealtimeThread` are not compatible.

Available since RTSJ 2.0 adds new exception

getLastReleaseTime

Signature

```
public  
javax.realtime.AbsoluteTime getLastReleaseTime()
```

Description

Equivalent to `getLastReleaseTime(null)`

Available since RTSJ 2.0

getLastReleaseTime(AbsoluteTime)

Signature

```
public  
javax.realtime.AbsoluteTime getLastReleaseTime(AbsoluteTime dest)
```

Description

Return the absolute time of this thread's last release, whether periodic or aperiodic.

¹¹⁸Section [A.3.3.11](#)

The clock in the returned absolute time shall be the realtime clock for aperiodic releases and the clock used for the periodic release for periodic releases.

Returns

the last release time in `dest`. When `dest` is `null`, create a new absolute time instance in the current memory area.

Available since RTSJ 2.0

getEffectiveStartTime

Signature

```
public  
javax.realtime.AbsoluteTime getEffectiveStartTime()
```

Description

Equivalent to `getEffectiveStartTime(null)`.

Available since RTSJ 2.0

getEffectiveStartTime(AbsoluteTime)

Signature

```
public  
javax.realtime.AbsoluteTime getEffectiveStartTime(AbsoluteTime dest)
```

Description

Determine the effective start time of this realtime thread. This is not necessarily the same as the start time in the release parameters.

- When the release parameters' start time is relative, the effective start time is the time of the first release.
- When the release parameters' start time is an absolute time after `start()` is invoked, the effective start time is the same as the release parameters' start time.
- When the release parameters' start time is an absolute time before `start()` is invoked, the effective start time depends on the phasing policy.

The default is to set the effective start time equal to the time `start()` is invoked.

Returns

The effective start time in `dest`. When `dest` is `null`, return the effective start time in an [AbsoluteTime](#)¹¹⁹ instance created in the current memory area.

Available since RTSJ 2.0

getCurrentConsumption(RelativeTime)

Signature

```
public static  
javafx.realtime.RelativeTime getCurrentConsumption(RelativeTime dest)
```

Description

Determine the CPU consumption for this release.

Throws

`IllegalStateException` when the caller is not a [RealtimeThread](#)¹²⁰.

Returns

When `dest` is `null`, return the CPU consumption in a [RelativeTime](#)¹²¹ instance created in the current execution context. When `dest` is not `null`, return the CPU consumption in `dest`

Available since RTSJ 2.0

getCurrentConsumption

Signature

```
public static  
javafx.realtime.RelativeTime getCurrentConsumption()
```

Description

Equivalent to `getCurrentConsumption(null)`.

Available since RTSJ 2.0

¹¹⁹Section [9.4.1.1](#)

¹²⁰Section [5.4.2.2](#)

¹²¹Section [9.4.1.3](#)

getMinConsumption(RelativeTime)

Signature

```
public  
javafx.realtime.RelativeTime getMinConsumption(RelativeTime dest)
```

Description

Get the minimum CPU consumption measured for any completed release of this thread.

Returns

the minimum CPU consumption in `dest`. When `dest` is null return the minimum CPU consumption in a [RelativeTime](#)¹²² instance created in the current memory area.

Available since RTSJ 2.0

getMinConsumption

Signature

```
public  
javafx.realtime.RelativeTime getMinConsumption()
```

Description

Equivalent to `getMinConsumption(null)`.

Available since RTSJ 2.0

getMaxConsumption(RelativeTime)

Signature

```
public  
javafx.realtime.RelativeTime getMaxConsumption(RelativeTime dest)
```

Description

Get the maximum CPU consumption measured for any completed release of this thread.

¹²²Section [9.4.1.3](#)

Returns

the maximum CPU consumption in `dest`. When `dest` is `null` return the maximum CPU consumption in a [RelativeTime](#)¹²³ instance created in the current memory area.

Available since RTSJ 2.0

getMaxConsumption

Signature

```
public  
    javax.realtime.RelativeTime getMaxConsumption()
```

Description

Equivalent to `getMaxConsumption(null)`.

Available since RTSJ 2.0

getDispatcher

Signature

```
public  
    javax.realtime.TimeDispatcher getDispatcher()
```

Description

Get the dispatcher responsible for handling sleep requests issued by this thread

[See Section Timable.getDispatcher\(\)](#)

Available since RTSJ 2.0

fire

Signature

```
public final  
    void fire()
```

¹²³Section [9.4.1.3](#)

Description

Used by the `Clock`¹²⁴ infrastructure to cause a call to `waitForNextRelease`¹²⁵ to return.

See Section `AsyncTimable.fire()`

Available since RTSJ 2.0

mayUseHeap

Signature

```
public  
boolean mayUseHeap()
```

Description

Determine whether or not this `schedulable` may use the heap.

Returns

`true` only when this `Schedulable` may allocate on the heap and may enter `HeapMemory`.

Available since RTSJ 2.0

awaken

Signature

```
public final  
void awaken()
```

Description

Used by the `Clock`¹²⁶ infrastructure to cause a call to `sleep`¹²⁷ to return.

See Section `Schedulable.awaken()`

Available since RTSJ 2.0

¹²⁴Section 10.4.2.1

¹²⁵Section 5.4.1

¹²⁶Section 10.4.2.1

¹²⁷Section 5.4.2.2.2

5.5 Rationale

The RTSJ platform's priority-preemptive dispatching model is very similar to the dispatching model found in the majority of commercial realtime operating systems. However, the dispatching semantics were purposefully relaxed in order to allow execution on a wide variety of operating systems. Thus, it is appropriate to specify realtime threads by extending `java.lang.Thread`.

The `ReleaseParameters` and `MemoryParameters` provided to the `RealtimeThread` constructor allow for a number of common realtime thread types, including periodic threads.

The `MemoryParameters` class is provided with a may-use-heap option in order to enable time-critical schedulables to execute in preference to the garbage collector given appropriate assignment of execution eligibility when `false`. The memory access and assignment semantics of these heapless schedulables are designed to guarantee that the execution of such threads does not lead to an inconsistent heap state.

Chapter 6

Scheduling

6.1 Overview

Scheduling is a key differentiator between a conventional Java implementation and a realtime Java implementation. Whereas conventional Java implementations relies on some sort of fair scheduling, a realtime Java implementation must provide a realtime scheduler. In a realtime scheduler, ensuring that critical tasks finish on time is more important than overall throughput or fairness.

The scheduler required by this specification is fixed-priority preemptive with at least 28 unique priority levels. It is represented by the class `FirstInFirstOutScheduler`, a subclass of `PriorityScheduler`, and is called the *base scheduler*. As the name implies, this scheduler does not time-slice threads at a given priority, but rather runs each to completion, so long as no higher priority thread becomes ready to run and no other processor is available for the higher priority thread. In that case, the current thread is preempted by the higher priority thread.

The schedulables required by this specification are denoted by the `Schedulable` interface and include the classes `RealtimeThread` and `AsyncBaseEventHandler` along with its subclasses. The base scheduler assigns processor resources according to the schedulables' release characteristics, execution eligibility, affinity, and processing group values. Subclasses of these schedulables are also schedulables and behave as these required classes.

The scheduler dispatches a schedulable, that is ready to run, on a CPU. Some systems, such as multicore systems, have more than one CPU to choose from. By default, a ready schedulable would be dispatched on the next available CPU; however, the specification provides an interface, `Affinity` to control, on which sets of CPUs a given schedulable may run.

An instance of the `SchedulingParameters` class contains values of execution eligibility. A schedulable is considered to have the execution eligibility represented

by the `SchedulingParameters` object currently bound to it. For implementations providing only the base scheduler, the scheduling parameters object is an instance of `PriorityParameters` (a subclass of `SchedulingParameters`).

An instance of the `ReleaseParameters` class or its subclasses, `PeriodicParameters`, `AperiodicParameters`, and `SporadicParameters`, contains values that define a particular release characteristic. A schedulable is considered to have the release characteristics of a single associated instance of the `ReleaseParameters` class.

For a realtime thread, the scheduler defines the behavior of the realtime thread's `waitForNextRelease` and `waitForNextReleaseInterruptible` methods. For all `Schedulables`, the scheduler monitors cost overrun and deadline miss conditions based on its release parameters. Release parameters also govern the treatment of the minimum interarrival time for sporadic schedulables.

The `ThreadGroup` class has special significance in an RTSJ implementation. As in conventional Java, the maximum priority of a thread is governed in part by its thread group, but the CPU affinity of a thread is also governed by its thread group along with the `Affinity` class. Furthermore, there are two important subclasses: `SchedulingGroup` and `ProcessingGroup`. These classes provide additional means of managing tasks.

An instance of the `SchedulingGroup` provides scheduling constraints for schedulables similar to how a `ThreadGroup` does for conventional Java threads. The scheduler and maximum `SchedulingParameters` can be set. In fact, a schedulable can only be created in an instance of `SchedulingParameters` or its subclass. Therefore the root thread group and the thread group of the initial thread must both be scheduling groups in an RTSJ implementation.

The `ProcessingGroup` class is a subclass of `SchedulingGroup`. An instance of the `ProcessingGroup` class contains values that define a temporal scope for a processing group. When a schedulable has an associated instance of the `ProcessingGroup` class, it is said to execute within the temporal scope defined by that instance. A single instance of the `ProcessingGroup` class can be, and typically is, associated with many schedulables. In an implementation that supports cost enforcement, the combined processor demand of all of the schedulables associated with an instance of the `ProcessingGroup` class must not exceed the values in that instance (i.e., the defined temporal scope). The processor demand is determined by the `Scheduler`.

The scheduling classes provide the necessary support for realtime scheduling. These classes

- enable the definition of schedulables,
- manage the assignment of execution eligibility to schedulable objects,
- manage the execution of instances of the `AsyncBaseEventHandler` and `Real-timeThread` classes,
- assign release characteristics to schedulables,

- assign execution eligibility values to schedulables, and
- manage the execution of groups of schedulables that collectively exhibit additional release characteristics.

6.2 Definitions

Task — a unit of independent execution. In conventional Java, this is a thread. The `Schedulable` interface marks realtime tasks. The classes that implement `Schedulable` are subject to the scheduling behavior of realtime schedulers. Instances of these classes are referred to as *Schedulables* (SO) and provide three execution states: *executing*, *blocked*, and *eligible-for-execution*.

1. *Executing* refers to the state where the schedulable is currently running on a processor.
2. *Blocked* refers to the state where the schedulable is not among those schedulables that could be selected to have their state changed to executing. The blocked state will have a reason associated with it, e.g., blocked-for-I/O-completion, blocked-for-release-event, or blocked-by-cost-overflow.
3. *Eligible-for-execution* refers to the state where the schedulable could be selected to have its state changed to executing.

Each type of schedulable defines its own *release events*, for example, the release events for a periodic schedulable are caused by the passage of time and occur at programmatically specified intervals.

Release — the changing of the state of a schedulable from blocked-for-release-event to eligible-for-execution. When the state of a schedulable is blocked-for-release-event and a release event occurs then the state of the schedulable is changed to eligible-for-execution.

Otherwise, a state transition from blocked-for-release-event to eligible-for-execution is queued; this is known as a *pending release*. When the next transition of the schedulable into state blocked-for-release-event occurs, and there is a pending release, the state of the schedulable is immediately changed to eligible-for-execution. (Some actions implicitly clear any pending releases.)

Completion — the changing of the state of a schedulable from executing to blocked-for-release-event. Each completion corresponds to a release. A realtime thread is deemed to complete its most recent release when it terminates.

Deadline — a time before which a schedulable should complete. The i^{th} deadline is associated with the i^{th} release event and a *deadline miss* occurs when the i^{th} completion would occur after the i^{th} deadline.

Deadline monitoring — the process by which the implementation responds to deadline misses. When a deadline miss occurs for a schedulable object, the deadline miss handler, if any, for that schedulable is released. This behaves

as if there were an asynchronous event associated with the schedulable, to which the miss handler was bound, and which was fired when the deadline miss occurred.

Periodic, Sporadic, and Aperiodic — adjectives applied to schedulables which describe the temporal relationship between consecutive release events. Let R_i denote the time at which a schedulable has had the i^{th} release event occur. Ignoring the effect of release jitter:

1. a schedulable is periodic when there exists a value $T > 0$ such that for all i , $R_{i+1} - R_i = T$, where T is called the period;
2. a schedulable that is not periodic is said to be aperiodic; and
3. an aperiodic schedulable is said to be sporadic when there is a known value $T > 0$ such that for all i , $R_{i+1} - R_i \geq T$. T is then called the minimum interarrival time (MIT).

cost — the maximum amount of CPU time that a schedulable is allowed between a release and its associated completion.

Current CPU Consumption — the amount of CPU time that the schedulable has consumed since its last release.

Cost Overrun — the time at which a schedulable's current CPU consumption becomes greater than, or equal to, its cost.

Cost Monitoring — the process by which the implementation tracks CPU consumption and responds to cost overruns. When a cost overrun occurs for a schedulable, its cost overrun handler, if any, is released. This behaves as if there were an asynchronous event associated with the schedulable, to which the overrun handler was bound, and which is fired when a cost overrun occurs.

Cost Enforcement — the process by which the implementation ensures that the CPU consumption of a schedulable is no more than the value of the cost parameter in its associated `ReleaseParameters`. (Cost enforcement is an optional facility in an implementation of the RTSJ.)

Base Priority — the priority given in a schedulable's associated `PriorityParameters` object; the base priority of a Java thread is the priority returned by its `getPriority` method.

Enforced Priority — a priority below the idle priority, which ensures the schedulable has no execution eligibility.

Active Priority in the enforced state, the maximum of the *enforced priority* and any priority a task has acquired due to the action of priority inversion avoidance algorithms (see the *Synchronization Chapter*); otherwise, the maximum of a task's base priority and any priority it has acquired due to the action of priority inversion avoidance algorithms.

Processing Group — a collection of tasks whose combined execution has further execution time constraints which the scheduler uses to govern the group's

execution eligibility.

Base Scheduler — an instance of the `FirstInFirstOutScheduler` class as defined in this specification. This is the initial default scheduler.

Round-Robin Scheduler — an instance of the `RoundRobinScheduler` class as defined in this specification. It is specified to execute in tandem with the base scheduler in a predictable fashion.

Processor — a logical processing element that is capable of physically executing a single thread of control at any point in time. Hence, multicore platforms have multiple processors, platforms that support hyperthreading also have more than one processor. It is assumed that all processors are capable of executing the same instruction sets.

Affinity — is a set of processors on which the global scheduling of a schedulable can be supported.

Idle Task — a notional system or VM-provided task that consumes all CPU time not used by other tasks. It may be an actual process or thread, or it may be a power-saving mode that halts or slows the CPU, or it may be an artificial construction. For the purposes of this specification, it has a priority below that of all non-blocked tasks and above that of tasks blocked due to cost overrun. Details of its implementation are not specified here.

6.3 Semantics

Scheduling semantics determines which task runs when. Both *The Java Virtual Machine Specification*[6] and *The Java Language Specification*[5] are silent on the semantics for scheduling; only for semantics for synchronization is provided. Since scheduling is central to realtime programming, here is a detail semantic applicable across the classes defined below, along with definitions of the required scheduling algorithms. Semantics that apply to particular classes, constructors, methods, and fields can be found in the class description and the constructor, method, and field detail sections.

6.3.1 Schedulers

There are four basic requirements for schedulers.

1. A scheduler may only change the execution eligibility of the schedulables which it manages and only in accordance with its scheduling algorithm.
2. Each scheduler provided for application code by an RTSJ implementation must have documentation describing its semantics including at least the following: the algorithm used to determine eligibility, what schedulables may be scheduled by it, the subclasses of `Scheduler` and `SchedulingParameters` used to control

the scheduler, and any other classes needed by the scheduler.

3. Every implementation must provide a round-robin scheduler and a first in first out scheduler using priorities above the ten (1–10) conventional Java priorities as documented below.
4. Tasks with a conventional Java priority (1–10) should be scheduled such that when two or more threads run at the same priority, one thread cannot block another indefinitely and not violate the requirements dictated by `java.lang.Thread`.

The scheduler can be changed independently of the `SchedulingParameters` and vice versa only when the `Schedulable` in question is descheduled. Rescheduling will throw an `IllegalStateException` when called on a `Schedulable` scheduling parameters that are inconsistent with its scheduler. Trying to add a handler with `SchedulingParameters` that do not match its scheduler to an event will also result in an `IllegalStateException` being thrown.

6.3.2 The Base Scheduler

The semantics for the base scheduler assume a uniprocessor or shared memory multiprocessor execution environment. Scheduling is priority preemptive with run to completion, also known as first-in-first-out (FIFO) semantics. The base scheduler supports the execution of all schedulables.

6.3.2.1 Priorities

The base scheduler is a priority scheduler with the following requirements.

1. The base scheduler must support at least 28 distinct values (realtime priorities) that can be stored in an instance of `PriorityParameters` in addition to the values 1 through 10 required to support the priorities defined by `java.lang.Thread`.
2. The realtime priority values must be greater than 10, and they must include all integers from the base scheduler's `getMinPriority()` value to its `getMaxPriority()` value inclusive.
3. Higher priority values in an instance of `PriorityParameters` have a higher execution eligibility.
4. The 10 priorities defined for `java.lang.Thread` must effectively have lower execution eligibility than the realtime priorities.
5. When the round-robin scheduler is present, the base scheduler must support at least one priority value numerically greater than the maximum allowable round-robin priority.
6. For realtime scheduling, the base priority of each `Schedulable` under the control of the base scheduler must be from the range of realtime priorities. A

- Schedulable** with a priority in the `java.lang.Thread` range will be scheduled as if it were an instance of `java.lang.Thread`.
7. Assignment of any of the realtime priority values to any **Schedulable** controlled by the base priority scheduler is legal. It is the responsibility of application logic to make rational priority assignments.
 8. The base scheduler does not use the `importance` value in the `ImportanceParameters` subclass of `PriorityParameters`.
 9. Calling the `java.lang.Thread.setPriority` on a thread can only be used to set the thread's priority to a conventional Java priority (1–10).
 10. For schedulables managed by the base scheduler, the implementation must not change the execution eligibility for any reason other than
 - (a) the implementation of a priority inversion avoidance algorithm requires it, or
 - (b) as a result of a program's request to change the priority parameters associated with one or more schedulables; e.g., by changing a value in a scheduling parameter object that is used by one or more schedulables, or by using `setSchedulingParameters()` to give a schedulable a different `SchedulingParameters` value.
 11. Use of `Thread.setPriority()`, any of the methods defined for schedulables, or any of the methods defined for parameter objects must not affect the correctness of the priority inversion avoidance algorithms controlled by `PriorityCeilingEmulation` and `PriorityInheritance`—see Chapter 7.
 12. When schedulable *A* managed by the base scheduler creates a Java thread, *B*, then the initial base priority of *B* is the minimum of the priority value returned by the `getMaxPriority` method of *B*'s `java.lang.ThreadGroup` object and the priority of *A*.
 13. `PriorityScheduler.getNormPriority()` shall be set to

```

1 ((PriorityScheduler.getMaxPriority() -
2  PriorityScheduler.getMinPriority()) / 3) +
3  PriorityScheduler.getMinPriority()
      
```

 14. Hardware priorities, where supported, have values above the base scheduler's priority range (see Section 12.3.4).

6.3.2.2 Dispatching

The execution scheduling semantics described in this section are defined in terms of a conceptual model that contains a set of queues of schedulables that are eligible for execution. There is, conceptually, one queue for each priority on each processor. No implementation structures are necessarily implied by the use of this conceptual

model. It is assumed that no time elapses during operations described using this model, and therefore no simultaneous operations are possible.

The RTSJ dispatching model specifies its dispatching rules for the default priority scheduler.

1. A **Schedulable** can become a running schedulable only when it is ready and one of the processors in its requested affinity is available.
2. When two schedulables have different active priorities and request the same processor, the schedulable with the higher active priority will always execute in preference to the schedulable with the lower value when both are eligible for execution.
3. Processors are allocated to schedulables based on each schedulable's active priority and their associated affinity.
4. Schedulable dispatching is the process by which one ready schedulable is selected for execution on a processor. This selection is done at certain points during the execution of a schedulable called *schedulable dispatching points*.
5. A schedulable reaches a *schedulable dispatching point* whenever it becomes blocked, when it terminates, or when a higher priority schedulable becomes ready for execution on its processor. That is, a schedulable that is executing will continue to execute until it either blocks, terminates or is preempted by a higher-priority schedulable.
6. The dispatching policy is specified in terms of ready queues and schedulable states. The ready queues are purely conceptual; there is no requirement that such lists physically exist in an implementation. A ready queue is an ordered list of ready schedulable objects. The first position in a queue is called the head of the queue, and the last position is called the tail of the queue.
7. A schedulable is ready when it is in a ready queue, or when it is running. Each processor has one ready queue for each priority value. At any instant, each ready queue of a processor contains exactly the set of schedulables of that priority that are ready for execution on that processor, but are not running on any processor; that is, those schedulables that are ready, are not running on any processor, and can be executed using that processor.
8. A schedulable can be on the ready queues of more than one processor.
9. Each processor has one running schedulable, which is the schedulable currently being executed by that processor. Whenever a schedulable running on a processor reaches a schedulable dispatching point, a new schedulable object is selected to run on that processor. The schedulable selected is the one at the head of the highest priority nonempty ready queue for that processor; this schedulable is then removed from all ready queues to which it belongs.
10. In a multiprocessor system, a schedulable can be on the ready queues of more than one processor. At the extreme, when several processors share the same set

of ready schedulables, the contents of their ready queues are identical, and so they can be viewed as sharing one ready queue, and can be implemented that way. Thus, the dispatching model covers multiprocessors where dispatching is implemented using a single ready queue, as well as those with separate dispatching domains.

11. The dispatching mechanism must enable the preemption of the execution of schedulables and Java threads with a bounded delay at a point not governed by the preempted object. The bound on this delay may be implementation-defined, and could be the time to the next point in execution that the heap is in a consistent state or some similar restriction. The implementation should document this bound.
12. A schedulable that is preempted by a higher priority schedulable is placed in the queue for its active priority, at a position determined by the implementation. The implementation must document the algorithm used for such placement. It is recommended that a preempted schedulable be placed at the front of the appropriate queue.
13. A realtime thread that performs a `yield()` is placed at the tail of the queue (dictated by its affinity) for its active priority level.
14. A blocked schedulable that becomes eligible for execution is added to the tail of the queues (dictated by its affinity) for that priority. This behavior also applies to the initial release of a schedulable.
15. A schedulable whose active priority is raised as a result of explicitly setting its base priority (through the `PriorityParameters` `setPriority()` method, the `RealtimeThread` `setSchedulingParameters()` method, or `Thread`'s `setPriority()` method) is added to the tail of the queues (dictated by its affinity) for its new priority level.
16. Queuing when priorities are adjusted by priority inversion avoidance algorithms is governed by semantics specified in the *Synchronization* chapter.

6.3.2.3 Parameter Values

The scheduler uses the values contained in the different parameter objects associated with a schedulable to control the behavior of the schedulable. The scheduler determines what values are valid for the schedulables it manages, which defaults apply and how changes to parameter values are acted upon by the scheduler. Invalid parameter values result in exceptions, as documented in the relevant classes and methods.

1. The default values for the base scheduler are as follows.
 - (a) Scheduling parameters are copied from the creating schedulable when possible; when the creating schedulable does not have scheduling parameters, the default is an instance of the default priority parameters value.

- (b) Release parameters default to an instance of the default aperiodic parameters (see **AperiodicParameters**).
- (c) Memory parameters default to **null** which signifies that memory allocation by the schedulable is not constrained by the scheduler.
- (d) The default scheduling parameter values for parameter objects created by a schedulable controlled by the base scheduler are given by the following table (see **FirstInFirstOutScheduler**).

Attribute	Default Value
<i>Priority parameters</i> priority	norm priority
<i>Importance parameters</i> importance	No default. A value must be supplied.

2. All numeric or **RelativeTime** attributes in parameter values must be greater than or equal to zero.
3. Values of period must be greater than zero.
4. Deadline values in **ReleaseParameters** objects must be less than or equal to their period values (where applicable), but the deadline may be greater than the minimum interarrival time in a **SporadicParameters** object.
5. Changes to scheduling, release, memory, and processing group parameters (by methods on the schedulables bound to the parameters or by altering the parameter objects themselves) have the following effects.
 - (a) They potentially modify the behavior of the scheduler with regard to those schedulables. When such changes in behavior take effect depends on the parameter in question, and the type of schedulable, as described below.
6. When changes to a parameter type—scheduling, release, memory, and processing group—take effect depends on the parameter type.
 - (a) Changes to scheduling parameters take effect immediately except when constrained by priority inversion avoidance algorithms.
 - (b) Changes to release parameters depend on the parameter being changed, the type of release parameter object and the type of schedulable:
 - i. changes to the deadline and the deadline miss handler take effect at each release event as follows: when the i_{th} release event occurred at a time t_i , then the i^{th} deadline is the time $t_i + D_i$, where D_i is the value of the deadline stored in the schedulable's release parameters object at the time t_i . When a deadline miss occurs then it is the deadline miss handler that was installed in the schedulable's release parameters at time t_i that is released;
 - ii. changes to cost and the cost overrun handler take effect immediately;

- iii. changes to the period and start time values in **PeriodicParameters** objects are described in “Release of realtime Threads” below;
 - iv. changes to the additional values in **AperiodicParameters** objects and **SporadicParameters** are described, respectively, in “Aperiodic Release Control” and “Sporadic Release Control”, below; and
 - v. changes to the type of release parameters object generally take effect after completion, except as documented in the following sections.
- (c) Changes to memory parameters take effect immediately.
 - (d) Changes to processing group parameters take effect as described in “Processing Groups” below.
 - (e) Changes to the scheduler responsible for a schedulable object take effect at completion.
 - (f) Changes to cost enforcement state (i.e., enabling or disabling cost enforcement on a processing group or release parameters object associated with one or more schedulables) take effect at the next release of the associated **ProcessingGroup** or associated **Schedulable**, respectively.

6.3.2.4 Cost Monitoring and Cost Enforcement

The cost of a schedulable is defined by the value returned by invoking the **getCost** method of the schedulable’s release parameters object. When a schedulable is initially released its current CPU consumption is zero, and as the schedulable executes the current CPU consumption increases. For cost monitoring, an implementation must conform to the following requirements.

1. If, at any time, due to either execution of the schedulable or a change in the schedulable’s cost, the current CPU consumption becomes greater than or equal to the current cost of the schedulable, then a cost overrun is triggered.
2. The implementation is required to document the granularity at which the current CPU consumption is updated.
3. When a cost overrun is triggered, the cost overrun handler associated with the **Schedulable**, if any, is released. No further action is taken.
4. The current CPU consumption is reset to zero when the schedulable is next released (i.e. it moves from the blocked-for-release-event state to the eligible-for-execution state).

When cost enforcement is supported, an implementation must conform to the following requirements.

1. When a cost overrun is triggered, in addition to releasing any cost overrun handler, the following actions must be performed.
 - (a) When the most recent release of the schedulable is the i^{th} release, and the $i + 1$ release event has not yet occurred, the following must hold.
 - i. When the state of the schedulable is either executing or eligible-for-

- execution, the schedulable is placed into the state blocked-by-cost-overflow. There may be a bounded delay between the time at which a cost overflow occurs and the time at which the schedulable becomes blocked-by-cost-overflow.
- ii. Otherwise, the schedulable must have been blocked for a reason other than blocked-by-cost-overflow. In this case, the state change to blocked-by-cost-overflow is left pending; when the blocking condition for the schedulable is removed, then its state changes to blocked-by-cost-overflow. There may be a bounded delay between the time at which the blocking condition is removed and the time at which the schedulable becomes blocked-by-cost-overflow.
- (b) When the most recent release of the schedulable is the i^{th} release, and the $i + 1$ release event has occurred, the current CPU consumption is set to zero, the schedulable remains in its current state and the cost monitoring system considers the most recent release to now be the $i + 1$ release.
2. When the i^{th} release event occurs for a schedulable, the action taken depends on the state of the schedulable.
 - (a) When the schedulable is blocked-by-cost-overflow then the cost monitoring system considers the most recent release to be the i^{th} release, the current CPU consumption is set to zero and the schedulable is made eligible for execution;
 - (b) When the schedulable is blocked for a reason other than blocked-by-cost-overflow then
 - i. when there is a pending state change to blocked-by-cost-overflow then the pending state change is removed, the cost monitoring system considers the most recent release to be the i^{th} release, the current CPU consumption is set to zero, and the schedulable remains in its current blocked state;
 - ii. otherwise, no cost monitoring action occurs.
 - (c) When the schedulable is not blocked, no cost monitoring action occurs.
 3. When the i^{th} release of a schedulable completes, and the cost monitoring system considers the most recent release to be the i^{th} release, then the current CPU consumption is set to zero and the cost monitoring system considers the most recent release to be the $i + 1$ release. Otherwise, no cost monitoring action occurs.
 4. Changes to the cost parameter take effect immediately.
 - (a) When the new cost is less than or equal to the current CPU consumption, and the old cost was greater than the current CPU consumption, then a cost overflow is triggered.
 - (b) When the new cost is greater than the current CPU consumption,

- i. in the case that the schedulable is blocked-by-cost-overflow, the schedulable is made eligible for execution;
 - ii. in the case that the schedulable is blocked for a reason other than blocked-by-cost-overflow and there is a pending state change to blocked-by-cost-overflow, the pending state change is removed;
 - iii. in all other cases, no cost monitoring action occurs.
- 5. When a schedulable changes state to blocked-by-cost-overflow, it must behave as if its base priority has been reduced to a priority below that of the idle task. In other words, unless its active priority has been modified by a priority inversion avoidance algorithm as defined in this specification, it should not be scheduled on any CPU. Upon moving out of this state, it will resume execution as if its base priority had been restored to its configured base priority.
- 6. The state of the cost monitoring system for a schedulable can be *reset* by the scheduler (see 6.3.2.5 in the **Release of a Realtime Thread** section, below). When the most recent release of the schedulable is considered to be the m^{th} release and the most recent release event for the schedulable was the n^{th} release event (where $n > m$), a reset causes the cost monitoring system to consider the most recent release to be the n^{th} release, and to zero the current CPU consumption.

6.3.2.5 Release of a Realtime Thread

The repeated release of a realtime thread is achieved by executing in a loop and invoking the `RealtimeThread.waitForNextRelease`¹ methods, or its interruptible equivalent `RealtimeThread.waitForNextReleaseInterruptible`) within that loop. For simplicity, unless otherwise stated, the semantics in this section apply to both forms of this method.

1. A realtime thread's release characteristics are determined by the following:
 - (a) the invocation of the realtime thread's `start` method and the value of its phasing policy parameter (if applicable);
 - (b) the action of the `RealtimeThread` methods `waitForNextRelease`, `schedule`, and `deschedule`;
 - (c) the occurrence of deadline misses and whether or not a miss handler is installed; and
 - (d) whether the passing of time generates periodic release events or calls to the `release` method generates aperiodic release events.
2. The *initial release event* depends on the type of release parameters given the realtime thread:

¹The method `RealtimeThread.waitForNextPeriod` has been replaced by `RealtimeThread.waitForNextRelease` as of RTSJ 2.0. The same goes for its interruptible equivalent.

- (a) for a realtime thread with periodic parameters, the *initial release event* occurs in response to the invocation of its **start** method in accordance with the start time specified in its release parameters and its assigned phasing policy—see **PeriodicParameters** and **PhasingPolicy**;
 - (b) For a realtime thread with aperiodic parameters, the *initial release event* occurs immediately in response to the invocation of its **start** method.
3. Changes to the start time in a realtime thread’s **PeriodicParameters** object only have an effect on its initial release time. Consequently, when a **PeriodicParameters** object is bound to multiple realtime threads, a change in the start time may affect all, some or none, of those threads, depending on whether or not **start** has been invoked on them.
 4. When subsequent release events occur also depends on the type of release parameters given to the realtime thread:
 - (a) for periodic realtime threads, each period (and hence each release) falls due, except as described below (in 6d), at regular intervals such that when the i^{th} release event occurred at a time t_i , the $i + 1$ release event occurs at the time $t_i + T_i$, where T_i is the value of the period stored in the realtime thread’s **PeriodicParameters** object at the time t_i ;
 - (b) for aperiodic realtime threads, a release occurs with each call of the release method, except as described below (in 6d); and
 - (c) for sporadic realtime threads, a release occurs with each call of the release method, except, as described below (in 6d), when additional regulation is required to enforce MIT as defined in *Sporadic Release Control* below.
 5. Each release of an aperiodic realtime thread is an arrival.
 - (a) When the thread has release parameters of type **AperiodicParameters**, then the arrival may become a release event for the thread according to the semantics given in “Aperiodic Release Control” below.
 - (b) When the thread has release parameters of type **SporadicParameters**, then the arrival may become a release event for the thread according to the semantics given in “Sporadic Release Control” below.
 - (c) When the thread has release parameters of a type other than **SporadicParameters** then the arrival is a release event, and the arrival-time is the release event time.
 6. The implementation should behave effectively as if the following state variables were added to a realtime thread’s state,
 - boolean **descheduled**,
 - integer **pendingReleases**,
 - integer **missCount**, and
 - boolean **lastReturn**;
 and manipulated by the actions as described below.
 - (a) Initially

- `descheduled` = false,
 - `pendingReleases` = 0,
 - `missCount` = 0, and
 - `lastReturn` = true.
- (b) When the realtime thread's `deschedule` method is invoked: set the value of `descheduled` to true. When `descheduled` is true, the realtime thread is said to be *descheduled*.
- (c) When the realtime thread's `schedule` method is invoked: set the value of `descheduled` to false; then when the thread is blocked-for-release-event, set the value of `pendingReleases` and `missCount` to zero, and tell the cost monitoring and enforcement system to reset for this thread.
- (d) A realtime thread that has been descheduled and is blocked-for-release-event will not receive any further release events until after it has been rescheduled by a call to `schedule`; this means that no deadline misses can occur until the thread has been rescheduled.
- (e) When each release event occurs
 - i. when the state of the realtime thread is blocked-for-release-event (that is, it is waiting in `waitForNextRelease`) and the thread is descheduled then do nothing,
 - ii. when the state is blocked-for-release-event and the thread is scheduled, increment the value of `pendingReleases`, inform cost monitoring and enforcement that the next release event has occurred, and notify the thread to make it eligible for execution;
 - iii. otherwise when the thread is in a release, increment the value of `pendingReleases`, and inform cost monitoring and enforcement that the next release event has occurred.
- (f) On each deadline miss, there are two cases:
 - i. When the realtime thread has a deadline miss handler, set the value of `descheduled` to true, atomically release the handler with its `fireCount` increased by the value of `missCount + 1`, and zero `missCount`;
 - ii. Otherwise, add one to the `missCount` value.
- (g) When the `waitForNextRelease` method is invoked by the current realtime thread there are three possible behaviors depending on the value of `missCount` and `lastReturn`.
 - i. When `missCount` is zero, apply any pending parameter changes, inform cost monitoring and enforcement of completion, and then wait while `descheduled` is true, or `pendingReleases` is zero. Then set the `lastReturn` value to true, decrement `pendingReleases`, and return true.
 - ii. When `missCount` is greater than zero and the `lastReturn` value is false, completion occurs: decrement the `missCount` value; then

- apply any pending parameter changes, decrement `pendingReleases`, inform cost monitoring and enforcement the realtime thread has completed and return `false`;
- iii. Otherwise, when `missCount` is greater than zero and the `lastReturn` value is `true`, decrement the `missCount` value and set the `lastReturn` value to `false` and return `false`.
7. An invocation of the `waitForNextRelease` method with release parameters where `ReleaseParameters.isRousable` return `true` behaves as described above with the following differences.
- (a) When the invocation commences with an instance of `AsynchronouslyInterruptedException` (AIE) is pending on the realtime thread, then the invocation immediately completes abruptly by throwing that pending instance as an `InterruptedException`. When this occurs, the most recent release has not completed. When the pending instance is the generic AIE instance, then the interrupt state of the realtime thread is cleared.
 - (b) When an instance of AIE becomes pending on the realtime thread while it is blocked-for-release-event, and the realtime thread is descheduled, then the AIE remains pending until the realtime thread is no longer descheduled. The associated reschedule acts as a release event. Execution then continues as in 7d where the time value used as t_{int} is the time at which the schedulable was rescheduled.
 - (c) When an instance of AIE becomes pending on the realtime thread while it is blocked-for-release-event and it is not descheduled, then this acts as a release event. Execution then continues as in 7d, where the time value used as t_{int} is the time at which the AIE becomes pending.
 - (d)
 - i. The realtime thread is made eligible for execution.
 - ii. Upon execution, the invocation completes abruptly by throwing the pending AIE instance as an `InterruptedException`. When the pending instance is the generic AIE instance then the interrupt state of the realtime thread is cleared.
 - iii. The deadline associated with this release is the time $t_{int} + D_{int}$, where D_{int} is the value of the deadline stored in the realtime thread's release parameters object at the time t_{int} .
 - iv. The next release time for the realtime thread will be $t_{int} + T_{int}$, where T_{int} is the value of the period stored in the realtime thread's release parameters object at the time t_{int} .
 - v. Cost monitoring and enforcement is informed of the release event.

When the thrown AIE instance is caught, the AIE becomes pending again (as per the usual semantics for AIE) until it is explicitly cleared.

8. Changes to release parameter types are treated as a pseudo RESTART of the

realtime thread and

- (a) any old pending releases are cleared
- (b) any old arrival queue is flushed
- (c) any outstanding call to deschedule is cleared
- (d) any outstanding deadline misses are cleared

The effect on the thread falls into one of four main cases.

- (a) When the realtime thread is not waiting for next release event and is not descheduled,
 - i. there is no effect until the end of current release, and
 - ii. when the change occurs, it is a pseudo restart of the thread, i.e., when the new parameters are aperiodic, the release is immediate and when the parameters are periodic, the periodic start time algorithm is used.
- (b) When the realtime thread is not waiting for next release event, but there is an outstanding descheduled,
 - i. there is an immediate “schedule” of the thread,
 - ii. there is no further effect until end of current release, and
 - iii. when change occurs, it is a pseudo restart of the thread, i.e., when new parameters are aperiodic, the release is immediate, and when new parameters are periodic, the periodic start time algorithm is used.
- (c) When the realtime thread is waiting for next release event, is not descheduled, and the release parameter type is changed,
 - i. from Periodic to Aperiodic, at the next periodic release event occurs, the thread becomes aperiodic with an immediate release, or
 - ii. from Aperiodic to Periodic, there is an immediate pseudo restart of the thread using the periodic start time algorithm.
- (d) When the realtime thread is waiting for the next release event and the type of release parameters is changed, but there is an outstanding descheduled,
 - i. the change is from Periodic to Aperiodic, there is an immediate “schedule” of the thread, and when the next periodic release event occurs, the thread becomes aperiodic with an immediate release, or
 - ii. the change is from Aperiodic to Periodic, there is an immediate “schedule” of the thread and there is an immediate pseudo restart of the thread using the periodic start time algorithm.

6.3.2.5.1 UML Diagrams for Realtime Thread Releases The three UML diagrams in Figures 6.1, 6.2, and 6.3, are provided to illustrate the foregoing rules for releasing realtime threads. The first two figures are for a thread without a deadline miss handler. The first is a UML sequence diagram of some example Realtime Thread releases. The second is a UML state chart of the release process for a realtime thread. The third is a UML state chart of the release process for a realtime thread with a

Figure 6.1: Sequence Diagram of Some Example Realtime Thread Releases

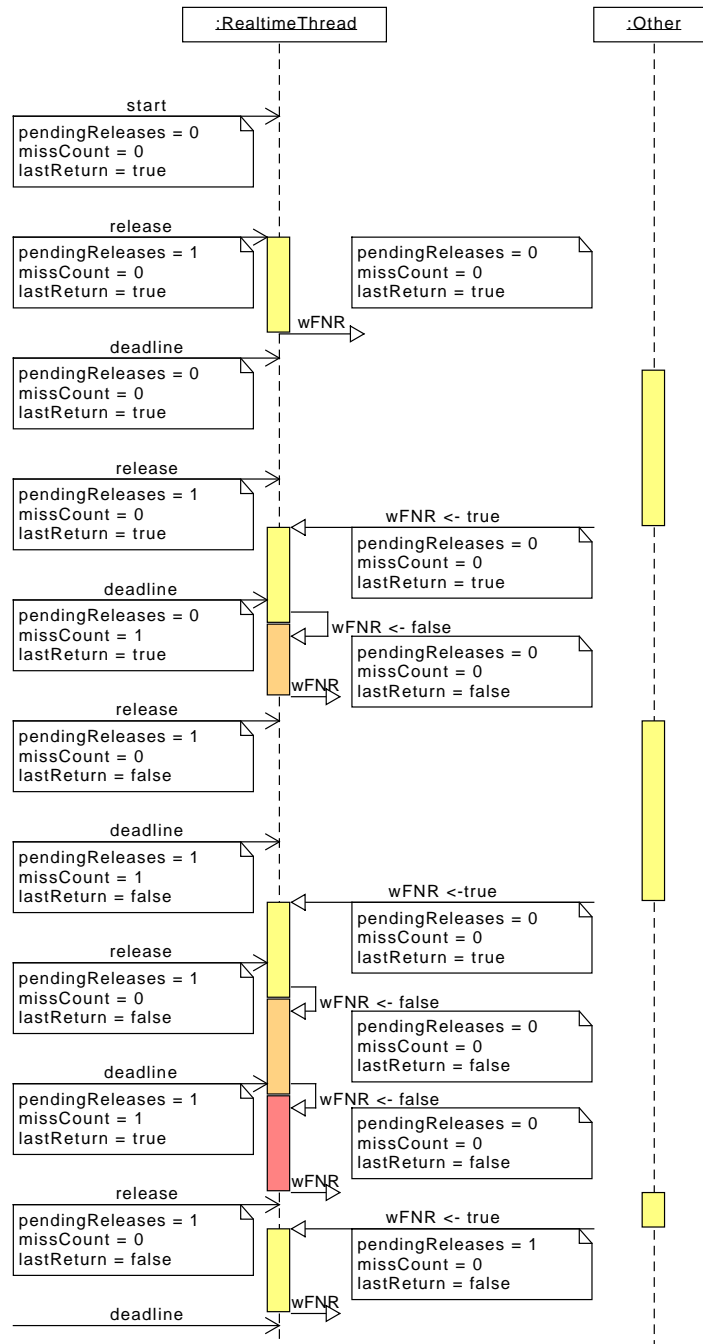


Figure 6.2: A State Chart for a Realtime Thread without a Deadline Miss Handler

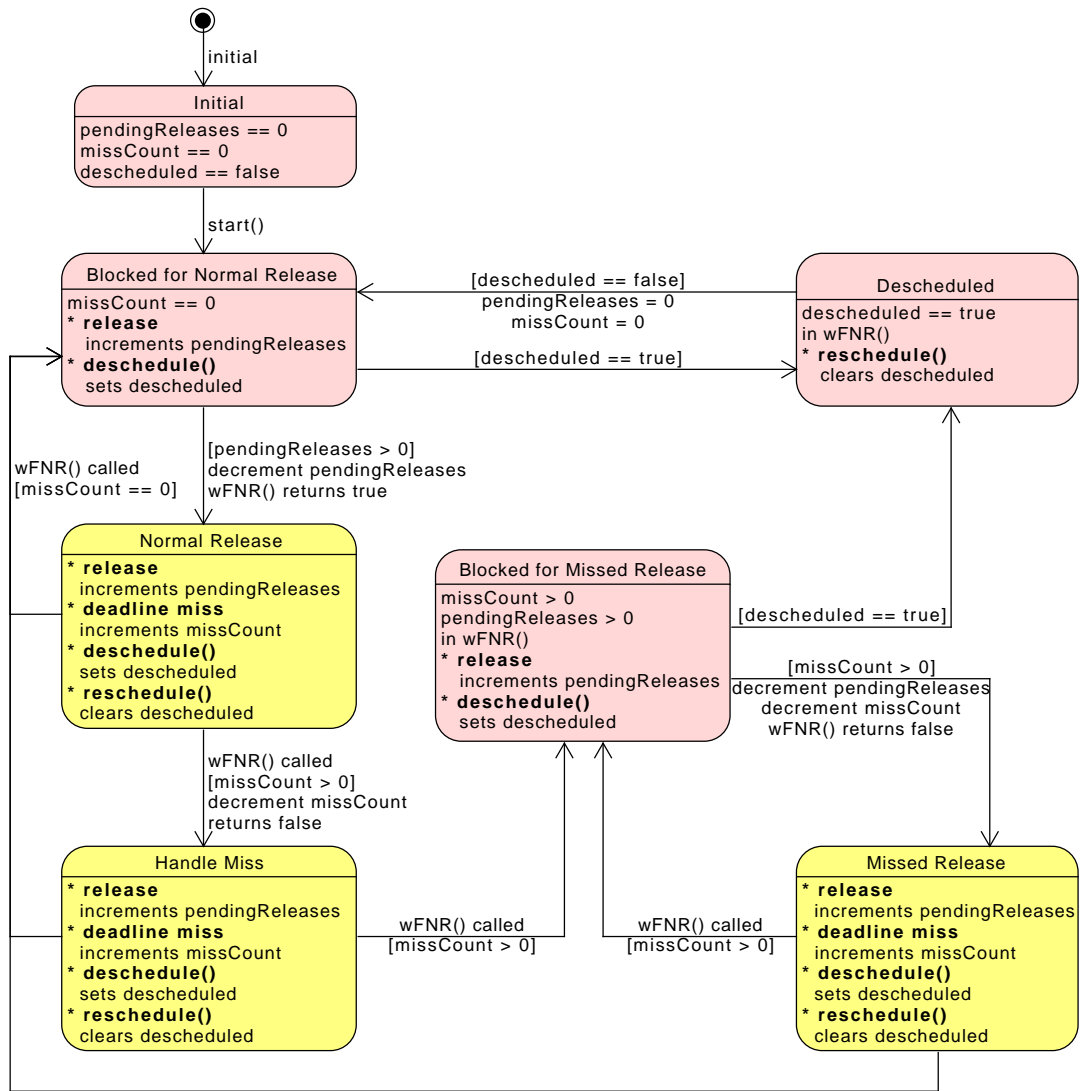
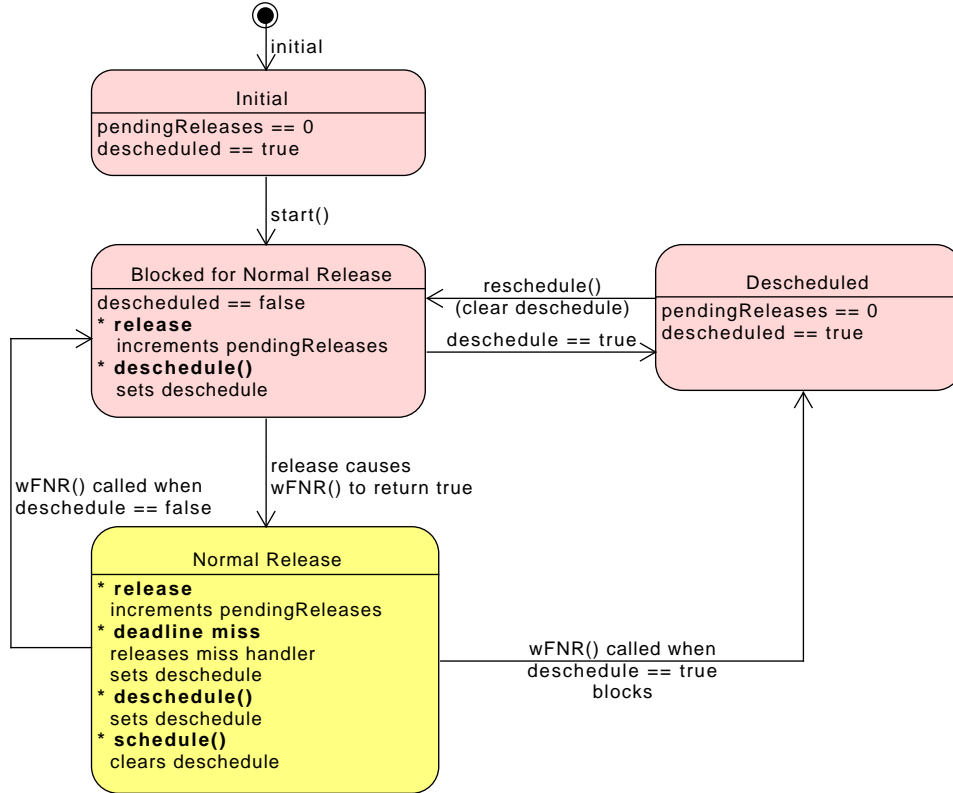


Figure 6.3: A State Chart for a Realtime Thread with a Deadline Miss Handler



deadline miss handler.

In Figure 6.1, a yellow background marks the execution of a normal release, an orange background marks the execution of a miss handler, and a red background marks the execution of a missed release. Both the miss handler and all missed releases are eligible to run as soon as the previous release is finish. A normal release, which encounters a deadline miss during its execution is not complete until its miss handler completes.

In the other two figures, a yellow background marks releases and a pink background marks blocked states. There are three release states: normal release, miss handler, and missed release. They can only be left by a call to `waitForNextRelease` or its equivalent. The miss handler state is part of a normal release that misses its deadline during the release. There are two blocked-for-release-event states: blocked for normal release and blocked for missed release. It is only in these states that descheduling can occur, because only completion occurs upon their entry. In addition, the blocked

for missed release is a ephemeral state, since the deadline miss has already occurred before the state is entered, so state is left immediately. It is there to enable all actions that occur on completion.

6.3.2.6 Aperiodic Release Control

Aperiodic schedulables are released in response to events occurring, such as the starting of a realtime thread, the calling of the `release` method of a realtime thread, or the firing of an associated asynchronous event for an asynchronous event handler. The occurrence of these events, each of which is a potential release event, is termed an *arrival*, and the time that they occur is termed the *arrival time*.

The base scheduler behaves effectively as if it maintained a queue, called the arrival time queue, for each aperiodic schedulable object. This queue maintains information related to each release event (including any parameters passed with the release mechanism) from its “arrival” time until the associated release completes, or another release event occurs — whichever is later. When an arrival is accepted into the arrival time queue, then it is a release event and the time of the release event is the arrival time. The initial size of this queue is an attribute of the schedulable’s aperiodic parameters, and is set when an aperiodic parameter object is first associated with the schedulable. Over time the queue may become full and its behavior in this situation is determined by the queue overflow policy specified in the schedulable’s aperiodic parameters. There are four overflow policies defined:

Policy	Action on Overflow
IGNORE	Silently ignore the arrival. The arrival is not accepted, no release event occurs, and, when the arrival was caused programmatically (such as by invoking <code>fire</code> on an asynchronous event), the caller is not informed that the arrival has been ignored.
EXCEPT	Throw an <code>ArrivalTimeQueueOverflowException</code> . The arrival is not accepted, and no release event occurs, but when the arrival was caused programmatically, the caller will have <code>ArrivalTimeQueueOverflowException</code> thrown.

REPLACE	The arrival is not accepted and no release event occurs. When the completion associated with the last release event in the queue has not yet occurred, and the deadline has not been missed, the release event time for that release event is replaced with the arrival time of the new arrival and any associated parameters overwritten. This will alter the deadline for that release event. When the completion associated with the last release event has occurred, or the deadline has already been missed, the behavior of the REPLACE policy is equivalent to the IGNORE policy.
SAVE	Behave effectively as if the queue were expanded as necessary to accommodate the new arrival. The arrival is accepted and a release event occurs.

Under the **SAVE** policy the queue can grow and shrink over time.

Changes to the queue overflow policy take effect immediately. When an arrival occurs and the queue is full, the policy applied is the policy as defined at that time.

6.3.2.7 Sporadic Release Control

Sporadic parameters include a minimum interarrival time, MIT, that characterizes the expected frequency of releases. When an arrival is accepted implementation behaves as if it calculates the earliest time at which the next arrival could be accepted, by adding the current MIT to the arrival time of this accepted arrival. The scheduler guarantees that each sporadic schedulable it manages, is released at most once in any MIT. It implements two mechanisms for enforcing this rule:

1. *Arrival-time regulation* controls the work-load by considering the time between arrivals. When a new arrival occurs earlier than the expected next arrival time then a MIT violation has occurred, and the scheduler acts to prevent a release from occurring that would break the “one release per MIT” guarantee. Three arrival-time MIT-violation policies are supported:

Policy	Action on Violation
IGNORE	Silently ignore the violating arrival. The arrival is not accepted, no release event occurs, and, when the arrival was caused programmatically (such as by invoking fire on an asynchronous event), the caller is not informed that the arrival has been ignored.

EXCEPT	Throw a <code>MITViolationException</code> . The arrival is not accepted, and no release event occurs, but when the arrival was caused programmatically, the caller will have <code>MITViolationException</code> thrown.
REPLACE	The arrival is not accepted and no release event occurs. When the completion associated with the last release event in the queue has not yet occurred, and the deadline has not been missed, then the release event time for that release event is replaced with the arrival time of the new arrival and any associated parameters overwritten. This will alter the deadline for that release event. When the completion associated with the last release event has occurred, or the deadline has already been missed, the behavior of the REPLACE policy is equivalent to the IGNORE policy.

2. *Execution-time regulation* occurs when the MIT violation policy SAVE is in effect. Under this policy all arrivals are accepted, but the scheduler behaves effectively as if released schedulable objects were further constrained by a scheduling policy that restricts execution to at most one release per MIT. This policy is only able to delay the effective release of a schedulable. The deadline of each release event is always set relative to its arrival time. This policy may not schedule the effective release of an async event handler until after its deadline has passed. In this case the deadline miss handler is released at the deadline time even though the related async event has not yet reached its effective release.

The SAVE policy makes no direct use of the next expected arrival time, but it maintains the value in case the MIT violation policy is changed from SAVE to one of the arrival-time regulation policies.

The *effective release time* of a release event i is the earliest time that the handler can be released in response to that release event. It is determined for each release event based on the MIT policy in force at the release event time:

1. For IGNORE, EXCEPT and REPLACE the effective release time is the release event time.
2. For SAVE the effective release time of release event i is the effective release time of release event $i-1$ plus the current value of the MIT.

The scheduler will delay the release associated with the release event at the head of the arrival time queue until the current time is greater than or equal to the effective release time of that release event.

Changes to minimum interarrival time and the MIT violation policy take effect immediately, but only affect the next expected arrival time, and effective release

time, for release events that occur after the change.

6.3.2.8 Release Control for Asynchronous Event Handlers

Asynchronous event handlers can be associated with one or more asynchronous events. When an asynchronous event is fired, all handlers associated with it are released, according to the semantics below:

1. Each firing of an associated asynchronous event is an arrival. If the handler has release parameters of type **AperiodicParameters**, then the arrival may become a release event for the handler, according to the semantics given in “Aperiodic Release Control” above. When the handler has release parameters of type **SporadicParameters**, the arrival may become a release event for the handler, according to the semantics given in “Sporadic Release Control” above. When the handler has release parameters of a type other than **SporadicParameters**, the arrival is a release event, and the arrival-time is the release event time.
2. For each release event that occurs for a handler, an entry is made in the arrival-time queue and the handler’s **fireCount** is incremented by one.
3. Initially a handler is considered to be blocked-for-release-event and its **fireCount** is zero.
4. Releases of a handler are serialized by having its **handleAsyncEvent** method invoked repeatedly while its **fireCount** is greater than zero:
 - (a) Before invoking **handleAsyncEvent**, the **fireCount** is decremented and the front entry (when still present) removed from the arrival-time queue.
 - (b) Each invocation of **handleAsyncEvent**, in this way, is a release.
 - (c) The return from **handleAsyncEvent** is the completion of a release.
 - (d) Processing of any exceptions thrown by **handleAsyncEvent** occurs prior to completion.
5. The deadline for a release is relative to the release event time and determined at the release event time according to the value of the deadline contained in the handler’s release parameters. This value does not change, except as described previously for handlers using a REPLACE policy for MIT violation or arrival-time queue overflow.
6. The application code can directly modify the **fireCount**.
 - (a) The **getAndDecrementPendingFireCount** method decreases the **fireCount** by one (when it is greater than zero), and returns the old value. This removes the front entry from the arrival-time queue but otherwise has no effect on the scheduling of the current schedulable, nor the handler itself. Any data parameter passed with the associated fire request is lost.
 - (b) The **getAndClearPendingFireCount** method is functionally equivalent to invoking **getAndDecrementPendingFireCount** until it returns zero, and returning the original **fireCount** value. Any data parameters passed with

the associated fire requests are lost.

7. The scheduler may delay the invocation of `handleAsyncEvent` to ensure the effective release time honors any restrictions imposed by the MIT violation policy, when applicable, of that release event.
8. Cost monitoring and enforcement for an asynchronous event handler interacts with release events and completions as previously defined with the added requirement that at the completion of `handleAsyncEvent`, when the `fireCount` is now zero, then the cost monitoring and enforcement system is told to reset for this handler.
9. The value of `ReleaseParameters.isRousable` controls whether a call to `Schedulable.interrupt` caused a premature release or only affects a running schedulable.
 - (a) When interrupt is called on a Schedulable and the Schedulable is running, the interrupt is marked as pending and as soon as AI code is entered, an AIE is thrown.
 - (b) When interrupt is called on a Schedulable that is waiting for a release or its start time, the interrupt is marked as pending.
 - (c) Depending on the value of the new `ReleaseParameters` property, start will prematurely complete, i.e., start user code, or simply wait for the start time to occur.
 - (d) Depending on the value of the new `ReleaseParameters` property, the next release of a handler will occur immediately or not, but in both cases an AIE will be pending until the next AI method.

6.3.3 The Round-Robin Scheduler

The round-robin scheduler specified by the RTSJ is a fixed-quantum, fixed-priority priority-preemptive scheduler that interacts predictably with the base scheduler. The time at which a quantum expires may be calculated either from last task switch or on a heartbeat. It uses the `PriorityParameters` class for the configuration of schedulable priorities. It may not be present on all systems, but if it is present then it will obey the semantics specified here.

When a schedulable managed by the round-robin scheduler is scheduled, it will run either until it blocks (as on a monitor or for some I/O operation), voluntarily relinquishes the CPU (as for sleep), is priority preempted, or its quantum has expired.

The scheduler is not responsible for ensuring that a release, such as an event handler, will complete within the quantum. A release which would run longer than its quantum will be rescheduled at the end of that quantum, when another task with the same priority is ready to run, even if it has not completed. When this is not the desired behavior, the `FirstInFirstOutScheduler` should be used instead.

6.3.3.1 Priorities

Priorities in the round-robin scheduler are as in the base scheduler, and priority values are numerically equivalent between the two. Schedulables managed by the round-robin scheduler behave as if they are scheduled from the same FIFO queue as schedulables managed by the base scheduler of the same numeric priority, except that they will consume no more than one quantum of execution time before being moved to the tail of the queue. Implementations are permitted to use a single, shared queue for this purpose.

If the round-robin scheduler is present, its priorities will have the same properties as the base scheduler, except for the following.

1. The round-robin scheduler must support at least one priority, and may support an arbitrarily large number of priorities.
2. All round-robin priorities must be greater than 10, and they must include all integers from the round-robin scheduler's `getMinPriority()` value to its `getMaxPriority()` value, inclusive.
3. The round-robin scheduler does not use the `importance` value in the `ImportanceParameters` subclass of `PriorityParameters`.
4. `RoundRobinScheduler.getNormPriority()` shall be set to

```
1 ((RoundRobinScheduler.getMaxPriority() -
2  RoundRobinScheduler.getMinPriority()) / 3) +
3  RoundRobinScheduler.getMinPriority()
```

The round-robin scheduler may provide priorities strictly lower than the base scheduler or a set of priorities partially or entirely overlapping with the priorities provided by the base scheduler.

6.3.4 Associating Schedulables with Schedulers

Please review for elb: New semantics for Scheduler selection

The **Scheduler** associated with a **Schedulable** at the time it is started is derived from its configuration and the configuration of the task (an instance of **Thread** or **Schedulable**) that started it. The start time of a **RealtimeThread** is the time at which its `RealtimeThread.start()` method is invoked, and the start time of an event handler is the time at which it is attached to an event with `AsyncBaseEvent.addHandler()`. For the following discussion, we will call the **Schedulable** being started **so** and the thread or **Schedulable** active when it is started **parent**. Every **Schedulable** has an associated **SchedulingGroup**; we call the **SchedulingGroup** associated with **so**, **sg**. The **Scheduler** for **so** is determined as follows.

1. When `Scheduler.setScheduler()` has been used to explicitly configure a scheduler for **so**, that scheduler will be the scheduler associated with **so**.

2. When `parent` is an instance of `Schedulable` and the scheduler associated with `parent` is an instance of the class returned by `sg.getScheduler()`, then the scheduler associated with `so` will be the scheduler associated with `parent`.
3. When `parent` is not an instance of `Schedulable` (i.e., it is a Java `Thread`) but is currently scheduled with a realtime `Scheduler` and that scheduler is an instance of the class returned by `sg.getScheduler()`, then `so` will use the scheduler currently associated with `parent`.
4. When the default scheduler is an instance of the class returned by `sg.getScheduler()`, then `so` will use the default scheduler.
5. When none of these conditions hold, a scheduler cannot be determined for `so` and an `IllegalStateException` will be thrown.

Schedulables must always have a compatible `Scheduler` and `SchedulingParameters` any time these are explicitly configured. This means that appropriate configuration objects must be passed in at construction time, and that all later changes must be compatible; if both the `Scheduler` and `SchedulingParameters` must be changed in such a way that neither is compatible with the current configuration, `setScheduler()` may be called on the `Schedulable` with both a scheduler and compatible parameters passed at the same time.

End review request

6.3.5 Managing Groups of Schedulables

Conventional Java provides the class `ThreadGroup` to manage groups of threads. Only minimal functionality is provided: limiting priority, setting daemon status, and interrupting a group of threads at once. RTSJ extends this concept in two ways: limiting CPU affinity through the `Affinity` class and providing subclasses for managing `Schedulables`.

6.3.5.1 Scheduling Groups

The `SchedulingGroup` subclass of `ThreadGroup` provides a means of constraining the possible scheduling parameters, affinity, and scheduler of tasks. The `setMaxPriority` method on `ThreadGroup` only pertains to tasks scheduled in the conventional Java range (1–10), and not to tasks scheduled with a realtime scheduler. To ensure that this works and that conventional thread groups must not need to be scope aware, an implementation must enforce several restrictions:

1. only tasks in a scheduling group may use a realtime scheduler,
2. instances of `Schedulable` may only be created in a scheduling group,
3. the root `ThreadGroup` instance must be an instance of `SchedulingGroup`,
4. the `ThreadGroup` instance of the initial thread must be an instance of `SchedulingGroup`,

5. an instance of `SchedulingGroup` may not have a parent that is not an instance of `SchedulingGroup`, and
6. all children of a `SchedulingGroup` allocated in a `ScopedMemory` must be instances of `SchedulingGroup`.

Furthermore, the enumeration methods on a scheduling group are aware of scoped memory and the referential integrity restrictions discussed in Chapter 11, Alternative Memory Areas. The enumeration methods of `SchedulingGroup` will not return references to any descendants allocated in a `ScopedMemory` to which references may not be made from the current allocation context. That is, if a newly allocated object in the current allocation context could not safely hold a reference to a descendant of the `ScopedMemory`, that descendant will not be included in the array returned by `enumerate()`. For processing such `SchedulingGroups`, a visitor must be used.

The maximum priority and scheduler restrictions on `SchedulingGroup` and `ThreadGroup` apply only to the base priority of a task belonging to that group. Priority inversion avoidance algorithms (see Chapter 7, Synchronization) may cause a task to temporarily obtain a priority notionally higher than its maximum base priority as specified in its associated instance of `ThreadGroup`.

6.3.5.2 Processing Groups

A processing group is defined by an instance of the `ProcessingGroup` subclass of `SchedulingGroup` and each schedulable that is bound to that parameter object is called a *member* of that processing group. A processing group instance acts as a proxy for its members, but enforcement does have an effect on the execution of member threads.

6.3.5.2.1 Semantics for Processing Groups

1. The deadline of a processing group is defined by the value returned by invoking the `getDeadline` method of the processing group object.
2. A deadline miss for the processing group is triggered when any member of the processing group consumes CPU time at a time greater than the deadline for the most recent release of the processing group.
3. When a processing group misses a deadline:
 - (a) when the processing group has a miss handler, it is released for execution,
 - (b) otherwise, the processing group has no miss handler, no action is taken.
4. The cost of a processing group is defined by the value returned by invoking the `getCost` method of the processing group object.
5. When a processing group is initially released, its current CPU consumption is zero and as the members of the processing group execute, the current CPU consumption increases. The current CPU consumption is set to zero in response to certain actions as described below.

6. If, at any time, due to either execution of the members of the processing group or a change in the group's cost, the current CPU consumption becomes greater than or equal to the current cost of the processing group, then a cost overrun is triggered. The implementation is required to document the granularity at which the current CPU consumption is updated.
7. When the affinity of the group contains more than one processor, the granularity enforced may be as large as the base granularity times the number of processors in the group's affinity.
8. When a cost overrun is triggered, the cost overrun handler associated with the processing group, if any, is released.
9. When more than one processing group monitoring a given task or set of tasks reach their limits at the same time, *all* corresponding handlers are released in an unspecified order.
10. *Any* group entering enforcement between a given group and the root enforces that group.
11. When cost enforcement is supported, enabled, and triggered, the processing group enters the **enforced state**. For each member of the processing group:
 - (a) the schedulable is placed into the enforced state; and
 - (b) when a schedulable is in the enforced state, the base scheduler schedules that schedulable effectively as if it has a base priority lower than that of a notional idle task.
12. When the release event occurs for a processing group, the action taken depends on the state of the processing group.
 - (a) When the processing group is not in the enforced state, the current CPU consumption for the group is set to zero.
 - (b) Otherwise, the processing group is in the enforced state. It is removed from the enforced state, the current CPU consumption of the group is set to zero, and each member of the group is removed from the enforced state.
13. Changes to the cost, minimum and maximum, take effect immediately.
 - (a) When the new cost is less than or equal to the current CPU consumption, and the old cost was greater than the current CPU consumption, a cost overrun is triggered.
 - (b) When the new cost is greater than the current CPU consumption there are two case:
 - i. when the processing group is enforced, then the processing group behaves as defined in semantic 12;
 - ii. otherwise, no cost monitoring and enforcement action occurs.
14. Changes to other parameters take place as follows:
 - (a) **start** can only be changed before the parameters group is started, i.e.,

- before the start time or before the parameter object is associated with any schedulable and changes take effect immediately;
- (b) **period** can be change at each release, so the next period is set based on the current value of the processing group's period;
 - (c) **deadline** can change at each release, so the next deadline is set based on the current value of the processing group's deadline;
 - (d) **OverflowHandler** can change at each release, so the overflowHandler is set based on the current value of the processing group's overflowHandler; and
 - (e) **MissHandler** can change at each release, so the missHandler is set based on the current value of the processing group's missHandler.
 - (f) **UnderrunHandler** can change at each release, so the underrunHandler is set based on the current value of the processing group's underrunHandler.
15. Changes to the membership of the processing group take effect immediately.
 16. The start time for the processing group may be relative or absolute.
 - (a) When the start time is absolute, the processing group behaves effectively as if the initial release time were the start time.
 - (b) When the start time is relative, the initial release time is computed relative to the time that the processing group is constructed (if the relative start time is passed to the constructor) or the `setStart()` method is called, as appropriate.

Note that until a processing group starts (i.e., its start time has been reached) it will perform no cost monitoring or enforcement on the Schedulables that it contains. Once a processing group is started, it behaves effectively as if it runs continuously until the defining `ProcessingGroup` object is freed.

6.4 Package javax.realtime

6.4.1 Interfaces

6.4.1.1 BoundSchedulable

Interfaces

`javax.realtime.Schedulable`

Description

A marker interface to provide a type safe reference to all schedulables that are bound to a single underlying thread. A `RealtimeThread`² is by definition bound.

6.4.1.2 RealtimeExecutionContext

Description

All RTSJ objects that encapsulate execution. This type includes `Schedulable` and `javax.realtime.device.InterruptServiceRoutine`. It is used by `Affinity` to remove the need to have a reference into the `javax.realtime.device` package.

6.4.1.3 Schedulable

Interfaces

`Runnable`

`javax.realtime.Timable`

`javax.realtime.RealtimeExecutionContext`

Description

Handlers and other objects can be dispatched by a `Scheduler`³ when they provide a `run()` method and the methods defined below. The `Scheduler`⁴ uses this information to create a suitable context to execute the `run()` method.

²Section 5.4.2.2

³Section 6.4.3.12

⁴Section 6.4.3.12

6.4.1.3.1 Methods

getMemoryParameters

Signature

```
public  
    javax.realtime.MemoryParameters getMemoryParameters()
```

Description

Gets a reference to the [MemoryParameters](#)⁵ object for this schedulable.

Returns

A reference to the current [MemoryParameters](#)⁶ object.

setMemoryParameters(MemoryParameters)

Signature

```
public  
    void setMemoryParameters(MemoryParameters memory)
```

Description

Sets the memory parameters associated with this instance of **Schedulable**.

This change becomes effective under conditions determined by the scheduler controlling the schedulable. For instance, the change may be immediate or it may be delayed until the next release of the schedulable object. See the documentation for the scheduler for details.

Parameters

memory A [MemoryParameters](#)⁷ object which will become the memory parameters associated with **this** after the method call. When **null**, the default value is governed by the associated scheduler (a new object is created when the default value is not **null**). (See [PriorityScheduler](#)⁸.)

Throws

⁵Section [11.4.2.4](#)

⁶Section [11.4.2.4](#)

⁷Section [11.4.2.4](#)

⁸Section [6.4.3.8](#)

`IllegalArgumentException` when `memory` is not compatible with the schedulable's scheduler. Also when this schedulable may not use the heap and `memory` is located in heap memory.

`IllegalAssignmentError` when the schedulable cannot hold a reference to `memory`, or when `memory` cannot hold a reference to this schedulable instance.

`IllegalStateException` when the schedulable's scheduler prohibits this parameter change at this time due to the state of the schedulable.

getReleaseParameters

Signature

```
public  
javafx.realtime.ReleaseParameters getReleaseParameters()
```

Description

Gets a reference to the `ReleaseParameters`⁹ object for this schedulable.

Returns

A reference to the current `ReleaseParameters`¹⁰ object.

setReleaseParameters(ReleaseParameters)

Signature

```
public  
void setReleaseParameters(ReleaseParameters release)
```

Description

Sets the release parameters associated with this instance of `Schedulable`.

This change becomes effective under conditions determined by the scheduler controlling the schedulable. For instance, the change may be immediate or it may be delayed until the next release of the schedulable. The different properties of the release parameters may take effect at different times. See the documentation for the scheduler for details.

Parameters

⁹Section 6.4.3.10

¹⁰Section 6.4.3.10

release A [ReleaseParameters](#)¹¹ object which will become the release parameters associated with this after the method call, and take effect as determined by the associated scheduler. When **null**, the default value is governed by the associated scheduler (a new object is created when the default value is not **null**). (See [PriorityScheduler](#)¹².)

Throws

IllegalArgumentException Thrown when **release** is not compatible with the associated scheduler. Also when this schedulable may not use the heap and **release** is located in heap memory.

IllegalAssignmentError when **this** object cannot hold a reference to **release** or **release** cannot hold a reference to **this**.

IllegalThreadStateException when the schedulable's scheduler prohibits the changing of the release parameter at this time due to the state of the schedulable.

getScheduler

Signature

```
public  
    javax.realtime.Scheduler getScheduler()
```

Description

Gets a reference to the [Scheduler](#)¹³ object for this schedulable.

Returns

A reference to the associated [Scheduler](#)¹⁴ object.

setScheduler(Scheduler)

Signature

```
public  
    void setScheduler(Scheduler scheduler)
```

Description

¹¹Section [6.4.3.10](#)

¹²Section [6.4.3.8](#)

¹³Section [6.4.3.12](#)

¹⁴Section [6.4.3.12](#)

Sets the reference to the Scheduler object. The timing of the change must be agreed between the scheduler currently associated with this schedulable, and `scheduler`. If the `Schedulable` is running, its associated `SchedulingParameters` (if any) must be compatible with `scheduler`.

Parameters

`scheduler` A reference to the scheduler that will manage execution of this schedulable. Null is not a permissible value.

Throws

`IllegalArgumentException` Thrown when `scheduler` is null, or the schedulable's existing parameter values are not compatible with `scheduler`. Also when this schedulable may not use the heap and `scheduler` is located in heap memory.

`IllegalAssignmentError` when the schedulable cannot hold a reference to `scheduler` or the current `Schedulable` is running and its associated `SchedulingParameters` are incompatible with `scheduler`.

`SecurityException` when the caller is not permitted to set the scheduler for this schedulable.

`IllegalThreadStateException` when `scheduler` refuses to accept this schedulable at this time due to the state of the schedulable.

setScheduler(Scheduler, SchedulingParameters, ReleaseParameters, MemoryParameters)

Signature

```
public
void setScheduler(Scheduler scheduler,
                  SchedulingParameters scheduling,
                  ReleaseParameters release,
                  MemoryParameters memoryParameters)
```

Description

Sets the scheduler and associated parameter objects. The timing of the change must be agreed between the scheduler currently associated with this schedulable, and `scheduler`.

Parameters

`scheduler` A reference to the scheduler that will manage the execution of this schedulable. Null is not a permissible value.

scheduling A reference to the [SchedulingParameters](#)¹⁵ which will be associated with **this**. When **null**, the default value is governed by **scheduler** (a new object is created when the default value is not **null**). (See [PriorityScheduler](#)¹⁶.)

release A reference to the [ReleaseParameters](#)¹⁷ which will be associated with **this**. When **null**, the default value is governed by **scheduler** (a new object is created when the default value is not **null**). (See [PriorityScheduler](#)¹⁸.)

memoryParameters A reference to the [MemoryParameters](#)¹⁹ which will be associated with **this**. When **null**, the default value is governed by **scheduler** (a new object is created when the default value is not **null**). (See [PriorityScheduler](#)²⁰.)

Throws

IllegalArgumentException Thrown when **scheduler** is **null** or the parameter values are not compatible with **scheduler**. Also thrown when this schedulable may not use the heap and **scheduler**, **scheduling** **release**, **memoryParameters**, or **group** is located in heap memory.

IllegalAssignmentError when **this** object cannot hold references to all the parameter objects or the parameters cannot hold references to **this**.

IllegalThreadStateException when **scheduler** prohibits the changing of the scheduler or a parameter at this time due to the state of the schedulable.

SecurityException when the caller is not permitted to set the scheduler for this schedulable.

getSchedulingParameters

Signature

```
public
    javax.realtime.SchedulingParameters getSchedulingParameters()
```

Description

Gets a reference to the [SchedulingParameters](#)²¹ object for this schedulable.

Returns

¹⁵Section [6.4.3.14](#)

¹⁶Section [6.4.3.8](#)

¹⁷Section [6.4.3.10](#)

¹⁸Section [6.4.3.8](#)

¹⁹Section [11.4.2.4](#)

²⁰Section [6.4.3.8](#)

²¹Section [6.4.3.14](#)

A reference to the current [SchedulingParameters](#)²² object.

setSchedulingParameters(SchedulingParameters)

Signature

```
public  
void setSchedulingParameters(SchedulingParameters scheduling)
```

Description

Sets the scheduling parameters associated with this instance of **Schedulable**.

This change becomes effective under conditions determined by the scheduler controlling the schedulable. For instance, the change may be immediate or it may be delayed until the next release of the schedulable. See the documentation for the scheduler for details.

Parameters

scheduling A reference to the [SchedulingParameters](#)²³ object. When **null**, the default value is governed by the associated scheduler (a new object is created when the default value is not **null**). (See [PriorityScheduler](#)²⁴.)

Throws

IllegalArgumentException Thrown when **scheduling** is not compatible with the associated scheduler. Also when this schedulable may not use the heap and **scheduling** is located in heap memory.

[IllegalAssignmentError](#) when **this** object cannot hold a reference to **scheduling** or **scheduling** cannot hold a reference to **this**.

IllegalThreadStateException when the schedulable's scheduler prohibits the changing of the scheduling parameter at this time due to the state of the schedulable object.

getSchedulingGroup

Signature

```
public  
javax.realtime.SchedulingGroup getSchedulingGroup()
```

Description

²²Section 6.4.3.14

²³Section 6.4.3.14

²⁴Section 6.4.3.8

Gets a reference to the [SchedulingGroup](#)²⁵ instance of this schedulable.

Returns

A reference to the current [SchedulingGroup](#)²⁶ object.

Available since since RTSJ 2.0

getConfigurationParameters

Signature

```
public  
    javafx.realtime.ConfigurationParameters getConfigurationParameters()
```

Description

Gets a reference to the [ConfigurationParameters](#)²⁷ object for this schedulable.

Returns

A reference to the associated [ConfigurationParameters](#)²⁸ object.

Available since RTSJ 2.0

getMinConsumption(RelativeTime)

Signature

```
public  
    javafx.realtime.RelativeTime getMinConsumption(RelativeTime dest)
```

Description

Determine the minimum CPU consumption for this schedulable in any single release. When this method is called on the current schedulable, the CPU consumption of the current release is not considered. When **dest** is **null**, return the minimum consumption in a [RelativeTime](#)²⁹ instance from the current allocation context. When **dest** is not **null**, return the minimum consumption in **dest**

Parameters

dest when not **null** is the object in which to return the result.

²⁵Section [6.4.3.13](#)

²⁶Section [6.4.3.13](#)

²⁷Section [5.4.2.1](#)

²⁸Section [5.4.2.1](#)

²⁹Section [9.4.1.3](#)

Returns

the minimum time consumed in any release.

Available since RTSJ 2.0

getMinConsumption

Signature

```
public  
    javax.realtime.RelativeTime getMinConsumption()
```

Description

Equivalent to `getMinConsumption(null)`.

Returns

the minimum time consumed in any release.

Available since RTSJ 2.0

getMaxConsumption(RelativeTime)

Signature

```
public  
    javax.realtime.RelativeTime getMaxConsumption(RelativeTime dest)
```

Description

Determine the maximum CPU consumption for this schedulable in any single release. When this method is called on the current schedulable, the CPU consumption of the current release is not considered. When `dest` is `null`, return the maximum consumption in a `RelativeTime`³⁰ instance from the current allocation context. When `dest` is not `null`, return the maximum consumption in `dest`

Parameters

`dest` when not `null` is the object in which to return the result.

Returns

the maximum time consumed in any release.

Available since RTSJ 2.0

³⁰Section 9.4.1.3

getMaxConsumption

Signature

```
public  
    javafx.realtime.RelativeTime getMaxConsumption()
```

Description

Equivalent to `getMaxConsumption(null)`.

Returns

the maximum time consumed in any release.

Available since RTSJ 2.0

mayUseHeap

Signature

```
public  
    boolean mayUseHeap()
```

Description

Determine whether or not this `schedulable` may use the heap.

Returns

`true` only when this `Schedulable` may allocate on the heap and may enter the Heap.

Available since RTSJ 2.0

interrupt

Signature

```
public  
    void interrupt()
```

Description

Generates the generic `AsynchronouslyInterruptedException`³¹ and targets it at this, and sets the interrupted state to pending. As with `Thread.interrupt()`, blocking operations that are interruptible are interrupted.

³¹Section 8.4.2.1

Available since RTSJ 2.0

awaken

Signature

```
public  
void awaken()  
throws IllegalStateException
```

Description

Provides a means for a [Clock](#)³² to end a sleep.

Throws

`IllegalStateException` when called from user code.

Available since RTSJ 2.0

6.4.2 Enumerations

6.4.2.1 MinimumInterarrivalPolicy

Inheritance

```
java.lang.Object  
  java.lang.Enum  
    javax.realtime.MinimumInterarrivalPolicy
```

Description

Defines the set of policies for handling interarrival time violations in [SporadicParameters](#)³³. Each policy governs every instance of [Schedulable](#)³⁴ which has [SporadicParameters](#)³⁵ with that minimum interarrival time policy.

Available since RTSJ 2.0

³²Section 10.4.2.1

³³Section 6.4.3.15

³⁴Section 6.4.1.3

³⁵Section 6.4.3.15

6.4.2.1.1 Enumeration Constants

EXCEPT

```
public static final EXCEPT
```

Description

Represents the “EXCEPT” policy for minimum interarrival time. Under this policy, when an arrival time of a release occurs at a time less than the last release time plus its minimum interarrival time, the `fire()` method shall throw a preallocated instance of `MITViolationException`³⁶.

IGNORE

```
public static final IGNORE
```

Description

Represents the “IGNORE” policy for minimum interarrival time. Under this policy, when an arrival time of a release occurs at a time less than the last release time plus its minimum interarrival time, the new arrival time is ignored.

REPLACE

```
public static final REPLACE
```

Description

Represents the “REPLACE” policy for minimum interarrival time. Under this policy, when an arrival time of a release occurs at a time less than the last release time plus its minimum interarrival time, the information for this arrival replaces a previous arrival.

SAVE

```
public static final SAVE
```

Description

³⁶Section 15.3.2.6

Represents the “SAVE” policy for minimum interarrival time. Under this policy, when an arrival time of a release occurs at a time less than the last release time plus its minimum interarrival time, the new time is not compared to the specified minimum interarrival time, effectively ignoring that minimum interarrival time.

6.4.2.1.2 Methods

values

Signature

```
public static  
    javax.realtime.MinimumInterarrivalPolicy[] values()
```

Description

valueOf(String)

Signature

```
public static  
    javax.realtime.MinimumInterarrivalPolicy valueOf(String name)
```

Description

value

Signature

```
public  
    java.lang.String value()
```

Description

Determine the string corresponding to this value.

Returns

the corresponding string.

value(String)

Signature

```
public static  
javax.realtime.MinimumInterarrivalPolicy value(String value)
```

Description

Convert a string into a policy type.

Parameters

value is the string to convert.

Returns

the corresponding policy type.

6.4.2.2 QueueOverflowPolicy

Inheritance

```
java.lang.Object  
  java.lang.Enum  
    javax.realtime.QueueOverflowPolicy
```

Description

Defines the set of policies for handling overflow on arrival time queues used by [SporadicParameters](#)³⁷ and [SporadicParameters](#)³⁸,

Available since RTSJ 2.0

6.4.2.2.1 Enumeration Constants

EXCEPT

```
public static final EXCEPT
```

Description

³⁷Section [6.4.3.15](#)

³⁸Section [6.4.3.15](#)

Represents the “EXCEPT” policy which means, when an arrival occurs and its time should be queued but the queue already holds a number of times equal to the initial queue length, the `fire()` method shall throw a `ArrivalTimeQueueOverflowException`³⁹.

IGNORE

```
public static final IGNORE
```

Description

Represents the “IGNORE” policy which means, when an arrival occurs and its time should be queued, but the queue already holds a number of times equal to the initial queue length, the arrival is ignored.

REPLACE

```
public static final REPLACE
```

Description

Represents the “REPLACE” policy which means, when an arrival occurs and should be queued but the queue already holds a number of times equal to the initial queue length, the information for this arrival replaces a previous arrival.

SAVE

```
public static final SAVE
```

Description

Represents the “SAVE” policy which means, when an arrival occurs and should be queued but the queue is full, the queue is lengthened and the arrival time is saved. This policy does not update the “initial queue length” as it alters the actual queue length. Since the `SAVE` policy grows the arrival time queue as necessary, for the `SAVE` policy the initial queue length is only an optimization.

6.4.2.2.2 Methods

³⁹Section 15.3.2.1

values

Signature

```
public static  
    javax.realtime.QueueOverflowPolicy[] values()
```

Description

valueOf(String)

Signature

```
public static  
    javax.realtime.QueueOverflowPolicy valueOf(String name)
```

Description

value

Signature

```
public  
    java.lang.String value()
```

Description

Determine the string corresponding to this value.

Returns

the corresponding string.

value(String)

Signature

```
public static  
    javax.realtime.QueueOverflowPolicy value(String value)
```

Description

Convert a string into a policy type.

Parameters

`value` is the string to convert.

Returns

the corresponding policy type.

6.4.3 Classes

6.4.3.1 Affinity

Inheritance

`java.lang.Object`
`javax.realtime.Affinity`

Description

This is the API for all processor-affinity-related aspects of the RTSJ. It includes a factory that generates **Affinity** objects, and methods that control the CPU affinity used by `java.lang.ThreadGroup` to control the affinity of all its tasks. With it, the affinity of every task in the JVM can be controlled.

An affinity is a set of processors that can be associated with certain types of tasks. Each `java.lang.Thread` and `RealtimeExecutionContext`⁴⁰ can be associated with an affinity. Groups of these can be assigned an affinity through their `java.lang.ThreadGroup`.

Each implementation supports an array of predefined affinity sets. They can be used either to reflect the scheduling arrangement of the underlying OS or they can be used by the system designer to impose defaults for groups of task. A program is only allowed to dynamically create new affinity sets with cardinality of one. This restriction reflects the concern that not all operating systems will support multiprocessor affinity sets.

The processor membership of an affinity set is immutable. The tasks associations of an affinity set are mutable. The processor affinity of a task can be changed by static methods in this class. The internal representation of a set of processors in an **Affinity** instance is not specified, but the representation that is used to communicate with this class is a **BitSet** where each bit corresponds to a logical processor ID. The relationship between logical and physical processors is beyond the scope of this specification, and may change.

The affinity set factory only generates usable **Affinity** instances; i.e., affinity sets that (at least when they are created) can be used with `set(Affinity, Re-`

⁴⁰Section 6.4.1.2

`altimeExecutionContext`)⁴¹, `set(Affinity, Thread)`⁴², and `set(Affinity, ThreadGroup)`⁴³. The factory cannot create an affinity set with more than one processor member, but such affinity sets are supported. They may be internally created by the RTSJ runtime at startup time.

The set of affinity sets created at startup (the predefined set) is visible through the `getPredefinedAffinities(Affinity[])`⁴⁴ method. The affinity set factory may be used to create affinity sets with a single processor member at any time. This operation only supports processor members that are available to the JVM at the time of creation.

External changes to the set of processors available to the RTSJ runtime is likely to cause serious trouble ranging from violation of assumptions underlying schedulability analysis to freezing the entire RTSJ runtime, so when a system is capable of such manipulation it should not exercise it on RTSJ processes.

Tasks are subject to both their own processor affinity and that of their thread group. Their processor affinity is governed by the intersection of the thread group's affinity and the schedulable's affinity. The intersection of a thread group's affinity set with the schedulable's affinity set must contain at least one entry. Trying to set a task's affinity outside its thread group always fails. Trying to setting the affinity of a thread group that does not intersect with the thread group of its tasks will also fail.

Ordinarily, an execution context inherits its creator's affinity set, but

- Java threads do not inherit affinity from `Schedulable`⁴⁵,
- instance of `AsyncBaseEventHandler`⁴⁶ that are not bound are not affected, and
- a `Schedulable` does not inherit affinity from Java threads.

When a task does not inherit its creator's affinity set, its initial affinity set is set to all processors and is thus only limited by its thread group.

There is no public constructor for this class. All instances must be created by the factory method (`generate`).

Available since RTSJ 2.0

6.4.3.1.1 Methods

⁴¹Section 6.4.3.1.1

⁴²Section 6.4.3.1.1

⁴³Section 6.4.3.1.1

⁴⁴Section 6.4.3.1.1

⁴⁵Section 6.4.1.3

⁴⁶Section 8.4.3.3

getPredefinedAffinitiesCount

Signature

```
public static final  
int getPredefinedAffinitiesCount()
```

Description

Determine the minimum array size required to store references to all the predefined processor affinity sets.

Returns

The minimum array size required to store references to all the predefined affinity sets.

getPredefinedAffinities

Signature

```
public static final  
javax.realtime.Affinity[] getPredefinedAffinities()
```

Description

Equivalent to invoking `getPredefinedAffinitySets(null)`.

Returns

an array of the predefined affinity sets.

getPredefinedAffinities(Affinity)

Signature

```
public static final  
javax.realtime.Affinity[] getPredefinedAffinities(javax.realtime.Affinity[] des
```

Description

Determine what affinity sets are predefined by the Java runtime.

Parameters

dest The destination array, or `null`.

Throws

`IllegalArgumentException` when `dest` is not large enough.

Returns

`dest` or a newly created array when `dest` is `null`, populated with references to the predefined affinity sets. When `dest` has excess entries, those entries are filled with `null`.

isSetAffinitySupported

Signature

```
public static final  
boolean isSetAffinitySupported()
```

Description

Determine whether or not affinity control is supported.

Returns

`true` when the `set(Affinity, Thread)`⁴⁷ family of methods is supported.

generate(BitSet)

Signature

```
public static final  
javax.realtime.Affinity generate(BitSet set)
```

Description

Determine the Affinity corresponding to a `BitSet`, where each bit in `set` represents a CPU.

Platforms that support specific affinity sets will register those `Affinity` instances with `Affinity`⁴⁸. They appear in the arrays returned by `getPredefinedAffinities()`⁴⁹ and `getPredefinedAffinities(Affinity[])`⁵⁰.

Parameters

`set` is the `BitSet` to convert into an `Affinity`.

Throws

`NullPointerException` when `set` is `null`.

⁴⁷Section 6.4.3.1.1

⁴⁸Section 6.4.3.1

⁴⁹Section 6.4.3.1.1

⁵⁰Section 6.4.3.1.1

`IllegalArgumentException` when `set` does not refer to a valid set of processors, where “valid” is defined as the bitset from a predefined affinity set, or a bitset of cardinality one containing a processor from the set returned by `getAvailableProcessors()`. The definition of “valid set of processors” is system dependent; however, every set consisting of one valid processor makes up a valid bit set, and every bit set correspond to a predefined affinity set is valid.

Returns

The resulting `Affinity`.

getAvailableProcessors

Signature

```
public static final  
java.util.BitSet getAvailableProcessors()
```

Description

This method is equivalent to `getAvailableProcessors(BitSet)`⁵¹ with a null argument.

Returns

the set of processors available to the program.

getAvailableProcessors(BitSet)

Signature

```
public static final  
java.util.BitSet getAvailableProcessors(BitSet dest)
```

Description

In systems where the set of processors available to a process is dynamic (e.g., because of system management operations or because of fault tolerance capabilities), the set of available processors shall reflect the processors that are allocated to the RTSJ runtime and are currently available to execute tasks.

Parameters

dest When **dest** is non-null, use **dest** as the returned value. When it is null, create a new `BitSet`.

⁵¹Section 6.4.3.1.1

Returns

A `BitSet` representing the set of processors currently valid for use in the `bitset` argument to `generate(BitSet)`⁵².

get(RealtimeExecutionContext)*Signature*

```
public static final
    javafx.runtime.Affinity get(RealtimeExecutionContext task)
```

Description

Determine the affinity set instance associated with `task`.

Parameters

`task` is the execution context to query.

Returns

The associated affinity.

set(Affinity, RealtimeExecutionContext)*Signature*

```
public static final
    void set(Affinity set,
             RealtimeExecutionContext task)
    throws ProcessorAffinityException
```

Description

Set the processor affinity of a `task`.

Parameters

`set` is the processor affinity

`task` is the execution context whose affinity will be set.

Throws

`IllegalArgumentException` when the intersection of `set` the affinity of any `ThreadGroup` instance containing `task` is empty.

`ProcessorAffinityException` is thrown when the runtime fails to set the affinity for platform-specific reasons.

`NullPointerException` when `set` or `task` is null.

⁵²Section 6.4.3.1.1

get(Thread)

Signature

```
public static final  
    javax.realtime.Affinity get(Thread thread)
```

Description

Determine the affinity set instance associated with `thread`.

Parameters

`thread` a Java thread, or one of its subclasses (including `RealtimeThread`⁵³).

Returns

The associated affinity set.

set(Affinity, Thread)

Signature

```
public static final  
    void set(Affinity set,  
            Thread thread)  
    throws ProcessorAffinityException
```

Description

Set the processor affinity of a Java thread or `RealtimeThread`⁵⁴ to `set`.

Parameters

`set` The processor affinity set

`thread` The thread or realtime thread.

Throws

`IllegalArgumentException` when the intersection of `set` and the affinity of any `ThreadGroup` instance containing `thread` is empty.

`ProcessorAffinityException` when the runtime fails to set the affinity for platform-specific reasons.

`NullPointerException` when `set` or `thread` is null.

⁵³Section 5.4.2.2

⁵⁴Section 5.4.2.2

get(ThreadGroup)

Signature

```
public static final  
    javax.realtime.Affinity get(ThreadGroup group)
```

Description

Determine the affinity set instance associated with `group`.

Parameters

group An instance of `java.lang.ThreadGroup`

Returns

The associated affinity set.

set(Affinity, ThreadGroup)

Signature

```
public static final  
    void set(Affinity set,  
            ThreadGroup group)  
    throws ProcessorAffinityException
```

Description

Set the processor affinity of `group` to `set`.

Parameters

set The processor affinity set

group The processing group parameters instance.

Throws

`IllegalArgumentException` when `set` and the affinity of any task in `group` is empty.

`ProcessorAffinityException` when the runtime fails to set the affinity for platform-specific reasons or `group` contains more than one processor.

`NullPointerException` when `set` or `group` is null.

getProcessors

Signature

```
public final  
java.util.BitSet getProcessors()
```

Description

Return a `BitSet` representing the processor affinity set for this `Affinity`.

Returns

A newly created `BitSet` representing this `Affinity`.

getProcessors(BitSet)*Signature*

```
public final  
java.util.BitSet getProcessors(BitSet dest)
```

Description

Determine the set of CPUs representing the processor affinity of this `Affinity`.

Parameters

dest Set **dest** to the `BitSet` value. When **dest** is `null`, create a new `BitSet` in the current allocation context.

Returns

A `BitSet` representing the processor affinity set of this `Affinity`.

isProcessorInSet(int)*Signature*

```
public final  
boolean isProcessorInSet(int processorId)
```

Description

Ask whether a processor is included in this affinity set.

Parameters

processorId a number identifying a single CPU in a multiprocessor system.

Returns

`true` when and only when **processorNumber** is represented in this affinity set.

applyTo(BoundAsyncEventHandler)

Signature

```
public final  
void applyTo(BoundAsyncEventHandler aeh)  
throws ProcessorAffinityException
```

Description

Set the processor affinity of a bound AEH to **this**.

Parameters

aeh The bound async event handler

Throws

IllegalArgumentException when intersection of **this** with the affinity of any group containing **aeh** is empty.

ProcessorAffinityException Thrown when the runtime fails to set the affinity for platform-specific reasons.

NullPointerException when **aeh** is null.

applyTo(Thread)

Signature

```
public final  
void applyTo(Thread thread)  
throws ProcessorAffinityException
```

Description

Set the processor affinity of a Java thread or **RealtimeThread**⁵⁵ to **this**.

Parameters

thread The thread or realtime thread.

Throws

IllegalArgumentException when intersection of **this** with the affinity of any group containing **thread** is empty.

ProcessorAffinityException when the runtime fails to set the affinity for platform-specific reasons.

NullPointerException when **thread** is null.

⁵⁵Section 5.4.2.2

applyTo(ThreadGroup)

Signature

```
public final  
void applyTo(ThreadGroup group)  
throws ProcessorAffinityException
```

Description

Set the processor affinity of `group` to `this`.

Parameters

`group` The processing group parameters instance.

Throws

`IllegalArgumentException` when `this` and the affinity of any task in `group` is empty.

`ProcessorAffinityException` when the runtime fails to set the affinity for platform-specific reasons or `group` contains more than one processor.

`NullPointerException` when `group` is null.

applyTo(ActiveEventDispatcher)

Signature

```
public final  
void applyTo(javax.realtime.ActiveEventDispatcher<?, ?> dispatcher)  
throws ProcessorAffinityException
```

Description

Set the processor affinity of `dispatcher` to `this`.

Parameters

`dispatcher` is the dispatcher instance.

Throws

`IllegalArgumentException` when intersection of `this` with the affinity of any `group` containing `dispatcher` is empty.

`ProcessorAffinityException` when the runtime fails to set the affinity for platform-specific reasons.

`NullPointerException` when `dispatcher` is null.

6.4.3.2 AperiodicParameters

Inheritance

```

java.lang.Object
  javax.realtime.ReleaseParameters
    javax.realtime.AperiodicParameters

```

Description

When a reference to an **AperiodicParameters** object is given as a parameter to a schedulable's constructor or passed as an argument to one of the schedulable's setter methods, the **AperiodicParameters** object becomes the release parameters object bound to that schedulable. Changes to the values in the **AperiodicParameters** object affect that schedulable. When bound to more than one schedulable, changes to the values in the **AperiodicParameters** object affect *all* of the associated objects. Note that this is a one-to-many relationship and *not* a many-to-many.

Only changes to an **AperiodicParameters** object caused by methods on that object cause the change to propagate to all schedulables using the object. For instance, calling **setCost** on an **AperiodicParameters** object will make the change, then notify that the scheduler that the parameter object has changed. At that point the object is reconsidered for every schedulable that uses it. Invoking a method on the **RelativeTime** object that is the cost for this object may change the cost but it does not pass the change to the scheduler at that time. That change must not change the behavior of the schedulable's that use the parameter object until a setter method on the **AperiodicParameters** object is invoked, or the parameter object is used in **setReleaseParameters()** or a constructor for a schedulable.

The implementation must use modified copy semantics for each **HighResolutionTime**⁵⁶ parameter value. The value of each time object should be treated as if it were copied at the time it is passed to the parameter object, but the object reference must also be retained. For instance, the value returned by **getCost()** must be the same object passed in by **setCost()**, but any changes made to the time value of the cost must not take effect in the associated **AperiodicParameters** instance unless they are passed to the parameter object again, e.g. with a new invocation of **setCost**.

Correct initiation of the deadline miss and cost overrun handlers requires that the underlying system know the arrival time of each aperiodic task. For an instance of **RealtimeThread**⁵⁷ the arrival time is the time at which the **start()**

⁵⁶Section 9.4.1.2

⁵⁷Section 5.4.2.2

Table 6.3: AperiodicParameters Default Values

Attribute	Value
cost	<code>new RelativeTime(0,0)</code>
deadline	<code>new RelativeTime(Long.MAX_VALUE, 999999)</code>
overrunHandler	None
missHandler	None
rounable	false
Arrival time queue size	0
Queue overflow policy	SAVE

is invoked. For other instances of `Schedulable`⁵⁸, the required behaviors may require the implementation to behave effectively as if it maintained a queue of arrival times.

When the release parameters for a `RealtimeThread` are set to an instance of this class or one of its subclasses, the thread does not start executing code until the `RealtimeThread.release()`⁵⁹ method is called.

The following tables gives the default values for the constructors parameters.

Caution: This class is explicitly unsafe for multithreading when being changed. Code that mutates instances of this class should synchronize at a higher level.

6.4.3.2.1 Fields

`arrivalTimeQueueOverflowExcept`

```
public static final arrivalTimeQueueOverflowExcept
```

Description

Represents the “EXCEPT” policy for dealing with arrival time queue overflow. Under this policy, when an arrival occurs and its time should be queued but the queue already holds a number of times equal to the initial queue length defined by `this` then the `fire()` method shall throw a `ArrivalTimeQueueOverflowException`⁶⁰. Any other associated semantics are governed by the schedulers for

⁵⁸Section 6.4.1.3

⁵⁹Section 5.4.1

⁶⁰Section 15.3.2.1

the schedulables using these aperiodic parameters. When the arrival is a result of a happening to which the instance of `AsyncEventHandler`⁶¹ is bound then the arrival time is ignored.

Available since RTSJ 1.0.1 Moved here from SporadicParameters.

Deprecated since RTSJ version since RTSJ 2.0

arrivalTimeQueueOverflowIgnore

```
public static final arrivalTimeQueueOverflowIgnore
```

Description

Represents the “IGNORE” policy for dealing with arrival time queue overflow. Under this policy, when an arrival occurs and its time should be queued, but the queue already holds a number of times equal to the initial queue length defined by `this` then the arrival is ignored. Any other associated semantics are governed by the schedulers for the schedulables using these aperiodic parameters.

Available since RTSJ 1.0.1 Moved here from SporadicParameters.

Deprecated since RTSJ version since RTSJ 2.0

arrivalTimeQueueOverflowReplace

```
public static final arrivalTimeQueueOverflowReplace
```

Description

Represents the “REPLACE” policy for dealing with arrival time queue overflow. Under this policy, when an arrival occurs and should be queued but the queue already holds a number of times equal to the initial queue length defined by `this` then the information for this arrival replaces a previous arrival. Any other associated semantics are governed by the schedulers for the schedulables using these aperiodic parameters.

Available since RTSJ 1.0.1 Moved here from SporadicParameters.

Deprecated since RTSJ version since RTSJ 2.0

⁶¹Section 8.4.3.5

arrivalTimeQueueOverflowSave

```
public static final arrivalTimeQueueOverflowSave
```

Description

Represents the “SAVE” policy for dealing with arrival time queue overflow. Under this policy, when an arrival occurs and should be queued but the queue is full, then the queue is lengthened and the arrival time is saved. Any other associated semantics are governed by the schedulers for the schedulables using these aperiodic parameters. This policy does not update the “initial queue length” as it alters the actual queue length. Since the SAVE policy grows the arrival time queue as necessary, for the SAVE policy the initial queue length is only an optimization.

Available since RTSJ 1.0.1 Moved here from SporadicParameters.

Deprecated since RTSJ version since RTSJ 2.0

6.4.3.2.2 Constructors

AperiodicParameters(RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler, boolean)*Signature*

```
public  
AperiodicParameters(RelativeTime cost,  
                    RelativeTime deadline,  
                    AsyncEventHandler overrunHandler,  
                    AsyncEventHandler missHandler,  
                    boolean rousable)
```

Description

Create an AperiodicParameters object.

Available since RTSJ 2.0

Parameters

cost Processing time per invocation. On implementations which can measure the amount of time a schedulable object is executed, this value is the maximum amount of time a schedulable receives. On implementations which cannot measure execution time, it is not possible to determine when any particular object exceeds cost. When `null`, the default value is a new instance of `RelativeTime(0,0)`.

deadline The latest permissible completion time measured from the release time of the associated invocation of the schedulable. When `null`, the default value is a new instance of `RelativeTime(Long.MAX_VALUE, 999999)`.

overflowHandler This handler is invoked when an invocation of the schedulable exceeds cost. Not required for minimum implementation. When `null`, the default value is no overflow handler.

missHandler This handler is invoked when the `run()` method of the schedulable object is still executing after the deadline has passed. When `null`, the default value is no miss handler.

releasable determines whether or not an instance of `Schedulable` can be prematurely released by a thread interrupt.

Throws

`IllegalArgumentException` when the time value of **cost** is less than zero, or the time value of **deadline** is less than or equal to zero.

`IllegalAssignmentError` when **cost**, **deadline**, **overflowHandler** or **missHandler** cannot be stored in this.

AperiodicParameters(RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler)

Signature

```
public
AperiodicParameters(RelativeTime cost,
                    RelativeTime deadline,
                    AsyncEventHandler overflowHandler,
                    AsyncEventHandler missHandler)
```

Description

Create an `AperiodicParameters` object.

Parameters

cost Processing time per invocation. On implementations which can measure the amount of time a schedulable object is executed, this value is the maximum

amount of time a schedulable receives. On implementations which cannot measure execution time, it is not possible to determine when any particular object exceeds cost. When `null`, the default value is a new instance of `RelativeTime(0,0)`.

deadline The latest permissible completion time measured from the release time of the associated invocation of the schedulable. When `null`, the default value is a new instance of `RelativeTime(Long.MAX_VALUE, 999999)`.

overflowHandler This handler is invoked when an invocation of the schedulable exceeds cost. Not required for minimum implementation. When `null`, the default value is no overflow handler.

missHandler This handler is invoked when the `run()` method of the schedulable object is still executing after the deadline has passed. When `null`, the default value is no miss handler.

Throws

`IllegalArgumentException` when the time value of `cost` is less than zero, or the time value of `deadline` is less than or equal to zero.

`IllegalAssignmentError` when `cost`, `deadline`, `overflowHandler` or `missHandler` cannot be stored in `this`.

AperiodicParameters(RelativeTime, AsyncEventHandler, boolean)

Signature

```
public
AperiodicParameters(RelativeTime deadline,
                    AsyncEventHandler missHandler,
                    boolean rousable)
```

Description

Create an `AperiodicParameters` object. This constructor is equivalent to

```
AperiodicParameters(null, deadline, null, missHandler, rousable)
```

Available since RTSJ 2.0

Parameters

deadline is the time after start of a release by which the release action should be completed.

`missHandler` is a handler to call when the deadline is missed.

`rousable` determines whether or not an interrupt with cause an early release.

AperiodicParameters(RelativeTime)

Signature

```
public  
AperiodicParameters(RelativeTime deadline)
```

Description

Create an `AperiodicParameters` object. This constructor is equivalent to

```
AperiodicParameters(null, deadline, null, null, false)
```

Available since RTSJ 2.0

Parameters

`deadline` is the time after start of a release by which the release action should be completed.

AperiodicParameters

Signature

```
public  
AperiodicParameters()
```

Description

Create an `AperiodicParameters` object. This constructor is equivalent to

```
AperiodicParameters(null, null, null, null, false)
```

Available since RTSJ 1.0.1

6.4.3.2.3 Methods

getArrivalTimeQueueOverflowPolicy

Signature

```
public  
    javax.realtime.QueueOverflowPolicy getArrivalTimeQueueOverflowPolicy()
```

Description

Gets the behavior of the arrival time queue in the event of an overflow.

Returns

The behavior of the arrival time queue as a string.

Available since RTSJ 2.0

setArrivalTimeQueueOverflowPolicy(QueueOverflowPolicy)

Signature

```
public  
    void setArrivalTimeQueueOverflowPolicy(QueueOverflowPolicy policy)
```

Description

Sets the policy for the arrival time queue for when the insertion of a new element would make the queue size greater than the initial size given in **this**.

Parameters

policy is a queue overflow policy to use for handlers associated with **this**.

Available since RTSJ 2.0.

setInitialArrivalTimeQueueLength(int)

Signature

```
public  
    void setInitialArrivalTimeQueueLength(int initial)
```

Description

Sets the initial number of elements the arrival time queue can hold without lengthening the queue. The initial length of an arrival queue is set when the schedulable using the queue is constructed, after that time changes in the initial queue length are ignored.

Parameters

initial The initial length of the queue.

Throws

IllegalArgumentException when **initial** is less than zero.

Available since RTSJ 1.0.1 Moved here from SporadicParameters.

getInitialArrivalTimeQueueLength

Signature

```
public  
int getInitialArrivalTimeQueueLength()
```

Description

Gets the initial number of elements the arrival time queue can hold. This returns the initial queue length currently associated with this parameter object. When the overflow policy is **SAVE** the initial queue length may not be related to the current queue lengths of schedulables associated with this parameter object.

Returns

The initial length of the queue.

Available since RTSJ 1.0.1 Moved here from SporadicParameters.

setDeadline(RelativeTime)

Signature

```
public  
void setDeadline(RelativeTime deadline)
```

Description

Sets the deadline value.

When this parameter object is associated with any schedulable object (by being passed through the schedulable's constructor or set with a method such as **RealtimeThread.setReleaseParameters(ReleaseParameters)**⁶²) the deadline of those schedulables is altered as specified by each schedulable's respective scheduler.

Parameters

⁶²Section 5.4.1

Table 6.4: FirstInFirstOut Default PriorityParameter Values

Attribute	Default Value
Priority	norm priority

deadline The latest permissible completion time measured from the release time of the associated invocation of the schedulable. When **deadline** is **null**, the deadline is set to a new instance of `RelativeTime(Long.MAX_VALUE, 999999)`.

Throws

`IllegalArgumentException` when the time value of **deadline** is less than or equal to zero, or when the new value of this deadline is incompatible with the scheduler for any associated schedulable.

`IllegalAssignmentError` `IllegalAssignmentError` when **deadline** cannot be stored in **this**.

6.4.3.3 FirstInFirstOutScheduler

Inheritance

```

java.lang.Object
  javax.realtime.Scheduler
    javax.realtime.PriorityScheduler
      javax.realtime.FirstInFirstOutScheduler

```

Description

A version of `PriorityScheduler`⁶³ where once a thread is scheduled at a given priority, it runs until it is blocked or is preempted by a higher priority thread. When preempted, it remains the next thread ready for its priority. This is the default scheduler for realtime tasks. It represents the required (by the RTSJ) priority-based scheduler. The default instance is the base scheduler which does fixed priority, preemptive scheduling.

This scheduler, like all schedulers, governs the default values for scheduling-related parameters in its client schedulables. The defaults are as follows:

The system contains one instance of the `FirstInFirstOutScheduler` which is the system's base scheduler and is returned by `FirstInFirstOutScheduler.instance()`. The instance returned by the `instance()`⁶⁴ method is the *base scheduler* and is

⁶³Section 6.4.3.8

⁶⁴Section 6.4.3.3.1

returned by `Scheduler.getDefaultScheduler()`⁶⁵ unless the default scheduler is reset with `Scheduler.setDefaultScheduler(Scheduler)`⁶⁶.

Available since RTSJ 2.0

6.4.3.3.1 Methods

instance

Signature

```
public static  
    javax.realtime.FirstInFirstOutScheduler instance()
```

Description

Obtain a reference to the distinguished instance of `PriorityScheduler` which is the system's base scheduler.

Returns

A reference to the distinguished instance `PriorityScheduler`.

getMaxPriority

Signature

```
public  
    int getMaxPriority()
```

Description

Obtain the maximum priority available for a schedulable managed by this scheduler.

Returns

The value of the maximum priority.

⁶⁵Section 6.4.3.12.2

⁶⁶Section 6.4.3.12.2

getMinPriority

Signature

```
public  
int getMinPriority()
```

Description

Obtain the minimum priority available for a schedulable managed by this scheduler.

Returns

The minimum priority used by this scheduler.

getNormPriority

Signature

```
public  
int getNormPriority()
```

Description

Obtain the normal priority available for a schedulable managed by this scheduler.

Returns

The value of the normal priority.

getPolicyName

Signature

```
public  
java.lang.String getPolicyName()
```

Description

Obtain the policy name of **this**.

Returns

The policy name (Fixed Priority First In First Out) as a string.

reschedule(Thread, int)

Signature

```
public  
void reschedule(Thread thread,  
                 int priority)
```

Description

Promotes a `java.lang.Thread` to realtime priority under this scheduler. The affected thread will be scheduled as if it were a `RealtimeThread`⁶⁷ of the given priority. This does not make the affected thread a `RealtimeThread`, however, and it will not have access to facilities reserved for instances of `RealtimeThread`.

Parameters

thread The thread to promote to realtime scheduling.
priority An integer priority equivalent to a priority set via `PriorityParameters`⁶⁸ on a `RealtimeThread`.

Throws

`IllegalArgumentException` when **priority** is not between `getMinPriority()`⁶⁹ and `getMaxPriority()`⁷⁰, inclusive.

6.4.3.4 ImportanceParameters

Inheritance

```
java.lang.Object  
  javax.realtime.SchedulingParameters  
    javax.realtime.PriorityParameters  
      javax.realtime.ImportanceParameters
```

Description

Importance is an additional scheduling metric that may be used by some priority-based scheduling algorithms during overload conditions to differentiate execution order among threads of the same priority.

In some realtime systems an external physical process determines the period of many threads. When rate-monotonic priority assignment is used to assign priorities, many of the threads in the system may have the same priority because

⁶⁷Section 5.4.2.2

⁶⁸Section 6.4.3.7

⁶⁹Section 6.4.3.3.1

⁷⁰Section 6.4.3.3.1

their periods are the same. However, it is conceivable that some threads may be more important than others and in an overload situation importance can help the scheduler decide which threads to execute first. The base scheduling algorithm represented by `PriorityScheduler`⁷¹ must not consider importance.

6.4.3.4.1 Constructors

ImportanceParameters(int, int)

Signature

```
public
    ImportanceParameters(int priority,
                        int importance)
```

Description

Create an instance of `ImportanceParameters`.

Parameters

priority The priority value assigned to schedulables that use this parameter instance. This value is used in place of the value passed to `Thread.setPriority`.
importance The importance value assigned to schedulable objects that use this parameter instance.

6.4.3.4.2 Methods

getImportance

Signature

```
public
    int getImportance()
```

Description

Gets the importance value.

⁷¹Section 6.4.3.8

Returns

The value of importance for the associated instances of `Schedulable`⁷².

setImportance(int)*Signature*

```
public  
void setImportance(int importance)
```

Description

Set the importance value. When this parameter object is associated with any schedulable (by being passed through the schedulable's constructor or set with a method such as `RealtimeThread.setSchedulingParameters(SchedulingParameters)`⁷³) the importance of those schedulables is altered at a moment controlled by the schedulers for the respective schedulables.

Parameters

importance The value to which importance is set.

Throws

`IllegalArgumentException` when the given importance value is incompatible with the scheduler for any of the schedulables which are presently using this parameter object.

toString*Signature*

```
public  
java.lang.String toString()
```

Description

Print the value of the priority and importance values of the associated instance of `Schedulable`⁷⁴

⁷²Section 6.4.1.3

⁷³Section 5.4.1

⁷⁴Section 6.4.1.3

6.4.3.5 OneShotParameters

Inheritance

```
java.lang.Object
  javax.realtime.ReleaseParameters
    javax.realtime.OneShotParameters
```

Description

Parameters for realtime threads that are only released once. A thread using this release parameters may not use `RealtimeThread.waitForNextRelease()`⁷⁵ or have its `RealtimeThread.release()`⁷⁶ methods called. Calling these methods results in an `IllegalThreadStateException`.

6.4.3.5.1 Constructors

OneShotParameters(RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler)

Signature

```
public
OneShotParameters(RelativeTime cost,
                  RelativeTime deadline,
                  AsyncEventHandler overrunHandler,
                  AsyncEventHandler missHandler)
```

Description

A constructor for both cost and deadline monitoring.

Parameters

`cost` is the maximum cost for the initial release
`deadline` is the deadline for the initial release
`overrunHandler` is the handler to call on cost overrun.
`missHandler` is the handler to call on deadline miss.

⁷⁵Section 5.4.1

⁷⁶Section 5.4.1

OneShotParameters

Signature

```
public  
OneShotParameters()
```

Description

A constructor for not having any restrictions on or monitoring of scheduling.

6.4.3.6 PeriodicParameters

Inheritance

```
java.lang.Object  
  javax.realtime.ReleaseParameters  
    javax.realtime.PeriodicParameters
```

Description

This release parameter indicates that the schedulable is released on a regular basis. For an [AsyncEventHandler](#)⁷⁷, this means that the handler is either released by a periodic timer, or the associated event occurs periodically. For a [RealtimeThread](#)⁷⁸, this means that the [RealtimeThread.waitForNextRelease](#)⁷⁹ method will unblock the associated realtime thread at the start of each period.

When a reference to a **PeriodicParameters** object is given as a parameter to a schedulable's constructor or passed as an argument to one of the schedulable's setter methods, the **PeriodicParameters** object becomes the release parameters object bound to that schedulable. Changes to the values in the **PeriodicParameters** object affect that schedulable object. When bound to more than one schedulable then changes to the values in the **PeriodicParameters** object affect *all* of the associated objects. Note that this is a one-to-many relationship and *not* a many-to-many.

Only changes to a **PeriodicParameters** object caused by methods on that object cause the change to propagate to all schedulable objects using the object. For instance, calling **setCost** on an **PeriodicParameters** object will make the change, then notify that the scheduler that the parameter object has changed. At that point the object is reconsidered for every SO that uses it. Invoking a method

⁷⁷Section [8.4.3.5](#)

⁷⁸Section [5.4.2.2](#)

⁷⁹Section [5.4.1](#)

Table 6.5: PeriodicParameter Default Values

Attribute	Default Value
start	new RelativeTime(0,0)
period	No default. A value must be supplied
cost	new RelativeTime(0,0)
deadline	new RelativeTime(period)
overrunHandler	None
missHandler	None

on the `RelativeTime` object that is the cost for this object may change the cost but it does not pass the change to the scheduler at that time. That change must not change the behavior of the SOs that use the parameter object until a setter method on the `PeriodicParameters` object is invoked, or the parameter object is used in `setReleaseParameters()` or a constructor for an SO.

Periodic parameters use `HighResolutionTime`⁸⁰ values for period and start time. Since these times are expressed as a `HighResolutionTime`⁸¹ values, these values use accurate timers with nanosecond granularity. The actual resolution available and even the quantity the timers measure depend on the clock associated with each time value.

The implementation must use modified copy semantics for each `HighResolutionTime`⁸² parameter value. The value of each time object should be treated as if it were copied at the time it is passed to the parameter object, but the object reference must also be retained. For instance, the value returned by `getCost()` must be the same object passed in by `setCost()`, but any changes made to the time value of the cost must not take effect in the associated `PeriodicParameters` instance unless they are passed to the parameter object again, e.g. with a new invocation of `setCost`.

The following table gives the default parameter values for the constructors.

Periodic release parameters are strictly informational when they are applied to async event handlers. They must be used for any feasibility analysis, but release of the async event handler is not entirely controlled by the scheduler.

Caution: This class is explicitly unsafe for multithreading when being changed. Code that mutates instances of this class should synchronize at a higher level.

⁸⁰Section 9.4.1.2

⁸¹Section 9.4.1.2

⁸²Section 9.4.1.2

6.4.3.6.1 Constructors

PeriodicParameters(RelativeTime)

Signature

```
public  
PeriodicParameters(RelativeTime period)
```

Description

Create a `PeriodicParameters` object with the specified period and all other attributes set to their default values. This constructor has the same effect as invoking `PeriodicParameters(null, period, null, null, null, null, false)`

Available since RTSJ 1.0.1

PeriodicParameters(HighResolutionTime, RelativeTime)

Signature

```
public  
PeriodicParameters(javax.realtime.HighResolutionTime<?> start,  
                    RelativeTime period)
```

Description

Create a `PeriodicParameters` object with the specified period and start times, and all other attributes set to their default values. This constructor has the same effect as invoking `PeriodicParameters(start, period, null, null, null, null, false)`

Available since RTSJ 1.0.1

PeriodicParameters(HighResolutionTime, RelativeTime, RelativeTime, boolean)

Signature

```
public
PeriodicParameters(javax.realtime.HighResolutionTime<?> start,
                    RelativeTime period,
                    RelativeTime deadline,
                    boolean rousable)
```

Description

Create a `PeriodicParameters` object with the specified deadline, period and start times, and all other attributes set to their default values. This constructor has the same effect as invoking `PeriodicParameters(start, period, null, deadline, null, null, null, rousable)`

Available since RTSJ 2.0

PeriodicParameters(HighResolutionTime, RelativeTime, RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler)

Signature

```
public
PeriodicParameters(javax.realtime.HighResolutionTime<?> start,
                    RelativeTime period,
                    RelativeTime cost,
                    RelativeTime deadline,
                    AsyncEventHandler overrunHandler,
                    AsyncEventHandler missHandler)
```

Description

Create a `PeriodicParameters` object with the specified start, period, cost, deadline, overrunHandler, and missHandler parameters and rousable set to its default values. This constructor has the same effect as invoking `PeriodicParameters(start, period, null, deadline, overrunHandler, missHandler, false)`

PeriodicParameters(HighResolutionTime, RelativeTime, RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler, boolean)

Signature

```
public
PeriodicParameters(javax.realtime.HighResolutionTime<?> start,
                    RelativeTime period,
                    RelativeTime cost,
                    RelativeTime deadline,
                    AsyncEventHandler overrunHandler,
                    AsyncEventHandler missHandler,
                    boolean rousable)
```

Description

Create a `PeriodicParameters` object with attributes set to the specified values.

Available since RTSJ 2.0*Parameters*

start Time at which the first release begins (i.e. the realtime thread becomes eligible for execution.) When a `RelativeTime`, this time is relative to the first time the thread becomes activated (that is, when `start()` is called). When an `AbsoluteTime`, then the first release is the maximum of the start parameter and the time of the call to the associated `RealtimeThread.start()` method (modified according to any phasing policy). When null, the default value is a new instance of `RelativeTime(0,0)`.

period The period is the interval between successive unblocks of the `RealtimeThread.waitForNextRelease`⁸³ method. There is no default value. When **period** is null an exception is thrown.

cost Processing time per release. On implementations which can measure the amount of time a schedulable is executed, this value is the maximum amount of time a schedulable receives per release. When null, the default value is a new instance of `RelativeTime(0,0)`.

deadline The latest permissible completion time measured from the release time of the associated invocation of the schedulable. When null, the default value is new instance of `RelativeTime(period)`.

overrunHandler This handler is invoked when an invocation of the schedulable exceeds cost in the given release. Implementations may ignore this parameter. When null, the default value is no overrun handler.

⁸³Section 5.4.1

missHandler This handler is invoked when the `run()` method of the schedulable is still executing after the deadline has passed. When null, the default value is no deadline miss handler.

rousable when `true`, and interrupt will cause an early release, otherwise not.

Throws

IllegalArgumentException when the **period** is `null` or its time value is not greater than zero, or when the time value of **cost** is less than zero, or when the time value of **deadline** is not greater than zero, or when the clock associated with the **cost** is not the realtime clock, or when the clock associated with the **start**, **deadline** and **period** parameters are not the same.

IllegalAssignmentError when **start** period, **cost**, **deadline**, **overrunHandler** or **missHandler** cannot be stored in **this**.

6.4.3.6.2 Methods

getPeriod

Signature

```
public  
javax.realtime.RelativeTime getPeriod()
```

Description

Determine the current value of period.

Returns

the object last used to set the period containing the current value of period.

getPeriod(RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime getPeriod(RelativeTime value)
```

Description

Determine the current value of period.

Returns

value or, when **null**, the last object used to set the period, set to the current value of period.

getStart

Signature

```
public  
    javax.realtime.HighResolutionTime<?> getStart()
```

Description

Determine the time used to start an instance of **Schedulable**, which is not necessarily the time at which it actually started.

Returns

the object last used to set the start containing the current value of start.

setDeadline(RelativeTime)

Signature

```
public  
    void setDeadline(RelativeTime deadline)
```

Description

Sets the deadline value.

When this parameter object is associated with any schedulable object (by being passed through the schedulable's constructor or set with a method such as **RealtimeThread.setReleaseParameters(ReleaseParameters)**⁸⁴) the deadline of those schedulables is altered as specified by each schedulable's respective scheduler.

Parameters

deadline The latest permissible completion time measured from the release time of the associated invocation of the schedulable. When **deadline** is **null**, the deadline is set to a new instance of **RelativeTime** equal to **period**.

Throws

IllegalArgumentException when the time value of **deadline** is less than or equal to zero, or when the new value of this deadline is incompatible with the scheduler for any associated schedulable.

⁸⁴Section 5.4.1

IllegalAssignmentError IllegalAssignmentError when `deadline` cannot be stored in `this`.

setPeriod(RelativeTime)

Signature

```
public  
void setPeriod(RelativeTime period)
```

Description

Sets the period.

Parameters

period The value to which `period` is set.

Throws

IllegalArgumentException when the given period is `null` or its time value is not greater than zero. Also when `period` is incompatible with the scheduler for any associated schedulable or when an associated **AsyncBaseEventHandler**⁸⁵ is associated with a **Timer**⁸⁶ whose period does not match `period`.

IllegalAssignmentError when period cannot be stored in `this`.

setStart(HighResolutionTime)

Signature

```
public  
void setStart(javax.realtime.HighResolutionTime<?> start)
```

Description

Sets the start time.

The effect of changing the start time for any schedulables associated with this parameter object is determined by the scheduler associated with each schedulable.

Note: An instance of **PeriodicParameters** may be shared by several schedulables. A change to the start time may take effect on a subset of these schedulables. That leaves the start time returned by **getStart** unreliable as a way to determine the start time of a schedulable.

Parameters

⁸⁵Section 8.4.3.3

⁸⁶Section 10.4.2.6

start The new start time. When `null`, the default value is a new instance of `RelativeTime(0,0)`.

Throws

`IllegalArgumentException` when the given start time is incompatible with the scheduler for any of the schedulable objects which are presently using this parameter object.

`IllegalAssignmentError` when **start** cannot be stored in **this**.

6.4.3.7 PriorityParameters

Inheritance

java.lang.Object
 javax.realtime.SchedulingParameters
 javax.realtime.PriorityParameters

Description

Instances of this class should be assigned to schedulables that are managed by schedulers which use a single integer to determine execution order. The base scheduler required by this specification and represented by the class `PriorityScheduler`⁸⁷ is such a scheduler.

6.4.3.7.1 Constructors

PriorityParameters(int)

Signature

```
public  
PriorityParameters(int priority)
```

Description

Create an instance of `PriorityParameters`⁸⁸ with the given priority.

Parameters

⁸⁷Section 6.4.3.8

⁸⁸Section 6.4.3.7

priority The priority assigned to schedulables that use this parameter instance.

6.4.3.7.2 Methods

isCompatible(Class)

Signature

```
public  
boolean isCompatible(java.lang.Class<javax.realtime.Scheduler> type)
```

Description

Determine whether **this** scheduling parameters can be used by tasks scheduled by instances of **type**.

Parameters

type of scheduler to check against

Returns

true when and only when **this** can be used with **type** as the scheduler.

Available since RTSJ 2.0

getPriority

Signature

```
public  
int getPriority()
```

Description

Gets the priority value.

Returns

The priority.

setPriority(int)

Signature

```
public  
void setPriority(int priority)
```

Description

Set the priority value. When this parameter object is associated with any schedulable (by being passed through the schedulable's constructor or set with a method such as `RealtimeThread.setSchedulingParameters(SchedulingParameters)`⁸⁹) the base priority of those schedulables is altered as specified by each schedulable's scheduler.

Parameters

priority The value to which priority is set.

Throws

`IllegalArgumentException` when the given priority value is incompatible with the scheduler for any of the schedulables which are presently using this parameter object.

toString

Signature

```
public  
java.lang.String toString()
```

Description

Converts the priority value to a string.

Returns

A string representing the value of priority.

6.4.3.8 PriorityScheduler

Inheritance

```
java.lang.Object  
  javax.realtime.Scheduler
```

⁸⁹Section 5.4.1

Table 6.6: PriorityScheduler Default PriorityParameter Values

Attribute	Default Value
Priority	norm priority

`javax.realtime.PriorityScheduler`

Description

Class which represents the required (by the RTSJ) priority-based schedulers. The default instance is the base scheduler which uses a fixed priority, first-in-first-out, preemptive scheduling algorithm.

This scheduler, like all schedulers, governs the default values for scheduling-related parameters in its client schedulables. The defaults are as follows:

Note that the system contains one instance of the `PriorityScheduler` which is the system's base scheduler and is returned by `FirstInFirstOutScheduler.instance()`⁹⁰. It may, however, contain instances of subclasses of `PriorityScheduler` created through this class' protected constructor. The instance returned by the `FirstInFirstOutScheduler.instance()` method, the *base scheduler*, is returned by `Scheduler.getDefaultScheduler()`⁹¹ unless the default scheduler is changed with `Scheduler.setDefaultScheduler(Scheduler)`⁹².

6.4.3.8.1 Fields

MAX_PRIORITY

```
public static final MAX_PRIORITY
```

Description

The maximum priority value used by the implementation.

Deprecated since RTSJ version as of RTSJ 1.0.1 Use the `getMaxPriority`⁹³ method instead.

⁹⁰Section 6.4.3.3.1

⁹¹Section 6.4.3.12.2

⁹²Section 6.4.3.12.2

⁹³Section 6.4.3.8.3

MIN_PRIORITY

```
public static final MIN_PRIORITY
```

Description

The minimum priority value used by the implementation.

Deprecated since RTSJ version as of RTSJ 1.0.1 Use the `getMinPriority`⁹⁴ method instead.

6.4.3.8.2 Constructors

PriorityScheduler

Signature

```
protected  
PriorityScheduler()
```

Description

Construct an instance of `PriorityScheduler`. Applications will likely not need any instance other than the default instance.

6.4.3.8.3 Methods

getPolicyName

Signature

```
public  
java.lang.String getPolicyName()
```

Description

Gets the policy name of `this`.

⁹⁴Section [6.4.3.8.3](#)

Returns

The policy name (Fixed Priority) as a string.

getMaxPriority*Signature*

```
public abstract  
int getMaxPriority()
```

Description

Gets the maximum priority available for a schedulable managed by this scheduler.

Returns

The value of the maximum priority.

getMinPriority*Signature*

```
public abstract  
int getMinPriority()
```

Description

Gets the minimum priority available for a schedulable managed by this scheduler.

Returns

The minimum priority used by this scheduler.

getNormPriority*Signature*

```
public abstract  
int getNormPriority()
```

Description

Gets the normal priority available for a schedulable managed by this scheduler.

Returns

The value of the normal priority.

reschedule(Thread, int)

Signature

```
public abstract  
void reschedule(Thread thread,  
                 int priority)
```

Description

Promotes a `java.lang.Thread` to realtime priority under this scheduler. The affected thread will be scheduled as if it were a `RealtimeThread`⁹⁵ of the given priority. This does not make the affected thread a `RealtimeThread`, however, and it will not have access to facilities reserved for instances of `RealtimeThread`.

Parameters

thread The thread to promote to realtime scheduling.

priority An integer priority equivalent to a priority set via `PriorityParameters`⁹⁶ on a `RealtimeThread`.

Throws

`IllegalArgumentException` when priority is not between `getMinPriority()`⁹⁷ and `getMaxPriority()`⁹⁸, inclusive.

Available since RTSJ 2.0

6.4.3.9 ProcessingGroup

Inheritance

```
java.lang.Object  
  java.lang.ThreadGroup  
    javax.realtime.SchedulingGroup  
      javax.realtime.ProcessingGroup
```

Description

A descendant class of `ThreadGroup` for handling tasks, instances of `Schedulable`⁹⁹ and `java.lang.Thread`, as a single group. The cost of the group can be both

⁹⁵Section 5.4.2.2

⁹⁶Section 6.4.3.7

⁹⁷Section 6.4.3.8.3

⁹⁸Section 6.4.3.8.3

⁹⁹Section 6.4.1.3

traced and limited over a given period. The motivation for this class is to enable the execution demands of a group of tasks to be bound.

A processing group has an associated affinity. The precision of cost monitoring is dependent on the number of processes in the thread group. In the worst case, it is the base precision times the number of processes in the processing group. The default affinity is that which was inherited from the parent **SchedulingGroup**.

For all tasks with a reference to an instance of **ProcessingGroup** *p*, no more than *p.cost* will be allocated to the execution of these schedulables on the processors associated with its processing group in each interval of time given by *p.period* after the time indicated by *p.start*. No execution of the schedulables will be allowed on any processor other than these processors. There must be at least one processor in the intersection between a schedulable object's affinity and its processing group's affinity.

Logically **ProcessingGroup** represents a virtual server. This server has a start time, a period, a cost (budget), and a deadline. The server can only logically execute when (a) it has not consumed more execution time in its current release than the cost (budget) parameter, (b) one of its associated schedulables is executable and is the most eligible of the executable schedulables. When the server is logically executable, the associated schedulables are executed.

When the cost has been consumed, any **overrunHandler** is released, and the server is not eligible for logical execution until the period is finished. At this point, its allocated cost (budget) is replenished. When the server is logically executing when its deadline expires, any associated **missHandler** is released.

The deadline and cost parameters of all the associated schedulable objects have the same impact as they would if the objects were not bound to a processing group.

Processing group parameters use **HighResolutionTime**¹⁰⁰ values for cost, deadline, period and start time. Since those times are expressed as a **HighResolutionTime**¹⁰¹, the values use accurate timers with nanosecond granularity. The actual resolution available and even the quantity it measures depends on the clock associated with each time value.

When a reference to a **ProcessingGroup** object is given as a parameter to a schedulable's constructor or passed as an argument to one of the schedulable's setter methods, the **ProcessingGroup** object becomes the processing group parameters object bound to that schedulable object. Changes to the values in the **ProcessingGroup** object affect that schedulable object. When bound to more than one schedulable then changes to the values in the **ProcessingGroup** object affect *all* of the associated objects. Note that this is a one-to-many relationship

¹⁰⁰Section 9.4.1.2

¹⁰¹Section 9.4.1.2

Table 6.7: ProcessingGroup Default Values

Attribute	Default Value
start	new RelativeTime(0,0)
period	No default. A value must be supplied
cost	No default. A value must be supplied
deadline	new RelativeTime(period)
minimum	null, no minimum
overrunHandler	None
missHandler	None
underrunHandler	None
rousable	false

and *not* a many-to-many.

The implementation must use copy semantics for each [HighResolutionTime](#)¹⁰² parameter value. The value of each time object should be copied at the time it is passed to the parameter object, and the object reference must not be retained. Only changes to a `ProcessingGroup` object caused by methods on that object are immediately visible to the scheduler. For instance, invoking `setPeriod()` on a `ProcessingGroup` object will make the change, then notify that the scheduler that the parameter object has changed. At that point the scheduler's view of the processing group parameters object is updated. Invoking a method on the `RelativeTime` object that is the period for this object may change the period but it does not pass the change to the scheduler at that time. That new value for period must not change the behavior of the SOs that use the parameter object until a setter method on the `ProcessingGroup` object is invoked or a constructor for an SO.

The following table gives the default parameter values for the constructors.

Caution: This class is explicitly unsafe in multithreaded situations when it is being changed. No synchronization is done. It is assumed that users of this class who are mutating instances will be doing their own synchronization at a higher level.

Caution: The `cost` parameter time should be considered to be measured against the target platform.

¹⁰²Section [9.4.1.2](#)

Available since RTSJ 2.0

6.4.3.9.1 Constructors

ProcessingGroup(SchedulingGroup, String, HighResolutionTime, RelativeTime, RelativeTime, AsyncEventHandler, RelativeTime, AsyncEventHandler)

Signature

```
public
ProcessingGroup(SchedulingGroup parent,
                String name,
                javax.realtime.HighResolutionTime<?> start,
                RelativeTime period,
                RelativeTime cost,
                AsyncEventHandler overrun,
                RelativeTime minimum,
                AsyncEventHandler underrun)
```

Description

Create a ProcessingGroup

Parameters

parent is the parent **SchedulingGroup**¹⁰³ of this ProcessingGroup.
name is a string identifier for this group.
start is when monitoring should begin.
period is an amount of time for cost and overrun monitoring and for cost enforcement.
cost is the maximum total execution time of all tasks in the group during a given **period**.
overrun is called when the the total execution of all tasks in the group exceeds **cost** for a given **period**.
minimum is the least amount of processing time for all the tasks in this group together.

¹⁰³Section 6.4.3.13

`underrun` is called at the end of period when the total processing time of all tasks was less than minimum in the last period.

ProcessingGroup(SchedulingGroup, String, HighResolutionTime, RelativeTime, RelativeTime, AsyncEventHandler)

Signature

```
public
ProcessingGroup(SchedulingGroup parent,
                String name,
                javax.realtime.HighResolutionTime<?> start,
                RelativeTime period,
                RelativeTime cost,
                AsyncEventHandler overrun)
```

Description

Create a `ProcessingGroup` with the current `SchedulingGroup` as its parent.

Equivalent to `ProcessingGroup(parent, name, start, period, cost, overrun, null, null)`.

ProcessingGroup(String, HighResolutionTime, RelativeTime, RelativeTime, AsyncEventHandler)

Signature

```
public
ProcessingGroup(String name,
                javax.realtime.HighResolutionTime<?> start,
                RelativeTime period,
                RelativeTime cost,
                AsyncEventHandler overrun)
```

Description

Create a `ProcessingGroup` with the current `SchedulingGroup` as its parent and with both minimum and underrun set to null.

Equivalent to `ProcessingGroup(Scheduler.currentSchedulable().getSchedulingGroup(), name, start, period, cost, overrun, null, null)`.

6.4.3.9.2 Methods

getStart

Signature

```
public  
    javax.realtime.HighResolutionTime<?> getStart()
```

Description

Obtain the value used to determine **start**. This is not necessarily the absolute time corresponding to the actual start of the processing group. Use **getEffectiveStart**¹⁰⁴ for obtaining the actual start time.

Returns

the value that was specified in the constructor or by the last call to **setStart()**, with its original values.

setStart(HighResolutionTime)

Signature

```
public  
    void setStart(javax.realtime.HighResolutionTime<?> start)  
    throws IllegalArgumentException,  
           IllegalAssignmentError
```

Description

Sets the value of **start**. When the processing group is already started this method alters the value of this object's start time property, but has no other effect.

Parameters

start The new value for **start**. When **null**, the default value is a new instance of **RelativeTime(0,0)**.

Throws

IllegalArgumentException when **start** is a relative time value and less than zero.

¹⁰⁴Section 6.4.3.9.2

getEffectiveStart(AbsoluteTime)

Signature

```
public  
javax.realtime.AbsoluteTime getEffectiveStart(AbsoluteTime dest)
```

Description

Obtain the actual time of the group started.
Equivalent to `getEffectiveStart(null)`.

Parameters

dest is a time value to fill.

Returns

either **dest**, when **dest** is not null, or a reference a new instance of **AbsoluteTime** otherwise, that represents the time at which this group actually started.

getEffectiveStart

Signature

```
public  
javax.realtime.AbsoluteTime getEffectiveStart()
```

Description

Obtain the actual time of the group started.
Equivalent to `getEffectiveStart(null)`.

Returns

A reference a new instance of **AbsoluteTime** that represents the time at which this group started.

getPeriod(RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime getPeriod(RelativeTime dest)
```

Description

Gets the value of **period** and returns it in the provided **RelativeTime**¹⁰⁵ object.

¹⁰⁵Section 9.4.1.3

Parameters

dest An instance of `RelativeTime` which will be set to the currently configured `period`. If **dest** is null, a new `RelativeTime` will be created in the current allocation context.

Returns

A reference to **dest**, or a newly created object if **dest** is null.

getPeriod

Signature

```
public  
javax.realtime.RelativeTime getPeriod()
```

Description

Gets the value of `period`.
Equivalent to `getPeriod(null)`.

Returns

A reference to a newly allocated instance of `RelativeTime`¹⁰⁶ that represents the value of `period`.

setPeriod(RelativeTime)

Signature

```
public  
void setPeriod(RelativeTime period)  
throws IllegalArgumentException,  
    IllegalAssignmentError
```

Description

Sets the value of `period`.

Parameters

period The new value for `period`. There is no default value. When **period** is null an exception is thrown.

Throws

¹⁰⁶Section 9.4.1.3

`IllegalArgumentException` when `period` is `null`, or its time value is not greater than zero. When the implementation does not support processing group deadline less than `period`, and `period` is not equal to the current value of the processing group's deadline, the deadline is set to a clone of `period` created in the same memory area as `period`.

getMaxCost(RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime getMaxCost(RelativeTime dest)
```

Description

Gets the value of `cost`. and returns it in the provided `RelativeTime`¹⁰⁷ object.

Parameters

dest An instance of `RelativeTime` which will be set to the currently configured `cost`. If `dest` is `null`, a new `RelativeTime` will be created in the current allocation context.

Returns

A reference to `dest`, or a newly created object if `dest` is `null`.

getMaxCost

Signature

```
public  
javax.realtime.RelativeTime getMaxCost()
```

Description

Gets the value of `cost`.

Equivalent to `getMaxCost(null)`.

Returns

a reference to a newly allocated object containing the value of `cost`.

¹⁰⁷Section 9.4.1.3

setMaxCost(RelativeTime)

Signature

```
public  
void setMaxCost(RelativeTime cost)  
throws IllegalArgumentException,  
       IllegalAssignmentError
```

Description

Sets the value of `cost`.

Parameters

`cost` The new value for `cost`. When `null`, an exception is thrown.

Throws

`IllegalArgumentException` when `cost` is `null` or its time value is less than zero.

getMinimumCost(RelativeTime)

Signature

```
public  
java.xml.realtime.RelativeTime getMinimumCost(RelativeTime dest)
```

Description

Gets the value of `minimum`. and returns it in the provided `RelativeTime`¹⁰⁸ object.

Parameters

`dest` An instance of `RelativeTime` which will be set to the currently configured `minimum`. If `dest` is `null`, a new `RelativeTime` will be created in the current allocation context.

Returns

A reference to `dest`, or a newly created object if `dest` is `null`.

getMinimumCost

Signature

¹⁰⁸Section 9.4.1.3

```
public  
    javax.realtime.RelativeTime getMinimumCost()
```

Description

Gets the value of `minimum` and returns it in a newly allocated object.
Equivalent to `getMinimumCost(null)`.

Returns

a reference to the value of `minimum`.

setMinimumCost(RelativeTime)

Signature

```
public  
    void setMinimumCost(RelativeTime cost)  
    throws IllegalArgumentException,  
           IllegalAssignmentError
```

Description

Sets the value of `minimum`.

Parameters

`cost` The new value for `minimum`. When `null`, an exception is thrown.

Throws

`IllegalArgumentException` when `minimum` is `null` or its time value is less than zero.

getCostUnderrunHandler

Signature

```
public  
    javax.realtime.AsyncEventHandler getCostUnderrunHandler()
```

Description

Gets the cost underrun handler.

Returns

A reference to an instance of `AsyncEventHandler`¹⁰⁹ that is cost overrun handler of `this`.

¹⁰⁹Section 8.4.3.5

setCostUnderrunHandler(AsyncEventHandler)

Signature

```
public  
void setCostUnderrunHandler(AsyncEventHandler handler)  
throws IllegalArgumentException
```

Description

Sets the cost underrun handler.

Parameters

handler This handler is invoked when the `run()` method of and of the the schedulables attempt to execute for more than `cost` time units in any period. When `null`, no handler is attached, and any previous handler is removed.

Throws

`IllegalArgumentException` when `handler` cannot be stored in `this`.

getCostOverrunHandler

Signature

```
public  
javax.realtime.AsyncEventHandler getCostOverrunHandler()
```

Description

Gets the cost overrun handler.

Returns

A reference to an instance of `AsyncEventHandler`¹¹⁰ that is cost overrun handler of `this`.

setCostOverrunHandler(AsyncEventHandler)

Signature

```
public  
void setCostOverrunHandler(AsyncEventHandler handler)  
throws IllegalArgumentException
```

Description

¹¹⁰Section 8.4.3.5

Sets the cost overrun handler.

Parameters

handler This handler is invoked when the `run()` method of and of the the schedulables attempt to execute for more than `cost` time units in any period. When `null`, no handler is attached, and any previous handler is removed.

Throws

`IllegalAssignmentError` when `handler` cannot be stored in `this`.

enforcingCost

Signature

```
public  
boolean enforcingCost()
```

Description

Determine whether or not cost is being enforced for releases.

Returns

`true` when enforcing code.

Available since RTSJ 2.0

enforceCost(boolean)

Signature

```
public  
void enforceCost(boolean value)  
throws UnsupportedOperationException
```

Description

Set cost enforcement.

Parameters

`value` `true` when enforcing code.

Throws

`UnsupportedOperationException`

Available since RTSJ 2.0

getCurrentCost(RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime getCurrentCost(RelativeTime dest)
```

Description

Get the cost used in the current period so far.

Parameters

dest is the instance to use for returning the time. If **dest** is null, the result will be returned in a newly allocated object.

Returns

dest containing the cost of the current period

getLastCost(RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime getLastCost(RelativeTime dest)
```

Description

Get the total cost used in the last period.

Parameters

dest is the instance to use for returning the time. If **dest** is null, the result will be returned in a newly allocated object.

Returns

dest containing the cost of the last period

getGranularity

Signature

```
public  
long getGranularity()
```

Description

Determine the granularity of cost monitoring and cost enforcement.

Returns

the granularity in nanoseconds.

setGranularity(long)

Signature

```
public  
void setGranularity(long nanos)  
throws IllegalArgumentException
```

Description

Set the granularity of cost monitoring and cost enforcement. The system provides a lower bounds for this. When set below the lower bound, granularity is set to this lower bound. In general, this is the precision of the realtime clock.

Parameters

nanos the new granularity in nanoseconds.

Throws

IllegalArgumentException when **nanos** is less than one.

6.4.3.10 ReleaseParameters

Inheritance

```
java.lang.Object  
  javafx.realtime.ReleaseParameters
```

Interfaces

```
Cloneable  
Serializable
```

Description

The top-level class for release characteristics of schedulable objects. When a reference to a **ReleaseParameters** object is given as a parameter to a constructor of a schedulable, the **ReleaseParameters** object becomes bound to the object being created. Changes to the values in the **ReleaseParameters** object affect the constructed object. When given to more than one constructor, then changes to the values in the **ReleaseParameters** object affect *all* of the associated objects. Note that this is a one-to-many relationship and *not* a many-to-many. Only changes to an **ReleaseParameters** object caused by methods on that object cause the change to propagate to all schedulables using the object. For instance, invoking **setDeadline** on a **ReleaseParameters** instance will make the change, and then notify that the scheduler that the object has been changed. At that point the object is reconsidered for every SO that uses it. Invoking a method on the **RelativeTime** object that is the deadline for this object may change the time

Table 6.8: ReleaseParameter Default Values

Attribute	Default Value
cost	new RelativeTime(0,0)
deadline	no default
overrunHandler	None
missHandler	None
rousable	false

value but it does not pass the new time value to the scheduler at that time. Even though the changed time value is referenced by `ReleaseParameters` objects, it will not change the behavior of the SOs that use the parameter object until a setter method on the `ReleaseParameters` object is invoked, or the parameter object is used in `setReleaseParameters()` or a constructor for a schedulable.

Release parameters use `HighResolutionTime`¹¹¹ values for cost, and deadline. Since the times are expressed as a `HighResolutionTime`¹¹² values, these values use accurate timers with nanosecond granularity. The actual precision available and even the quantity the timers measure depend on the clock associated with each time value.

The implementation must use modified copy semantics for each `HighResolutionTime`¹¹³ parameter value. The value of each time object should be treated as when it were copied at the time it is passed to the parameter object, but the object reference must also be retained. For instance, the value returned by `getCost()` must be the same object passed in by `setCost()`, but any changes made to the time value of the cost must not take effect in the associated `ReleaseParameters` instance unless they are passed to the parameter object again, e.g. with a new invocation of `setCost`.

The following table gives the default parameter values for the constructors.

Caution: This class is explicitly unsafe for multithreading when being changed. Code that mutates instances of this class should synchronize at a higher level.

6.4.3.10.1 Constructors

¹¹¹Section 9.4.1.2

¹¹²Section 9.4.1.2

¹¹³Section 9.4.1.2

ReleaseParameters

Signature

```
protected  
ReleaseParameters()
```

Description

Create a new instance of `ReleaseParameters`. This constructor creates a default `ReleaseParameters` object, i.e., it is equivalent to `ReleaseParameters(null, null, null, null)`.

ReleaseParameters(RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler)

Signature

```
protected  
ReleaseParameters(RelativeTime cost,  
                  RelativeTime deadline,  
                  AsyncEventHandler overrunHandler,  
                  AsyncEventHandler missHandler)
```

Description

Create a new instance of `ReleaseParameters` with the given parameter values and rousable defaulting to false. It is equivalent to `@code{ReleaseParameters(cost, deadline, overrunHandler, missHandler, false)}`.

ReleaseParameters(RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler, boolean)

Signature

```
protected  
ReleaseParameters(RelativeTime cost,  
                  RelativeTime deadline,  
                  AsyncEventHandler overrunHandler,  
                  AsyncEventHandler missHandler,  
                  boolean rousable)
```

Description

Create a new instance of `ReleaseParameters` with the given parameter values.

Available since RTSJ 2.0*Parameters*

cost - Processing time units per release. On implementations which can measure the amount of time a schedulable object is executed, When null, the default value is a new instance of `RelativeTime(0,0)`.

deadline - The latest permissible completion time measured from the release time of the associated invocation of the schedulable. There is no default for deadline in this class. The default must be determined by the subclasses.

overflowHandler - This handler is invoked when an invocation of the schedulable exceeds cost. In the minimum implementation overflowHandler is ignored. When null, no application event handler is executed on cost overrun.

missHandler - This handler is invoked when the `run()` method of the schedulable is still executing after the deadline has passed. When null, no application event handler is executed on the miss deadline condition.

rousable determines whether or not an instance of `Schedulable` can be prematurely released by a thread interrupt.

Throws

`java.lang.IllegalArgumentException` - when the time value of cost is less than zero, or the time value of deadline is less than or equal to zero or the clock associated with the **cost** parameters is not the realtime clock.

`IllegalAssignmentError` - when cost, deadline, overflowHandler, or missHandler cannot be stored in this.

6.4.3.10.2 Methods

clone*Signature*

```
public  
java.lang.Object clone()
```

Description

Return a clone of **this**. This method should behave effectively as when it constructed a new object with clones of the high-resolution time values of **this**.

- The new object is in the current allocation context.
- **clone** does not copy any associations from **this** and it does not implicitly bind the new object to a SO.
- The new object has clones of all high-resolution time values (deep copy).
- References to event handlers are copied (shallow copy.)

Available since RTSJ 1.0.1

getCost

Signature

```
public  
javafx.realtime.RelativeTime getCost()
```

Description

Determine the current value of cost.

Returns

the object last used to set the cost containing the current value of cost.

getCost(RelativeTime)

Signature

```
public  
javafx.realtime.RelativeTime getCost(RelativeTime value)
```

Description

Determine the current value of cost.

Returns

value or, when **null**, the last object used to set the cost, set to the current value of cost.

getCostOverrunHandler

Signature


```
public  
javax.realtime.AsyncEventHandler getCostOverrunHandler()
```

Description

Gets a reference to the cost overrun handler.

Returns

A reference to the associated cost overrun handler.

getDeadline

Signature

```
public  
javax.realtime.RelativeTime getDeadline()
```

Description

Determine the current value of deadline.

Returns

the object last used to set the deadline containing the current value of deadline.

getDeadline(RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime getDeadline(RelativeTime value)
```

Description

Determine the current value of deadline.

Returns

`value` or, when `null`, the last object used to set the deadline, set to the current value of deadline.

getDeadlineMissHandler

Signature

```
public  
javax.realtime.AsyncEventHandler getDeadlineMissHandler()
```

Description

Gets a reference to the deadline miss handler.

Returns

A reference to the deadline miss handler.

setCost(RelativeTime)*Signature*

```
public  
void setCost(RelativeTime cost)
```

Description

Sets the cost value.

When this parameter object is associated with any schedulable object (by being passed through the schedulable's constructor or set with a method such as `RealtimeThread.setReleaseParameters(RelaseParameters)`¹¹⁴) the cost of those schedulables is altered as specified by each schedulable's respective scheduler.

Parameters

cost Processing time units per release. On implementations which can measure the amount of time a schedulable is executed, this value is the maximum amount of time a schedulable receives per release. On implementations which cannot measure execution time, it is not possible to determine when any particular object exceeds cost. When `null`, the default value is a new instance of `RelativeTime(0,0)`.

Throws

`IllegalArgumentException` when the time value of **cost** is less than zero, or the clock associated with the **cost** parameters is not the realtime clock.

`IllegalAssignmentError` when **cost** cannot be stored in **this**.

setCostOverrunHandler(AsyncEventHandler)*Signature*

```
public  
void setCostOverrunHandler(AsyncEventHandler handler)
```

¹¹⁴Section 5.4.1

Description

Sets the cost overrun handler.

When this parameter object is associated with any schedulable object (by being passed through the schedulable's constructor or set with a method such as `RealtimeThread.setReleaseParameters(ReleaseParameters)`¹¹⁵) the cost overrun handler of those schedulables is altered as specified by each schedulable's respective scheduler.

Parameters

handler This handler is invoked when an invocation of the schedulable attempts to exceed **cost** time units in a release. A **null** value of **handler** signifies that no cost overrun handler should be used.

Throws

`IllegalAssignmentError` when **handler** cannot be stored in **this**.

setDeadline(RelativeTime)

Signature

```
public  
void setDeadline(RelativeTime deadline)
```

Description

Sets the deadline value.

When this parameter object is associated with any schedulable object (by being passed through the schedulable's constructor or set with a method such as `RealtimeThread.setReleaseParameters(ReleaseParameters)`¹¹⁶) the deadline of those schedulables is altered as specified by each schedulable's respective scheduler.

Parameters

deadline The latest permissible completion time measured from the release time of the associated invocation of the schedulable. The default value of the deadline must be controlled by the classes that extend `ReleaseParameters`.

Throws

`IllegalArgumentException` when **deadline** is **null**, the time value of **deadline** is less than or equal to zero, or when the new value of this deadline is incompatible with the scheduler for any associated schedulable.

`IllegalAssignmentError` when **deadline** cannot be stored in **this**.

¹¹⁵Section 5.4.1

¹¹⁶Section 5.4.1

setDeadlineMissHandler(AsyncEventHandler)

Signature

```
public  
void setDeadlineMissHandler(AsyncEventHandler handler)
```

Description

Sets the deadline miss handler.

When this parameter object is associated with any schedulable object (by being passed through the schedulable's constructor or set with a method such as `RealtimeThread.setReleaseParameters(ReleaseParameters)`¹¹⁷) the deadline miss handler of those schedulables is altered as specified by each schedulable's respective scheduler.

Parameters

handler This handler is invoked when any release of the schedulable fails to complete before the deadline passes. A `null` value of **handler** signifies that no deadline miss handler should be used.

Throws

`IllegalAssignmentError` when **handler** cannot be stored in **this**.

isRousable

Signature

```
public  
boolean isRousable()
```

Description

Determine whether or not a thread interrupt will cause instances of `Schedulable` associated with an instance of this class will be prematurely released.

Returns

`true` when rousable and `false` when not.

Available since RTSJ 2.0

¹¹⁷Section 5.4.1

setRousable(boolean)

Signature

```
public  
void setRousable(boolean value)
```

Description

Dictate whether or not a thread interrupt will cause instances of **Schedulable** associated with an instance of this class will be prematurely released.

Parameters

value is **true** when rousable and **false** when not.

Available since RTSJ 2.0

enforcingCost

Signature

```
public  
boolean enforcingCost()
```

Description

Determine whether or not cost is being enforced for releases.

Returns

true when enforcing code.

Available since RTSJ 2.0

enforceCost(boolean)

Signature

```
public  
void enforceCost(boolean value)  
throws UnsupportedOperationException
```

Description

Set cost enforcement.

Parameters

value **true** when enforcing code.

Throws

`UnsupportedOperationException`

Available since RTSJ 2.0

6.4.3.11 RoundRobinScheduler

Inheritance

`java.lang.Object`
`javax.realtime.Scheduler`
`javax.realtime.PriorityScheduler`
`javax.realtime.RoundRobinScheduler`

Description

Class which represents a priority-based round-robin scheduler.

The default instance of this scheduler (returned by `instance()`¹¹⁸) represents the RTSJ-specified round-robin scheduler.

Available since RTSJ 2.0

6.4.3.11.1 Methods

instance*Signature*

```
public static  
javax.realtime.RoundRobinScheduler instance()
```

Description

Return a reference to the distinguished instance of `RoundRobinScheduler` which is the RTSJ-specified round-robin scheduler.

Throws

`UnsupportedOperationException` if this platform has no default round-robin scheduler.

¹¹⁸Section 6.4.3.11.1

Returns

A reference to the distinguished instance of `RoundRobinScheduler`

setQuantum(RelativeTime)*Signature*

```
public  
void setQuantum(RelativeTime quantum)  
throws UnsupportedOperationException,  
       IllegalArgumentException
```

Description

Set the quantum of this instance of `RoundRobinScheduler`. This takes effect at the end of the current quantum.

Parameters

quantum The new quantum to use. Copy semantics are used for this argument, and future changes to **quantum** will not affect this scheduler unless it is again passed to `setQuantum()`.

Throws

`UnsupportedOperationException` if this scheduler's quantum is not configurable at runtime.

`IllegalArgumentException` if the provided quantum is null, less than zero, or not appropriate for this platform.

getQuantum*Signature*

```
public  
java.xml.realtime.RelativeTime getQuantum()
```

Description

Get the quantum of this instance of `RoundRobinScheduler`.

Returns

a newly-allocated `RelativeTime` containing the currently-configured quantum of this scheduler.

getQuantum(RelativeTime)

Signature

```
public  
    javax.realtime.RelativeTime getQuantum(RelativeTime dest)
```

Description

Get the quantum of this instance of RoundRobinScheduler.

Parameters

dest return the quantum in **dest** . When **dest** is **null**, allocate a new [RelativeTime](#)¹¹⁹ instance to hold the returned value.

Returns

The currently-configured quantum of this scheduler.

getMaxPriority

Signature

```
public  
    int getMaxPriority()
```

Description

Gets the maximum priority available for a schedulable managed by this scheduler.

Returns

The value of the maximum priority.

getMinPriority

Signature

```
public  
    int getMinPriority()
```

Description

Gets the minimum priority available for a schedulable managed by this scheduler.

Returns

The minimum priority used by this scheduler.

¹¹⁹Section [9.4.1.3](#)

getNormPriority

Signature

```
public  
int getNormPriority()
```

Description

Gets the normal priority available for a schedulable managed by this scheduler.

Returns

The value of the normal priority.

getPolicyName

Signature

```
public  
java.lang.String getPolicyName()
```

Description

Gets the policy name of `this`.

Returns

The policy name (Fixed Priority Round Robin) as a string.

reschedule(Thread, int)

Signature

```
public  
void reschedule(Thread thread,  
                 int priority)
```

Description

Promotes a `java.lang.Thread` to realtime priority under this scheduler. The affected thread will be scheduled as if it were a `RealtimeThread`¹²⁰ of the given priority. This does not make the affected thread a `RealtimeThread`, so it will not have access to facilities reserved for instances of `RealtimeThread`.

The method `Thread.setPriority(int)` can be used to reschedule back to the conventional Java priority levels.

¹²⁰Section 5.4.2.2

Parameters

thread The thread to promote to realtime scheduling.

priority An integer priority equivalent to a priority set via `PriorityParameters`¹²¹ on a `RealtimeThread`.

Throws

`IllegalArgumentException` when **thread** is null or **priority** is not between `getMinPriority()`¹²² and `getMaxPriority()`¹²³, inclusive.

6.4.3.12 Scheduler

Inheritance

java.lang.Object
 javax.realtime.Scheduler

Description

An instance of **Scheduler** manages the execution of schedulables.

Subclasses of **Scheduler** are used for alternative scheduling policies and should define an `instance()` class method to return the default instance of the subclass. The name of the subclass should be descriptive of the policy, allowing applications to deduce the policy available for the scheduler obtained via `Scheduler.getDefaultScheduler`¹²⁴ (e.g., `EDFScheduler`).

6.4.3.12.1 Constructors

Scheduler

Signature

protected
`Scheduler()`

Description

Create an instance of **Scheduler**.

¹²¹Section 6.4.3.7

¹²²Section 6.4.3.11.1

¹²³Section 6.4.3.11.1

¹²⁴Section 6.4.3.12.2

6.4.3.12.2 Methods

getDefaultScheduler

Signature

```
public static  
javax.realtime.Scheduler getDefaultScheduler()
```

Description

Gets a reference to the default scheduler.

Returns

A reference to the default scheduler.

setDefaultScheduler(Scheduler)

Signature

```
public static  
void setDefaultScheduler(Scheduler scheduler)
```

Description

Sets the default scheduler. This is the scheduler given to instances of schedulables when they are constructed by a Java thread. The default scheduler is set to the required **PriorityScheduler**¹²⁵ at startup.

Parameters

scheduler The **Scheduler** that becomes the default scheduler assigned to new schedulables created by Java threads. When **null** nothing happens.

Throws

SecurityException when the caller is not permitted to set the default scheduler.

inSchedulableExecutionContext

Signature

¹²⁵Section 6.4.3.8

```
public static  
boolean inSchedulableExecutionContext()
```

Description

Determine whether the current calling context is a [Schedulable](#)¹²⁶: [Realtime-Thread](#)¹²⁷ or [AsyncBaseEventHandler](#)¹²⁸.

Returns

`true` when yes and `false` otherwise.

Available since RTSJ 2.0

currentSchedulable

Signature

```
public static  
javafx.realtime.Schedulable currentSchedulable()
```

Description

Get the current execution context when called from a [Schedulable](#)¹²⁹ execution context.

Throws

[ClassCastException](#) when the caller is not a [Schedulable](#)¹³⁰

Returns

the current [Schedulable](#)¹³¹.

Available since RTSJ 2.0

getPolicyName

Signature

¹²⁶Section [6.4.1.3](#)

¹²⁷Section [5.4.2.2](#)

¹²⁸Section [8.4.3.3](#)

¹²⁹Section [6.4.1.3](#)

¹³⁰Section [6.4.1.3](#)

¹³¹Section [6.4.1.3](#)

```
public abstract  
java.lang.String getPolicyName()
```

Description

Gets a string representing the policy of **this**. The string value need not be interned, but it must be created in a memory area that does not cause an illegal assignment error when stored in the current allocation context and does not cause a **MemoryAccessError**¹³² when accessed.

Returns

A **String** object which is the name of the scheduling policy used by **this**.

6.4.3.13 SchedulingGroup

Inheritance

```
java.lang.Object  
  java.lang.ThreadGroup  
    javax.realtime.SchedulingGroup
```

Description

An enhanced **ThreadGroup** in which a **Schedulable**¹³³ may be started. Limits for what realtime scheduler and scheduling parameters can be enforced on all tasks in this group. A normal **ThreadGroup** may not contain instance of **Schedulable**¹³⁴.

Available since RTSJ 2.0

6.4.3.13.1 Constructors

SchedulingGroup(String)

Signature

```
public  
SchedulingGroup(String name)
```

¹³²Section 15.3.3.3

¹³³Section 6.4.1.3

¹³⁴Section 6.4.1.3

throws `IllegalStateException`,
`IllegalAssignmentError`

Description

Create a new group with the current `ThreadGroup` instance as its parent, so long as it is an instance of `SchedulingGroup`.

Parameters

`name` is the name of the new group

Throws

`IllegalStateException` when the parent `ThreadGroup` instance is not an instance of `SchedulingGroup`.

`IllegalAssignmentError` when the parent `ThreadGroup` instance is not assignable to this.

SchedulingGroup(SchedulingGroup, String)

Signature

```
public  
SchedulingGroup(SchedulingGroup parent,  
                String name)
```

Description

Create a new scheduling group.

Parameters

`parent`

`name` is the name of the new group

Throws

`IllegalStateException` when the parent `ThreadGroup` instance is not an instance of `SchedulingGroup`.

`IllegalAssignmentError` when the parent `ThreadGroup` instance is not assignable to this.

6.4.3.13.2 Methods

getMaxEligibility

Signature

```
public  
javax.realtime.SchedulingParameters getMaxEligibility()
```

Description

Find the upper bound on scheduling eligibility that tasks in this group may have. For example, when it is an instance of `PriorityParameters`, it gives the maximum base priority any task in this group.

Returns

the scheduling parameter instance denoting the upper bound on the scheduling eligibility of threads in this group, `null` if no such bound has been specified.

setMaxEligibility(SchedulingParameters)

Signature

```
public  
void setMaxEligibility(SchedulingParameters parameters)  
throws IllegalStateException
```

Description

Set the upper bound on scheduling eligibility that tasks in this group may have. For example, when it is an instance of `PriorityParameters`, it sets the maximum base priority any task in this group. If a task in the group has a higher eligibility than specified in `parameters`, the task's eligibility is set to the max specified in `parameters`.

Parameters

`parameters` the scheduling parameter instance denoting the new upper bound on the scheduling eligibility of threads in this group.

Throws

`IllegalStateException` when `parameters` are not consistent with the scheduler type.

getScheduler

Signature

```
public  
java.lang.Class<javax.realtime.Scheduler> getScheduler()
```

Description

Find the type of scheduler tasks in this group may use. The scheduler of each thread must be an instance of the type returned. The default is `class<Scheduler>`, but it may be set to any subtype.

Returns

the scheduler type

setScheduler(Class)*Signature*

```
public  
void setScheduler(java.lang.Class<javax.realtime.Scheduler> type)
```

Description

Limit the schedulers that may be used for tasks in this group.

Parameters

type is the type of scheduler of which the schedulers of all tasks must be instances.

Throws

`IllegalStateException` when a thread in the group has a scheduler that is not an instance of **type** or `getMaxEligibility`¹³⁵ returns parameters that are inconsistent with the scheduler type.

6.4.3.14 SchedulingParameters

Inheritance

```
java.lang.Object  
  javax.realtime.SchedulingParameters
```

Interfaces

```
Cloneable  
Serializable
```

Description

¹³⁵Section 6.4.3.13.2

Subclasses of `SchedulingParameters` (`PriorityParameters`¹³⁶, `ImportanceParameters`¹³⁷, and any others defined for particular schedulers) provide the parameters to be used by the `Scheduler`¹³⁸. Changes to the values in a parameters object affects the scheduling behavior of all the `Schedulable`¹³⁹ objects to which it is bound.

Caution: This class is explicitly unsafe for multithreading when being changed. Code that mutates instances of this class should synchronize at a higher level.

6.4.3.14.1 Constructors

SchedulingParameters

Signature

```
protected  
SchedulingParameters()
```

Description

Create a new instance of `SchedulingParameters`.

Available since RTSJ 1.0.1

6.4.3.14.2 Methods

clone

Signature

```
public  
java.lang.Object clone()
```

Description

¹³⁶Section 6.4.3.7

¹³⁷Section 6.4.3.4

¹³⁸Section 6.4.3.12

¹³⁹Section 6.4.1.3

Return a clone of **this**. This method should behave effectively as if it constructed a new object with clones of the high-resolution time values of **this**.

- The new object is in the current allocation context.
- **clone** does not copy any associations from **this** and it does not implicitly bind the new object to a SO.
- The new object has clones of all high-resolution time values (deep copy).
- References to event handlers are copied (shallow copy.)

Available since RTSJ 1.0.1

isCompatible(Class)

Signature

```
public  
boolean isCompatible(java.lang.Class<javax.realtime.Scheduler> type)
```

Description

Determine whether **this** scheduling parameters can be used by tasks scheduled by instances of **type**.

Parameters

type of scheduler to check against

Returns

true when and only when **this** can be used with **type** as the scheduler.

Available since RTSJ 2.0

6.4.3.15 SporadicParameters

Inheritance

```
java.lang.Object  
  javax.realtime.ReleaseParameters  
    javax.realtime.AperiodicParameters  
      javax.realtime.SporadicParameters
```

Description

A notice to the scheduler that the associated schedulable's run method will be released aperiodically but with a minimum time between releases.

When a reference to a **SporadicParameters** object is given as a parameter to a schedulable's constructor or passed as an argument to one of the schedulable's

Table 6.9: SporadicParameters Default Values

Attribute	Value
minInterarrival time	No default. A value must be supplied
cost	new RelativeTime(0,0)
deadline	new RelativeTime(mit)
overflowHandler	None
missHandler	None
rousable	false
MIT violation policy	SAVE
Arrival queue overflow policy	SAVE
Initial arrival queue length	0

setter methods, the **SporadicParameters** object becomes the release parameters object bound to that schedulable. Changes to the values in the **SporadicParameters** object affect that schedulable object. When bound to more than one schedulable then changes to the values in the **SporadicParameters** object affect *all* of the associated objects. Note that this is a one-to-many relationship and *not* a many-to-many.

The implementation must use modified copy semantics for each **HighResolutionTime**¹⁴⁰ parameter value. The value of each time object should be treated as when it were copied at the time it is passed to the parameter object, but the object reference must also be retained. Only changes to a **SporadicParameters** object caused by methods on that object cause the change to propagate to all schedulables using the parameter object. For instance, calling **setCost** on a **SporadicParameters** object will make the change, then notify that the scheduler that the parameter object has changed. At that point the object is reconsidered for every SO that uses it. Invoking a method on the **RelativeTime** object that is the cost for this object may change the cost but it does not pass the change to the scheduler at that time. That change must not change the behavior of the SOs that use the parameter object until a setter method on the **SporadicParameters** object is invoked, or the parameter object is used in **setReleaseParameters()** or a constructor for an SO.

The following table gives the default parameter values for the constructors.

This class enables the application to specify one of four possible behaviors that indicate what to do when an arrival occurs that is closer in time to the previous arrival than the value given in this class as minimum interarrival time,

¹⁴⁰Section 9.4.1.2

what to do when, for any reason, the queue overflows, and the initial size of the queue.

Caution: This class is explicitly unsafe for multithreading when being changed. Code that mutates instances of this class should synchronize at a higher level.

6.4.3.15.1 Fields

mitViolationExcept

```
public static final mitViolationExcept
```

Description

Represents the “EXCEPT” policy for dealing with minimum interarrival time violations. Under this policy, when an arrival time for any instance of **Schedulable**¹⁴¹ which has **this** as its instance of **ReleaseParameters**¹⁴² occurs at a time less than the minimum interarrival time defined here then the **fire()** method shall throw **MITViolationException**¹⁴³. Any other associated semantics are governed by the schedulers for the schedulables using these sporadic parameters. When the arrival time is a result of a happening to which the instance of **AsyncEventHandler**¹⁴⁴ is bound then the arrival time is ignored.

Deprecated since RTSJ version since RTSJ 2.0

mitViolationIgnore

```
public static final mitViolationIgnore
```

Description

Represents the “IGNORE” policy for dealing with minimum interarrival time violations. Under this policy, when an arrival time for any instance of **Schedulable**¹⁴⁵ which has **this** as its instance of **ReleaseParameters**¹⁴⁶ occurs at a time less than the minimum interarrival time defined here then the new arrival

¹⁴¹Section 6.4.1.3

¹⁴²Section 6.4.3.10

¹⁴³Section 15.3.2.6

¹⁴⁴Section 8.4.3.5

¹⁴⁵Section 6.4.1.3

¹⁴⁶Section 6.4.3.10

time is ignored. Any other associated semantics are governed by the schedulers for the schedulables using these sporadic parameters.

Deprecated since RTSJ version since RTSJ 2.0

mitViolationSave

```
public static final mitViolationSave
```

Description

Represents the “SAVE” policy for dealing with minimum interarrival time violations. Under this policy the arrival time for any instance of [Schedulable](#)¹⁴⁷ which has `this` as its instance of [ReleaseParameters](#)¹⁴⁸ is not compared to the specified minimum interarrival time. Any other associated semantics are governed by the schedulers for the schedulable objects using these sporadic parameters.

Deprecated since RTSJ version since RTSJ 2.0

mitViolationReplace

```
public static final mitViolationReplace
```

Description

Represents the “REPLACE” policy for dealing with minimum interarrival time violations. Under this policy when an arrival time for any instance of [Schedulable](#)¹⁴⁹ which has `this` as its instance of [ReleaseParameters](#)¹⁵⁰ occurs at a time less than the minimum interarrival time defined here then the information for this arrival replaces a previous arrival. Any other associated semantics are governed by the schedulers for the schedulables using these sporadic parameters.

Deprecated since RTSJ version since RTSJ 2.0

6.4.3.15.2 Constructors

¹⁴⁷Section [6.4.1.3](#)

¹⁴⁸Section [6.4.3.10](#)

¹⁴⁹Section [6.4.1.3](#)

¹⁵⁰Section [6.4.3.10](#)

SporadicParameters(RelativeTime)

Signature

```
public  
SporadicParameters(RelativeTime minInterarrival)
```

Description

Create a SporadicParameters object. This constructor is equivalent to:
SporadicParameters(minInterarrival, null, null, null, null, false)

Available since RTSJ 1.0.1

SporadicParameters(RelativeTime, RelativeTime)

Signature

```
public  
SporadicParameters(RelativeTime minInterarrival,  
                   RelativeTime deadline)
```

Description

Create a SporadicParameters object. This constructor is equivalent to:
SporadicParameters(minInterarrival, null, deadline, null, null, false)

Available since RTSJ 2.0

SporadicParameters(RelativeTime, RelativeTime, AsyncEventHandler, boolean)

Signature

```
public  
SporadicParameters(RelativeTime minInterarrival,  
                   RelativeTime deadline,  
                   AsyncEventHandler missHandler,  
                   boolean rousable)
```

Description

Create a `SporadicParameters` object. This constructor is equivalent to:
`SporadicParameters(minInterarrival, deadline, null, missHandler, null, rousable)`

Available since RTSJ 2.0

SporadicParameters(RelativeTime, RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler)

Signature

```
public
SporadicParameters(RelativeTime minInterarrival,
                   RelativeTime cost,
                   RelativeTime deadline,
                   AsyncEventHandler overrunHandler,
                   AsyncEventHandler missHandler)
```

Description

Create a `SporadicParameters` object. This constructor is equivalent to:

```
code{SporadicParameters(minInterarrival, cost, deadline, overrunHandler, missHandler, false)}.
```

SporadicParameters(RelativeTime, RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler, boolean)

Signature

```
public
SporadicParameters(RelativeTime minInterarrival,
                   RelativeTime cost,
                   RelativeTime deadline,
                   AsyncEventHandler overrunHandler,
                   AsyncEventHandler missHandler,
                   boolean rousable)
```

Description

Create a `SporadicParameters` object.

Available since RTSJ 2.0*Parameters*

minInterarrival The release times of the schedulable will occur no closer than this interval. This time object is treated as if it were copied. Changes to **minInterarrival** will not effect the **SporadicParameters** object. There is no default value. When **minInterarrival** is **null** an illegal argument exception is thrown.

cost Processing time per release. On implementations which can measure the amount of time a schedulable is executed, this value is the maximum amount of time a schedulable receives per release. When **null**, the default value is a new instance of **RelativeTime(0,0)**.

deadline The latest permissible completion time measured from the release time of the associated invocation of the schedulable. When **null**, the default value is a new instance of **RelativeTime(mit)**.

overrunHandler This handler is invoked when an invocation of the schedulable exceeds **cost**. Not required for minimum implementation. When **null** no overrun handler will be used.

missHandler This handler is invoked when the **run()** method of the schedulable is still executing after the deadline has passed. When **null**, no deadline miss handler will be used.

roustable determines whether or not an instance of **Schedulable** can be prematurely released by a thread interrupt.

Throws

IllegalArgumentException when **minInterarrival** is **null** or its time value is not greater than zero, or the time value of **cost** is less than zero, or the time value of **deadline** is not greater than zero, or when the clocks associated with **deadline** and **minInterarrival** parameters are not identical.

IllegalAssignmentError when **minInterarrival**, **cost**, **deadline**, **overrunHandler** or **missHandler** cannot be stored in **this**.

6.4.3.15.3 Methods

getMinimalInterarrival*Signature*

public


```
javax.realtime.RelativeTime getMinimalInterarrival()
```

Description

Determine the current value of minimal interarrival.

Returns

the object last used to set the minimal interarrival containing the current value of minimal interarrival.

getMinimumInterarrival(RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime getMinimumInterarrival(RelativeTime value)
```

Description

Determine the current value of minimum interarrival.

Returns

`value` or, when `null`, the last object used to set the minimal interarrival, set to the current value of minimal interarrival.

Available since RTSJ 2.0

setMinimumInterarrival(RelativeTime)

Signature

```
public  
void setMinimumInterarrival(RelativeTime minimum)
```

Description

Set the minimum interarrival time.

Parameters

minimum The release times of the schedulable will occur no closer than this interval.

Throws

`IllegalArgumentException` when `minimum` is `null` or its time value is not greater than zero.

`IllegalAssignmentError` when `minimum` cannot be stored in `this`.

setMinimumInterarrivalPolicy(MinimumInterarrivalPolicy)

Signature

```
public  
void setMinimumInterarrivalPolicy(MinimumInterarrivalPolicy policy)
```

Description

Sets the policy for handling the arrival time queue when the new arrival time is closer to the previous arrival time than the minimum interarrival time given in **this**.

Parameters

policy is the current policy for MIT violations.

Available since RTSJ 2.0

getMinimumInterarrivalPolicy

Signature

```
public  
javax.realtime.MinimumInterarrivalPolicy getMinimumInterarrivalPolicy()
```

Description

Gets the arrival time queue policy for handling minimal interarrival time underflow.

Returns

The minimum interarrival time violation behavior as a string.

Available since RTSJ 2.0

6.5 Rationale

As specified, the required semantics of this section establish a scheduling policy that is very similar to the scheduling policies found on the vast majority of realtime operating systems and kernels in commercial use today. The semantics for the base scheduler accommodate existing practice, which is a stated goal of the effort.

There is an important division between priority schedulers that force periodic context switching between tasks at the same priority, and those that do not cause these context switches. By not specifying time slicing^[1] behavior this specification

calls for the latter type of priority scheduler. In POSIX terms, `SCHED_FIFO` meets the RTSJ requirements for the base scheduler, but `SCHED_RR` does not meet those requirements.

Although a system may not implement the first release (start) of a schedulable as unblocking that schedulable, under the base scheduler those semantics apply; i.e., the schedulable is added to the tail of the queue for its active priority.

Some research shows that, given a set of reasonable common assumptions, 32 distinct priority levels are a reasonable choice for close-to-optimal scheduling efficiency when using the rate-monotonic priority assignment algorithm on a single processor system (256 priority levels provide better efficiency). This specification requires at least 28 distinct priority levels as a compromise noting that implementations of this specification will exist on systems with logic executing outside of the Java Virtual Machine and may need priorities above, below, or both for system activities.

The default behavior for implementations that support cost monitoring and enforcement is that a schedulable receives no more than `cost` units of CPU time during each release. The programmer must explicitly change the cost attribute to override the scheduler. The RTSJ allows schedulables to self suspend during a release, in addition to that which might be necessary to acquire a lock. These self suspensions must be time bounded. Any self suspension which is not time bounded may undermine the cost enforcement model specified in this document, as it may result in a schedulable suspending beyond its next release event. This can result in more time being allocated than any associated schedulability analysis might assume. See Dos Santos and Wellings for a full discussion on the problem [4].

Cost enforcement may be deferred while the overrun schedulable holds locks that are out of application control, such as locks used to protect garbage collection. Applications should include the resulting jitter in any analysis that depends on cost enforcement.

6.5.1 SchedulingGroup and ProcessingGroup

Please review for elb: Scheduling and processing group rationale

The `SchedulingGroup` and `ProcessingGroup` classes were added in RTSJ 2.0 to *a)* support the notion of a subsystem constrained by the greater system configuration, and *b)* generalize the existing notion of cost monitoring and enforcement for schedulables to groups of schedulables. In addition, they provide a way to allow Java threads to be elevated to realtime scheduling priorities in a controlled fashion.

A combination of security manager policy and the `SchedulingGroup` hierarchy may be used to constrain the maximum priority directly configurable by an entire subsystem. To achieve this, a `SchedulingGroup` with an appropriate maximum priority must be created, the security manager must be configured to disallow threads in that `SchedulingGroup` from accessing their parent `SchedulingGroup`,

and all threads for the subsystem must be created in that `SchedulingGroup`. This tactic may even be used recursively.

Similar practice can be used with `ProcessingGroup` to constrain the maximum execution time allowable to a subsystem, or other properties configurable in a processing group.

As previously mentioned, a motivation for adding `SchedulingGroup` as a subclass of `ThreadGroup` is to clarify the relationship between Java threads and realtime schedulers. In order to obtain realtime priorities, a Java thread must belong to a `SchedulingGroup`. Its access to realtime scheduling is then restricted (with the exception of priority inversion avoidance protocols, which ignore such restrictions) by the configuration of its `SchedulingGroup`. This allows Java threads to obtain realtime priorities in a controlled and predictable fashion. Likewise, realtime threads (but not necessarily other schedulables) may obtain non-realtime standard Java priorities by calling `Thread.setPriority()` on their `RealtimeThread` object. To start a realtime thread with a non-realtime priority, this call must be made prior to the time at which the realtime thread is started.

A `ProcessingGroup` can also be used to apply cost monitoring and enforcement to a collection of standard Java threads. However, note that placing a Java thread directly in a `ProcessingGroup`, which is an instance of `SchedulingGroup`, may allow it to obtain realtime priorities. This can be avoided by placing the Java threads in a Java `ThreadGroup` which is in turn the child of an appropriately-configured `ProcessingGroup` and applying security manager restrictions.

End review request

6.5.2 Multiprocessor Support

The support that the RTSJ provides for multiprocessor systems is primarily constrained by the support it can expect from the underlying operating system. The following have had the most impact on the level of support that has been specified.

1. The notion of processor *affinity* is common across operating systems and has become the accepted way to specify the constraints on which processor a thread can execute. In some sense, processor affinities can be viewed as additional release or scheduling parameters. However, to add them to the parameter classes requires the support to be distributed throughout the specification with a proliferation of new constructor methods. To avoid this, support is grouped together within the `Affinity` class. The class also provides the addition of processor affinity support to Java threads without modifying the thread object's visible API.
2. The range of processors on which global scheduling is possible is dictated by the operating system. For SMP architectures, global scheduling across all the processors in the system is typically supported. However, an application

and an operator can constrain threads and processes to execute only within a subset of the processors. As the number of processors increase, the scalability of global scheduling is called into question. Hence, for NUMA architectures some partitioning of the processors is likely to be performed by the OS. Hence, global scheduling across all processors will not be possible in these systems. For these reasons, the RTSJ supports an array of *predefined* affinities. These are implementation-defined. They can be used either to reflect the scheduling arrangement of the underlying OS or they can be used by the system designer to impose defaults for, say, Java threads, non-heap realtime schedulables etc. A program is only allowed to dynamically create new affinities with cardinality of one. This restriction reflects the concern that not all operating systems will support multiprocessor affinities.

3. Many OSs give system operators command-level dynamic control over the set of processors allocated to a processes. Consequently, the realtime JVM has no control over whether processors are dynamically added or removed from its OS process. Predictability is a prime concern of the RTSJ. Clearly, dynamic changes to the allocated processors will have a dramatic, and possibly catastrophic, effect on the ability of the program to meet timing requirements. Hence, the RTSJ assumes that the processor set allocated to the RTSJ process does not change during its execution. A system that is capable of such manipulations should not exercise it on RTSJ processes.
4. The reason the expert group decided not to add affinities to scheduling parameters is that ASEH do not have a single server thread, hence forcing a particular affinity would complicate the implementation.

6.5.3 Impact of Clock Granularity

All time-triggered computation can suffer from release jitter. This is defined to be the variation in the actual time the computation becomes available for execution from its scheduled release time. The amount of release jitter depends on two factors. The first is the granularity of the clock/timer used to trigger the release. For example, a periodic event handler that is due to be released at absolute time T will actually be release at time $T + \delta$. δ is the difference between T and the first time the timer clock advances to T_0 , where $T_0 \geq T$. The upper bound of δ is the value returned from calling the `getResolution` method of the associated clock. It is for this reason that the implementation of release times for periodic activities must use absolute rather than relative time values, in order to avoid the drift accumulating.

The second contribution to release jitter is also related to the clock/timer. It is the duration of interval between T_0 being signaled by the clock/timer and the time this event is noticed by the underlying operating system or platform (perhaps because interrupts have been disabled). A compliant implementation of SCJ should

document the maximum value of δ for the realtime clock.

6.5.4 Deadline Miss Detection

Although RTSJ supports deadline miss detection, it is important to understand the intrinsic limitations of the facility. The SCJ facility is supported using a time-triggered event. All time-triggered computation can suffer from release jitter. Hence, any deadline miss handler may not be released until sometime after the deadline has expired. The handlers actual execution will depend on its priority relative to other schedulables.

A related limitation is that a deadline can be missed but not detected. This can occur when the deadline has been set at a smaller granularity than the detecting timer. Consider an absolute deadline of D . Suppose that the next absolute time that the timer can recognize is $D + \delta$. When the associate thread finishes after D but before $D + \delta$, it will have missed its deadline, but this miss will have been undetected.

A third limitation is due to the inherent race condition that is present when checking for deadline misses. A deadline miss is defined to occur when a schedulable has not completed the computation associated with its release before its deadline. This completion event is signalled in the application code by the return of the `handleAsyncEvent` method or a call to `waitForNextRelease` etc. When this occurs, the infrastructure reschedules/cancels the timing event that signals the miss of a deadline. This is clearly a race condition. The timer event could fire between the last statement the completion event and the rescheduling/canceling of the timer event. Hence a deadline miss could be signalled when arguably the application had performed all of its computation.

Chapter 7

Synchronization

7.1 Overview

One of the strengths of Java is its language support for multithreading. This requires synchronization. In a realtime system, there are additional requirement on this synchronization. Therefore this specification not only tightens the semantics of the synchronization declarations, but it also provides addition classes that specifically manage synchronization.

This specification strengthens the semantics of Java **synchronized** code by mandating monitor execution eligibility control, commonly referred to as priority inversion control. The **MonitorControl** class is defined as the superclass of all such execution eligibility control algorithms. Its subclasses **PriorityInheritance** and **PriorityCeilingEmulation** avoid unbounded priority inversions, which would be unacceptable in realtime systems.

The classes described below provide two main services.

1. They enable the setting of a priority inversion control policy either as the default or for specific objects.
2. They also provide wait-free communication between schedulables (especially instances of **Schedulable**, whose **mayUseHeap** is **false**) and regular Java threads.

These classes establish a framework for priority inversion management that applies to priority-oriented schedulers in general, and a specific set of requirements for the base priority scheduler. The wait-free queue classes provide safe, concurrent access to data shared between instances of realtime thread without heap access and schedulable objects subject to garbage collection delays.

7.2 Definitions

Scheduling Eligibility Inversion — when a more important task is blocked by a less important task. This is usually caused by synchronization, where a more important task must wait for a less important task to release a required resource, which can in turn be blocked by a task of intermediate importance. The classical example in priority inversion in a system with a priority-based scheduler.

Governed by — An object *A* that has been assigned (either by default or via an explicit method call) to the `MonitorControlPolicy` α is said to be *governed by* α .

Open issue 7.2.1 (elb)

More definitions here?

End of issue 7.2.1

7.3 Semantics

Synchronization semantics has two main aspects: the monitor control and scheduling. The first determines which inversion avoidance is to use. The second determines how it is done. Since, only priority-based schedulers are defined in the RTSJ, the semantics is only completely defined for priority-based schedulers.

7.3.1 Monitor Control

The specification provides for two monitor control policies with the following semantics.

1. The initial default monitor control policy shall be `PriorityInheritance`. The default policy can be altered by using the `setMonitorControl()` method.
2. Notwithstanding the preceding rule, an RTSJ implementation may allow the program to establish a different initial default monitor control policy at JVM startup. The program can query the initial default monitor control policy via the method `RealtimeSystem.getInitialMonitorControl`.
3. The `PriorityCeilingEmulation` monitor control policy is also required.
4. An implementation that provides any additional `MonitorControl` subclasses must document their effects, particularly with respect to priority inversion control.
5. An object's monitor control policy affects *each* entity that attempts to lock the object; i.e., regular Java threads as well as schedulables.
6. When a task, thread or schedulable, enters synchronized code, the target object's monitor control policy must be supported by the thread or schedulable's

scheduler; otherwise an `IllegalThreadStateException` is thrown. An implementation that defines a new `MonitorControl` subclass must document which (if any) schedulers do not support this policy.

7.3.2 Priority Schedulers

The two schedulers provided by the RTSJ must both handle synchronization in the same way. All tasks governed by these schedulers are subject to the following semantics when they synchronize on objects governed by monitor control policies defined in this section.

1. Each thread or schedulable has a *base priority* and an *active priority*. A thread or schedulable that holds a lock on a PCE-governed object also has a *ceiling priority*.
2. The *base priority* for a task is limited by the maximum priority of its scheduling groups' maximum scheduling parameters.
3. The *active priority* for a task is independent of its scheduling groups.
4. The *base priority* for a task `t` is initially the priority that `t` has when it is created. The base priority is updated (immediately) as an effect of invoking any of the following methods:
 - (a) `pparam.setPriority(prio)`, where `t` is a schedulable with `pparams` as its `SchedulingParameters` and `pparams` is an instance of `PriorityParameters` or one of its subclasses, where the new base priority is `prio`;
 - (b) `t.setSchedulingParameters(pparams)`, where `t` is a schedulable and `pparams` is an instance of `PriorityParameters`, where the new base priority is `pparams.getPriority()`;
 - (c) `t.setPriority(prio)`, when `t` is a schedulable object the new base priority is `prio`, and when it is a Java thread the new base priority is the lesser of `prio` and the maximum priority for `t`'s thread group; and
 - (d) `sg.setMaxEligibility(pparams)`, when `sg` is in `t`'s `SchedulingGroup` hierarchy and the priority of `pparams` is less than the current base priority of `t`, where the new base priority is the priority specified in `pparams` as a result of setting the task's scheduling parameters to `pparams`.
5. When the task `t` does not hold any locks, its active priority is the same as its base priority. In such a situation, modification of the priority of `t` through an invocation of any of the above priority-setting methods for `t` causes `t` to be placed at the tail of its relevant queue (ready, blocked on a particular object, etc.) at its new priority when the new priority is higher than the old priority, and at the beginning otherwise.
6. When task `t` holds one or more locks, then `t` has a set of *priority sources*. The *active priority* for `t` at any point in time is the maximum of the priorities associated with all of these sources. The priority sources resulting from the

monitor control policies defined in this section, and their associated priorities for a schedulable \mathbf{t} , are as follows:

- (a) *Source* \mathbf{t} itself
Associated Priority The base priority for \mathbf{t}
Note This may have been changed (either synchronously or asynchronously) while \mathbf{t} has been holding its lock(s).
- (b) *Source* Each object locked by \mathbf{t} and governed by a **PriorityCeilingEmulation** policy
Associated Priority The maximum value **ceil**, where **ceil** is the ceiling of a **PriorityCeilingEmulation** policy governing an object locked by \mathbf{t} .
Note This value is also referred to as the *ceiling priority* for \mathbf{t} .
- (c) *Source* Each task attempting to synchronize on an object locked by \mathbf{t} and governed by a **PriorityInheritance** policy
Associated Priority The maximum active priority over all such threads and schedulables
Note This rule accounts for recursive priority inheritance.
- (d) *Source* Each task attempting to synchronize on an object locked by \mathbf{t} and governed by a **PriorityCeilingEmulation** policy.
Associated Priority The maximum active priority over all such threads and schedulables
Note This rule, which in effect allows a **PriorityCeilingEmulation** lock to behave like a **PriorityInheritance** lock, helps avoid unbounded priority inversions that could otherwise occur in the presence of nested synchronizations involving a mix of **PriorityCeilingEmulation** and **PriorityInheritance** policies.

7. The addition of a priority source for \mathbf{t} either leaves \mathbf{t} 's active priority unchanged, or increases it. When \mathbf{t} 's active priority is unchanged, \mathbf{t} 's status in its relevant queue(s), e.g., blocked waiting for some object, is not affected. When \mathbf{t} 's active priority is increased, \mathbf{t} is placed at the tail of the relevant queue(s) at its new active priority level.
8. The removal of a priority source for \mathbf{t} either leaves \mathbf{t} 's active priority unchanged, or decreases it. When \mathbf{t} 's active priority is unchanged, then \mathbf{t} 's status in its relevant queue, e.g., blocked waiting for some object, is not affected. When \mathbf{t} 's active priority is decreased and \mathbf{t} is either ready or running, then \mathbf{t} must be

placed at the head of the ready queue at its new active priority level. When \mathbf{t} 's active priority is decreased and \mathbf{t} is blocked, then \mathbf{t} is queued at the end of the queue for the new priority when it becomes unblocked.

The above rules have four main consequences.

1. A thread or schedulable \mathbf{t} 's priority sources from 6b are added and removed synchronously; i.e., they are established based on \mathbf{t} 's entering or leaving synchronized code. However, priority sources from 6a, 6c, and 6d may be added and removed asynchronously, as an effect of actions by other threads or schedulables.
2. A task holding only one lock, when it releases this lock, has its active priority set to its base priority.
3. A task's active priority is never less than its base priority.
4. When a task blocks at a call of `obj.wait()`, it releases the lock on `obj` and hence relinquishes the priority source(s) based on `obj`'s monitor control policy. The task will be queued at a new active priority that reflects the loss of these priority sources.

Please review for elb: Priority inversion avoidance across schedulers

When modifying the active priority of a task, the active priority may exceed the priority range of the task's scheduler. (E.g., a thread scheduled on the standard Java scheduler may be assigned a priority greater than 10, or a thread scheduled on the round robin scheduler may be assigned a priority greater than the round robin max priority but within the default scheduler priority range.) In this case, the task will be rescheduled on the default scheduler until its active priority is once again within the range schedulable on its associated scheduler. A task scheduled on the round robin scheduler, however, need not be moved to the default scheduler while its active priority remains within the allowable range for the round robin scheduler. Any scheduler not defined in this standard must specify the behavior of tasks associated with it with respect to these priority-based monitor control policies.

End review request

Since base priorities may be shared (i.e., the same `PriorityParameters` object may be associated with multiple schedulables), a given base priority may be the active priority for some but not all of its associated schedulables. It is a consequence of other rules that, when a thread or schedulable \mathbf{t} attempts to synchronize on an object `obj` governed by a `PriorityCeilingEmulation` policy with ceiling `ceil`, then \mathbf{t} 's active priority may exceed `ceil` but \mathbf{t} 's base priority must not. In contrast, once \mathbf{t} has successfully synchronized on `obj`, then \mathbf{t} 's base priority may also exceed `obj`'s monitor control policy's ceiling. Note that either or both of \mathbf{t} 's base priority and `obj`'s monitor control policy may have been dynamically modified.

7.3.3 Additional Schedulers

Schedulers based on criteria other than priority, for example, deadline in a deadline first scheduler, must consider how synchronization is handled to avoid scheduling eligibility inversion. Such a scheduler must conform to the following semantics for tasks managed by that scheduler when they synchronize on objects with the monitor control policies defined above.

1. An implementation that defines a new **Scheduler** subclass must document which (if any) monitor control policies the new scheduler does not support.
2. An implementation must document how, if at all, the semantics of synchronization differ from the rules defined for the default **PriorityInheritance** instance and for the **PriorityCeilingEmulation** policy. It must supply documentation for the behavior of the new scheduler with priority inheritance and priority ceiling emulation protocol equivalent to the semantics for the default priority scheduler found in the previous section.

7.4 Package javax.realtime

7.4.1 Classes

7.4.1.1 MonitorControl

Inheritance

java.lang.Object
 javax.realtime.MonitorControl

Description

Abstract superclass for all monitor control policy objects.

7.4.1.1.1 Constructors

MonitorControl

Signature

protected
MonitorControl()

Description

Invoked from subclass constructors.

7.4.1.1.2 Methods

getMonitorControl(Object)

Signature

public static
javax.realtime.MonitorControl getMonitorControl(Object obj)

Description

Gets the monitor control policy of the given instance of `Object`.

Parameters

`obj` The object being queried.

Throws

`IllegalArgumentException` when `obj` is `null`.

Returns

The monitor control policy of the `obj` parameter.

getMonitorControl

Signature

```
public static  
    javafx.realtime.MonitorControl getMonitorControl()
```

Description

Gets the current default monitor control policy.

Returns

The default monitor control policy object.

setMonitorControl(MonitorControl)

Signature

```
public static  
    javafx.realtime.MonitorControl setMonitorControl(MonitorControl policy)
```

Description

Sets the *default monitor control policy*. This policy does not affect the monitor control policy of any already created object, it will, however, govern any object subsequently constructed, until either:

1. a new "per-object" policy is set for that object. This will alter the monitor control policy for a single object without changing the default policy.
2. a new default policy is set.

Like the per-object method (see `setMonitorControl(Object, MonitorControl)`¹, the setting of the default monitor control policy occurs immediately.

Parameters

¹Section [7.4.1.1.2](#)

policy The new monitor control policy. When **null** nothing happens.

Throws

SecurityException when the caller is not permitted to alter the default monitor control policy.

IllegalArgumentException when **policy** is not in immortal memory.

UnsupportedOperationException when **policy** is not a supported monitor control policy.

Returns

The default **MonitorControl** policy that was replaced.

Available since RTSJ 1.0.1 The return type is changed from **void** to **MonitorControl**.

setMonitorControl(Object, MonitorControl)

Signature

```
public static  
javax.realtime.MonitorControl setMonitorControl(Object obj,  
                                                MonitorControl policy)
```

Description

Immediately sets **policy** as the monitor control policy for **obj**.

A thread or schedulable that is queued for the lock associated with **obj**, or is in **obj**'s wait set, is not rechecked (e.g., for a **CeilingViolationException**) under **policy**, either as part of the execution of **setMonitorControl** or when it is awakened to (re)acquire the lock.

The thread or schedulable invoking **setMonitorControl** must already hold the lock on **obj**.

Parameters

obj The object that will be governed by the new policy.

policy The new policy for the object. When **null** nothing will happen.

Throws

IllegalArgumentException Thrown when **obj** is **null** or **policy** is not in immortal memory.

UnsupportedOperationException when **policy** is not a supported monitor control policy.

IllegalMonitorStateException when the caller does not hold a lock on **obj**.

Returns

The current `MonitorControl` policy for `obj`, which will be replaced.

Available since RTSJ 1.0.1 The return type is changed from `void` to `MonitorControl`.

7.4.1.2 PriorityCeilingEmulation

Inheritance

```
java.lang.Object
  javax.realtime.MonitorControl
    javax.realtime.PriorityCeilingEmulation
```

Description

Monitor control class specifying the use of the priority ceiling emulation protocol (also known as the "highest lockers" protocol). Each `PriorityCeilingEmulation` instance is immutable; it has an associated *ceiling*, initialized at construction and queryable but not updatable thereafter.

When a thread or schedulable synchronizes on a target object governed by a `PriorityCeilingEmulation` policy, then the target object becomes a priority source for the thread or schedulable object. When the object is unlocked, it ceases serving as a priority source for the thread or schedulable. The practical effect of this rule is that the thread or schedulable's active priority is boosted to the policy's ceiling when the object is locked, and is reset when the object is unlocked. The value that it is reset to may or may not be the same as the active priority it held when the object was locked; this depends on other factors (e.g. whether the thread or schedulable's base priority was changed in the interim).

The implementation must perform the following checks when a thread or schedulable `t` attempts to synchronize on a target object governed by a `PriorityCeilingEmulation` policy with ceiling `ceil`:

- `t`'s base priority does not exceed `ceil`
- `t`'s ceiling priority (when `t` is holding any other `PriorityCeilingEmulation` locks) does not exceed `ceil`.

Thus for any object `targetObj` that will be governed by priority ceiling emulation, the programmer needs to provide (via `MonitorControl.setMonitorControl(Object, MonitorControl)`²) a `PriorityCeilingEmulation` policy whose ceiling is at least as high as the maximum of the following values:

- the highest base priority of any thread or schedulable that could synchronize on `targetObj`

²Section 7.4.1.1.2

- the maximum ceiling priority value that any thread or schedulable object could have when it attempts to synchronize on `targetObj`.

More formally:

- When a thread or schedulable `t` whose base priority is `p1` attempts to synchronize on an object governed by a `PriorityCeilingEmulation` policy with ceiling `p2`, where `p1 > p2`, then a `CeilingViolationException` is thrown in `t`. A `CeilingViolationException` is likewise thrown in `t` when `t` is holding a `PriorityCeilingEmulation` lock and has a ceiling priority exceeding `p2`.

The values of `p1` and `p2` are passed to the constructor for the exception and may be queried by an exception handler.

A consequence of the above rule is that a thread or schedulable may nest synchronizations on `PriorityCeilingEmulation`-governed objects as long as the ceiling for the inner lock is not less than the ceiling for the outer lock.

The possibility of nested synchronizations on objects governed by a mix of `PriorityInheritance` and `PriorityCeilingEmulation` policies requires one other piece of behavior in order to avoid unbounded priority inversions. When a thread or schedulable holds a `PriorityInheritance` lock, then any `PriorityCeilingEmulation` lock that it either holds or attempts to acquire will exhibit priority inheritance characteristics. This rule is captured above in the definition of priority sources (4.d).

When a thread or schedulable `t` attempts to synchronize on a `PriorityCeilingEmulation`-governed object with ceiling `ceil`, then `ceil` must be within the priority range allowed by `t`'s scheduler; otherwise, an `IllegalThreadStateException` is thrown. Note that this does not prevent a regular Java thread from synchronizing on an object governed by a `PriorityCeilingEmulation` policy with a ceiling higher than 10.

The priority ceiling for an object `obj` can be modified by invoking `MonitorControl.setMonitorControl(obj, newPCE)` where `newPCE`'s ceiling has the desired value.

See also [MonitorControl](#)³ [PriorityInheritance](#)⁴, and [CeilingViolationException](#)⁵.

7.4.1.2.1 Methods

³Section [7.4.1.1](#)

⁴Section [7.4.1.3](#)

⁵Section [15.3.2.2](#)

instance(int)

Signature

```
public static  
    javax.realtime.PriorityCeilingEmulation instance(int ceiling)
```

Description

Return a `PriorityCeilingEmulation` object with the specified ceiling. This object is in `ImmortalMemory`. All invocations with the same ceiling value return a reference to the same object.

Parameters

ceiling Priority ceiling value.

Throws

`IllegalArgumentException` when **ceiling** is outside of the range of permitted priority values (e.g., less than `PriorityScheduler.instance().getMinPriority()` or greater than `PriorityScheduler.instance().getMaxPriority()` for the base scheduler).

Available since RTSJ 1.0.1

getCeiling

Signature

```
public  
    int getCeiling()
```

Description

Gets the priority ceiling for this `PriorityCeilingEmulation` object.

Returns

The priority ceiling.

Available since RTSJ 1.0.1

getMaxCeiling

Signature

```
public static  
    javax.realtime.PriorityCeilingEmulation getMaxCeiling()
```

Description

Gets a `PriorityCeilingEmulation` object whose ceiling is `PriorityScheduler.instance().getMaxCeiling()`. This method returns a reference to a `PriorityCeilingEmulation` object allocated in immortal memory. All invocations of this method return a reference to the same object.

Returns

A `PriorityCeilingEmulation` object whose ceiling is `PriorityScheduler.instance().getMaxCeiling()`.

Available since RTSJ 1.0.1

7.4.1.3 PriorityInheritance

Inheritance

```
java.lang.Object  
    javax.realtime.MonitorControl  
        javax.realtime.PriorityInheritance
```

Description

Singleton class specifying use of the priority inheritance protocol. When a thread or schedulable `t1` attempts to enter code that is synchronized on an object `obj` governed by this protocol, and `obj` is currently locked by a lower-priority thread or schedulable `t2`, then

1. When `t1`'s active priority does not exceed the maximum priority allowed by `t2`'s scheduler, then `t1` becomes a priority source for `t2`; `t1` ceases to serve as a priority source for `t2` when either `t2` releases the lock on `obj`, or `t1` ceases attempting to synchronize on `obj` (e.g., when `t1` incurs an ATC).
2. Otherwise (i.e., `t1`'s active priority exceeds the maximum priority allowed by `t2`'s scheduler), an `IllegalThreadStateException` is thrown in `t1`.

Note on the 2nd rule: throwing the exception in `t1`, rather than in `t2`, ensures that the exception is synchronous.

See also [MonitorControl](#)⁶ and [PriorityCeilingEmulation](#)⁷

⁶Section [7.4.1.1](#)

⁷Section [7.4.1.2](#)

7.4.1.3.1 Methods

instance

Signature

```
public static  
javax.realtime.PriorityInheritance instance()
```

Description

Return a reference to the singleton `PriorityInheritance`.

This is the default `MonitorControl` policy in effect at system startup.

The `PriorityInheritance` instance shall be allocated in `ImmortalMemory`.

7.4.1.4 WaitFreeReadQueue

Inheritance

```
java.lang.Object  
  javax.realtime.WaitFreeReadQueue
```

Description

A queue that can be non-blocking for consumers. The `WaitFreeReadQueue` class is intended for single-reader multiple-writer communication, although it may also be used (with care) for multiple readers. A *reader* is generally a instance of `Schedulable` with may not use the heap, and the *writers* are generally regular Java threads or heap-using instances of `Schedulable`. Communication is through a bounded buffer of Objects that is managed first-in-first-out. The principal methods for this class are `write` and `read`

- The `write` method appends a new element onto the queue. It is synchronized, and blocks when the queue is full. It may be called by more than one writer, in which case, the different callers will write to different elements of the queue.
- The `read` method removes the oldest element from the queue. It is not synchronized and does not block; it will return `null` when the queue is empty. Multiple reader threads or schedulables are permitted, but when two or more intend to read from the same `WaitFreeWriteQueue` they will need to arrange explicit synchronization.

For convenience, and to avoid requiring a reader to poll until the queue is non-empty, this class also supports instances that can be accessed by a reader that blocks on queue empty. To obtain this behavior, the reader needs to invoke the `waitForData()` method on a queue that has been constructed with a `notify` parameter set to `true`.

`WaitFreeReadQueue` is one of the classes enabling instances of `Schedulable` that may not use the heap and conventional Java threads to synchronize on an object without the risk of that `Schedulable` instance incurring Garbage Collector latency due to priority inversion avoidance management.

Incompatibility with V1.0: Three exceptions previously thrown by the constructor have been deleted. These are

- `java.lang.IllegalAccessException`,
- `java.lang.ClassNotFoundException`, and
- `java.lang.InstantiationException`.

These exceptions were in error. Their deletion may cause compile-time errors in code using the previous constructor. The repair is to remove the exceptions from the catch clause around the constructor invocation.

7.4.1.4.1 Constructors

WaitFreeReadQueue(Runnable, Runnable, int, MemoryArea, boolean)

Signature

```
public
WaitFreeReadQueue(Runnable writer,
                  Runnable reader,
                  int maximum,
                  MemoryArea memory,
                  boolean notify)
throws IllegalArgumentException,
      MemoryScopeException,
      InaccessibleAreaException
```

Description

Constructs a queue containing up to **maximum** elements in **memory**. The queue has an unsynchronized and nonblocking **read()** method and a synchronized and blocking **write()** method.

The **writer** and **reader** parameters, when non-null, are checked to insure that they are compatible with the **MemoryArea** specified by **memory** (when non-null.) When **memory** is null and both **Runnable**s are non-null, the constructor will select the nearest common scoped parent memory area, or when there is no such scope it will use immortal memory. When all three parameters are null, the queue will be allocated in immortal memory.

reader and **writer** are not necessarily the only instances of **Schedule** that will access the queue; moreover, there is no check that they actually access the queue at all.

Note: that the wait free queue's internal queue is allocated in **memory**, but the memory area of the wait free queue instance itself is determined by the current allocation context.

Parameters

writer An instance of **Runnable** or null.

reader An instance of **Runnable** or null.

maximum The maximum number of elements in the queue.

memory The **MemoryArea**⁸ in which internal elements are allocated.

notify A flag that establishes whether a reader is notified when the queue becomes non-empty.

Throws

IllegalArgumentException when an argument holds an invalid value. The **writer** argument must be null, a reference to a **Thread**, or a reference to a schedulable (a **RealtimeThread**, or an **AsyncEventHandler**.) The **reader** argument must be null, a reference to a **Thread**, or a reference to a schedulable. The **maximum** argument must be greater than zero.

InaccessibleAreaException when **memory** is a scoped memory that is not on the caller's scope stack.

MemoryScopeException when either **reader** or **writer** is non-null and the **memory** argument is not compatible with **reader** and **writer** with respect to the assignment and access rules for memory areas.

WaitFreeReadQueue(Runnable, Runnable, int, MemoryArea)

⁸Section 11.4.2.3

Signature

```
public
WaitFreeReadQueue(Runnable writer,
                  Runnable reader,
                  int maximum,
                  MemoryArea memory)
throws IllegalArgumentException,
MemoryScopeException,
InaccessibleAreaException
```

Description

Constructs a queue containing up to `maximum` elements in `memory`. The queue has an unsynchronized and nonblocking `read()` method and a synchronized and blocking `write()` method.

Equivalent to `WaitFreeReadQueue(writer, reader, maximum, memory, false)`

WaitFreeReadQueue(int, MemoryArea, boolean)

Signature

```
public
WaitFreeReadQueue(int maximum,
                  MemoryArea memory,
                  boolean notify)
throws IllegalArgumentException,
InaccessibleAreaException
```

Description

Constructs a queue containing up to `maximum` elements in `memory`. The queue has an unsynchronized and nonblocking `read()` method and a synchronized and blocking `write()` method.

Equivalent to `WaitFreeReadQueue(null, null, maximum, memory, notify)`

Available since RTSJ 1.0.1

WaitFreeReadQueue(int, boolean)

Signature

```
public
WaitFreeReadQueue(int maximum,
                   boolean notify)
throws IllegalArgumentException
```

Description

Constructs a queue containing up to **maximum** elements in immortal memory. The queue has an unsynchronized and nonblocking **read()** method and a synchronized and blocking **write()** method.

Equivalent to `WaitFreeReadQueue(null, null, maximum, null, notify)`

Available since RTSJ 1.0.1

7.4.1.4.2 Methods

clear

Signature

```
public
void clear()
```

Description

Sets **this** to empty.

Note: This method needs to be used with care. Invoking **clear** concurrently with **read** or **write** can lead to unexpected results.

isEmpty

Signature

```
public
boolean isEmpty()
```

Description

Queries the queue to determine if **this** is empty.

Note: This method needs to be used with care since the state of the queue may change while the method is in progress or after it has returned.

Returns

true when **this** is empty; **false** when **this** is not empty.

isFull

Signature

```
public  
boolean isFull()
```

Description

Queries the system to determine if **this** is full.

Note: This method needs to be used with care since the state of the queue may change while the method is in progress or after it has returned.

Returns

true when **this** is full; **false** when **this** is not full.

read

Signature

```
public  
T read()
```

Description

Reads the least recently inserted element from the queue and returns it as the result, unless the queue is empty. When the queue is empty, **null** is returned.

Returns

The instance of **T** read, or else **null** when **this** is empty.

size

Signature

```
public  
int size()
```

Description

Queries the queue to determine the number of elements in **this**.

Note: This method needs to be used with care since the state of the queue may change while the method is in progress or after it has returned.

Returns

The number of positions in **this** occupied by elements that have been written but not yet read.

waitForData*Signature*

```
public  
void waitForData()  
throws UnsupportedOperationException,  
       InterruptedException
```

Description

When **this** is empty block until a writer inserts an element.

Note: When there is a single reader and no asynchronous invocation of **clear**, then it is safe to invoke **read** after **waitForData** and know that **read** will find the queue non-empty.

Implementation note: To avoid reader and writer synchronizing on the same object, the reader should not be notified directly by a writer. (This is the issue that the non-wait queue classes are intended to solve).

Throws

UnsupportedOperationException when **this** has not been constructed with **notify** set to **true**.

InterruptedException when the thread is interrupted by **interrupt()** or **AsynchronouslyInterruptedException.fire()**⁹ during the time between calling this method and returning from it.

Available since RTSJ 1.0.1 **InterruptedException** was added to the **throws** clause.

⁹Section 8.4.2.1.2

write(T)

Signature

```
public synchronized  
void write(T value)  
throws MemoryScopeException,  
        InterruptedException
```

Description

A synchronized and blocking write. This call blocks on queue full and will wait until there is space in the queue.

Parameters

value The `java.lang.Object` that is placed in the queue.

Throws

`InterruptedException` when the thread is interrupted by `interrupt()` or `AsynchronouslyInterruptedException.fire()`¹⁰ during the time between calling this method and returning from it.

`MemoryScopeException` when a memory access error or illegal assignment error would occur while storing `object` in the queue.

Available since RTSJ 1.0.1 The return type is changed to `void` since it *always* returned `true`, and `InterruptedException` was added to the `throws` clause.

7.4.1.5 WaitFreeWriteQueue

Inheritance

```
java.lang.Object  
    javax.realtime.WaitFreeWriteQueue
```

Description

A queue that can be non-blocking for producers. The `WaitFreeWriteQueue` class is intended for single-writer multiple-reader communication, although it may also be used (with care) for multiple writers. A *writer* is generally an instance `Schedulable` which may not use the heap, and the *readers* are generally conventional Java threads or instances of `Schedulable` which use the heap. Communication is through a bounded buffer of `Objects` that is managed first-in-first-out. The principal methods for this class are `write` and `read`.

¹⁰Section 8.4.2.1.2

- The `write` method appends a new element onto the queue. It is not synchronized, and does not block when the queue is full (it returns `false` instead). Multiple writer threads or schedulables are permitted, but when two or more threads intend to write to the same `WaitFreeWriteQueue` they will need to arrange explicit synchronization.
- The `read` method removes the oldest element from the queue. It is synchronized, and will block when the queue is empty. It may be called by more than one reader, in which case the different callers will read different elements from the queue.

`WaitFreeWriteQueue` is one of the classes enabling schedulables which may not use the heap and regular Java threads to synchronize on an object without the risk of the schedulable incurring Garbage Collector latency due to priority inversion avoidance management.

Incompatibility with V1.0: Three exceptions previously thrown by the constructor have been deleted from the `throws` clause. These are

- `java.lang.IllegalAccessException`,
- `java.lang.ClassNotFoundException`, and
- `java.lang.InstantiationException`.

Including these exceptions on the `throws` clause was an error. Their deletion may cause compile-time errors in code using the previous constructor. The repair is to remove the exceptions from the `catch` clause around the constructor invocation.

7.4.1.5.1 Constructors

`WaitFreeWriteQueue(Runnable, Runnable, int, MemoryArea)`

Signature

```
public
WaitFreeWriteQueue(Runnable writer,
                   Runnable reader,
                   int maximum,
                   MemoryArea memory)
throws IllegalArgumentException,
MemoryScopeException,
InaccessibleAreaException
```

Description

Constructs a queue in `memory` with an unsynchronized and nonblocking `write()` method and a synchronized and blocking `read()` method.

The `writer` and `reader` parameters, when non-null, are checked to insure that they are compatible with the `MemoryArea` specified by `memory` (when non-null.) When `memory` is null and both `Runnable`s are non-null, the constructor will select the nearest common scoped parent memory area, or when there is no such scope it will use immortal memory. When all three parameters are null, the queue will be allocated in immortal memory.

`reader` and `writer` are not necessarily the only threads or schedulables that will access the queues; moreover, there is no check that they actually access the queue at all.

Note: that the wait free queue's internal queue is allocated in `memory`, but the memory area of the wait free queue instance itself is determined by the current allocation context.

Parameters

`writer` is an instance of `Schedulable` or null.

`reader` An instance of `Schedulable` or null.

`maximum` The maximum number of elements in the queue.

`memory` The `MemoryArea`¹¹ in which `this` and internal elements are allocated.

Throws

`IllegalArgumentException` when an argument holds an invalid value. The `writer` argument must be null, a reference to a `Thread`, or a reference to a schedulable (a `RealtimeThread`, or an `AsyncEventHandler`.) The `reader` argument must be null, a reference to a `Thread`, or a reference to a schedulable. The `maximum` argument must be greater than zero.

`MemoryScopeException` when either `reader` or `writer` is non-null and the `memory` argument is not compatible with `reader` and `writer` with respect to the assignment and access rules for memory areas.

`InaccessibleAreaException` when `memory` is a scoped memory that is not on the caller's scope stack.

WaitFreeWriteQueue(int, MemoryArea)

Signature

¹¹Section 11.4.2.3

```
public
WaitFreeWriteQueue(int maximum,
                    MemoryArea memory)
throws IllegalArgumentException,
    InaccessibleAreaException
```

Description

Constructs a queue containing up to `maximum` elements in `memory`. The queue has an unsynchronized and nonblocking `write()` method and a synchronized and blocking `read()` method.

Equivalent to `WaitFreeWriteQueue(null,null,mximum, memory)`

Available since RTSJ 1.0.1

WaitFreeWriteQueue(int)

Signature

```
public
WaitFreeWriteQueue(int maximum)
throws IllegalArgumentException
```

Description

Constructs a queue containing up to `maximum` elements in immortal memory. The queue has an unsynchronized and nonblocking `write()` method and a synchronized and blocking `read()` method.

Equivalent to `WaitFreeWriteQueue(null,null,mximum, null)`

Available since RTSJ 1.0.1

7.4.1.5.2 Methods

clear

Signature

```
public  
void clear()
```

Description

Sets **this** to empty.

isEmpty*Signature*

```
public  
boolean isEmpty()
```

Description

Queries the system to determine if **this** is empty.

Note: This method needs to be used with care since the state of the queue may change while the method is in progress or after it has returned.

Returns

True, when **this** is empty. False, when **this** is not empty.

isFull*Signature*

```
public  
boolean isFull()
```

Description

Queries the system to determine if **this** is full.

Note: This method needs to be used with care since the state of the queue may change while the method is in progress or after it has returned.

Returns

True, when **this** is full. False, when **this** is not full.

read*Signature*

```
public synchronized  
T read()
```

throws `InterruptedException`

Description

A synchronized and possibly blocking operation on the queue.

Throws

`InterruptedException` when the thread is interrupted by `interrupt()` or `AsynchronouslyInterruptedException.fire()`¹² during the time between calling this method and returning from it.

Returns

The `T` least recently written to the queue. When `this` is empty, the calling schedulable blocks until an element is inserted; when it is resumed, `read` removes and returns the element.

Available since RTSJ 1.0.1 Throws `InterruptedException`

size

Signature

```
public  
int size()
```

Description

Queries the queue to determine the number of elements in `this`.

Note: This method needs to be used with care since the state of the queue may change while the method is in progress or after it has returned.

Returns

The number of positions in `this` occupied by elements that have been written but not yet read.

force(T)

Signature

```
public  
boolean force(T value)
```

¹²Section 8.4.2.1.2

throws `MemoryScopeException`,
`IllegalArgumentException`

Description

Unconditionally insert `value` into `this`, either in a vacant position or else overwriting the most recently inserted element. The `boolean` result reflects whether, at the time that `force()` returns, the position at which `value` was inserted was vacant (`false`) or occupied (`true`).

Parameters

`value` An instance of `T` to insert.

Throws

`MemoryScopeException` when a memory access error or illegal assignment error would occur while storing `value` in the queue.

`IllegalArgumentException` when `value` is `null`.

Returns

`true` when `value` has overwritten an element that was occupied when the function returns; `false` otherwise (it has been inserted into a position that was vacant when the function returns)

write(T)

Signature

```
public  
boolean write(T value)  
throws MemoryScopeException,  
        IllegalArgumentException
```

Description

Inserts `value` into `this` when `this` is non-full and otherwise has no effect on `this`; the `boolean` result reflects whether `value` has been inserted. When the queue was empty and one or more threads or schedulables were waiting to read, then one will be awakened after the write. The choice of which to awaken depends on the involved scheduler(s).

Parameters

`value` An instance of `T` to insert.

Throws

`MemoryScopeException` when a memory access error or illegal assignment error would occur while storing `value` in the queue.

`IllegalArgumentException` when value is `null`.

Returns

`true` when the queue was non-full; `false` otherwise.

7.5 Rationale

Java's rules for **synchronized** code provide a means for mutual exclusion but do not prevent unbounded priority inversions and thus are insufficient for realtime applications. This specification strengthens the semantics for **synchronized** code by mandating priority inversion control, in particular by furnishing classes for priority inheritance and priority ceiling emulation. Priority inheritance is more widely implemented in realtime operating systems and thus is the initial default mechanism in this specification.

Priority ceiling emulation is also a useful protocol. It is necessary for blocking out interrupts in interrupt service routines and simplifies scheduling analysis for single core systems. Since it can easily be implemented in user space, it is required as well.

Since the same object may be accessed from synchronized code by both a schedulable which may not use the heap and an arbitrary thread or schedulable which may, unwanted dependencies may result. To avoid this problem, this specification provides three wait-free queue classes as an alternative means for safe, concurrent data accesses without priority inversion.

Chapter 8

Asynchrony

8.1 Overview

One of the most important aspects of this specification is the support for asynchronous control flow. Mechanisms are provided for both starting a task asynchronously and interrupting the execution of a thread or other task. This specifications provides mechanisms that

- bind the execution of program logic to the occurrence of internal and external events;
- enable asynchronous transfer of control; and
- facilitate the asynchronous termination of realtime threads.

The first of is provided by asynchronous event handling. Using this, an application can define some computation that is executed every time an event is “fired,” either from a clock or from some signal. The second is Asynchronous Transfer of Control (ATC), which provides a means of stopping some calculation prematurely. ATC may also be used to terminate a realtime thread safely.

8.1.1 Events and Event Handling

Asynchronous event handling is captured by the classes `AsyncBaseEvent` (AE), `AsyncBaseEventHandler` (AEH) and `AbstractBoundAsyncEventHandler`, along with their subclasses. An AE is an object used to direct event occurrences to asynchronous event handlers. An event occurrence may be initiated by application logic, by mechanisms internal to the RTSJ implementation (see the handlers in `PeriodicParameters`), or by some external input such as a clock, a signal, or an interrupt.

An asynchronous event occurrence is initiated in program logic by the invocation of the `fire` method of an AE. The `fire` method dispatches all handlers associated with its event. This means that dispatching occurs in the execution context of the caller.

An asynchronous event that is initiated from an external source has additional requirements and hence additional API features. These features are captured by the `ActiveEvent` interface. Since external events do not have a full execution context of their own, this category of events must provide an alternate execution context. In order to give the programmer control over this execution context, the specification defines the abstract class `ActiveEventDispatcher` to provide execution context for dispatching. By convention, subclasses provide a `trigger` method for initiating dispatching. Triggering simply informs this execution context to start dispatching. The `trigger` method is not defined in `ActiveEventDispatcher`, since some classes need a `trigger` method with an argument and others do not. The types of `ActiveEvent` supported are described in subsequent chapters.

An AEH is a schedulable embodying code that is released for execution in response to the occurrence of an associated event. Each AEH behaves as if it is executed by a `RealtimeThread` except that it is not permitted to use the `waitForNextRelease()` method. There is not necessarily a separate realtime thread for each AEH, but the server realtime thread (returned by `currentRealtimeThread()`) remains constant during each execution of the `handleAsyncEvent()` method. The interface `BoundAsyncBaseEventHandler` is used to mark subclasses of `AsyncBaseEventHandler`, such as `BoundAsyncEventHandler`, which have a dedicated realtime server thread. Such a server thread is associated with one and only one bound AEH for the lifetime of that AEH.

8.1.2 Asynchronous Transfer of Control

The `interrupt()` method in `java.lang.Thread` provides rudimentary asynchronous communication by setting a pollable and resettable flag in the target thread, and by throwing a synchronous exception when the target thread is blocked at an invocation of `wait()`, `sleep()`, `join()`, or an operation that throws `InterruptedException`. This specification generalizes the notion of interrupt to all Tasks, offering a more comprehensive asynchronous execution control facility without requiring polling. For `RealtimeThreads`, the effect of `Thread.interrupt()` must be extended by adding an overridden version in `RealtimeThread`.

This new mechanism, called Asynchronous Transfer of Control (ATC), is based on throwing and propagating an exception that, though asynchronous, is deferred where necessary in order to avoid data structure corruption. The main elements of ATC are embodied in the class `AsynchronouslyInterruptedException`, its subclass `Timed`, the interface `Interruptible`, and in the semantics of the `interrupt` method in `Schedulable`.

A method indicates its eligibility for asynchronous interruption by including the checked exception `AsynchronouslyInterruptedException` in its `throws` clause. If a schedulable is asynchronously interrupted while executing such a method, then an

AIE will be delivered as soon as the schedulable is outside of a section in which ATC is deferred. Several idioms are available for handling an AIE, giving the programmer the choice of using `catch` clauses and a low-level mechanism with specific control over propagation, or a higher-level facility that enables specifying the interruptible code, the handler, and the result retrieval as separate methods.

8.2 Definitions

Asynchronous Event (AE) — An instance of one of the subclasses of the `javax.realtime.AsyncBaseEvent` class.

Asynchronous Event Handler (AEH) — An instance of one of the subclasses of the `AsyncBaseEventHandler` class.

Bound Asynchronous Event Handler (Bound AEH) — An instance of one of the subclasses of the `BoundAsyncBaseEventHandler` class.

Asynchronous Transfer of Control (ATC) — A nonlocal transfer of program control in a task initiated from outside that task.

Asynchronously Interrupted Exception (AIE) — An instance of the `javax.realtime.AsynchronouslyInterruptedException` class (a subclass of `java.lang.InterruptedException`).

Asynchronously Interruptible method (AI-method) — A method or constructor that includes `AsynchronouslyInterruptedException` explicitly (that is not a subclass of `AsynchronouslyInterruptedException`) in its throws clause.

Lexical Scope — The textual region within programming block, such as a constructor, method, or statement, excluding the code within any class declarations, and the code within any class instance creation expressions for anonymous classes, contained therein. The lexical scope of a construct does not include the bodies of any methods or constructors that this code invokes.

ATC-deferred section — A synchronized statement, a static initializer or any method or constructor without `AsynchronouslyInterruptedException` in its throws clause. As specified in the introduction to Chapter 8 in *Java Language Specification*, a synchronized method is equivalent to a non-synchronized method with the body of the method contained in a synchronized statement. Thus, a synchronized AI method behaves like an AI method containing only an ATC-deferred statement.

Interruptible blocking methods — The RTSJ and standard Java methods that are explicitly interruptible by an AIE. The interruptible blocking methods comprise

- `HighResolutionTime.waitForObject()`,
- `Object.wait()`,
- `Thread.sleep()`,

- `RealtimeThread.sleep()`,
- `Thread.join()`,
- `ScopedMemory.join()`,
- `ScopedMemory.joinAndEnter()`,
- `RealtimeThread.waitForNextRelease()`,
- `WaitFreeWriteQueue.read()`,
- `WaitFreeReadQueue.waitForData()`,
- `WaitFreeReadQueue.write()`,
- `WaitFreeDequeue.blockingRead()`,
- `WaitFreeDequeue.blockingWrite()`

and their overloaded forms.

Bounded execution time — As a particular task or schedulable may not be scheduled on a CPU for an arbitrarily long period of time, bounds on the responsiveness of a given task or schedulable are defined in terms of execution time during which that task is scheduled on a CPU and executing. Time during which a task is blocked, either voluntarily, pending acquisition of a resource, or due to a higher-priority task executing on the CPUs available to it, is not considered execution time.

8.3 Semantics

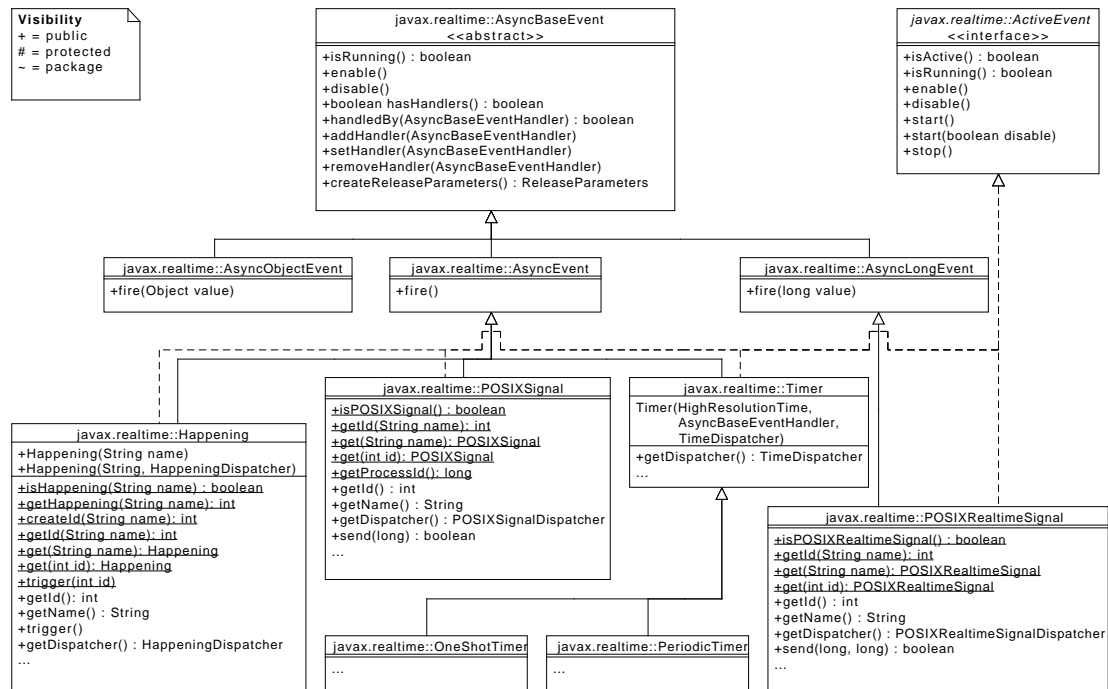
Basic event types are passive: they are not directly associated with a thread of control. They are intended to be fired programmatically. Handling external events, such as clocks (see Chapter 10) and happenings (see Chapter 12), requires an execution context. The `ActiveEvent` interface is provided to mark these and provide additional execution semantics. Figure 8.1 illustrates the event hierarchy.

8.3.1 Asynchronous Events and their Handlers

The following twelve points give the basic semantics for asynchronous events and their handlers. Semantics that apply to particular classes, constructors, methods, and fields are provided in the class description and the constructor, method, and field specifications.

1. When an asynchronous event occurs (by either program logic or by the triggering of a happening) and the event is enabled, its attached handlers (that is, AEHs that have been added to the AE by the execution of `addHandler()`) are released for execution. Every occurrence of an event increments the `fireCount` in each attached handler. Handlers may elect to execute logic for each occurrence of the event or not.

Figure 8.1: The Event Class Hierarchy



2. The release of attached handlers occurs in execution eligibility order (priority order, from highest to lowest, with the default `PriorityScheduler`) and at the active priority of the schedulable that invoked the `fire` method. The release of handlers resulting from a happening or a timer must begin within a bounded time (ignoring time consumed by unrelated activities in the system). This worst-case response interval must be documented for some reference architecture.
3. The release of attached handlers is an atomic operation with respect to adding and removing handlers.
4. The logical release of an attached handler may occur before the previous release has completed.
5. A deadline may be associated with each logical release of an attached handler. The deadline is relative to the occurrence of the associated event.
6. AEs and AEHs may be created and used by any program logic within the constraints of the memory assignment rules.
7. More than one AEH may be added to an AE. However, adding an AEH to an AE has no effect if the AEH is already attached to the AE.
8. The same AEH may be added to more than one AE.
9. By default all AEHs are considered to be daemons (the daemon status being

- set by their constructors). An AEH can be set to have a non daemon status after it has been created and before it has been attached to an AE.
10. The object returned by `currentRealtimeThread()` while an AEH is running shall behave with respect to memory access and assignment rules as if it were allocated in the same memory area as the AEH.
 11. System-related termination activity (such as execution of finalizers for scoped objects in scopes that become unreferenced) triggered when an AEH becomes unfirable is not subject to cost enforcement or deadline miss detection.
 12. AEs and AEHs behave effectively as if changes to an AEH's fireability are contained in synchronized blocks, and the AEH holds that lock while it is in the process of becoming unfirable.

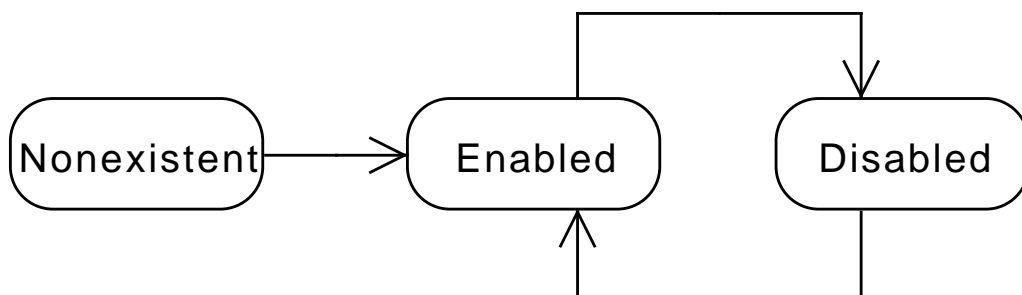
An RTSJ program terminates when and only when

1. all nondaemon threads (either regular Java threads or realtime threads) are terminated,
2. the `fireCounts` of all nondaemon bound AEHs or nondaemon AEHs are zero and all releases are completed, and
3. there are no nondaemon Bound AEHs or AEHs attached to timers or async events associated with happenings.

Though dispatchers have a thread, this thread is a daemon thread and does not itself hinder termination.

`AsyncBaseEvent` provides two basic states: enabled and disabled. In the enabled state, fire causes all associated handlers to be dispatched, whereas fire does nothing when the event is disabled. Figure 8.2 illustrates this state space.

Figure 8.2: States of a Simple AsyncBaseEvent



8.3.2 Active Events and Dispatching

Active events refine the semantics of `AsyncBaseEventHandler` with the addition of execution semantics to support second level interrupt handling. The `fire` method of an event runs in the Java execution context of the caller. For events that represent external signals, whether a certain time is reached or something has occurred, there may not be a Java execution context, or at least that context is of necessity limited and often needs to have a very short duration; dispatching an unlimited number of handlers is not acceptable. They require an additional execution context for releasing handlers.

In order to be able to distinguish between events that are caused to be fired by an outside mechanism from those that are fired from another thread, the former extend the `ActiveEvent` interface. Each class implementing `ActiveEvent` must provide its own `trigger` method for initiating the handler release by releasing another execution context. Since the `trigger` methods may vary in the number of their arguments depending on the type of event, they are not provided by the `ActiveEvent` class. Each `trigger` method must act as if it calls the `fire` method on its event and then terminates. Hence `trigger` has the same functional behavior as `fire`, but runs in this other execution context.

This extra execution context is exposed to the user as an `ActiveEventDispatcher`. There is an active event dispatcher for each kind of active event. The programmer does not need to write a dispatcher, but just creates the one of the corresponding type. The programmer does determine the priority and the affinity of a dispatcher, as well as determine the mapping between dispatchers and events.

Each event has a single dispatcher, but a dispatcher may serve many events. As with `fire`, the dispatcher releases handlers in reverse priority order, i.e., from highest to lowest. This enables the programmer to control the number of these execution contexts and still optimize how handlers are released.

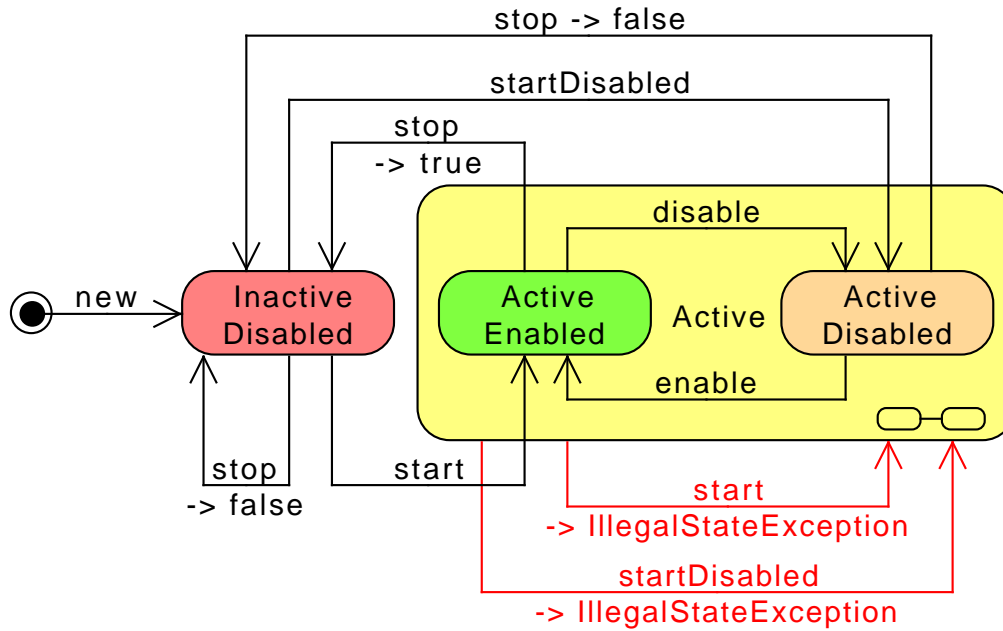
The state space of an `ActiveEvent` is an extension of the state space for an `AsyncBaseEvent` depicted in Figure 8.2. `ActiveEvent` adds the notion of active and inactive on top of enabled and disabled, as depicted in Figure 8.3. Note that the enabled-disabled distinction only splits the active state. The inactive state is by definition disabled.

8.3.3 Asynchronous Transfer of Control

Asynchronously interrupting a schedulable consists of the following activities.

1. **Generation** of an asynchronous interrupt exception — this is the event in the underlying system that makes the AIE available to the program.
2. **Delivery** of the asynchronous interrupt exception to the target schedulable— this is the action that invokes the search for and execution of an appropriate

Figure 8.3: States of an ActiveEvent



handler.

Between the generation of an AIE and its delivery, the exception is held *pending*. The AIE remains pending (even after delivery) until it is **cleared** by the program logic using `clear()` or `doInterruptible()`.

The following eight points define the semantics of ATC. Semantics that apply to particular classes, constructors, methods, and fields will be found in their detail sections, respectively.

1. An AIE is generated for a given schedulable when the `fire()` method is called on an AIE for which the schedulable object is executing within the `doInterruptible()` method or the `Schedulable.interrupt()` method is called; the latter is also effectively called when an AIE is generated by internal virtual machine mechanisms (such as an interrupted I/O operation) that are asynchronous to the execution of the program logic which is the target of the AIE. An AIE becomes pending upon generation and remains pending until explicitly cleared or replaced by another AIE.
2. The `Schedulable.interrupt()` method causes the target task to throw a

generic AIE and has the behaviors defined for `Thread.interrupt()`. This is the only interaction between the ATC mechanism and the conventional `interrupt()` mechanism.

3. An AIE is delivered to a schedulable when it is executing in a method declared to throw AIE, except in an ATC-deferred section as defined below.
 - (a) The generation of an AIE through the `fire()` mechanism behaves as if it set an asynchronously-interrupted status in the schedulable.
 - i. When the schedulable is blocked within an interruptible blocking method or invokes an interruptible blocking method when this asynchronously-interrupted status is set, the invocation immediately completes by throwing the pending AIE and clearing the asynchronously-interrupted status.
 - ii. When a pending AIE is explicitly cleared then the asynchronously-interrupted status is also cleared.
 - (b) Methods which block through mechanisms other than the interruptible blocking methods, (for example, blocking methods in `java.io.*`) must be prevented from blocking indefinitely when invoked from a method with `AsynchronouslyInterruptedException` in its `throws` clause. When an AIE is generated and the target schedulable's control is blocked inside one of these methods invoked from an AI-method, the implementation may either unblock the blocked call, raise an `InterruptedException` on behalf of the call, or allow the call to complete normally if the implementation determines that the call would unblock within a bounded period of time defined by the implementation.
 - (c) When an AI-method is attempting to acquire an object lock when an associated AIE is generated, the attempt to acquire the lock is abandoned.
 - (d) When control is in the lexical scope of an ATC-deferred section when an AIE (targeted at the executing schedulable) is generated, the AIE is not delivered until the first subsequent attempt to transfer control to code that is not ATC deferred. At that point, control is transferred to the `catch` or `finally` clause of the nearest dynamically-enclosing `try` statement that *i)* has a handler for the generated AIE (that is a handler naming the AIE's class or any of its superclasses, or a `finally` clause) and *ii)* is in an ATC-deferred section. Intervening handlers and `finally` clauses that are not in ATC-deferred sections are not executed, but object locks are released.

See section 11.3 of *The Java Language Specification* second edition for an explanation of the terms, *dynamically enclosing* and *handler*. The RTSJ uses those JLS definitions unaltered. Note that if synchronized code is abandoned as a result of this control transfer, the associated locks are

released.

4. Constructors are allowed to include `AsynchronouslyInterruptedException` in their `throws` clause and if they do will be asynchronously interruptible under the same conditions as AI methods.
5. Native methods that include `AsynchronouslyInterruptedException` in their `throws` clause have implementation-specific behavior.
6. An implementation must deliver the transfer of control in a schedulable that is subject to asynchronous interruption (in an AI-method but not in a synchronized block) within a bounded execution time of that schedulable. This worst-case response interval must be documented for some reference architecture.
7. Instances of the `Timed` class have a logically associated timer. When the timer fires, the schedulable executing the instance's `doInterruptible` method must have the AIE generated within a bounded execution time of the schedulable. This worst-case response interval must be documented for some reference architecture.
8. An AIE only has the semantics defined here when it originates with the `AsynchronouslyInterruptedException.fire()` method, the `Schedulable.interrupt()` method or from within the realtime VM. If an AIE is thrown from program logic using the Java `throw` statement, it uses the same semantics as throwing any other instance of a subclass of `Exception`, it is processed as a normal exception, and has no affect on the pending state of any AIE, and no affect on the firing of the AIE concerned.

8.3.3.1 Summary of ATC Operation

The RTSJ's approach to ATC is designed to follow the above principles. It is based on exceptions and is an extension of the current Java language rules for `java.lang.Thread.interrupt()`. In summary, ATC works as follows.

When `so` is an instance of a schedulable and the `interrupt()` method is called on the schedulable associated with that object then:

1. When control is in an ATC-deferred section, then the AIE remains in a pending state. Execution continues normally until the first attempt to return to an AI method or invoke an AI method or exit a synchronized block within an AI method. Then ATC follows option 2 as appropriate.
2. When control is not in an ATC-deferred section, then control is transferred to the `catch` or `finally` clause of the nearest dynamically-enclosing a `try` statement that has a handler for the generated AIE (that is a handler naming the AIE's class or any of its superclasses, or a `finally` clause) and which is in an ATC-deferred section. Intervening handlers and `finally` clauses that are not in ATC-deferred sections are not executed, but objects locks are released.

See section 11.3 of *The Java Language Specification* second edition [1] for an explanation of the terms *dynamically enclosing* and *handlers*. The RTSJ uses those definitions unaltered.

3. When control is in an interruptible blocking method, the schedulable object is awakened and the generated AIE (which is a subclass of `InterruptedException`) is thrown with regular Java semantics (the AIE is still marked as pending). ATC then follows option 1 or 2 as appropriate.
4. When control is transferred from an ATC-deferred section to an AI method through the action of propagating an exception while an AIE is pending, when the transition to the AI-method occurs, the thrown exception is discarded and replaced by the pending AIE.

An AIE may be generated while another AIE is pending. Because AI code blocks are nested by method invocation (a stack-based nesting) there is a natural precedence among active instances of AIE. Let AIE_0 be the AIE raised when the `Schedulable.interrupt()` method is invoked and AIE_i ($i = 1, \dots, n$, for n unique instances of AIE) be the AIE generated when `AIE.fire()` is invoked. In the following, the phrase “a frame deeper on the stack than this frame” refers to a stack frame further from stack base. The phrase “a frame shallower on the stack than this frame” refers to a stack frame nearer to the stack base.

1. When the current AIE is an AIE_0 and the new AIE is an AIE_x associated with any frame on the stack, the new AIE (AIE_x) is discarded.
2. When the current AIE is an AIE_x and the new AIE is an AIE_0 , the current AIE (AIE_x) is replaced by the new AIE (AIE_0).
3. When the current AIE is an AIE_x and the new AIE is an AIE_y from a frame deeper on the stack, the new AIE (AIE_y) is discarded.
4. When the current AIE is an AIE_x and the new AIE is an AIE_y from a frame shallower on the stack, the current AIE (AIE_x) is replaced by the new AIE (AIE_y).
5. When the current AIE is an AIE_0 and the new AIE is an AIE_0 , or when the current AIE is an AIE_x and the new AIE is an AIE_x , the new AIE is discarded.

When `clear()` is called on a pending AIE or that AIE is superseded by another, the first AIE’s pending state is cleared. Clearing a nonpending AIE (with the `clear()` method) has no effect.

8.4 Package *javax.realtime*

8.4.1 Interfaces

8.4.1.1 ActiveEvent

Interfaces

javax.realtime.Releasable

Description

This is the interface for defining the active event system. Classes implementing **ActiveEvent** are used to connect events that take place outside the Java virtual machine to RTSJ activities.

When an event takes place outside the Java virtual machine, some event-specific code within the Java virtual machine executes. That code notifies the **ActiveEvent** infrastructure of this event by calling a **trigger** method in the event.

8.4.1.1.1 Methods

isActive

Signature

```
public  
boolean isActive()
```

Description

Determine the activation state of this event, i.e., it has been started but not yet stopped again.

Returns

true when active, **false** otherwise.

isRunning

Signature

```
public  
boolean isRunning()
```

Description

Determine the running state of this event, i.e., it is both active and enabled.

Returns

`true` when active and enabled, `false` otherwise.

start*Signature*

```
public  
void start()  
throws IllegalStateException
```

Description

Start this active event.

Throws

`IllegalStateException` when this event has already been started.

start(boolean)*Signature*

```
public  
void start(boolean disabled)  
throws IllegalStateException
```

Description

Start this active event.

Parameters

`disabled` true for starting in a disabled state.

Throws

`IllegalStateException` when this event has already been started.

stop

Signature

```
public  
boolean stop()  
throws IllegalStateException
```

Description

Stop this active event.

Throws

IllegalStateException when this event is not running.

Returns

the previous enabled state.

enable

Signature

```
public  
void enable()
```

Description

Change the state of the event so that associated handlers are release on fire. Each subclass provides a means of dispatching its handlers when requested. This method enables that request mechanism.

disable

Signature

```
public  
void disable()
```

Description

Change the state of the event so that associated handlers are skipped on fire. Each subclass provides a fire method as means of dispatching its handlers when requested. This method disables that request mechanism.

8.4.1.2 BoundAsyncBaseEventHandler

Interfaces

`javax.realtime.BoundSchedulable`

Description

An marker interface for all schedulables that are bound to a single thread of control. It is required to enable references to all bound handlers.

8.4.1.3 Interruptible

Description

`InterruptedException` is an interface implemented by classes that will be used as arguments on the methods `doInterruptible()` of `AsynchronouslyInterruptedException`¹ and its subclasses. `doInterruptible()` invokes the implementations of the methods in this interface.

8.4.1.3.1 Methods

`run(AsynchronouslyInterruptedException)`

Signature

```
public  
void run(AsynchronouslyInterruptedException exception)  
throws AsynchronouslyInterruptedException
```

Description

The main piece of code that is executed when an implementation is given to `doInterruptible()`. When a class is created that implements this interface (for example through an anonymous inner class) it must include the `throws` clause to make the method interruptible.

Parameters

¹Section [8.4.2.1](#)

exception The AIE object whose `doInterruptible` method is calling the `run` method. Used to invoke methods on [AsynchronouslyInterruptedException](#)² from within the `run()` method.

interruptAction(AsynchronouslyInterruptedException)

Signature

```
public  
void interruptAction(AsynchronouslyInterruptedException exception)
```

Description

This method is called by the system when the `run()` method is interrupted. Using this, the program logic can determine when the `run()` method completed normally or had its control asynchronously transferred to its caller.

Parameters

exception The currently pending AIE. Used to invoke methods on [AsynchronouslyInterruptedException](#)³ from within the `interruptAction()` method.

8.4.1.4 Releasable

Description

A base interface for everything that has a dispatcher.

8.4.1.4.1 Methods

getDispatcher

Signature

```
public  
D extends javax.realtime.ActiveEventDispatcher<D, T> getDispatcher()
```

Description

²Section [8.4.2.1](#)

³Section [8.4.2.1](#)

Obtain the dispatcher for `this`.

Returns

that dispatcher.

8.4.2 Exceptions

8.4.2.1 AsynchronouslyInterruptedException

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      java.lang.InterruptedException
        javax.realtime.AsynchronouslyInterruptedException
```

Description

A special exception that is thrown in response to an attempt to asynchronously transfer the locus of control of a schedulable.

A schedulable that is executing a method or constructor, which is declared with an `AsynchronouslyInterruptedException`⁴ in its `throws` clause, can be asynchronously interrupted except when it is executing in the lexical scope of a synchronized statement within that method/constructor. As soon as the schedulable object leaves the lexical scope of the method by calling another method/constructor it may be asynchronously interrupted when the called method/constructor is asynchronously interruptible. (See this chapter's introduction section for the detailed semantics).

The asynchronous interrupt is generated for a schedulable, `s`, when the `s.interrupt()` method is called or the `fire`⁵ method is called of an AIE for which `s` has a `doInterruptible` method call in progress.

When an asynchronous interrupt is generated when the target schedulable is executing within an ATC-deferred section, the asynchronous interrupt becomes pending. A pending asynchronous interrupt is delivered when the target schedulable next attempts to enter asynchronously interruptible code.

Asynchronous transfers of control (ATCs) are intended to allow long-running computations to be terminated without the overhead or latency of polling with `java.lang.Thread.interrupted()`.

⁴Section 8.4.2.1

⁵Section 8.4.2.1.2

When `Schedulable.interrupt`⁶, or `AsynchronouslyInterruptedException.fire()` is called, the `AsynchronouslyInterruptedException` is compared against any currently pending `AsynchronouslyInterruptedException` on the schedulable. When there is none, or when the depth of the `AsynchronouslyInterruptedException` is less than the currently pending `AsynchronouslyInterruptedException`; (i.e., it is targeted at a less deeply nested method call), the new `AsynchronouslyInterruptedException` becomes the currently pending `AsynchronouslyInterruptedException` and the previously pending `AsynchronouslyInterruptedException` is discarded. Otherwise, the new `AsynchronouslyInterruptedException` is discarded.

When an `AsynchronouslyInterruptedException` is caught, the catch clause may invoke the `clear()` method on the `AsynchronouslyInterruptedException` in which it is interested to see if the exception matches the pending `AsynchronouslyInterruptedException`. When so, the pending `AsynchronouslyInterruptedException` is cleared for the schedulable and `clear` returns true. Otherwise, the current AIE remains pending and `clear` returns false.

`Schedulable.interrupt()` generates the generic `AsynchronouslyInterruptedException` which will always propagate outward through interruptible methods until the generic `AsynchronouslyInterruptedException` is identified and handled. The pending state of the generic AIE is per-schedulable object.

Other sources (e.g., `AsynchronouslyInterruptedException.fire()` and `Timed`⁷) will generate specific instances of `AsynchronouslyInterruptedException` which applications can identify and thus limit propagation.

8.4.2.1.1 Constructors

AsynchronouslyInterruptedException

Signature

```
public
AsynchronouslyInterruptedException()
```

Description

Create an instance of `AsynchronouslyInterruptedException`.

⁶Section 6.4.1.3.1

⁷Section 8.4.2.2

8.4.2.1.2 Methods

getGeneric

Signature

```
public static  
javafx.realtime.AsynchronouslyInterruptedException getGeneric()
```

Description

Gets the singleton system generic `AsynchronouslyInterruptedException` that is generated when `Schedulable.interrupt()`⁸ is invoked.

Throws

`IllegalThreadStateException` when the current thread is a Java thread.

Returns

The generic `AsynchronouslyInterruptedException`.

enable

Signature

```
public  
boolean enable()
```

Description

Enable the throwing of this exception. This method is valid only when the caller has a call to `doInterruptible()` in progress. When invoked when no call to `doInterruptible()` is in progress, `enable` returns false and does nothing.

Returns

True when `this` was disabled before the method was called and the call was invoked whilst the associated `doInterruptible()` is in progress. False: otherwise.

⁸Section 6.4.1.3.1

disable

Signature

```
public synchronized  
boolean disable()
```

Description

Disable the throwing of this exception. When the `fire`⁹ method is called on `this` AIE whilst it is disabled, the fire is held pending and delivered as soon as the AIE is enabled and the interruptible code is within an AI-method. When an AIE is pending when the associated disable method is called, the AIE remains pending, and is delivered as soon as the AIE is enabled and the interruptible code is within an AI-method.

This method is valid only when the caller has a call to `doInterruptible()` in progress. If invoked when no call to `doInterruptible()` is in progress, `disable` returns false and does nothing.

Returns

True when `this` was enabled before the method was called and the call was invoked with the associated `doInterruptible()` in progress. False: otherwise.

isEnabled

Signature

```
public  
boolean isEnabled()
```

Description

Query the enabled status of this exception.

This method is valid only when the caller has a call to `doInterruptible()` in progress. If invoked when no call to `doInterruptible()` is in progress, `enable` returns false and does nothing.

Returns

True when this is enabled and the method call was invoked in the context of the associated `doInterruptible()`. False otherwise.

⁹Section 8.4.2.1.2

fire

Signature

```
public  
boolean fire()
```

Description

Generate this exception when its `doInterruptible()` has been invoked and not completed. When `this` is the only outstanding AIE on the schedulable object that invoked this AIE's `doInterruptible(Interruptible)`¹⁰ method, this AIE becomes that schedulable's current AIE. Otherwise, it only becomes the current AIE when it is at a less deep level of nesting compared with the current outstanding AIE.

Returns

True when `this` is not disabled and it has an invocation of a `doInterruptible()` in progress and there is no outstanding fire request. False otherwise.

doInterruptible(Interruptible)

Signature

```
public  
boolean doInterruptible(Interruptible logic)
```

Description

Executes the `run()` method of the given `Interruptible`¹¹. This method may be on the stack in exactly one `Schedulable`¹² object. An attempt to invoke this method in a schedulable while it is on the stack of another or the same schedulable will cause an immediate return with a value of false.

The `run` method of given `Interruptible` is always entered with the exception in the enabled state, but that state can be modified with `enable()`¹³ and `disable()`¹⁴ and the state can be observed with `isEnabled()`¹⁵.

This AIE is cleared on return from `doInterruptible()`.

Parameters

¹⁰Section 8.4.2.1.2

¹¹Section 8.4.1.3

¹²Section 6.4.1.3

¹³Section 8.4.2.1.2

¹⁴Section 8.4.2.1.2

¹⁵Section 8.4.2.1.2

logic An instance of an `Interruptible`¹⁶ whose `run()` method will be called.

Throws

`IllegalThreadStateException` when called on the generic `Asynchronously-InterruptedException`.

`IllegalArgumentException` when `logic` is `null`.

Returns

True when the method call completed normally. False when another call to `doInterruptible` has not completed.

Available since RTSJ 2.0 no longer throws `IllegalThreadStateException` when called from a Java thread.

clear

Signature

```
public
boolean clear()
```

Description

Atomically see if `this` is pending on the currently executing schedulable, and when so, make it non-pending.

Returns

True when `this` was pending. False when `this` was not pending.

Available since RTSJ 1.0.1

Available since RTSJ 2.0 no longer throws `IllegalThreadStateException` when called from a Java thread.

8.4.2.2 Timed

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      java.lang.InterruptedException
```

¹⁶Section 8.4.1.3


```

    javax.realtime.AsynchronouslyInterruptedException
    javax.realtime.Timed

```

Description

Create a scope in a [Schedulable](#)¹⁷ object which will be asynchronously interrupted at the expiration of a timer. This timer will begin measuring time at some point between the time `doInterruptible()` is invoked and the time the `run()` method of the `Interruptible` object is invoked. Each call of `doInterruptible()` on an instance of `Timed` will restart the timer for the amount of time given in the constructor or the most recent invocation of `resetTime()`. The timer is cancelled when it has not expired before the `doInterruptible()` method has finished.

All memory use of an instance of `Timed` occurs during construction or the first invocation of `doInterruptible()`. Subsequent invocations of `doInterruptible()` do not allocate memory.

When the timer fires, the resulting AIE will be generated for the schedulable within a bounded execution time of the targeted schedulable.

Typical usage: `new Timed(T).doInterruptible(interruptible);`

8.4.2.2.1 Constructors

Timed(HighResolutionTime)

Signature

```

public
Timed(javax.realtime.HighResolutionTime<?> time)
throws IllegalArgumentException,
    UnsupportedOperationException

```

Description

Create an instance of `Timed` with a timer set to `time`. When the `time` is in the past the [AsynchronouslyInterruptedException](#)¹⁸ mechanism is activated immediately after or when the `doInterruptible()` method is called.

Parameters

time When `time` is a [RelativeTime](#)¹⁹ value, it is the interval of time be-

¹⁷Section 6.4.1.3

¹⁸Section 8.4.2.1

¹⁹Section 9.4.1.3

tween the invocation of `doInterruptible()` and when the schedulable is asynchronously interrupted. When `time` is an `AbsoluteTime`²⁰ value, the timer asynchronously interrupts at this time (assuming the timer has not been cancelled).

Throws

`IllegalArgumentException` when `time` is `null`.

`UnsupportedOperationException` when `time` is not based on a `Clock`²¹.

8.4.2.2.2 Methods

`doInterruptible(Interruptible)`

Signature

```
public  
boolean doInterruptible(Interruptible logic)
```

Description

Execute a time-out method. Starts the timer and executes the `run()` method of the given `Interruptible`²² object.

Parameters

`logic` `logic` An instance of an `Interruptible`²³ whose `run()` method will be called.

Throws

`IllegalArgumentException` `IllegalArgumentException` when `logic` is `null`.

`IllegalThreadStateException` `IllegalThreadStateException` when called on the generic `AsynchronouslyInterruptedException`.

Returns

True when the method call completed normally. False when another call to `doInterruptible` has not completed.

²⁰Section 9.4.1.1

²¹Section 10.4.2.1

²²Section 8.4.1.3

²³Section 8.4.1.3

resetTime(HighResolutionTime)

Signature

```
public  
void resetTime(javax.realtime.HighResolutionTime<?> time)
```

Description

To set the time-out for the next invocation of `doInterruptible()`.

Parameters

time This can be an absolute time or a relative time. When `null` or not based on a `Clock`²⁴, the time-out is not changed.

restart(HighResolutionTime)

Signature

```
public  
void restart(javax.realtime.HighResolutionTime<?> time)
```

Description

Reset the timeout. When this `Timed`²⁵ instance is executing, adjust the timeout to `time` and restart the timer. When the instance is not executing, adjust the timeout for the next invocation.

Parameters

time The new timeout.

Throws

`IllegalArgumentException` when `time` is `null` or a relative time less than zero.

`UnsupportedOperationException` when `time` is not based on a `Clock`²⁶

Available since RTSJ 2.0

8.4.3 Classes

8.4.3.1 ActiveEventDispatcher

²⁴Section 10.4.2.1

²⁵Section 8.4.2.2

²⁶Section 10.4.2.1

Inheritance

java.lang.Object
 javax.realtime.ActiveEventDispatcher

Interfaces

javax.realtime.RealtimeExecutionContext

Description

Provides a means of dispatching a set of **ActiveEvent**²⁷s. It acts as if it contains a RealtimeThread to perform this task. The priority of this thread can be specified when a dispatcher object is created. The default dispatcher runs at the highest realtime priority on the base scheduler.

Application code cannot extend this class.

8.4.3.1.1 Constructors

ActiveEventDispatcher(SchedulingParameters, SchedulingGroup)*Signature*

```
protected  
ActiveEventDispatcher(SchedulingParameters schedule,  
                      SchedulingGroup group)
```

Description

Create a new dispatcher.

Parameters

schedule provide scheduling information to the new object.
group the SchedulingGroup of the thread of this dispatcher.

ActiveEventDispatcher(SchedulingParameters)*Signature*

```
protected  
ActiveEventDispatcher(SchedulingParameters schedule)
```

²⁷Section 8.4.1.1

Description

Create a new dispatcher.

Parameters

`schedule` provide scheduling information to the new object.

8.4.3.1.2 Methods

getSchedulingParameters*Signature*

```
public  
javax.realtime.SchedulingParameters getSchedulingParameters()
```

Description

Determine how the thread associated with this dispatcher is scheduled.

Returns

the scheduling parameters of the dispatcher thread.

getSchedulingGroup*Signature*

```
public  
javax.realtime.SchedulingGroup getSchedulingGroup()
```

Description

Determine in which group the thread associated with this dispatcher is.

Returns

the scheduling group of the dispatcher thread.

register(T)*Signature*

```
public abstract  
void register(T event)
```

```
throws RegistrationException,  
        IllegalStateException,  
        IllegalArgumentException
```

Description

Register an active event with this dispatcher.

Parameters

`event` to register

Throws

`RegistrationException` when `event` is already registered.
`IllegalStateException` when this object has been destroyed.
`IllegalArgumentException` when `event` is not stopped.

unregister(T)

Signature

```
public abstract  
void unregister(T event)  
throws DeregistrationException,  
        IllegalStateException,  
        IllegalArgumentException
```

Description

Deregister an active event from this dispatcher.

Parameters

`event` to deregister

Throws

`DeregistrationException` when `event` is already registered.
`IllegalStateException` when this object has been destroyed.
`IllegalArgumentException` when `event` is not stopped.

destroy

Signature

```
public abstract  
void destroy()
```

throws `IllegalStateException`

Description

Makes the dispatcher unusable.

Throws

`IllegalStateException` when called on a dispatcher that has one or more registered objects.

8.4.3.2 AsyncBaseEvent

Inheritance

java.lang.Object
 javafx.realtime.AsyncBaseEvent

Description

This is the base class for all asynchronous events, where asynchronous is in regards to running code, not external time. This class unifies the original `AsyncEvent`²⁸ with `AsyncLongEvent`²⁹ and `AsyncObjectEvent`³⁰.

Available since RTSJ 2.0

8.4.3.2.1 Methods

isRunning

Signature

```
public  
boolean isRunning()
```

Description

Determine the firing state (releasing or skipping) of this event, i.e., whether it is enabled or disabled.

²⁸Section 8.4.3.4

²⁹Section 8.4.3.6

³⁰Section 8.4.3.8

Returns

`true` when releasing, `false` when skipping.

handledBy(AsyncBaseEventHandler)*Signature*

```
public  
boolean handledBy(AsyncBaseEventHandler handler)
```

Description

Test to see if the handler given as the parameter is associated with `this`.

Parameters

handler The handler to be tested to determine if it is associated with `this`.

Returns

True when the parameter is associated with `this`. False when `handler` is `null` or the parameters is not associated with `this`.

enable*Signature*

```
public  
void enable()
```

Description

Change the state of the event so that associated handlers are release on fire. Each subclass provides a means of dispatching its handlers when requested. This method enables that request mechanism.

disable*Signature*

```
public  
void disable()
```

Description

Change the state of the event so that associated handlers are skipped on fire. Each subclass provides a fire method as means of dispatching its handlers when requested. This method disables that request mechanism.

addHandler(AsyncBaseEventHandler)

Signature

```
public  
void addHandler(AsyncBaseEventHandler handler)
```

Description

Add a handler to the set of handlers associated with this event. An instance of `AsyncBaseEvent` may have more than one associated handler. However, adding a handler to an event has no effect when the handler is already attached to the event.

The execution of this method is atomic with respect to the execution of the `fire()` method.

Note, there is an implicit reference to the handler stored in `this`. The assignment must be valid under any applicable memory assignment rules.

Parameters

handler The new handler to add to the list of handlers already associated with this. When `handler` is already associated with the event, the call has no effect.

Throws

`IllegalArgumentException` when `handler` is `null` or the handler has `PeriodicParameters`³¹. Only the subclass `PeriodicTimer`³² is allowed to have handlers with `PeriodicParameters`³³.

`IllegalAssignmentError` when this `AsyncBaseEvent` cannot hold a reference to `handler`.

`IllegalStateException` if the configured `Scheduler` and `SchedulingParameters` for `handler` are not compatible with one another.

setHandler(AsyncBaseEventHandler)

Signature

```
public  
void setHandler(AsyncBaseEventHandler handler)
```

Description

³¹Section 6.4.3.6

³²Section 10.4.2.3

³³Section 6.4.3.6

Associate a new handler with this event and remove all existing handlers. The execution of this method is atomic with respect to the execution of the `fire()` method.

Parameters

handler The instance of `AsyncBaseEventHandler`³⁴ to be associated with `this`. When `handler` is `null` then no handler will be associated with `this`, i.e., behave effectively as if `setHandler(null)` invokes `removeHandler(AsyncBaseEventHandler)`³⁵ for each associated handler.

Throws

`IllegalArgumentException` when `handler` has `PeriodicParameters`³⁶. Only the subclass `PeriodicTimer`³⁷ is allowed to have handlers with `PeriodicParameters`³⁸.

`IllegalAssignmentError` when this `AsyncBaseEvent` cannot hold a reference to `handler`.

removeHandler(AsyncBaseEventHandler)

Signature

```
public
void removeHandler(AsyncBaseEventHandler handler)
```

Description

Remove a handler from the set associated with this event. The execution of this method is atomic with respect to the execution of the `fire()` method.

A removed handler continues to execute until its `fireCount` becomes zero and it completes.

When `handler` has a scoped non-default initial memory area and execution of this method causes `handler` to become unfirable, this method shall not return until all related finalization has completed.

Parameters

handler The handler to be disassociated from `this`. When `null` nothing happens. When the `handler` is not already associated with `this` then nothing happens.

³⁴Section 8.4.3.3

³⁵Section 8.4.3.2.1

³⁶Section 6.4.3.6

³⁷Section 10.4.2.3

³⁸Section 6.4.3.6

hasHandlers

Signature

```
public  
boolean hasHandlers()
```

Description

Determine whether or not this event has any handlers

Returns

`true` when and only when at least one handler is associated with this event.

createReleaseParameters

Signature

```
public  
javax.realtime.ReleaseParameters createReleaseParameters()
```

Description

Create a [ReleaseParameters](#)³⁹ object appropriate to the release characteristics of this event. The default is the most pessimistic: [AperiodicParameters](#)⁴⁰. This is typically called by code that is setting up a handler for this event that will fill in the parts of the release parameters for which it has values, e.g., cost. The returned [ReleaseParameters](#)⁴¹ object is not bound to the event. Any changes in the event's release parameters are not reflected in previously returned objects.

When an event returns [PeriodicParameters](#)⁴², there is no requirement for an implementation to check that the handler is released periodically.

Returns

A new [ReleaseParameters](#)⁴³ object.

8.4.3.3 AsyncBaseEventHandler

Inheritance

³⁹Section 6.4.3.10

⁴⁰Section 6.4.3.2

⁴¹Section 6.4.3.10

⁴²Section 6.4.3.6

⁴³Section 6.4.3.10

java.lang.Object
 [javafx.realtime.AsyncBaseEventHandler](#)

Interfaces

[javafx.realtime.Schedulable](#)

Description

This is the base class for all asynchronous event handlers, where asynchronous is in regards to running code, not external time. This class unifies the original [AsyncEventHandler](#)⁴⁴ with [AsyncLongEventHandler](#)⁴⁵ and [AsyncObjectEventHandler](#)⁴⁶.

Available since RTSJ 2.0

8.4.3.3.1 Methods

getCurrentConsumption(RelativeTime)

Signature

```
public static  
javafx.realtime.RelativeTime getCurrentConsumption(RelativeTime dest)  
throws IllegalStateException
```

Description

Determine the CPU consumption for this release. When `dest` is `null`, return the CPU consumption in an otherwise unused [RelativeTime](#)⁴⁷ instance in the current execution context. Otherwise, when `dest` is not `null`, return the CPU consumption in `dest`

Parameters

`dest` when not `null` is the object in which to return the result.

Throws

`IllegalStateException` when the caller is not a [RealtimeThread](#)⁴⁸.

Returns

the time consumed in the current release.

⁴⁴Section [8.4.3.5](#)

⁴⁵Section [8.4.3.7](#)

⁴⁶Section [8.4.3.9](#)

⁴⁷Section [9.4.1.3](#)

⁴⁸Section [5.4.2.2](#)

getCurrentConsumption

Signature

```
public static  
    javax.realtime.RelativeTime getCurrentConsumption()
```

Description

Equivalent to `getCurrentConsumption(null)`.

Returns

the time consumed in the current release.

getPendingFireCount

Signature

```
protected  
    int getPendingFireCount()
```

Description

This is an accessor method for `fireCount`. The `fireCount` field nominally holds the number of times associated instances of `AsyncEvent`⁴⁹ have occurred that have not had the method `handleAsyncEvent()` invoked. It is incremented and decremented by the implementation of the RTSJ. The application logic may manipulate the value in this field for application-specific reasons.

Returns

The value held by `fireCount`.

getAndClearPendingFireCount

Signature

```
protected  
    int getAndClearPendingFireCount()
```

Description

This is an accessor method for `fireCount`. This method atomically sets the value of `fireCount` to zero and returns the value from before it was set to zero. This

⁴⁹Section 8.4.3.4

may be used by handlers for which the logic can accommodate multiple releases in a single execution.

The general form for using this is

```
public void handleAsyncEvent()
{
    int numberOfReleases = getAndClearPendingFireCount();
    <handle the events>
}
```

The effect of a call to `getAndClearPendingFireCount` on the scheduling of this AEH depends on the semantics of the scheduler controlling this AEH.

Returns

The value held by `fireCount` prior to setting the value to zero.

getAndDecrementPendingFireCount

Signature

```
protected
int getAndDecrementPendingFireCount()
```

Description

This is an accessor method for `fireCount`. This method atomically decrements, by one, the value of `fireCount` (when it is greater than zero) and returns the value from before the decrement. This method can be used in the `handleAsyncEvent()` method to handle multiple releases:

```
public void handleAsyncEvent()
{
    <setup>
    do
    {
        <handle the event>
    }
    while(getAndDecrementPendingFireCount() > 0);
}
```

This construction is necessary only in the case where a handler wishes to avoid the setup costs since the framework guarantees that `handleAsyncEvent()` will be invoked whenever the `fireCount` is greater than zero. The effect of a call to `getAndDecrementPendingFireCount` on the scheduling of this AEH depends on the semantics of the scheduler controlling this AEH.

Returns

The value held by `fireCount` prior to decrementing it by one.

getMemoryArea

Signature

```
public  
javax.realtime.MemoryArea getMemoryArea()
```

Description

This is an accessor method for the initial instance of `MemoryArea`⁵⁰ associated with `this`.

To determine the current status of the memory area stack associated with `this`, use the static methods defined in the `RealtimeThread`⁵¹ class. That is `RealtimeThread.getCurrentMemoryArea`⁵², `RealtimeThread.getInitialMemoryAreaIndex`⁵³, `RealtimeThread.getMemoryAreaStackDepth`⁵⁴.

Returns

The instance of `MemoryArea`⁵⁵ which was passed as the `area` parameter when `this` was created (or the default value when `area` was allowed to default).

getMemoryParameters

Signature

```
public  
javax.realtime.MemoryParameters getMemoryParameters()
```

Description

Gets a reference to the `MemoryParameters`⁵⁶ object for this schedulable.

Returns

A reference to the current `MemoryParameters`⁵⁷ object.

⁵⁰Section 11.4.2.3

⁵¹Section 5.4.2.2

⁵²Section 5.4.2.2.2

⁵³Section 5.4.2.2.2

⁵⁴Section 5.4.2.2.2

⁵⁵Section 11.4.2.3

⁵⁶Section 11.4.2.4

⁵⁷Section 11.4.2.4

getReleaseParameters

Signature

```
public  
    javax.realtime.ReleaseParameters getReleaseParameters()
```

Description

Gets a reference to the [ReleaseParameters](#)⁵⁸ object for this schedulable.

Returns

A reference to the current [ReleaseParameters](#)⁵⁹ object.

getScheduler

Signature

```
public  
    javax.realtime.Scheduler getScheduler()
```

Description

Gets a reference to the [Scheduler](#)⁶⁰ object for this schedulable.

Returns

A reference to the associated [Scheduler](#)⁶¹ object.

getSchedulingParameters

Signature

```
public  
    javax.realtime.SchedulingParameters getSchedulingParameters()
```

Description

Gets a reference to the [SchedulingParameters](#)⁶² object for this schedulable.

Returns

A reference to the current [SchedulingParameters](#)⁶³ object.

⁵⁸Section [6.4.3.10](#)

⁵⁹Section [6.4.3.10](#)

⁶⁰Section [6.4.3.12](#)

⁶¹Section [6.4.3.12](#)

⁶²Section [6.4.3.14](#)

⁶³Section [6.4.3.14](#)

getSchedulingGroup

Signature

```
public  
javax.realtime.SchedulingGroup getSchedulingGroup()
```

Description

Gets a reference to the [SchedulingGroup](#)⁶⁴ instance of this schedulable.

Returns

A reference to the current [SchedulingGroup](#)⁶⁵ object.

Available since [since RTSJ 2.0](#)

getConfigurationParameters

Signature

```
public  
javax.realtime.ConfigurationParameters getConfigurationParameters()
```

Description

Gets a reference to the [ConfigurationParameters](#)⁶⁶ object for this schedulable.

Returns

A reference to the associated [ConfigurationParameters](#)⁶⁷ object.

Available since [RTSJ 2.0](#)

setMemoryParameters(MemoryParameters)

Signature

```
public  
void setMemoryParameters(MemoryParameters memory)
```

Description

⁶⁴Section [6.4.3.13](#)

⁶⁵Section [6.4.3.13](#)

⁶⁶Section [5.4.2.1](#)

⁶⁷Section [5.4.2.1](#)

Sets the memory parameters associated with this instance of **Schedulable**.

This change becomes effective under conditions determined by the scheduler controlling the schedulable. For instance, the change may be immediate or it may be delayed until the next release of the schedulable object. See the documentation for the scheduler for details.

Parameters

memory A **MemoryParameters**⁶⁸ object which will become the memory parameters associated with **this** after the method call. When **null**, the default value is governed by the associated scheduler (a new object is created when the default value is not **null**). (See **PriorityScheduler**⁶⁹.)

Throws

IllegalArgumentException when **memory** is not compatible with the schedulable's scheduler. Also when this schedulable may not use the heap and **memory** is located in heap memory.

IllegalAssignmentError when the schedulable cannot hold a reference to **memory**, or when **memory** cannot hold a reference to this schedulable instance.

IllegalStateException when the schedulable's scheduler prohibits this parameter change at this time due to the state of the schedulable.

setReleaseParameters(ReleaseParameters)

Signature

```
public
void setReleaseParameters(ReleaseParameters release)
```

Description

Sets the release parameters associated with this instance of **Schedulable**.

This change becomes effective under conditions determined by the scheduler controlling the schedulable. For instance, the change may be immediate or it may be delayed until the next release of the schedulable. The different properties of the release parameters may take effect at different times. See the documentation for the scheduler for details.

Parameters

release A **ReleaseParameters**⁷⁰ object which will become the release parameters associated with this after the method call, and take effect as determined

⁶⁸Section 11.4.2.4

⁶⁹Section 6.4.3.8

⁷⁰Section 6.4.3.10

by the associated scheduler. When `null`, the default value is governed by the associated scheduler (a new object is created when the default value is not `null`). (See [PriorityScheduler](#)⁷¹.)

Throws

`IllegalArgumentException` Thrown when `release` is not compatible with the associated scheduler. Also when this schedulable may not use the heap and `release` is located in heap memory.

`IllegalAssignmentError` when `this` object cannot hold a reference to `release` or `release` cannot hold a reference to `this`.

`IllegalThreadStateException` when the schedulable's scheduler prohibits the changing of the release parameter at this time due to the state of the schedulable.

setScheduler(Scheduler)

Signature

```
public
void setScheduler(Scheduler scheduler)
```

Description

Sets the reference to the Scheduler object. The timing of the change must be agreed between the scheduler currently associated with this schedulable, and `scheduler`. If the `Schedulable` is running, its associated `SchedulingParameters` (if any) must be compatible with `scheduler`.

For an instance of `AsyncBaseEventHandler`, the `Schedulable` is *running* for the purpose of setting the scheduler if it is attached to an `AsyncEvent` (even if [AsyncBaseEvent.isRunning\(\)](#)⁷² would return `false` for that event).

Parameters

`scheduler scheduler` A reference to the scheduler that will manage execution of this schedulable. Null is not a permissible value.

Throws

`IllegalArgumentException` `IllegalArgumentException` Thrown when `scheduler` is `null`, or the schedulable's existing parameter values are not compatible with `scheduler`. Also when this schedulable may not use the heap and `scheduler` is located in heap memory.

⁷¹Section [6.4.3.8](#)

⁷²Section [8.4.3.2.1](#)

IllegalAssignmentError IllegalAssignmentError when the schedulable cannot hold a reference to `scheduler` or the current `Schedulable` is running and its associated `SchedulingParameters` are incompatible with `scheduler`.

SecurityException SecurityException when the caller is not permitted to set the scheduler for this schedulable.

IllegalThreadStateException IllegalThreadStateException when `scheduler` refuses to accept this schedulable at this time due to the state of the schedulable.

setScheduler(Scheduler, SchedulingParameters, ReleaseParameters, MemoryParameters)

Signature

```
public
void setScheduler(Scheduler scheduler,
                  SchedulingParameters scheduling,
                  ReleaseParameters release,
                  MemoryParameters memoryParameters)
```

Description

Sets the scheduler and associated parameter objects. The timing of the change must be agreed between the scheduler currently associated with this schedulable, and `scheduler`.

Parameters

scheduler A reference to the scheduler that will manage the execution of this schedulable. `Null` is not a permissible value.

scheduling A reference to the **SchedulingParameters**⁷³ which will be associated with `this`. When `null`, the default value is governed by `scheduler` (a new object is created when the default value is not `null`). (See **PriorityScheduler**⁷⁴.)

release A reference to the **ReleaseParameters**⁷⁵ which will be associated with `this`. When `null`, the default value is governed by `scheduler` (a new object is created when the default value is not `null`). (See **PriorityScheduler**⁷⁶.)

memoryParameters A reference to the **MemoryParameters**⁷⁷ which will be associated with `this`. When `null`, the default value is governed by `scheduler`

⁷³Section 6.4.3.14

⁷⁴Section 6.4.3.8

⁷⁵Section 6.4.3.10

⁷⁶Section 6.4.3.8

⁷⁷Section 11.4.2.4

(a new object is created when the default value is not `null`). (See [PriorityScheduler](#)⁷⁸.)

Throws

`IllegalArgumentException` Thrown when `scheduler` is `null` or the parameter values are not compatible with `scheduler`. Also thrown when this schedulable may not use the heap and `scheduler`, `scheduling release`, `memoryParameters`, or `group` is located in heap memory.

`IllegalAssignmentError` when `this` object cannot hold references to all the parameter objects or the parameters cannot hold references to `this`.

`IllegalThreadStateException` when `scheduler` prohibits the changing of the scheduler or a parameter at this time due to the state of the schedulable.

`SecurityException` when the caller is not permitted to set the scheduler for this schedulable.

setSchedulingParameters(SchedulingParameters)

Signature

```
public  
void setSchedulingParameters(SchedulingParameters scheduling)
```

Description

Sets the scheduling parameters associated with this instance of `Schedulable`.

This change becomes effective under conditions determined by the scheduler controlling the schedulable. For instance, the change may be immediate or it may be delayed until the next release of the schedulable. See the documentation for the scheduler for details.

Parameters

`scheduling` A reference to the [SchedulingParameters](#)⁷⁹ object. When `null`, the default value is governed by the associated scheduler (a new object is created when the default value is not `null`). (See [PriorityScheduler](#)⁸⁰.)

Throws

`IllegalArgumentException` Thrown when `scheduling` is not compatible with the associated scheduler. Also when this schedulable may not use the heap and `scheduling` is located in heap memory.

`IllegalAssignmentError` when `this` object cannot hold a reference to `scheduling` or `scheduling` cannot hold a reference to `this`.

⁷⁸Section 6.4.3.8

⁷⁹Section 6.4.3.14

⁸⁰Section 6.4.3.8

IllegalThreadStateException when the schedulable's scheduler prohibits the changing of the scheduling parameter at this time due to the state of the schedulable object.

setDaemon(boolean)

Signature

```
public final  
void setDaemon(boolean on)
```

Description

Marks this event handler as either a daemon event handler or a user event handler. A realtime virtual machine exits when the only schedulables and threads running are all daemon. This method must be called before the event handler is attached to any event. Once attached, it cannot be changed.

Parameters

on When true, marks this event handler as a daemon handler.

Throws

IllegalThreadStateException when this event handler is attached to an AE.
SecurityException when the current schedulable cannot modify this event handler.

Available since RTSJ 1.0.1

isDaemon

Signature

```
public final  
boolean isDaemon()
```

Description

Tests if this event handler is a daemon handler.

Returns

True when this event handler is a daemon handler; false otherwise.

Available since RTSJ 1.0.1

getDispatcher

Signature

```
public  
javax.realtime.TimeDispatcher getDispatcher()
```

Description

Get the dispatcher associated with this Timable.

See [Section Timable.getDispatcher\(\)](#)

Available since RTSJ 2.0

getMinConsumption(RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime getMinConsumption(RelativeTime dest)
```

Description

Determine the minimum CPU consumption of all completed releases. When `dest` is `null`, return the CPU consumption in an otherwise unused [RelativeTime](#)⁸¹ instance in the current execution context. Otherwise, when `dest` is not `null`, return the CPU consumption in `dest`

Parameters

`dest` when not `null` is the object in which to return the result.

Returns

the minimum time consumed in any release.

Available since RTSJ 2.0

getMinConsumption

Signature

```
public  
javax.realtime.RelativeTime getMinConsumption()
```

⁸¹Section [9.4.1.3](#)

Description

Same as `getMinConsumption(RelativeTime)`⁸² with a null argument.

Returns

the minimum time consumed in any release.

Available since RTSJ 2.0

getMaxConsumption(RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime getMaxConsumption(RelativeTime dest)
```

Description

Determine the maximum CPU consumption of all completed releases. When `dest` is `null`, return the CPU consumption in an otherwise unused `RelativeTime`⁸³ instance in the current execution context. Otherwise, when `dest` is not `null`, return the CPU consumption in `dest`

Parameters

`dest` when not `null` is the object in which to return the result.

Returns

the maximum time consumed in any release.

Available since RTSJ 2.0

getMaxConsumption

Signature

```
public  
javax.realtime.RelativeTime getMaxConsumption()
```

Description

Same as `getMaxConsumption(RelativeTime)`⁸⁴ with a null argument.

Returns

⁸²Section 8.4.3.3.1

⁸³Section 9.4.1.3

⁸⁴Section 8.4.3.3.1

the maximum time consumed in any release.

Available since RTSJ 2.0

mayUseHeap

Signature

```
public  
boolean mayUseHeap()
```

Description

Determine whether or not this `Schedulable` may use the heap.

Returns

`true` only when this `Schedulable` may allocate on the heap and may enter the Heap.

Available since RTSJ 2.0

interrupt

Signature

```
public  
void interrupt()
```

Description

Generates the generic `AsynchronouslyInterruptedException`⁸⁵ and targets it at this, and sets the interrupted state to pending. As with `Thread.interrupt()`, blocking operations that are interruptible are interrupted.

Available since RTSJ 2.0

isRousable

Signature

```
public  
boolean isRousable()
```

⁸⁵Section 8.4.2.1

Description

Determine if it is possible for an interruptible to prematurely release the handler.

Returns

true when it is possible, otherwise it is not.

setRousable(boolean)*Signature*

```
public  
void setRousable(boolean value)
```

Description

Set the state for whether a interrupt can prematurely release this handler or not.

Parameters

value is the new value of the wake by interrupt state.

awaken*Signature*

```
public final  
void awaken()
```

Description

Indicate that a sleep has ended.

See [Section `Schedulable.awaken\(\)`](#)

Available since RTSJ 2.0

run*Signature*

```
public  
void run()
```

Description

This method is only to be used by the infrastructure, and should not be called by the application.

The `handleAsyncEvent()` family of methods provides the equivalent functionality to `Runnable.run()` for asynchronous event handlers, including execution of the `logic` argument passed to this object's constructor. Applications should override that method or provide a `logic` object for the default implementation to invoke.

8.4.3.4 AsyncEvent

Inheritance

```
java.lang.Object
  javax.realtime.AsyncBaseEvent
    javax.realtime.AsyncEvent
```

Description

An asynchronous event can have a set of handlers associated with it, and when the event occurs, the `fireCount` of each handler is incremented, and the handlers are released (see [AsyncEventHandler](#)⁸⁶).

8.4.3.4.1 Constructors

AsyncEvent

Signature

```
public
AsyncEvent()
```

Description

Create a new `AsyncEvent` object.

8.4.3.4.2 Methods

⁸⁶Section 8.4.3.5

fire

Signature

```
public  
void fire()
```

Description

When enabled, release the asynchronous events associated with this instance of `AsyncEvent`. When no handlers are attached or this object is disabled the method does nothing, i.e., it skips the release.

- When the instance of `AsyncEvent` has more than one instance of `AsyncEventHandler` with release parameters object of type `AperiodicParameters` attached and the execution of `AsyncEvent.fire()` introduces the requirement to throw at least one type of exception, then all instances of `AsyncEventHandler` not affected by the exception are handled normally
- When the instance of `AsyncEvent` has more than one instance of `AsyncEventHandler` with release parameters object of type `SporadicParameters` attached and the execution of `AsyncEvent.fire()` introduces the simultaneous requirement to throw more than one type of exception or error then `MITViolationException`⁸⁷ has precedence over `ArrivalTimeQueueOverflowException`⁸⁸.

Throws

`MITViolationException` Thrown under the base priority scheduler's semantics when there is a handler associated with this event that has its MIT violated by the call to fire (and it has set the minimum inter-arrival time violation behavior to `MITViolationExcept`). Only the handlers which do not have their MITs violated are released in this situation.

`ArrivalTimeQueueOverflowException` when the queue of arrival time information overflows. Only the handlers which do not cause this exception to be thrown are released in this situation.

8.4.3.5 AsyncEventHandler

Inheritance

java.lang.Object

⁸⁷Section 15.3.2.6

⁸⁸Section 15.3.2.1

```

    javax.realtime.AsyncBaseEventHandler
    javax.realtime.AsyncEventHandler

```

Description

An asynchronous event handler encapsulates code that is released after an instance of `AsyncEvent`⁸⁹ to which it is attached occurs.

It is guaranteed that multiple releases of an event handler will be serialized. It is also guaranteed that (unless the handler explicitly chooses otherwise) for each release of the handler, there will be one execution of the `AsyncEventHandler.handleAsyncEvent()`⁹⁰ method. Control over the number of calls to `AsyncEventHandler.handleAsyncEvent()`⁹¹ is given by methods which manipulate a `fireCount`. These may be called by the application via sub-classing and overriding `AsyncEventHandler.handleAsyncEvent()`⁹².

Instances of `AsyncEventHandler` with a release parameter of type `SporadicParameters`⁹³ or `AperiodicParameters`⁹⁴ have a list of release times which correspond to the occurrence times of instances of `AsyncEvent`⁹⁵ to which they are attached. The minimum interarrival time specified in `SporadicParameters`⁹⁶ is enforced when a release time is added to the list. Unless the handler explicitly chooses otherwise, there will be one execution of the code in `AsyncEventHandler.handleAsyncEvent()`⁹⁷ for each entry in the list.

The deadline and the time each release event causes the AEH to become eligible for execution are properties of the scheduler that controls the AEH. For the base scheduler, the deadline for each release event is relative to its fire time, and the release takes place at fire time but execution eligibility may be deferred when the queue's MIT violation policy is `SAVE`.

Handlers may do almost anything a realtime thread can do. They may run for a long or short time, and they may block. (Note: blocked handlers may hold system resources.) A handler may not use the `RealtimeThread.waitForNextRelease`⁹⁸ method.

Normally, handlers are bound to an execution context dynamically when the instances of `AsyncEvent`⁹⁹s to which they are bound occur. This can introduce a

⁸⁹Section 8.4.3.4

⁹⁰Section 8.4.3.5.2

⁹¹Section 8.4.3.5.2

⁹²Section 8.4.3.5.2

⁹³Section 6.4.3.15

⁹⁴Section 6.4.3.2

⁹⁵Section 8.4.3.4

⁹⁶Section 6.4.3.15

⁹⁷Section 8.4.3.5.2

⁹⁸Section 5.4.1

⁹⁹Section 8.4.3.4

(small) time penalty. For critical handlers that cannot afford the expense, and where this penalty is a problem, `BoundAsyncEventHandler`¹⁰⁰s can be used.

The scheduler for an asynchronous event handler is inherited from the thread/schedulable that created it. When it was created from a Java thread, the scheduler is the current default scheduler.

The semantics for memory areas that were defined for realtime threads apply in the same way to instances of `AsyncEventHandler`. They may inherit a scope stack when they are created, and the single parent rule applies to the use of memory scopes for instances of `AsyncEventHandler` just as it does in realtime threads.

8.4.3.5.1 Constructors

AsyncEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Runnable)

Signature

```
public
AsyncEventHandler(SchedulingParameters scheduling,
                  ReleaseParameters release,
                  MemoryParameters memory,
                  MemoryArea area,
                  SchedulingGroup group,
                  ConfigurationParameters config,
                  Runnable logic)
```

Description

Create a handler with the given scheduling, release, memory, group, and configuration parameters to run the given logic.

Available since RTSJ 2.0

Parameters

¹⁰⁰Section 8.4.3.10

scheduling parameters for scheduling the new handler (and possibly other instances of [Schedulable](#)¹⁰¹). When **scheduling** is **null** and the creator is an instance of [Schedulable](#)¹⁰², [SchedulingParameters](#)¹⁰³ is a clone of the creator's value created in the same memory area as **this**. When **scheduling** is **null** and the creator is a Java thread, the contents and type of the new [SchedulingParameters](#) object is governed by the associated scheduler.

release parameters for scheduling the new handler (and possibly other instances of [Schedulable](#)¹⁰⁴). When **release** is **null** the new [AsyncEventHandler](#) will use a clone of the default [ReleaseParameters](#)¹⁰⁵ for the associated scheduler created in the memory area that contains the [AsyncEventHandler](#) object.

memory parameters for scheduling the new handler (and possibly other instances of [Schedulable](#)¹⁰⁶). When **memory** is **null**, the new [AsyncEventHandler](#) receives **null** value for its memory parameters, and the amount or rate of memory allocation for the new handler is unrestricted.

area the initial memory area of this handler.

group A [SchedulingGroup](#)¹⁰⁷ object which will be associated with the constructed instance. When **null**, **this** will not be associated with any scheduling group.

config parameters for reserving space for preallocated exceptions and change implementation specific per [Schedulable](#)¹⁰⁸ memory reservations, such as Java stack size, for the new handler (and possibly other instances of [Schedulable](#)¹⁰⁹. When **initial** is **null**, this [AsyncEventHandler](#) will reserve no space for preallocated exceptions and implementation-specific values will be set to their implementation-defined defaults.

logic The [Runnable](#) object whose **run()** method will serve as the logic for the new [AsyncEventHandler](#). When **logic** is **null**, the **handleAsyncEvent()** method in the new object will serve as its logic.

AsyncEventHandler(SchedulingParameters, ReleaseParameters, Runnable)

¹⁰¹Section [6.4.1.3](#)

¹⁰²Section [6.4.1.3](#)

¹⁰³Section [6.4.3.14](#)

¹⁰⁴Section [6.4.1.3](#)

¹⁰⁵Section [6.4.3.10](#)

¹⁰⁶Section [6.4.1.3](#)

¹⁰⁷Section [6.4.3.13](#)

¹⁰⁸Section [6.4.1.3](#)

¹⁰⁹Section [6.4.1.3](#)

Signature

```
public
    AsyncEventHandler(SchedulingParameters scheduling,
                     ReleaseParameters release,
                     Runnable logic)
```

Description

Calling this constructor is equivalent to calling `AsyncEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Runnable)`¹¹⁰ with arguments (scheduling, release, null, null, null, null, logic).

Available since RTSJ 2.0

AsyncEventHandler(SchedulingParameters, ReleaseParameters)

Signature

```
public
    AsyncEventHandler(SchedulingParameters scheduling,
                     ReleaseParameters release)
```

Description

Calling this constructor is equivalent to calling `AsyncEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Runnable)`¹¹¹ with arguments (scheduling, release, null, null, null, null, null)

Available since RTSJ 2.0

AsyncEventHandler(Runnable)

Signature

¹¹⁰Section 8.4.3.5.1

¹¹¹Section 8.4.3.5.1


```
public  
AsyncEventHandler(Runnable logic)
```

Description

Calling this constructor is equivalent to calling `AsyncEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Runnable)`¹¹² with arguments (null, null, null, null, null, null, logic).

AsyncEventHandler

Signature

```
public  
AsyncEventHandler()
```

Description

Create an instance of `AsyncEventHandler` with default values for all parameters.

See Section `AsyncEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Runnable)`

8.4.3.5.2 Methods

handleAsyncEvent

Signature

```
public  
void handleAsyncEvent()
```

Description

This method holds the logic which is to be executed when any `AsyncEvent`¹¹³ with which this handler is associated is fired. This method will be invoked repeatedly while `fireCount` is greater than zero.

¹¹²Section 8.4.3.5.1

¹¹³Section 8.4.3.4

The default implementation of this method invokes the `run` method of any non-null `logic` instance passed to the constructor of this handler.

This AEH acts as a source of "reference" for its initial memory area while it is released.

All throwables from (or propagated through) `handleAsyncEvent` are caught, a stack trace is printed and execution continues as if `handleAsyncEvent` had returned normally.

initialMemoryPinnable

Signature

```
public  
boolean initialMemoryPinnable()
```

Description

Test to see if the default memory area is a pinned scoped memory area.

Returns

true is the default memory area is a pinned scoped memory area.

Available since RTSJ 2.0

run

Signature

```
public final  
void run()
```

Description

This method is only to be used by the infrastructure, and should not be called by the application.

The `handleAsyncEvent()` family of methods provides the equivalent functionality to `Runnable.run()` for asynchronous event handlers, including execution of the `logic` argument passed to this object's constructor. Applications should override that method or provide a `logic` object for the default implementation to invoke.

8.4.3.6 AsyncLongEvent

Inheritance

java.lang.Object
 javax.realtime.AsyncBaseEvent
 javax.realtime.AsyncLongEvent

Description

A new type of event that carries a long as a payload.

See [Section AsyncEvent](#)

Available since RTSJ 2.0

8.4.3.6.1 Constructors

AsyncLongEvent

Signature

```
public  
    AsyncLongEvent()
```

Description

Create a new AsyncLongEvent object.

8.4.3.6.2 Methods

fire(long)

Signature

```
public  
    void fire(long value)
```

throws `MITViolationException`,
`ArrivalTimeQueueOverflowException`

Description

When enabled, release the handlers associated with this instance of `AsyncLongEvent` with the `long` passed by `fire(long)`¹¹⁴. When no handlers are attached or this object is disabled the method does nothing, i.e., it skips the release.

- When the instance of `AsyncLongEvent` is associated with more than one instance of `AsyncLongEventHandler`¹¹⁵ with release parameters object of type `AperiodicParameters`¹¹⁶ and the execution of `fire(long)`¹¹⁷ introduces the requirement to throw at least one type of exception, then all instances of `AsyncLongEventHandler`¹¹⁸ not affected by the exception are handled normally.
- When this instance of `AsyncLongEvent` is associated with more than one instance of `AsyncLongEventHandler`¹¹⁹ with release parameters object of type `SporadicParameters`¹²⁰ and the execution of `fire(long)`¹²¹ introduces the simultaneous requirement to throw more than one type of exception or error, then `MITViolationException`¹²² has precedence over `ArrivalTimeQueueOverflowException`¹²³.

Parameters

`value` is the payload passed to the event.

Throws

`MITViolationException` Thrown under the base priority scheduler's semantics, when there is a handler associated with this event that has its MIT violated by the call to fire (and it has set the minimum inter-arrival time violation behavior to `MITViolationExcept`). Only the handlers which do not have their MITs violated are released in this situation.

`ArrivalTimeQueueOverflowException` when the queue of arrival time information overflows. Only the handlers which do not cause this exception to be thrown are released in this situation.

¹¹⁴Section 8.4.3.6.2

¹¹⁵Section 8.4.3.7

¹¹⁶Section 6.4.3.2

¹¹⁷Section 8.4.3.6.2

¹¹⁸Section 8.4.3.7

¹¹⁹Section 8.4.3.7

¹²⁰Section 6.4.3.15

¹²¹Section 8.4.3.6.2

¹²²Section 15.3.2.6

¹²³Section 15.3.2.1

8.4.3.7 AsyncLongEventHandler

Inheritance

```
java.lang.Object
  javax.realtime.AsyncBaseEventHandler
    javax.realtime.AsyncLongEventHandler
```

Description

A version of [AsyncBaseEventHandler](#)¹²⁴ that carries a long value as payload.

Available since RTSJ 2.0

8.4.3.7.1 Constructors

AsyncLongEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, LongConsumer)

Signature

```
public
AsyncLongEventHandler(SchedulingParameters scheduling,
                      ReleaseParameters release,
                      MemoryParameters memory,
                      MemoryArea area,
                      SchedulingGroup group,
                      ConfigurationParameters config,
                      LongConsumer logic)
```

Description

Create an asynchronous event handler that receives a Long payload with each fire.

Parameters

¹²⁴Section [8.4.3.3](#)

scheduling parameters for scheduling the new handler (and possibly other instances of [Schedulable](#)¹²⁵). When **scheduling** is **null** and the creator is an instance of [Schedulable](#)¹²⁶, [SchedulingParameters](#)¹²⁷ is a clone of the creator's value created in the same memory area as **this**. When **scheduling** is **null** and the creator is a Java thread, the contents and type of the new [SchedulingParameters](#) object is governed by the associated scheduler.

release parameters for scheduling the new handler (and possibly other instances of [Schedulable](#)¹²⁸). When **release** is **null** the new [AsyncEventHandler](#) will use a clone of the default [ReleaseParameters](#)¹²⁹ for the associated scheduler created in the memory area that contains the [AsyncEventHandler](#) object.

memory parameters for scheduling the new handler (and possibly other instances of [Schedulable](#)¹³⁰). When **memory** is **null**, the new [AsyncEventHandler](#) receives **null** value for its memory parameters, and the amount or rate of memory allocation for the new handler is unrestricted.

area the initial memory area of this handler.

group parameters for providing CPU cost management on a set of [Schedulable](#)¹³¹s. When **null**, **this** will not be associated with any processing group.

config parameters for reserving space for preallocated exceptions and change implementation specific per [Schedulable](#)¹³² memory reservations, such as Java stack size, for the new handler (and possibly other instances of [Schedulable](#)¹³³. When **initial** is **null**, this [AsyncEventHandler](#) will reserve no space for preallocated exceptions and implementation-specific values will be set to their implementation-defined defaults.

logic is the logic to run for each fire. When **logic** is **null**, the `handleAsyncEvent()` method in the new object will serve as its logic.

AsyncLongEventHandler(SchedulingParameters, ReleaseParameters, LongConsumer)

¹²⁵Section [6.4.1.3](#)

¹²⁶Section [6.4.1.3](#)

¹²⁷Section [6.4.3.14](#)

¹²⁸Section [6.4.1.3](#)

¹²⁹Section [6.4.3.10](#)

¹³⁰Section [6.4.1.3](#)

¹³¹Section [6.4.1.3](#)

¹³²Section [6.4.1.3](#)

¹³³Section [6.4.1.3](#)

Signature

```
public
    AsyncLongEventHandler(SchedulingParameters scheduling,
                          ReleaseParameters release,
                          LongConsumer logic)
```

Description

Calling this constructor is equivalent to calling `AsyncLongEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, LongConsumer)`¹³⁴ with arguments (scheduling, release, null, null, null, null, logic).

AsyncLongEventHandler(SchedulingParameters, ReleaseParameters)

Signature

```
public
    AsyncLongEventHandler(SchedulingParameters scheduling,
                          ReleaseParameters release)
```

Description

Calling this constructor is equivalent to calling `AsyncLongEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, LongConsumer)`¹³⁵ with arguments (scheduling, release, null, null, null, null, null).

AsyncLongEventHandler(LongConsumer)

Signature

```
public
    AsyncLongEventHandler(LongConsumer logic)
```

Description

¹³⁴Section 8.4.3.7.1

¹³⁵Section 8.4.3.7.1

Calling this constructor is equivalent to calling `AsyncLongEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, LongConsumer)`¹³⁶ with arguments `(null, null, null, null, null, null, null, logic)`.

AsyncLongEventHandler

Signature

```
public
AsyncLongEventHandler()
```

Description

Create an instance of `AsyncLongEventHandler` with default values for all parameters.

See Section `AsyncLongEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, LongConsumer)`

8.4.3.7.2 Methods

handleAsyncEvent(long)

Signature

```
public
void handleAsyncEvent(long payload)
```

Description

This method holds the logic which is to be executed when any `AsyncEvent`¹³⁷ with which this handler is associated is fired. This method will be invoked repeatedly while `fireCount` is greater than zero.

This ALEH is a source of reference for its initial memory area while this ALEH is released.

¹³⁶Section 8.4.3.7.1

¹³⁷Section 8.4.3.4

All throwables from (or propagated through) `handleAsyncEvent` are caught, a stack trace is printed and execution continues as if `handleAsyncEvent` had returned normally.

Parameters

`payload` is the long value associated with a fire.

peekPending

Signature

```
public  
long peekPending()  
throws IllegalStateException
```

Description

Determine the next value queued for handling.

Throws

`IllegalStateException` when the fire count is zero.

Returns

The long value at the head of the queue of longs to be passed to `handleAsyncEvent(long)`¹³⁸.

run

Signature

```
public final  
void run()
```

Description

This method is only to be used by the infrastructure, and should not be called by the application.

The `handleAsyncEvent()` family of methods provides the equivalent functionality to `Runnable.run()` for asynchronous event handlers, including execution of the `logic` argument passed to this object's constructor. Applications should override that method or provide a `logic` object for the default implementation to invoke.

¹³⁸Section 8.4.3.7.2

8.4.3.8 AsyncObjectEvent

Inheritance

java.lang.Object
 [javax.realtime.AsyncBaseEvent](#)
 [javax.realtime.AsyncObjectEvent](#)

Description

A new type of event that carries an object as a payload.

[See Section AsyncEvent](#)

Available since RTSJ 2.0

8.4.3.8.1 Constructors

AsyncObjectEvent

Signature

```
public  
AsyncObjectEvent()
```

Description

Create a new `AsyncObjectEvent` instance.

8.4.3.8.2 Methods

fire(P)

Signature

```
public  
void fire(P value)
```

throws `MITViolationException`,
`ArrivalTimeQueueOverflowException`

Description

When enabled, fire this instance of `AsyncObjectEvent`. The asynchronous event handlers associated with this event will be released with the object passed by `fire`¹³⁹. When no handlers are attached or this object is disabled the method does nothing, i.e., it skips the release.

- When the instance of `AsyncObjectEvent` is associated with more than one instance of `AsyncObjectEventHandler`¹⁴⁰ with release parameters object of type `AperiodicParameters`¹⁴¹ and the execution of `fire`¹⁴² introduces the requirement to throw at least one type of exception, then all instances of `AsyncObjectEventHandler`¹⁴³ not affected by the exception are handled normally.
- When this instance of `AsyncObjectEvent` is associated with more than one instance of `AsyncObjectEventHandler`¹⁴⁴ with release parameters object of type `SporadicParameters`¹⁴⁵ and the execution of `fire`¹⁴⁶ introduces the simultaneous requirement to throw more than one type of exception or error, then `MITViolationException`¹⁴⁷ has precedence over `ArrivalTimeQueueOverflowException`¹⁴⁸.

Parameters

`value` is the payload passed to the event.

Throws

`MITViolationException` Thrown under the base priority scheduler's semantics when there is a handler associated with this event that has its MIT violated by the call to fire (and it has set the minimum inter-arrival time violation behavior to `MITViolationExcept`). Only the handlers which do not have their MITs violated are released in this situation.

`ArrivalTimeQueueOverflowException` when the queue of arrival time information overflows. Only the handlers which do not cause this exception to be thrown are released in this situation.

¹³⁹Section 8.4.3.8.2

¹⁴⁰Section 8.4.3.9

¹⁴¹Section 6.4.3.2

¹⁴²Section 8.4.3.8.2

¹⁴³Section 8.4.3.9

¹⁴⁴Section 8.4.3.9

¹⁴⁵Section 6.4.3.15

¹⁴⁶Section 8.4.3.8.2

¹⁴⁷Section 15.3.2.6

¹⁴⁸Section 15.3.2.1

8.4.3.9 AsyncObjectEventHandler

Inheritance

```
java.lang.Object
  javax.realtime.AsyncBaseEventHandler
    javax.realtime.AsyncObjectEventHandler
```

Description

A version of [AsyncBaseEventHandler](#)¹⁴⁹ that carries an `Object` value as payload.

Available since RTSJ 2.0

8.4.3.9.1 Constructors

AsyncObjectEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Consumer)

Signature

```
public
AsyncObjectEventHandler(SchedulingParameters scheduling,
                       ReleaseParameters release,
                       MemoryParameters memory,
                       MemoryArea area,
                       SchedulingGroup group,
                       ConfigurationParameters config,
                       java.util.function.Consumer<P> logic)
```

Description

Create an asynchronous event handler that receives a `Long` payload with each fire.

Parameters

¹⁴⁹Section [8.4.3.3](#)

scheduling parameters for scheduling the new handler (and possibly other instances of [Schedulable](#)¹⁵⁰). When **scheduling** is **null** and the creator is an instance of [Schedulable](#)¹⁵¹, [SchedulingParameters](#)¹⁵² is a clone of the creator's value created in the same memory area as **this**. When **scheduling** is **null** and the creator is a Java thread, the contents and type of the new [SchedulingParameters](#) object is governed by the associated scheduler.

release parameters for scheduling the new handler (and possibly other instances of [Schedulable](#)¹⁵³). When **release** is **null** the new [AsyncEventHandler](#) will use a clone of the default [ReleaseParameters](#)¹⁵⁴ for the associated scheduler created in the memory area that contains the [AsyncEventHandler](#) object.

memory parameters for scheduling the new handler (and possibly other instances of [Schedulable](#)¹⁵⁵). When **memory** is **null**, the new [AsyncEventHandler](#) receives **null** value for its memory parameters, and the amount or rate of memory allocation for the new handler is unrestricted.

area the initial memory area of this handler.

group parameters for providing CPU cost management on a set of [Schedulable](#)¹⁵⁶s. When **null**, **this** will not be associated with any processing group.

config parameters for reserving space for preallocated exceptions and change implementation specific per [Schedulable](#)¹⁵⁷ memory reservations, such as Java stack size, for the new handler (and possibly other instances of [Schedulable](#)¹⁵⁸). When **initial** is **null**, this [AsyncEventHandler](#) will reserve no space for preallocated exceptions and implementation-specific values will be set to their implementation-defined defaults.

logic is the logic to run for each fire. When **logic** is **null**, the `handleAsyncEvent` method in the new object will serve as its logic.

AsyncObjectEventHandler(SchedulingParameters, ReleaseParameters, Consumer)

¹⁵⁰Section 6.4.1.3

¹⁵¹Section 6.4.1.3

¹⁵²Section 6.4.3.14

¹⁵³Section 6.4.1.3

¹⁵⁴Section 6.4.3.10

¹⁵⁵Section 6.4.1.3

¹⁵⁶Section 6.4.1.3

¹⁵⁷Section 6.4.1.3

¹⁵⁸Section 6.4.1.3

Signature

```
public
AsyncObjectEventHandler(SchedulingParameters scheduling,
                        ReleaseParameters release,
                        java.util.function.Consumer<P> logic)
```

Description

Calling this constructor is equivalent to calling `AsyncObjectEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Consumer)`¹⁵⁹ with arguments (scheduling, release, null, null, null, null, logic).

AsyncObjectEventHandler(SchedulingParameters, ReleaseParameters)

Signature

```
public
AsyncObjectEventHandler(SchedulingParameters scheduling,
                        ReleaseParameters release)
```

Description

Calling this constructor is equivalent to calling `AsyncObjectEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Consumer)`¹⁶⁰ with arguments (scheduling, release, null, null, null, null, null)

AsyncObjectEventHandler(Consumer)

Signature

```
public
AsyncObjectEventHandler(java.util.function.Consumer<P> logic)
```

Description

¹⁵⁹Section 8.4.3.9.1

¹⁶⁰Section 8.4.3.9.1

Calling this constructor is equivalent to calling `AsyncObjectEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Consumer)`¹⁶¹ with arguments (null, null, null, null, null, null, null, logic).

Parameters

logic is the function to call on the object received.

AsyncObjectEventHandler

Signature

```
public
AsyncObjectEventHandler()
```

Description

Create an instance of `AsyncObjectEventHandler` with default values for all parameters.

See Section `AsyncObjectEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Consumer)`

8.4.3.9.2 Methods

handleAsyncEvent(P)

Signature

```
public
void handleAsyncEvent(P value)
```

Description

This method holds the logic which is to be executed when any `AsyncEvent`¹⁶² with which this handler is associated is fired. This method will be invoked repeatedly while `fireCount` is greater than zero.

¹⁶¹Section 8.4.3.9.1

¹⁶²Section 8.4.3.4

The default implementation of this method invokes the `run` method of any non-null `logic` instance passed to the constructor of this handler.

This AOEH is a source of reference for its initial memory area while this AOEH is released.

All throwables from (or propagated through) `handleAsyncEvent(P)` are caught, a stack trace is printed and execution continues as if `handleAsyncEvent(P)` had returned normally.

peekPending

Signature

```
public
P peekPending()
throws IllegalStateException
```

Description

Determine the next value queued for handling.

Throws

`IllegalStateException` when the fire count is zero.

Returns

The object reference at the head of the queue of object references to be passed to `handleAsyncEvent`¹⁶³.

run

Signature

```
public final
void run()
```

Description

This method is only to be used by the infrastructure, and should not be called by the application.

The `handleAsyncEvent()` family of methods provides the equivalent functionality to `Runnable.run()` for asynchronous event handlers, including execution of the `logic` argument passed to this object's constructor. Applications should override that method or provide a `logic` object for the default implementation to invoke.

¹⁶³Section 8.4.3.9.2

8.4.3.10 BoundAsyncEventHandler

Inheritance

```
java.lang.Object
  javax.realtime.AsyncBaseEventHandler
    javax.realtime.AsyncEventHandler
      javax.realtime.BoundAsyncEventHandler
```

Interfaces

```
javax.realtime.AsyncBaseEventHandler
```

Description

A bound asynchronous event handler is an instance of `AsyncEventHandler`¹⁶⁴ that is permanently bound to a dedicated realtime thread. Bound asynchronous event handlers are for use in situations where the added timeliness is worth the overhead of dedicating an individual realtime thread to the handler. Individual server realtime threads can only be dedicated to a single bound event handler.

8.4.3.10.1 Constructors

BoundAsyncEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, Runnable)

Signature

```
public
BoundAsyncEventHandler(SchedulingParameters scheduling,
                       ReleaseParameters release,
                       MemoryParameters memory,
                       MemoryArea area,
                       SchedulingGroup group,
                       ConfigurationParameters config,
                       Runnable logic)
```

Description

¹⁶⁴Section 8.4.3.5

Create an instance of `BoundAsyncEventHandler` with the specified parameters. The newly-created handler inherits the affinity of its creator.

Parameters

scheduling A `SchedulingParameters`¹⁶⁵ object which will be associated with the constructed instance. When `null`, and the creator is a Java thread, a `SchedulingParameters` object is created which has the default `SchedulingParameters` for the scheduler associated with the current thread. When `null`, and the creator is a schedulable object, the `SchedulingParameters` are inherited from the current schedulable (a new `SchedulingParameters` object is cloned).

release A `ReleaseParameters`¹⁶⁶ object which will be associated with the constructed instance. When `null`, this will have default `ReleaseParameters` for the BAEH's scheduler.

memory A `MemoryParameters`¹⁶⁷ object which will be associated with the constructed instance. When `null`, this will have no `MemoryParameters` and the handler can access the heap.

area The `MemoryArea`¹⁶⁸ for this. When `null`, the memory area will be that of the current thread/schedulable.

group A `SchedulingGroup`¹⁶⁹ object which will be associated with the constructed instance. When `null`, this will not be associated with any scheduling group.

config The `ConfigurationParameters`¹⁷⁰ associated with this (and possibly other instances of `Schedulable`¹⁷¹. When `config` is `null`, this `BoundAsyncEventHandler` will reserve no space for preallocated exceptions and implementation-specific values will be set to their implementation-defined defaults.

logic The `Runnable` object whose `run()` method is executed by `AsyncEventHandler.handleAsyncEvent()`¹⁷². When `null`, the default `handleAsyncEvent()` method invokes nothing.

Throws

`IllegalArgumentException` when `mayUseHeap` in `memory` is `true` and `logic`, any parameter object, or `this` is in heap memory. Also when `noheap` is `true`

¹⁶⁵Section 6.4.3.14

¹⁶⁶Section 6.4.3.10

¹⁶⁷Section 11.4.2.4

¹⁶⁸Section 11.4.2.3

¹⁶⁹Section 6.4.3.13

¹⁷⁰Section 5.4.2.1

¹⁷¹Section 6.4.1.3

¹⁷²Section 8.4.3.5.2

and `area` is heap memory.

`IllegalAssignmentError` when the new `AsyncEventHandler` instance cannot hold a reference to non-null values of `scheduling` `release` `memory` and `group`, or when those parameters cannot hold a reference to the new `AsyncEventHandler`. Also when the new `AsyncEventHandler` instance cannot hold a reference to non-null values of `area` and `logic`.

BoundAsyncEventHandler(SchedulingParameters, ReleaseParameters, Runnable)

Signature

```
public
BoundAsyncEventHandler(SchedulingParameters scheduling,
                      ReleaseParameters release,
                      Runnable logic)
```

Description

Create an instance of `BoundAsyncEventHandler` with the specified parameters. The newly-created handler inherits the affinity of its creator.

Equivalent to `BoundAsyncEventHandler(scheduling, release, null, null, null, config, logic)`

BoundAsyncEventHandler(SchedulingParameters, ReleaseParameters)

Signature

```
public
BoundAsyncEventHandler(SchedulingParameters scheduling,
                      ReleaseParameters release)
```

Description

Create an instance of `BoundAsyncEventHandler` with the specified parameters. The newly-created handler inherits the affinity of its creator.

Equivalent to `BoundAsyncEventHandler(scheduling, release, null, null, null, null, logic)`

BoundAsyncEventHandler(Runnable)

Signature

```
public  
BoundAsyncEventHandler(Runnable logic)
```

Description

Create an instance of `BoundAsyncEventHandler` with the specified parameters. The newly-created handler inherits the affinity of its creator.

Equivalent to `BoundAsyncEventHandler(null, null, null, null, null, null, logic)`

BoundAsyncEventHandler

Signature

```
public  
BoundAsyncEventHandler()
```

Description

Create an instance of `BoundAsyncEventHandler`. The newly-created handler inherits the affinity of its creator.

Equivalent to `BoundAsyncEventHandler(null, null, null, null, null, null, null)`

8.4.3.11 BoundAsyncLongEventHandler

Inheritance

```
java.lang.Object  
  javax.realtime.AsyncBaseEventHandler  
    javax.realtime.AsyncLongEventHandler  
      javax.realtime.BoundAsyncLongEventHandler
```

Interfaces

```
  javax.realtime.BoundAsyncBaseEventHandler
```

Description

A bound asynchronous event handler is an instance of `AsyncLongEventHandler`¹⁷³ that is permanently bound to a dedicated realtime thread. Bound asynchronous long event handlers are for use in situations where the added timeliness is worth the overhead of dedicating an individual realtime thread to the handler. Individual server realtime threads can only be dedicated to a single bound event handler.

Available since RTSJ 2.0

8.4.3.11.1 Constructors

BoundAsyncLongEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, SchedulingGroup, ConfigurationParameters, LongConsumer)

Signature

```
public
BoundAsyncLongEventHandler(SchedulingParameters scheduling,
                           ReleaseParameters release,
                           MemoryParameters memory,
                           MemoryArea area,
                           SchedulingGroup group,
                           ConfigurationParameters config,
                           LongConsumer logic)
```

Description

Create an instance of `BoundAsyncLongEventHandler` which specifies all possible parameters. The newly-created handler inherits the affinity of its creator.

Parameters

scheduling A `SchedulingParameters`¹⁷⁴ object which will be associated with the constructed instance. When null, and the creator is a Java thread, a `SchedulingParameters` object is created which has the default `SchedulingParameters` for the scheduler associated with the current thread. When null,

¹⁷³Section 8.4.3.7

¹⁷⁴Section 6.4.3.14

and the creator is a schedulable object, the `SchedulingParameters` are inherited from the current schedulable (a new `SchedulingParameters` object is cloned).

release A `ReleaseParameters`¹⁷⁵ object which will be associated with the constructed instance. When `null`, this will have default `ReleaseParameters` for the BAEH's scheduler.

memory A `MemoryParameters`¹⁷⁶ object which will be associated with the constructed instance. When `null`, this will have no `MemoryParameters` and the handler can access the heap.

area The `MemoryArea`¹⁷⁷ for this. When `null`, the memory area will be that of the current thread/schedulable.

group A `SchedulingGroup`¹⁷⁸ object which will be associated with the constructed instance. When `null`, this will not be associated with any scheduling group.

config The `ConfigurationParameters`¹⁷⁹ associated with this (and possibly other instances of `Schedulable`¹⁸⁰. When `config` is `null`, this `BoundAsyncEventHandler` will reserve no space for preallocated exceptions and implementation-specific values will be set to their implementation-defined defaults.

logic The `LongConsumer` object whose `accept()` method is executed by `AsyncLongEventHandler.handleAsyncEvent(long)`¹⁸¹. When `null`, the default `handleAsyncEvent(long)` method invokes nothing.

Throws

`IllegalArgumentException` when `mayUseHeap` in `memory` is `true` and `logic`, any parameter object, or `this` is in heap memory. Also when `noheap` is `true` and `area` is heap memory.

`IllegalAssignmentError` when the new `AsyncEventHandler` instance cannot hold a reference to non-null values of `scheduling` `release` `memory` and `group`, or when those parameters cannot hold a reference to the new `AsyncEventHandler`. Also when the new `AsyncEventHandler` instance cannot hold a reference to non-null values of `area` and `logic`.

¹⁷⁵Section 6.4.3.10

¹⁷⁶Section 11.4.2.4

¹⁷⁷Section 11.4.2.3

¹⁷⁸Section 6.4.3.13

¹⁷⁹Section 5.4.2.1

¹⁸⁰Section 6.4.1.3

¹⁸¹Section 8.4.3.7.2

BoundAsyncLongEventHandler(SchedulingParameters, ReleaseParameters, LongConsumer)

Signature

```
public
BoundAsyncLongEventHandler(SchedulingParameters scheduling,
                           ReleaseParameters release,
                           LongConsumer logic)
```

Description

BoundAsyncLongEventHandler(SchedulingParameters, ReleaseParameters)

Signature

```
public
BoundAsyncLongEventHandler(SchedulingParameters scheduling,
                           ReleaseParameters release)
```

Description

BoundAsyncLongEventHandler(LongConsumer)

Signature

```
public
BoundAsyncLongEventHandler(LongConsumer logic)
```

Description

BoundAsyncLongEventHandler

Signature

```
public
BoundAsyncLongEventHandler()
```

Description

Create an instance of `BoundAsyncLongEventHandler` using default values. This constructor is equivalent to `BoundAsyncLongEventHandler(null, null, null, null, null, false, null)`

8.4.3.12 BoundAsyncObjectEventHandler

Inheritance

```
java.lang.Object
  javax.realtime.AsyncBaseEventHandler
    javax.realtime.AsyncObjectEventHandler
      javax.realtime.BoundAsyncObjectEventHandler
```

Interfaces

```
javax.realtime.BoundAsyncBaseEventHandler
```

Description

A bound asynchronous event handler is an instance of `AsyncObjectEventHandler`¹⁸² that is permanently bound to a dedicated realtime thread. Bound asynchronous object event handlers are for use in situations where the added timeliness is worth the overhead of dedicating an individual realtime thread to the handler. Individual server realtime threads can only be dedicated to a single bound event handler.

Available since RTSJ 2.0

8.4.3.12.1 Constructors

¹⁸²Section 8.4.3.9

BoundAsyncObjectEventHandler(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, ProcessingGroup, ConfigurationParameters, Consumer)

Signature

```
public
BoundAsyncObjectEventHandler(SchedulingParameters scheduling,
                             ReleaseParameters release,
                             MemoryParameters memory,
                             MemoryArea area,
                             ProcessingGroup group,
                             ConfigurationParameters config,
                             java.util.function.Consumer<P> logic)
```

Description

Create an instance of `BoundAsyncObjectEventHandler` which specifies all possible parameters. The newly-created handler inherits the affinity of its creator.

Parameters

scheduling A `SchedulingParameters`¹⁸³ object which will be associated with the constructed instance. When `null`, and the creator is a Java thread, a `SchedulingParameters` object is created which has the default `SchedulingParameters` for the scheduler associated with the current thread. When `null`, and the creator is a schedulable object, the `SchedulingParameters` are inherited from the current schedulable (a new `SchedulingParameters` object is cloned).

release A `ReleaseParameters`¹⁸⁴ object which will be associated with the constructed instance. When `null`, this will have default `ReleaseParameters` for the BAEH's scheduler.

memory A `MemoryParameters`¹⁸⁵ object which will be associated with the constructed instance. When `null`, this will have no `MemoryParameters` and the handler can access the heap.

area The `MemoryArea`¹⁸⁶ for this. When `null`, the memory area will be that of the current thread/schedulable.

group A `SchedulingGroup`¹⁸⁷ object which will be associated with the con-

¹⁸³Section 6.4.3.14

¹⁸⁴Section 6.4.3.10

¹⁸⁵Section 11.4.2.4

¹⁸⁶Section 11.4.2.3

¹⁸⁷Section 6.4.3.13

structed instance. When `null`, this will not be associated with any scheduling group.

`config` The `ConfigurationParameters`¹⁸⁸ associated with this (and possibly other instances of `Schedulable`¹⁸⁹. When `config` is `null`, this `BoundAsyncEventHandler` will reserve no space for preallocated exceptions and implementation-specific values will be set to their implementation-defined defaults.

`logic` The `Consumer` object whose `accept()` method is executed by `AsyncObjectEventHandler.handleAsyncEvent(P)`¹⁹⁰. When `null`, the default `handleAsyncEvent(P)` method invokes nothing.

Throws

`IllegalArgumentException` when `mayUseHeap` in `memory` is `true` and `logic`, any parameter object, or `this` is in heap memory. Also when `noheap` is `true` and `area` is heap memory.

`IllegalAssignmentError` when the new `AsyncEventHandler` instance cannot hold a reference to non-null values of `scheduling`, `release`, `memory` and `group`, or when those parameters cannot hold a reference to the new `AsyncEventHandler`. Also when the new `AsyncEventHandler` instance cannot hold a reference to non-null values of `area` and `logic`.

BoundAsyncObjectEventHandler(SchedulingParameters, ReleaseParameters, Consumer)

Signature

```
public
BoundAsyncObjectEventHandler(SchedulingParameters scheduling,
                             ReleaseParameters release,
                             java.util.function.Consumer<P> logic)
```

Description

BoundAsyncObjectEventHandler(SchedulingParameters, ReleaseParameters)

¹⁸⁸Section 5.4.2.1

¹⁸⁹Section 6.4.1.3

¹⁹⁰Section 8.4.3.9.2

Signature

```
public  
BoundAsyncObjectEventHandler(SchedulingParameters scheduling,  
                             ReleaseParameters release)
```

*Description***BoundAsyncObjectEventHandler(Consumer)***Signature*

```
public  
BoundAsyncObjectEventHandler(java.util.function.Consumer<P> logic)
```

*Description***BoundAsyncObjectEventHandler***Signature*

```
public  
BoundAsyncObjectEventHandler()
```

Description

Create an instance of `BoundAsyncObjectEventHandler` using default values. This constructor is equivalent to `BoundAsyncObjectEventHandler(null, null, null, null, null, null)`

8.5 Rationale

The design of the asynchronous event handling facilities was intended to provide the necessary functionality while allowing efficient implementations and catering for a variety of realtime applications. In particular, in some realtime systems there may be

a large number of potential events and event handlers (numbering in the thousands or perhaps even the tens of thousands), although at any given time only a small number will be used. Thus it would not be appropriate to dedicate a realtime thread to each event handler. The RTSJ addresses this issue by allowing the programmer to specify an event handler either as not bound to a specific realtime thread (the class `AsyncBaseEventHandler`) or alternatively as bound to a dedicated realtime thread (the interface `BoundAsyncBaseEventHandler`). The RTSJ does not define at what point a non-bound event handler is bound to a realtime thread for its execution. Events are dataless: the `fire` method does not pass any data to the handler. This was intentional in the interest of simplicity and efficiency.

The ability to trigger an ATC in a schedulable is necessary in many kinds of realtime applications but must be designed carefully in order to minimize the risks of problems such as data structure corruption and deadlock. There is, invariably, a tension between the desire to cause an ATC to be immediate, and the desire to ensure that certain sections of code are executed to completion.

One basic decision was to allow ATC in a method only if the method explicitly permits this. The default of no ATC is reasonable, since legacy code might be written expecting no ATC, and asynchronously aborting the execution of such a method could lead to unpredictable results. Since the natural way to model ATC is with an exception (`AsynchronouslyInterruptedException`), the way that a method indicates its susceptibility to ATC is by including `AsynchronouslyInterruptedException` in its `throws` clause. Causing this exception to be thrown in a schedule `s` as an effect of calling `s.interrupt()` was a natural extension of the semantics of `interrupt` as currently defined by `java.lang.Thread`.

One ATC-deferred section is `synchronized` code. This is a context that needs to be executed completely in order to ensure a program operates correctly. If `synchronized` code were aborted, a shared object could be left in an inconsistent state. Note that by making `synchronized` code ATC-deferred, this specification avoids the problems that caused `Thread.stop()` to be deprecated and that have made the use of `Thread.destroy()`, (now also deprecated in Java 1.5) prone to deadlock. If `synchronized` code calls an AI-method and an associated AIE is generated, then if no appropriate handler is present in the `synchronized` code, the AIE will propagate through the code.

Constructors and `finally` clauses are subject to interruption if the program indicates so. However, if a constructor is aborted, an object might be only partially initialized. If the execution of a `finally` clause in an AI-method is aborted, needed cleanup code might not be performed. Indeed, a `finally` clause in an aborted AI-method will not be executed at all if the abort occurs before its execution begins. It is the programmer's responsibility to ensure that executing these constructs either does not induce unwanted ATC latency (if ATCs are not allowed) or does not produce

undesirable results (if ATCs are allowed).

A potential problem with using the exception mechanism to model ATC is that a method with a “catch-all” handler (for example a `catch` clause identifying `Exception` or even `Throwable` as the exception class) can inadvertently intercept an exception intended for a caller. This problem is avoided by having special semantics for catching an AIE. Even though a catch clause may catch an AIE, the exception will be propagated unless the handler invokes the `happened` method from AIE. Thus, if a schedulable is asynchronously interrupted while in a try block that has a handler such as

```
    catch (Throwable e) return;
```

the AIE will remain pending and will be thrown next time control enters or returns to an AI method.

This specification does not provide a special mechanism for terminating a realtime thread; ATC can be used to achieve this effect. This means that, by default, a realtime thread cannot be asynchronously terminated; to support asynchronous termination it needs to enter methods that are AI enabled at frequent intervals. Allowing termination as the default would have been questionable, bringing the same insecurities that are found in `Thread.stop()` and `Thread.destroy()`.

Chapter 9

Time

9.1 Overview

Realtime systems must be able to handle both very short time durations and very long ones. They also need to distinguish between relative time—a duration of time—and absolute time. Simply using a primitive integral value, such as `int` or `long`, does not provide the necessary range. Floating point primitive values, such as `float` and `double`, do not provide the necessary precision. Neither provides any type safety. This specification addresses this by requiring three time classes: `HighResolutionTime`, `AbsoluteTime`, and `RelativeTime`, where `HighResolutionTime` is the parent class of the other two.

Instances of `HighResolutionTime` may not be created, as the class exists to provide a common parent type for the other two classes. An instance of `AbsoluteTime` encapsulates an absolute time. An instance of `RelativeTime` encapsulates a point in time that is relative to some other absolute time value, which can be used to describe a time duration.

All methods returning a time object come in both allocating and nonallocating forms. The classes

- enable describing a point in time with up to nanosecond accuracy and precision (actual accuracy and precision is dependent on the precision of the underlying system),
- enable the distinction between absolute points in time, and times relative to some starting point or a time duration, and
- provide simple arithmetic operations for using them.

All time handling is based on these classes.

9.2 Definitions

Time Object — an instance of `AbsoluteTime` or `RelativeTime`. A *time object* is always associated with some `Chronograph`. By default, it is associated with the realtime clock.

Epoch — is the standard base time, conventionally January 1 00:00:00 GMT 1970. It is the point from which the realtime clock measures absolute time.

Time Value Representation — a compound format composed of 64 bits of millisecond timing, and 32 bits of nanoseconds within a millisecond. The millisecond constituent uses the 64 bits of a Java `long` while the nanosecond constituent uses the 32 bits of a Java `int`.

Normalized (Canonical) Time Value — unique values for the millisecond and nanosecond components of a point in time, including the case of 0 milliseconds or 0 nanoseconds, and a negative time value, according to the following four constraints:

1. when both millisecond and nanosecond components are nonzero, they have the same sign;
2. the algebraic time values of the time object is the algebraic sum of the two components;
3. the millisecond component represents the algebraic number of milliseconds in the time object, within a range of $[-2^{63}, 2^{63} - 1]$; and
4. the nanosecond component represents the algebraic number of nanoseconds within a millisecond in the time object, that is $[-10^6 + 1, 10^6 - 1]$.

Instances of `HighResolutionTime` classes always hold a normalized form of a time value. Values that cannot be normalized are not valid; for example, (`MAX_LONG` milliseconds, `MAX_INT` nanoseconds) cannot be normalized and is an illegal value.

The following table has examples of normalized representations.

time in ns	millis	nanos
2000000	2	0
1999999	1	999999
1000001	1	1
1	0	1
0	0	0
-1	0	-1
-999999	0	-999999
-1000000	-1	0
-1000001	-1	-1

9.3 Semantics

The points below define the general semantics of the time classes. Semantics specific to particular classes, constructors, methods, and fields are in the class description and the constructor, method, and field detail sections.

1. All time objects must maintain nanosecond precision and report their values in terms of millisecond and nanosecond constituents.
2. Time objects can be constructed from other time objects, from millisecond/-nanosecond values, from a `java.util.Date`, or obtained as a result of invocations of methods on instances of the `Chronograph` interface.
3. Time objects maintain and report time values in normalized form, but the normalized form is not required for input parameter values. This allows computations individually with time constituent parts using the full *signed* range and restrictions of the underlying type.
 - (a) Normalization is accomplished upon method invocation by methods that accept a time object represented with individual component parts, and executed as if the following hold.
 - i. The nanosecond parameter value, which may be negative, is algebraically added to the scaled millisecond parameter value. The sign of the result provides the sign for any nonzero resulting component.
 - ii. The absolute of the result is then partitioned, giving the number of integral milliseconds for the millisecond component, while the remaining fractional part provides the number of nanoseconds for the nanosecond component.
 - iii. The resulting components are then represented, and reported when necessary, with the above computed sign.
 - (b) Normalization is also performed on the result of operations by methods that perform time object addition and subtraction. Operations are executed using the appropriate arithmetic precision. If the final result of an operation can be represented in normalized form, then the operation must not throw arithmetic exceptions while producing intermediate results.
 - (c) The results of time objects operations and the normalization of results of operations performed with `millis` and `nanos`, individually as Java `long` and Java `int` types respectively, are not always equivalent. This is due to the possibility of overflow for `nanos` values outside of the normalized nanosecond range, that is $[-10^6 + 1, 10^6 - 1]$, when performing operations as `int` types, while the same values could be handled with no overflow in time object operations.
 - (d) When invoking setter methods that take as a parameter only one of the two time value components, the other component has implicitly the value of 0.

4. Although logically a negative time may represent time before the Epoch or a negative time interval involved in time operations, an **Exception** may be thrown if a negative absolute time or a negative time interval is given as a parameter to methods. In general, the time values accepted by a method may be a subset of the full time values range, and depend on the method.
5. A *time object* is always associated with a **Chronograph**. By default it is associated with the realtime clock. Chronographs are involved both in the setting as well as the usage of time objects, for example in comparisons.
6. Methods are provided to facilitate the handling of time objects generically via the **HighResolutionTime** class. These methods allow the conversion, according to a **Chronograph**, between **AbsoluteTime** objects and **RelativeTime** objects. These methods also allow the change of **Chronograph** association of a time object. Note that the conversions depend on the time at which they are performed. The semantics of these operations are listed in the following table:

Chronograph association and conversion this has chronograph_a and ms,ns	returned/updated object
this_is_absolute.absolute(chronograph_a)	chronograph_a
this_is_absolute.absolute(chronograph_b)	ms,ns chronograph_b
this_is_absolute.absolute(null)	ms,ns realtime_clock
this_is_absolute.relative(chronograph_a)	ms,ns chronograph_a
this_is_absolute.relative(chronograph_b)	chronograph_a.getTime().subtract(ms,ns) chronograph_b
this_is_absolute.relative(null)	chronograph_b.getTime().subtract(ms,ns) realtime_clock
this_is_relative.relative(chronograph_a)	realtime_clock.getTime().subtract(ms,ns) chronograph_a
this_is_relative.relative(chronograph_b)	ms,ns chronograph_b
this_is_relative.relative(null)	ms,ns realtime_clock
this_is_relative.absolute(chronograph_a)	ms,ns chronograph_a
this_is_relative.absolute(clock_b)	chronograph_a.getTime().add(ms,ns) chronograph_b
this_is_relative.absolute(null)	chronograph_b.getTime().add(ms,ns) realtime_clock
	realtime_clock.getTime().add(ms,ns)

7. Time objects must implement the **Comparable** interface.

9.4 Package javax.realtime

9.4.1 Classes

9.4.1.1 AbsoluteTime

Inheritance

```
java.lang.Object
  javax.realtime.HighResolutionTime
    javax.realtime.AbsoluteTime
```

Description

An object that represents a specific point in time given by milliseconds plus nanoseconds past some point in time fixed by its `Chronograph`. For the default realtime clock, the fixed point is the Epoch (January 1, 1970, 00:00:00 GMT). The correctness of the Epoch as a time base depends on the realtime clock synchronization with an external world time reference. This representation was designed to be compatible with the standard Java representation of an absolute time in the `java.util.Date` class.

A time object in normalized form represents negative time when both components are nonzero and negative, or one is nonzero and negative and the other is zero. For `add` and `subtract` negative values behave as they do in arithmetic.

Caution: This class is explicitly unsafe for multithreading when being changed. Code that mutates instances of this class should synchronize at a higher level.

9.4.1.1.1 Constructors

AbsoluteTime(Chronograph)

Signature

```
public
AbsoluteTime(Chronograph chronograph)
```

Description

Equivalent to `new AbsoluteTime(0,0,chronograph)`. The `chronograph` association is made with the `Chronograph` parameter. When `Chronograph` is `null` the association is made with the default realtime clock.

Available since RTSJ 2.0*Parameters*

chronograph The chronograph providing the association for the newly constructed object.

AbsoluteTime*Signature*

```
public  
AbsoluteTime()
```

Description

Equivalent to `new AbsoluteTime(0,0)`. The chronograph association is implicitly made with the default realtime clock.

AbsoluteTime(AbsoluteTime)*Signature*

```
public  
AbsoluteTime(AbsoluteTime time)  
throws IllegalArgumentException
```

Description

Make a new `AbsoluteTime` object from the given `AbsoluteTime` object. The new object will have the same chronograph association as the `time` parameter.

Parameters

time The `AbsoluteTime` object which is the source for the copy.

Throws

`IllegalArgumentException` when the `time` parameter is `null`.

AbsoluteTime(Date)*Signature*

```
public
AbsoluteTime(Date date)
throws IllegalArgumentException
```

Description

Equivalent to new `AbsoluteTime(date.getTime(),0)`. The chronograph association is implicitly made with the default realtime clock.

Parameters

date The `java.util.Date` representation of the time past the Epoch.

Throws

`IllegalArgumentException` when the `date` parameter is `null`.

AbsoluteTime(Date, Chronograph)

Signature

```
public
AbsoluteTime(Date date,
              Chronograph chronograph)
throws IllegalArgumentException
```

Description

Equivalent to new `AbsoluteTime(date.getTime(),0,chronograph)`.

Warning: While the `date` is used to set the milliseconds component of the new `AbsoluteTime` object (with nanoseconds component set to 0), the new object represents the `date` only when the `Chronograph` parameter has an epoch equal to Epoch.

The chronograph association is made with the `Chronograph` parameter. When `Chronograph` is `null` the association is made with the default realtime clock.

Available since RTSJ 2.0*Parameters*

date The `java.util.Date` representation of the time past the Epoch.

chronograph The chronograph providing the association for the newly constructed object.

Throws

`IllegalArgumentException` when the `date` parameter is `null`.

AbsoluteTime(long, int)

Signature

```
public  
AbsoluteTime(long millis,  
              int nanos)  
throws IllegalArgumentException
```

Description

Construct an `AbsoluteTime` object with time millisecond and nanosecond components past the realtime clock's Epoch (00:00:00 GMT on January 1, 1970) based on the parameter `millis` plus the parameter `nanos`. The construction is subject to `millis` and `nanos` parameters normalization. When, after normalization, the time object is negative, the time represented by this is time before the Epoch of its [Chronograph](#)¹. The chronograph association is implicitly made with the default realtime clock.

Parameters

`millis` is the desired value for the millisecond component of `this`. The actual value is the result of parameter normalization.

`nanos` is the desired value for the nanosecond component of `this`. The actual value is the result of parameter normalization.

Throws

`IllegalArgumentException` when there is an overflow in the millisecond component when normalizing.

AbsoluteTime(long, int, Chronograph)

Signature

```
public  
AbsoluteTime(long millis,  
              int nanos,  
              Chronograph chronograph)  
throws IllegalArgumentException
```

Description

¹Section [10.4.1.2](#)

Construct an `AbsoluteTime` object with time millisecond and nanosecond components past the epoch for `Chronograph`.

The value of the `AbsoluteTime` instance is based on the parameter `millis` plus the parameter `nanos`. The construction is subject to `millis` and `nanos` parameters normalization. When, after normalization, the time object is negative, the time represented by this is time before `this` chronograph's epoch. The chronograph association is made with the `Chronograph` parameter. When `Chronograph` is `null` the association is made with the default realtime clock.

Note: The start of a chronograph's epoch is an attribute of the chronograph. It is defined as the Epoch (00:00:00 GMT on Jan 1, 1970) for the default realtime clock, but other classes of chronograph may define other epochs.

Available since RTSJ 2.0

Parameters

`millis` The desired value for the millisecond component of `this`. The actual value is the result of parameter normalization.

`nanos` The desired value for the nanosecond component of `this`. The actual value is the result of parameter normalization.

`chronograph` The chronograph providing the association for the newly constructed object.

Throws

`IllegalArgumentException` when there is an overflow in the millisecond component when normalizing.

9.4.1.1.2 Methods

absolute(Chronograph)

Signature

```
public  
javax.realtime.AbsoluteTime absolute(Chronograph chronograph)
```

Description

Return a copy of `this` modified when necessary to have the specified chronograph association. A new object is allocated for the result. This method is the implementation of the `abstract` method of the `HighResolutionTime` base class. No conversion into `AbsoluteTime` is needed in this case. The result is associated

with the **Chronograph** passed as a parameter. When **Chronograph** is **null** the association is made with the default realtime clock.

Parameters

chronograph The **Chronograph** parameter is used only as the new chronograph association with the result, since no conversion is needed.

Returns

The copy of **this** in a newly allocated **AbsoluteTime** object, associated with the **Chronograph** parameter.

absolute(Chronograph, AbsoluteTime)

Signature

```
public  
javax.realtime.AbsoluteTime absolute(Chronograph chronograph,  
                                     AbsoluteTime dest)
```

Description

Convert the time of **this** to an absolute time, using the given instance of **Chronograph**² to determine the current time when necessary. When **Chronograph** is **null** the realtime chronograph is assumed. When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result. The chronograph association of the result is the **Chronograph** passed as a parameter. See the subclass comments for more specific information.

Parameters

chronograph The instance of **Chronograph**³ used to convert the time of **this** into absolute time, and the new chronograph association for the result.

dest When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Returns

The **AbsoluteTime** conversion in **dest** when **dest** is not **null**, otherwise the result is returned in a newly allocated object. It is associated with the **Chronograph** parameter.

relative(Clock)

Signature

²Section 10.4.1.2

³Section 10.4.1.2


```
public  
javax.realtime.RelativeTime relative(Clock clock)  
throws ArithmeticException
```

Description

Convert the time of `this` to a relative time, using the given instance of `Clock`⁴ to determine the current time. The calculation is the current time indicated by the given instance of `Clock`⁵ subtracted from the time given by `this`. When `clock` is `null` the default realtime clock is assumed. A destination object is allocated to return the result. The clock association of the result is with the `clock` passed as a parameter.

Parameters

`clock` The instance of `Clock`⁶ used to convert the time of `this` into relative time, and the new clock association for the result.

Throws

`ArithmeticException` when the result does not fit in the normalized format.

Returns

The `RelativeTime` conversion in a newly allocated object, associated with the `clock` parameter.

Deprecated since RTSJ version since version 2.0

relative(Chronograph)

Signature

```
public  
javax.realtime.RelativeTime relative(Chronograph chronograph)
```

Description

Convert the time of `this` to a relative time, using the given instance of `Chronograph`⁷ to determine the current time. The calculation is the current time indicated by the given instance of `Chronograph`⁸ subtracted from the time given by `this`. When `Chronograph` is `null` the default realtime clock is assumed. A

⁴Section 10.4.2.1

⁵Section 10.4.2.1

⁶Section 10.4.2.1

⁷Section 10.4.1.2

⁸Section 10.4.1.2

destination object is allocated to return the result. The chronograph association of the result is with the **Chronograph** passed as a parameter.

Parameters

chronograph The instance of **Chronograph**⁹ used to convert the time of **this** into relative time, and the new chronograph association for the result.

Throws

ArithmeticException when the result does not fit in the normalized format.

Returns

The **RelativeTime** conversion in a newly allocated object, associated with the **Chronograph** parameter.

Available since RTSJ 2.0

relative(Chronograph, RelativeTime)

Signature

```
public
    javax.realtime.RelativeTime relative(Chronograph chronograph,
                                         RelativeTime dest)
```

Description

Convert the time of **this** to a relative time, using the given instance of **Chronograph**¹⁰ to determine the current time. The calculation is the current time indicated by the given instance of **Chronograph**¹¹ subtracted from the time given by **this**. When **Chronograph** is **null** the default realtime clock is assumed. When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result. The chronograph association of the result is with the **Chronograph** passed as a parameter.

Parameters

chronograph The instance of **Chronograph**¹² used to convert the time of **this** into relative time, and the new chronograph association for the result.

dest When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Throws

⁹Section 10.4.1.2

¹⁰Section 10.4.1.2

¹¹Section 10.4.1.2

¹²Section 10.4.1.2

`ArithmeticException` when the result does not fit in the normalized format.

Returns

The `RelativeTime` conversion in `dest` when `dest` is not null, otherwise the result is returned in a newly allocated object. It is associated with the `Chronograph` parameter.

add(long, int)

Signature

```
public
javax.realtime.AbsoluteTime add(long millis,
                                int nanos)

throws ArithmeticException
```

Description

Create a new object representing the result of adding `millis` and `nanos` to the values from `this` and normalizing the result. The result will have the same chronograph association as `this`.

Parameters

`millis` The number of milliseconds to be added to `this`.

`nanos` The number of nanoseconds to be added to `this`.

Throws

`ArithmeticException` when the result does not fit in the normalized format.

Returns

A new `AbsoluteTime` object whose time is the normalization of `this` plus `millis` and `nanos`.

add(long, int, AbsoluteTime)

Signature

```
public
javax.realtime.AbsoluteTime add(long millis,
                                int nanos,
                                AbsoluteTime dest)

throws ArithmeticException
```

Description

Return an object containing the value resulting from adding `millis` and `nanos` to the values from `this` and normalizing the result. When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result. The result will have the same chronograph association as `this`, and the chronograph association with `dest` is ignored.

Parameters

`millis` The number of milliseconds to be added to `this`.

`nanos` The number of nanoseconds to be added to `this`.

`dest` When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Throws

`ArithmeticException` when the result does not fit in the normalized format.

Returns

the result of the normalization of `this` plus `millis` and `nanos` in `dest` when `dest` is not `null`, otherwise the result is returned in a newly allocated object.

add(RelativeTime)

Signature

```
public  
javax.realtime.AbsoluteTime add(RelativeTime time)  
throws ArithmeticException,  
        IllegalArgumentException
```

Description

Create a new instance of `AbsoluteTime` representing the result of adding `time` to the value of `this` and normalizing the result. The `Chronograph` associated with `this` and the `Chronograph` associated with the `time` parameter must be the same, and such association is used for the result.

Parameters

`time` The time to add to `this`.

Throws

`IllegalArgumentException` when the `Chronograph` associated with `this` and the `Chronograph` associated with the `time` parameter are different, or when the `time` parameter is `null`.

`ArithmeticException` when the result does not fit in the normalized format.

Returns

A new `AbsoluteTime` object whose time is the normalization of `this` plus the parameter `time`.

add(RelativeTime, AbsoluteTime)

Signature

```
public
javax.realtime.AbsoluteTime add(RelativeTime time,
                                AbsoluteTime dest)

throws ArithmeticException,
        IllegalArgumentException
```

Description

Return an object containing the value resulting from adding `time` to the value of `this` and normalizing the result. When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result. The `Chronograph` associated with `this` and the `Chronograph` associated with the `time` parameter must be the same, and such association is used for the result. The `Chronograph` associated with the `dest` parameter is ignored.

Parameters

`time` The time to add to `this`.
`dest` When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Throws

`IllegalArgumentException` when the `Chronograph` associated with `this` and the `Chronograph` associated with the `time` parameter are different, or when the `time` parameter is `null`.
`ArithmeticException` when the result does not fit in the normalized format.

Returns

the result of the normalization of `this` plus the `RelativeTime` parameter `time` in `dest` when `dest` is not `null`, otherwise the result is returned in a newly allocated object.

getDate

Signature

```
public
java.util.Date getDate()
```

throws `UnsupportedOperationException`

Description

Convert the time given by `this` to a `Date` format. Note that `Date` represents time as milliseconds so the nanoseconds of `this` will be lost.

Throws

`UnsupportedOperationException` when the chronograph associated with `this` does not have the concept of date.

Returns

A newly allocated `Date` object with a value of the time past the Epoch represented by `this`.

set(Date)

Signature

```
public  
void set(Date date)  
throws IllegalArgumentException
```

Description

Change the time represented by `this` to that given by the parameter. Note that `Date` represents time as milliseconds so the nanoseconds of `this` will be set to 0. The chronograph association is implicitly made with the default realtime clock.

Parameters

date A reference to a `Date` which will become the time represented by `this` after the completion of this method.

Throws

`IllegalArgumentException` when the parameter `date` is null.

subtract(AbsoluteTime)

Signature

```
public  
javax.realtime.RelativeTime subtract(AbsoluteTime time)  
throws IllegalArgumentException,  
    ArithmeticException
```

Description

Create a new instance of `RelativeTime` representing the result of subtracting `time` from the value of `this` and normalizing the result. The `Chronograph` associated with `this` and the `Chronograph` associated with the `time` parameter must be the same, and such association is used for the result.

Parameters

`time` The time to subtract from `this`.

Throws

`IllegalArgumentException` when the `Chronograph` associated with `this` and the `Chronograph` associated with the `time` parameter are different, or when the `time` parameter is `null`.

`ArithmeticException` when the result does not fit in the normalized format.

Returns

A new `RelativeTime` object whose time is the normalization of `this` minus the `AbsoluteTime` parameter `time`.

subtract(AbsoluteTime, RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime subtract(AbsoluteTime time,  
                                     RelativeTime dest)  
  
throws IllegalArgumentException,  
        ArithmeticException
```

Description

Return an object containing the value resulting from subtracting `time` from the value of `this` and normalizing the result. When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result. The `Chronograph` associated with `this` and the `Chronograph` associated with the `time` parameter must be the same, and such association is used for the result. The `Chronograph` associated with the `dest` parameter is ignored.

Parameters

`time` The time to subtract from `this`.

`dest` When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Throws

`IllegalArgumentException` when the `Chronograph` associated with `this` and the `Chronograph` associated with the `time` parameter are different, or when the `time` parameter is `null`.

ArithmeticException when the result does not fit in the normalized format.

Returns

the result of the normalization of **this** minus the **AbsoluteTime** parameter **time** in **dest** when **dest** is not **null**, otherwise the result is returned in a newly allocated object.

subtract(RelativeTime)

Signature

```
public
javax.realtime.AbsoluteTime subtract(RelativeTime time)
throws IllegalArgumentException,
    ArithmeticException
```

Description

Create a new instance of **AbsoluteTime** representing the result of subtracting **time** from the value of **this** and normalizing the result. The **Chronograph** associated with **this** and the **Chronograph** associated with the **time** parameter must be the same, and such association is used for the result.

Parameters

time The time to subtract from **this**.

Throws

IllegalArgumentException when the **Chronograph** associated with **this** and the **Chronograph** associated with the **time** parameter are different, or when the **time** parameter is **null**.

ArithmeticException when the result does not fit in the normalized format.

Returns

A new **AbsoluteTime** object whose time is the normalization of **this** minus the parameter **time**.

subtract(RelativeTime, AbsoluteTime)

Signature

```
public
javax.realtime.AbsoluteTime subtract(RelativeTime time,
                                     AbsoluteTime dest)
```


throws `IllegalArgumentException`,
`ArithmeticException`

Description

Return an object containing the value resulting from subtracting `time` from the value of `this` and normalizing the result. When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result. The `Chronograph` associated with `this` and the `Chronograph` associated with the `time` parameter must be the same, and such association is used for the result. The `Chronograph` associated with the `dest` parameter is ignored.

Parameters

`time` The time to subtract from `this`.

`dest` When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Throws

`IllegalArgumentException` when the `Chronograph` associated with `this` and the `Chronograph` associated with the `time` parameter are different, or when the `time` parameter is `null`.

`ArithmeticException` when the result does not fit in the normalized format.

Returns

the result of the normalization of `this` minus the `RelativeTime` parameter `time` in `dest` when `dest` is not `null`, otherwise the result is returned in a newly allocated object.

toString

Signature

```
public  
java.lang.String toString()
```

Description

Create a printable string of the time given by `this`.

The string shall be a decimal representation of the milliseconds and nanosecond values; formatted as follows "(2251 ms, 750000 ns)"

Returns

String object converted from the time given by `this`.

9.4.1.2 HighResolutionTime

Inheritance

java.lang.Object
 [javax.realtime.HighResolutionTime](#)

Interfaces

Comparable
Cloneable

Description

Class `HighResolutionTime` is the base class for `AbsoluteTime` and `RelativeTime`. It can be used to express time with nanosecond resolution. This class is never used directly; it is abstract and has no public constructor. Instead, one of its subclasses [AbsoluteTime](#)¹³ or [RelativeTime](#)¹⁴ should be used. When an API is defined that has a `HighResolutionTime` as a parameter, it can take either an absolute or a relative time and will do something appropriate.

Caution: This class is explicitly unsafe for multithreading when being changed. Code that mutates instances of this class should synchronize at a higher level.

9.4.1.2.1 Methods

`waitForObject(Object, HighResolutionTime)`

Signature

```
public static  
boolean waitForObject(Object target,  
                      javax.realtime.HighResolutionTime<?> time)  
throws InterruptedException,  
       IllegalMonitorStateException,  
       IllegalArgumentException,  
       UnsupportedOperationException
```

Description

Behaves like `target.wait()` but with the enhancement that it waits with a precision of `HighResolutionTime` and returns true when the associated notify

¹³Section [9.4.1.1](#)

¹⁴Section [9.4.1.3](#)

was received, false when timeout occurred. As for `target.wait()`, there is the possibility of spurious wakeup behavior.

The wait `time` may be relative or absolute, and it is controlled by the `clock` associated with it. When the wait `time` is relative, then the calling thread is blocked waiting on `target` for the amount of time given by `time`, and measured by the associated `clock`. When the wait `time` is absolute, then the calling thread is blocked waiting on `target` until the indicated `time` value is reached by the associated `clock`.

Parameters

target The object on which to wait. The current thread must have a lock on the object.

time The time for which to wait. When it is `RelativeTime(0,0)` then wait indefinitely. When it is `null` then wait indefinitely.

Throws

`InterruptedException` when this schedulable is interrupted by `RealtimeThread.interrupt`¹⁵ or `AsynchronouslyInterruptedException.fire`¹⁶ while it is waiting.

`IllegalArgumentException` when `time` represents a relative time less than zero.

`IllegalMonitorStateException` when `target` is not locked by the caller.

`UnsupportedOperationException` when the wait operation is not supported using the `clock` associated with `time`.

Returns

`true` when the notify was received before the timeout; `false` otherwise.

Available since RTSJ 2.0 updated to add a return value.

equals(T)

Signature

```
public
boolean equals(T time)
```

Description

Returns `true` when the argument `time` has the same type and values as `this`. Equality includes `Chronograph` association.

¹⁵Section 5.4.1

¹⁶Section 8.4.2.1.2

Parameters

`time` Value compared to `this`.

Returns

`true` when the parameter `time` is of the same type and has the same values as `this`.

getClock

Signature

```
public final
  javax.realtime.Clock getClock()
  throws UnsupportedOperationException
```

Description

Returns a reference to the `clock` associated with `this`.

Throws

`UnsupportedOperationException` when the time is based on a [Chronograph](#)¹⁷ that is not a [Clock](#)¹⁸.

Returns

A reference to the `clock` associated with `this`.

Available since RTSJ 1.0.1

getChronograph

Signature

```
public final
  javax.realtime.Chronograph getChronograph()
```

Description

Get a reference to the [Chronograph](#)¹⁹ associated with `this`.

Returns

A reference to the [Chronograph](#)²⁰ associated with `this`.

¹⁷Section [10.4.1.2](#)

¹⁸Section [10.4.2.1](#)

¹⁹Section [10.4.1.2](#)

²⁰Section [10.4.1.2](#)

Available since RTSJ 2.0

getMilliseconds

Signature

```
public final  
long getMilliseconds()
```

Description

Get the milliseconds component of **this**.

Returns

The milliseconds component of the time represented by **this**.

getNanoseconds

Signature

```
public final  
int getNanoseconds()
```

Description

Get the nanoseconds component of **this**.

Returns

The nanoseconds component of the time represented by **this**.

set(T)

Signature

```
public  
void set(T time)
```

Description

Change the value represented by **this** to that of the given **time**. The **Chronograph** associated with **this** is set to be the **Chronograph** associated with the **time** parameter.

Parameters

time The new value for **this**.

Throws

`IllegalArgumentException` when the parameter `time` is `null`.

`ClassCastException` when the type of `this` and the type of the parameter `time` are not the same.

Available since RTSJ 1.0.1 The description of the method in 1.0 was erroneous.

set(long)*Signature*

```
public
void set(long millis)
```

Description

Sets the millisecond component of `this` to the given argument, and the nanosecond component of `this` to 0. This method is equivalent to `set(millis, 0)`.

Parameters

millis This value shall be the value of the millisecond component of `this` at the completion of the call.

set(long, int)*Signature*

```
public
void set(long millis,
         int nanos)
throws IllegalArgumentException
```

Description

Sets the millisecond and nanosecond components of `this`. The setting is subject to parameter normalization. When after normalization the time is negative then the time represented by `this` is set to a negative value, but note that negative times are not supported everywhere. For instance, a negative relative time is an invalid value for a periodic thread's period.

Parameters

millis The desired value for the millisecond component of `this` at the completion of the call. The actual value is the result of parameter normalization.

nanos The desired value for the nanosecond component of **this** at the completion of the call. The actual value is the result of parameter normalization.

Throws

IllegalArgumentException when there is an overflow in the millisecond component while normalizing.

hashCode

Signature

```
public  
int hashCode()
```

Description

Returns a hash code for this object in accordance with the general contract of `Object.hashCode`. Time objects that are [equals²¹](#) equal have the same hash code.

Returns

The hashcode value for this instance.

clone

Signature

```
public  
java.lang.Object clone()
```

Description

Return a clone of **this**. This method should behave effectively as when it constructed a new object with the visible values of **this**. The new object is created in the current allocation context.

Available since RTSJ 1.0.1

compareTo(T)

Signature

²¹Section [9.4.1.2.1](#)

```
public  
int compareTo(T time)
```

Description

Compares **this** `HighResolutionTime` with the specified `HighResolutionTime` **time**.

Parameters

time Compares with the time of **this**.

Throws

`ClassCastException` when the **time** parameter is not of the same class as **this**.

`IllegalArgumentException` when the **time** parameter is not associated with the same chronograph as **this**, or when the **time** parameter is `null`.

Returns

a negative integer, zero, or a positive integer as this object is less than, equal to, or greater than **time**.

equals(Object)

Signature

```
public  
boolean equals(Object object)
```

Description

Returns `true` when the argument **object** has the same type and values as **this**. Equality includes `Chronograph` association.

Parameters

object Value compared to **this**.

Returns

`true` when the parameter **object** is of the same type and has the same values as **this**.

absolute(Chronograph)

Signature

```
public abstract  
javax.realtime.AbsoluteTime absolute(Chronograph chronograph)
```


Description

Convert the time of `this` to an absolute time, using the given instance of [Chronograph](#)²² to determine the current time when necessary. When `Chronograph` is `null` the realtime clock is assumed.

A destination object is allocated to return the result. The chronograph association of the result is the `Chronograph` passed as a parameter. See the subclass comments for more specific information.

Parameters

`chronograph` is the instance of [Chronograph](#)²³ used to convert the time of `this` into absolute time, and the new chronograph association for the result.

Returns

The `AbsoluteTime` conversion in a newly allocated object, associated with the `Chronograph` parameter.

absolute(Chronograph, AbsoluteTime)*Signature*

```
public abstract  
    javax.realtime.AbsoluteTime absolute(Chronograph chronograph,  
                                         AbsoluteTime dest)
```

Description

Convert the time of `this` to an absolute time, using the given instance of [Chronograph](#)²⁴ to determine the current time when necessary. When `Chronograph` is `null` the realtime chronograph is assumed. When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result. The chronograph association of the result is the `Chronograph` passed as a parameter. See the subclass comments for more specific information.

Parameters

`chronograph` The instance of [Chronograph](#)²⁵ used to convert the time of `this` into absolute time, and the new chronograph association for the result.

`dest` When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Returns

²²Section [10.4.1.2](#)

²³Section [10.4.1.2](#)

²⁴Section [10.4.1.2](#)

²⁵Section [10.4.1.2](#)

The `AbsoluteTime` conversion in `dest` when `dest` is not `null`, otherwise the result is returned in a newly allocated object. It is associated with the `Chronograph` parameter.

relative(Chronograph)

Signature

```
public abstract  
javax.realtime.RelativeTime relative(Chronograph chronograph)
```

Description

Convert the time of `this` to a relative time, using the given instance of `Chronograph`²⁶ to determine the current time when necessary. When `Chronograph` is `null` the realtime chronograph is assumed. A destination object is allocated to return the result. The chronograph association of the result is the `Chronograph` passed as a parameter. See the subclass comments for more specific information.

Parameters

`chronograph` The instance of `Chronograph`²⁷ used to convert the time of `this` into relative time, and the new chronograph association for the result.

Returns

The `RelativeTime` conversion in a newly allocated object, associated with the `Chronograph` parameter.

relative(Chronograph, RelativeTime)

Signature

```
public abstract  
javax.realtime.RelativeTime relative(Chronograph chronograph,  
                                     RelativeTime dest)
```

Description

Convert the time of `this` to a relative time, using the given instance of `Chronograph`²⁸ to determine the current time when necessary. When `Chronograph` is `null` the realtime chronograph is assumed. When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result. The

²⁶Section 10.4.1.2

²⁷Section 10.4.1.2

²⁸Section 10.4.1.2

chronograph association of the result is the **Chronograph** passed as a parameter. See the subclass comments for more specific information.

Parameters

chronograph The instance of **Chronograph**²⁹ used to convert the time of **this** into relative time, and the new chronograph association for the result.

dest When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Returns

The **RelativeTime**³⁰ conversion in **dest** when **dest** is not **null**, otherwise the result is returned in a newly allocated object.

9.4.1.3 RelativeTime

Inheritance

```
java.lang.Object
  javax.realtime.HighResolutionTime
    javax.realtime.RelativeTime
```

Description

An object that represents a time interval milliseconds/10³ + nanoseconds/10⁹ seconds long. It generally is used to represent a time relative to now.

The time interval is kept in normalized form. The range goes from [(-2⁶³) milliseconds + (-10⁶+1) nanoseconds] to [(2⁶³-1) milliseconds + (10⁶-1) nanoseconds].

A negative interval relative to now represents time in the past. For **add** and **subtract** negative values behave as they do in arithmetic.

Caution: This class is explicitly unsafe for multithreading when being changed. Code that mutates instances of this class should synchronize at a higher level.

9.4.1.3.1 Constructors

²⁹Section 10.4.1.2

³⁰Section 9.4.1.3

RelativeTime

Signature

```
public  
RelativeTime()
```

Description

Equivalent to `new RelativeTime(0,0)`.

The chronograph association is implicitly made with the realtime clock.

RelativeTime(Chronograph)

Signature

```
public  
RelativeTime(Chronograph chronograph)
```

Description

Equivalent to `new RelativeTime(0,0,chronograph)`.

The chronograph association is made with the `chronograph` parameter. When `chronograph` is null the association is made with the default realtime clock.

Available since RTSJ 2.0

Parameters

`chronograph` The chronograph providing the association for the newly constructed object.

RelativeTime(long, int)

Signature

```
public  
RelativeTime(long millis,  
              int nanos)  
throws IllegalArgumentException
```

Description

Construct a `RelativeTime` object representing an interval based on the parameter `millis` plus the parameter `nanos`. The construction is subject to `millis` and `nanos` parameters normalization. When there is an overflow in the millisecond component when normalizing then an `IllegalArgumentException` will be thrown. The chronograph association is implicitly made with the realtime clock.

Parameters

millis The desired value for the millisecond component of `this`. The actual value is the result of parameter normalization.

nanos The desired value for the nanosecond component of `this`. The actual value is the result of parameter normalization.

Throws

`IllegalArgumentException` when there is an overflow in the millisecond component when normalizing.

RelativeTime(long, int, Chronograph)

Signature

```
public
RelativeTime(long millis,
              int nanos,
              Chronograph chronograph)
throws IllegalArgumentException
```

Description

Construct a `RelativeTime` object representing an interval based on the parameter `millis` plus the parameter `nanos`. The construction is subject to `millis` and `nanos` parameters normalization. When there is an overflow in the millisecond component when normalizing then an `IllegalArgumentException` will be thrown.

The chronograph association is made with the `chronograph` parameter. When `chronograph` is `null` the association is made with the default realtime clock.

Available since RTSJ 2.0

Parameters

millis The desired value for the millisecond component of `this`. The actual value is the result of parameter normalization.

nanos The desired value for the nanosecond component of `this`. The actual value is the result of parameter normalization.

chronograph The chronograph providing the association for the newly constructed object.

Throws

IllegalArgumentException when there is an overflow in the millisecond component when normalizing.

RelativeTime(RelativeTime)

Signature

```
public  
RelativeTime(RelativeTime time)
```

Description

Make a new **RelativeTime** object from the given **RelativeTime** object. The new object will have the same chronograph association as the **time** parameter.

Parameters

time The **RelativeTime** object which is the source for the copy.

9.4.1.3.2 Methods

add(long, int)

Signature

```
public  
javax.realtime.RelativeTime add(long millis,  
                                int nanos)  
throws ArithmeticException
```

Description

Create a new object representing the result of adding **millis** and **nanos** to the values from **this** and normalizing the result. The result will have the same chronograph association as **this**. An **ArithmeticException** is when the result does not fit in the normalized format.

Parameters

millis The number of milliseconds to be added to **this**.

nanos The number of nanoseconds to be added to **this**.

Throws

ArithmeticException when the result does not fit in the normalized format.

Returns

A new **RelativeTime** object whose time is the normalization of **this** plus **millis** and **nanos**.

add(long, int, RelativeTime)

Signature

```
public
javax.realtime.RelativeTime add(long millis,
                                int nanos,
                                RelativeTime dest)

throws ArithmeticException
```

Description

Return an object containing the value resulting from adding **millis** and **nanos** to the values from **this** and normalizing the result. When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result. The result will have the same chronograph association as **this**, and the chronograph association with **dest** is ignored.

Parameters

millis The number of milliseconds to be added to **this**.

nanos The number of nanoseconds to be added to **this**.

dest When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Throws

ArithmeticException when the result does not fit in the normalized format.

Returns

the result of the normalization of **this** plus **millis** and **nanos** in **dest** when **dest** is not **null**, otherwise the result is returned in a newly allocated object.

add(RelativeTime)

Signature

```
public
javax.realtime.RelativeTime add(RelativeTime time)
throws IllegalArgumentException,
    ArithmeticException
```

Description

Create a new instance of **RelativeTime** representing the result of adding **time** to the value of **this** and normalizing the result.

The **Chronograph** associated with **this** and the **clock** associated with the **time** parameter are expected to be the same, and such association is used for the result.

Parameters

time The time to add to **this**.

Throws

IllegalArgumentException when the **Chronograph** associated with **this** and the **Chronograph** associated with the **time** parameter are different, or when the **time** parameter is **null**.

ArithmeticException when the result does not fit in the normalized format.

Returns

A new **RelativeTime** object whose time is the normalization of **this** plus the parameter **time**.

add(RelativeTime, RelativeTime)

Signature

```
public
javax.realtime.RelativeTime add(RelativeTime time,
                                RelativeTime dest)
throws IllegalArgumentException,
    ArithmeticException
```

Description

Return an object containing the value resulting from adding **time** to the value of **this** and normalizing the result. When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result.

The **Chronograph** associated with **this** and the **Chronograph** associated with the **time** parameter are expected to be the same, and such association is used for the result.

The **Chronograph** associated with the **dest** parameter is ignored.

Parameters

time The time to add to **this**.

dest When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Throws

IllegalArgumentException when the **Chronograph** associated with **this** and the **Chronograph** associated with the **time** parameter are different, or when the **time** parameter is **null**.

ArithmeticException when the result does not fit in the normalized format.

Returns

the result of the normalization of **this** plus the **RelativeTime** parameter **time** in **dest** when **dest** is not **null**, otherwise the result is returned in a newly allocated object.

subtract(RelativeTime)*Signature*

```
public  
javax.realtime.RelativeTime subtract(RelativeTime time)  
throws IllegalArgumentException,  
        ArithmeticException
```

Description

Create a new instance of **RelativeTime** representing the result of subtracting **time** from the value of **this** and normalizing the result.

The **Chronograph** associated with **this** and the **Chronograph** associated with the **time** parameter are expected to be the same, and such association is used for the result.

Parameters

time The time to subtract from **this**.

Throws

IllegalArgumentException when the **Chronograph** associated with **this** and the **Chronograph** associated with the **time** parameter are different, or when the **time** parameter is **null**.

ArithmeticException when the result does not fit in the normalized format.

Returns

A new **RelativeTime** object whose time is the normalization of **this** minus the parameter **time** parameter **time**.

subtract(RelativeTime, RelativeTime)

Signature

```
public
javax.realtime.RelativeTime subtract(RelativeTime time,
                                     RelativeTime dest)

throws IllegalArgumentException,
       ArithmeticException
```

Description

Return an object containing the value resulting from subtracting the value of **time** from the value of **this** and normalizing the result. When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result.

The **Chronograph** associated with **this** and the **Chronograph** associated with the **time** parameter are expected to be the same, and such association is used for the result.

The **Chronograph** associated with the **dest** parameter is ignored.

Parameters

time The time to subtract from **this**.

dest When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result.

Throws

IllegalArgumentException when the when the **Chronograph** associated with **this** and the **Chronograph** associated with the **time** parameter are different, or when the **time** parameter is **null**.

ArithmeticException when the result does not fit in the normalized format.

Returns

the result of the normalization of **this** minus the **RelativeTime** parameter **time** in **dest** when **dest** is not **null**, otherwise the result is returned in a newly allocated object.

scale(int)

Signature

```
public
javax.realtime.RelativeTime scale(int factor)
```

Description

Change the length of this relative time by multiplying it by **factor**.

Parameters

factor by which to increase the time interval.

Returns

a new object with **value** of this scaled by **factor**.

Available since RTSJ 2.0

scale(RelativeTime, int)

Signature

```
public  
javax.realtime.RelativeTime scale(RelativeTime time,  
                                   int factor)
```

Description

Set **time** to the value of **this** time by multiplied by **factor**.

Parameters

time in which to store the results.

factor by which to increase the time interval.

Returns

time with the value of **this** scaled by **factor**

Available since RTSJ 2.0

compareToZero

Signature

```
public  
int compareToZero()
```

Description

Compare **this** to relative time zero returning the result of the comparison.
Equivalent to `constantZero.compareTo(this)`

Returns

negative when **this** is less than zero, 0, when it is equal to zero and a positive
when **this** is greater than zero.

Available since RTSJ 2.0

toString

Signature

```
public  
java.lang.String toString()
```

Description

Create a printable string of the time given by **this**.

The string shall be a decimal representation of the milliseconds and nanosecond values; formatted as follows "(2251 ms, 750000 ns)"

Returns

String object converted from the time given by **this**.

compareTo(RelativeTime)

Signature

```
public  
int compareTo(RelativeTime time)
```

Description

Compares **this** `HighResolutionTime` with the specified `HighResolutionTime` **time**.

Parameters

time Compares with the time of **this**.

Throws

`ClassCastException` when the **time** parameter is not of the same class as **this**.

`IllegalArgumentException` when the **time** parameter is not associated with the same chronograph as **this**, or when the **time** parameter is `null`.

Returns

a negative integer, zero, or a positive integer as this object is less than, equal to, or greater than **time**.

absolute(Chronograph)

Signature

```
public  
javax.realtime.AbsoluteTime absolute(Chronograph chronograph)
```

Description

Convert the time of `this` to an absolute time, using the given instance of [Chronograph](#)³¹ to determine the current time when necessary. When `Chronograph` is `null` the realtime clock is assumed.

A destination object is allocated to return the result. The chronograph association of the result is the `Chronograph` passed as a parameter. See the subclass comments for more specific information.

Available since RTSJ 2.0

See [Section HighResolutionTime.absolute\(Chronograph\)](#)

absolute(Chronograph, AbsoluteTime)

Signature

```
public  
javax.realtime.AbsoluteTime absolute(Chronograph chronograph,  
                                     AbsoluteTime dest)
```

Description

Convert the time of `this` to an absolute time, using the given instance of [Chronograph](#)³² to determine the current time when necessary. When `Chronograph` is `null` the realtime chronograph is assumed. When `dest` is not `null`, the result is placed there and returned. Otherwise, a new object is allocated for the result. The chronograph association of the result is the `Chronograph` passed as a parameter. See the subclass comments for more specific information.

Available since RTSJ 2.0

See [Section HighResolutionTime.absolute\(Chronograph, AbsoluteTime\)](#)

³¹Section 10.4.1.2

³²Section 10.4.1.2

relative(Chronograph)

Signature

```
public  
    javax.realtime.RelativeTime relative(Chronograph chronograph)
```

Description

Convert the time of **this** to a relative time, using the given instance of **Chronograph**³³ to determine the current time when necessary. When **Chronograph** is **null** the realtime chronograph is assumed. A destination object is allocated to return the result. The chronograph association of the result is the **Chronograph** passed as a parameter. See the subclass comments for more specific information.

Available since RTSJ 2.0

See Section [HighResolutionTime.relative\(Chronograph\)](#)

relative(Chronograph, RelativeTime)

Signature

```
public  
    javax.realtime.RelativeTime relative(Chronograph chronograph,  
                                         RelativeTime dest)
```

Description

Convert the time of **this** to a relative time, using the given instance of **Chronograph**³⁴ to determine the current time when necessary. When **Chronograph** is **null** the realtime chronograph is assumed. When **dest** is not **null**, the result is placed there and returned. Otherwise, a new object is allocated for the result. The chronograph association of the result is the **Chronograph** passed as a parameter. See the subclass comments for more specific information.

Available since RTSJ 2.0

See Section [HighResolutionTime.relative\(Chronograph, RelativeTime\)](#)

³³Section [10.4.1.2](#)

³⁴Section [10.4.1.2](#)

9.5 Rationale

Time is the essence of realtime systems, and a method of expressing absolute time with sub-millisecond precision is an absolute minimum requirement. Expressing time in terms of nanoseconds has precedent and allows the implementation to provide time-based services, such as timers, using whatever precision it is capable of while the application requirements are expressed to an arbitrary level of precision.

The standard Java `java.util.Date` class uses milliseconds as its basic unit in order to provide sufficient range for a wide variety of applications. realtime programming generally requires finer resolution, and nanosecond resolution is fine enough for most purposes, but even a 64 bit realtime clock based in nanoseconds would have insufficient range in some situations, so a compound format composed of 64 bits of millisecond timing, and 32 bits of nanoseconds within a millisecond, was chosen.

The expression of millisecond and nanosecond constituents is consistent with other Java interfaces.

The expression of relative times allows for time-based metaphors such as deadline-based periodic scheduling where the cost of the task is expressed as a relative time and deadlines are usually represented as times relative to the beginning of the period.

Chapter 10

Clocks and Timers

10.1 Overview

In order to reason about time, the RTSJ needs not only to be able to express times and calculate with them; but it also needs to be able to determine the current time and allow actions to be performed when a given time is reached. For this purpose, the specification defines one interface and four classes: `Chronograph`, `Clock`, `Timer`, `PeriodicTimer`, and `OneShotTimer`.

A chronograph is used to measure time, whereas a clock is used to both measure time and react to its passage: a clock can get the current time and it can trigger timing events. At least one instance of the abstract `Clock` class, which implements `Chronograph`, is provided by the implementation, the system *realtime clock*, and this instance is made available as a singleton. The creation and use of other clocks and chronographs are discussed later (see Section 10.3.2).

The `Timer` classes provide the means of executing code at a particular point in time or repeatedly at a given interval. `Timer` is an abstract class and consequently only its subclasses can be instantiated. The `Timer` class provides the interface and underlying implementation for both one-shot and periodic timers. Instances of `OneShotTimer` and `PeriodicTimer` can be created and rescheduled specifying the initial firing time either as an `AbsoluteTime` or as a `RelativeTime`, to be considered from the application of the start command. The `PhasingPolicy` class defines the relationship between a `PeriodicTimer`'s start time and its first release time when the start time is in the past.

By attaching an `AsyncBaseEventHandler` to a `Timer`, the program can cause the release of the handler at a given time or after a given interval. An instance of `OneShotTimer` describes an event that is to be triggered at most once (unless restarted after expiration). It may be used as the source for time-outs and watchdog timing. An instance of `PeriodicTimer` fires on a periodic schedule. The period for

a `PeriodicTimer` is always specified as a `RelativeTime`.

10.2 Definitions

Timing Mechanism — something capable of representing and following the progress of time, by means of time values.

Chronograph — a passive timing mechanism, which can only provide the current time.

Clock — an active timing mechanism, which can both provide the current time and cause some action when a particular time is reached. All clocks are, by definition, chronographs, but not necessarily visa versa.

Monotonic Timing Mechanism — a timing mechanism whose time values always progress in one direction.

Monotonically Increasing Timing Mechanism — a timing mechanism whose time values never decrease. Monotonicity is a Boolean property, while time synchronization, uniformity, and accuracy are characteristics that depend on agreed tolerances.

Time Synchronization — a relation between two timing mechanisms. Two chronographs are synchronized when the difference between their time values is less than some specified offset. Synchronization in general degrades with time, and may be lost, given a specified offset.

Accuracy — the agreement between a chronograph and the true value that it measures (*e.g.*, absolute wall clock time).

Resolution — the minimal time value interval that can be represented by the clock model.

Precision — the smallest tick size that a particular chronograph will observe.

Uniformity — in this context, the measurement of the progress of time at a consistent rate, with a tolerance on the variability. Uniformity is affected by two other factors, *jitter* and *stability*.

Jitter — the distribution of the differences between when events are actually fired or noticed by the software and when they should have really occurred according to time in the real-world. Jitter might be caused by short-term and non-cumulative small time variation due to noise sources, such as thermal noise.

Stability — the resistance to jitter, in this case temporal jitter. Lack of stability can account for large and often cumulative variations, due to such occurrences such as supply voltage and temperature change.

Drift — the rate of change of the cumulative variation between two timing mechanisms.

Realtime Epoch — the time at which the realtime clock began ticking, defined by fiat as January 1, 1970 00:00:00 UTC.

- Epoch** — the date and time relative to which times on an RTSJ `Clock`, `c` are determined. The epoch for a clock is defined in terms of the *Realtime Epoch*, and is represented as the time elapsed on the realtime clock since the realtime Epoch at the time that `c` would have returned a timestamp of 0 ms and 0 ns.
- Counting Time** — the time accumulated by a `Timer`, while *active*, when created or rescheduled using a `RelativeTime` to specify the initial firing or skipping time. *Counting Time* is zeroed at the beginning of an activation and when rescheduled, while *active*, before the initial firing or skipping of an activation.

10.3 Semantics

The semantics of chronographs, clocks and timers are not simply functional. Temporal attributes dominate their behavior; therefore, the interaction between classes is critical to the overall understanding of the API. The class descriptions as well as their constructor, method, and field documentation given later provide detailed semantics to support the overall behavior.

10.3.1 Clock Model

Clocks and chronographs are backed by a physical means of measuring time. In practice, each one is driven by an oscillator that has susceptible variation due to its environment. There is always some difference between the desired frequency and the actual frequency of the oscillator, which is a major reason of synchronization loss. The RTSJ Clock model must take this variability into account and therefore establishes several invariants and expectations that can be relied upon by RTSJ applications and in turn must be provided by RTSJ implementations.

1. The *resolution* of the RTSJ Clock model is 1 nanosecond. This is the smallest unit of time that can be represented by a chronograph or timer via `HighResolutionTime` and its subclasses.
2. The *accuracy* of RTSJ definable chronographs and clocks is outside the scope of this specification. Accuracy is heavily dependent on hardware capabilities and platform characteristics. RTSJ providers and system integrators should characterize accuracy where possible.
3. The *precision* of RTSJ definable clock and chronograph (and, by proxy, the precision of the timers associated with clocks) are defined in terms of nanoseconds per observable tick, and provided to the application programmer via the various precision setters on `Clock` and `Chronograph`.
4. The realtime clock shall be monotonically increasing, and other clocks and chronographs should be monotonically increasing as well.

5. Time values returned by a chronograph should not be assumed to be comparable to the time values from another chronograph unless the user has platform-specific knowledge that the chronographs are compatible, except under specific circumstances described below.
6. The system or any other realtime clock is not necessarily synchronized with the external world, and the correctness of the epoch as a time base depends on such synchronization. It is as uniform and accurate as allowed by the underlying hardware.

If two **Chronograph** objects are both referenced to real time and return a value from `getEpochOffset()`, then time values from those **Chronographs** can be compared by applying their respective corrections. As documented in the `getEpochOffset()` method, its return value represents the offset of the associated **Chronograph** from the realtime clock Epoch. However, the results of any such comparison must be treated with caution as the accuracy of the two **Chronograph** objects may be different.

10.3.2 Clocks and Timables

A **Clock** is the basic mechanism of measuring time and triggering events based on the passage of time. A **Timer** can request a signal from the clock when a given time is reached. That signal should come as closed to the actual time requested as possible. A schedulable also uses a clock to implement the realtime sleep methods. Each clock instance shall be capable of reporting the achievable resolution of timers based on that clock. Each implementation shall have a default clock that is used whenever no other clock is specified. An application can also defined additional clocks.

A **Timer** uses a clock to measure time, which informs the timer's **TimeDispatcher** when the time has elapsed (relative time) or has been reached (absolute time). The **TimeDispatcher** causes the release of any **AsyncEventHandler** associated with the **Timer**. In the context of a **Timer**, *triggering* is the action that is performed by a **TimeDispatcher** that informs the **Timer** that it is time to *fire* or *skip*, where skip causes the normal action of fire not to be carried out.

A **Timer** is *active* when it has been started and not stopped since last started and it has a time in the future at which it is expected to fire or skip, else it is *not active*.

In the context of a **Timer**, *enabling* cause the **Timer** to fire when it is triggered, while *disabling* causes the **Timer** to skip when it is triggered. Enabling and disabling act as a mask over firing.

The behavior of a **OneShotTimer** is that of a **Timer** that does not automatically reschedule its triggering after an initial triggering, regardless of whether it fires or skips (when *disabled* and *active* when triggered). It is specified using an initial firing time.

The behavior of a **PeriodicTimer** is that of a **Timer** that automatically reschedules after each triggering, regardless of whether the triggering results in a fire or a

skip due to being disabled when triggered. It is specified using an initial firing time and an interval or period used for the self-rescheduling.

A **Clock** can also be used to regulate pauses in execution of any **Schedulable** through a realtime **sleep** method, hence timers and schedulables are classified as timables under the **Timable** interface.

Both **OneShotTimer** and **PeriodTimer** are given an initial firing time. A **PeriodicTimer** receives two clock references, within two **HighResolutionTimer** objects, which must be to the same clock. Thus the specification of the initial firing time and the interval or period must refer to the same clock.

A **Timer** is an **ActiveEvent**. This means that it has an associated dispatcher called **TimeDispatcher**. As with other active events, the application can either use the default dispatcher or create a new one with its own priority and affinity. A schedulable can also have a **TimeDispatcher** to manage sleeping.

At any given time, a timable, **Timer** or **Schedulable**, has at most one clock associated with it, on which the measurement of time for blocking is based. Each clock maintains a list of times, called alarms, that are provided to it from timables. The clock is armed with the next alarm. When that time arrives, the clock signals the **TimeDispatcher** associated with the alarm to signal its timable that the time has arrived.

In the case of a timer, the dispatcher triggers the timer thereby indicating it should fire or skip. In the case of a schedulable, the dispatcher triggers the schedulable to wake up from its sleep. Figure 10.1 illustrates how a timer interacts with an application-defined clock and Figure 10.2 depicts the same for using realtime sleep in a schedulable.

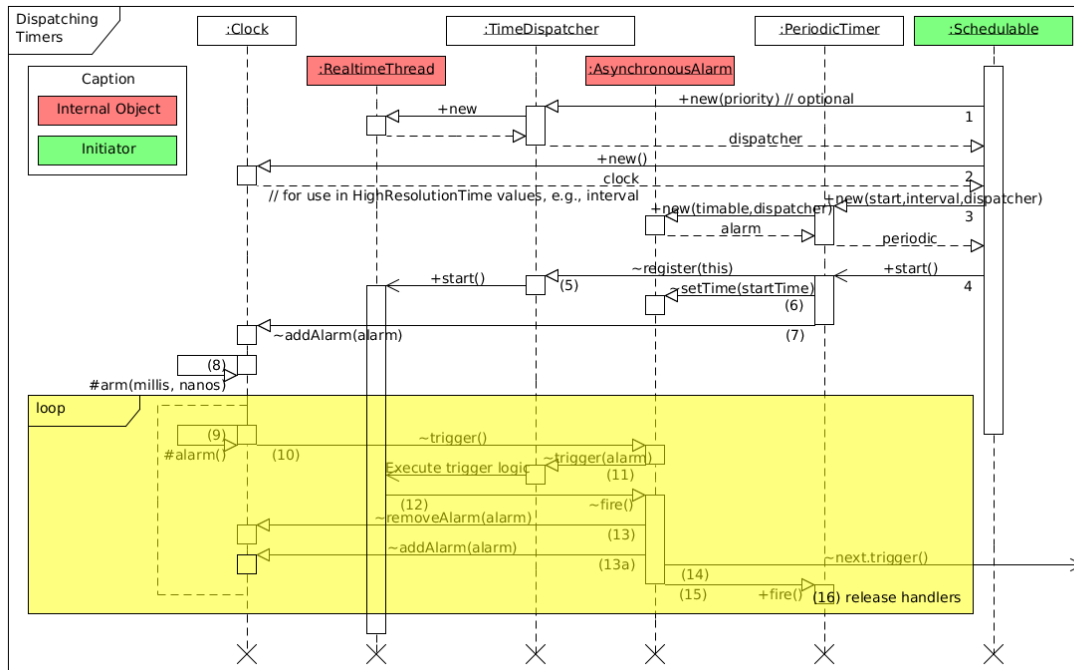
In each case, an external schedulable, depicted on the right, initializes the objects involved. A **TimeDispatcher** and a **Clock** are created. These are used when creating the **Timable** as illustrated with step one and two respectively in both diagrams. A developer can always use a pre-existing clock or dispatcher instead of creating new ones.

Each timable acts as if it had an internal object, depicted as an instance of **Alarm**, to manage the relationship between a timable and its dispatcher and clock. **Alarm** is shown simply to illustrate this relationship. It is created, step three in both diagrams, when the timable is created and it represents the next alarm that the timable should receive: a fire for a time or a wake up call for a realtime sleep on a schedulable.

At step four, the two sequences diverge. The application starts a timer with the **start** method, but a thread must call a realtime sleep method. In both cases, step four sets the timing in motion.

Steps (5) through (8) set up the time interval. For initiating the trigger for the first time, step (5) registers the timable with its dispatcher. Later starts or sleeps skip this step. Then the time is set in the alarm and the alarm is added to the clock.

Figure 10.1: Sequence Diagram for Using a Timer



When the new alarm is the next alarm to be triggered, the clock arranges to signal that time as in step (8). When the alarm is added anywhere else in the clock queue, step (8) is delayed until the removal of an alarm causes the added alarm to reach the top of the queue.

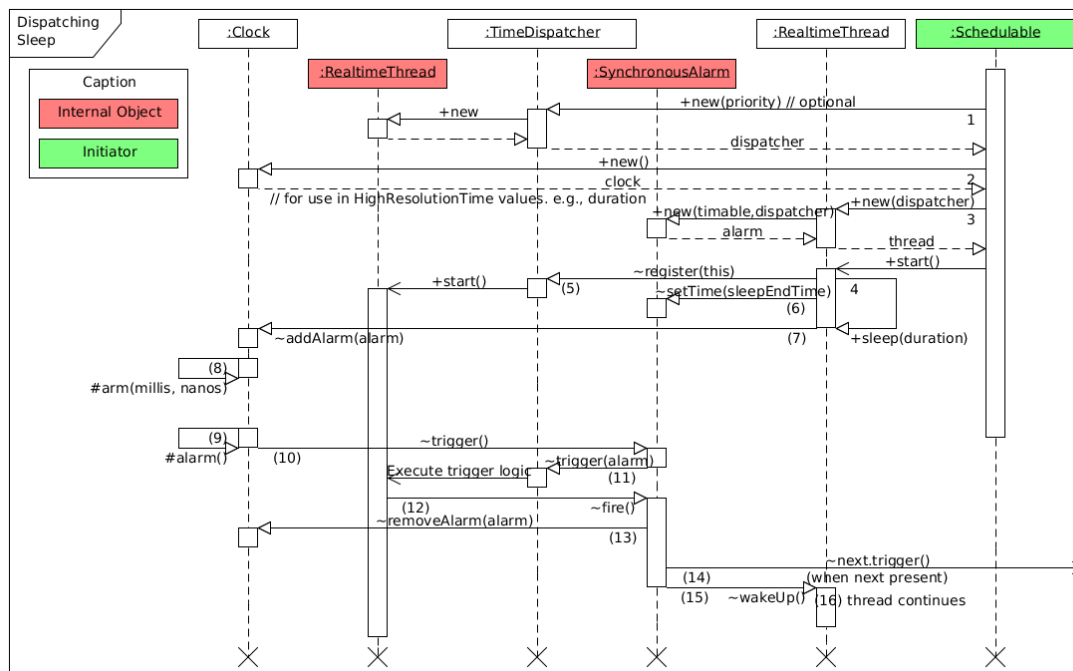
When the alarm time is reached, step (9), the clock triggers the alarm by calling trigger on the alarm event, step (10). This in turn triggers the dispatcher, step (11). This is an asynchronous call that causes the dispatcher's thread to take over control from the clocks interrupt handler.

In step (12), the dispatcher thread removes the alarm from the clock queue, possibly causing a new alarm to become active. In the periodic thread case, the alarm is rescheduled by incrementing the time in the alarm by the interval and adding it back into the queue. In all other cases, no new alarm is set.

In step (13) any subsequent alarms that were scheduled are also kicked off. The Clock queue is a two dimensional queue that is organized by the time of the alarm and, within any given time, the priority order, highest to lowest, of the dispatchers associated with the alarms. The trigger in step (10) always goes to the alarm with the highest priority dispatcher.

Finally in step (14), the dispatcher fires the alarm which results its timable being

Figure 10.2: Sequence Diagram for Realtime Sleep



fired or woken-up. In the case of a timer, this causes all its handlers to be released or, in the case of a schedulable, a sleep being woken up; this is marked as (15) in the diagrams.

Clocks and **TimeDispatchers** may be shared among many as timables as the needs of the application dictate. Different dispatchers can be used with a given clock and a dispatcher can service different clocks. The dispatcher should be chosen based on its priority and affinity, whereas a clock should be chosen based on the temporal reference, where the temporal reference may or may not be associated with clock time. For instance, one could use a clock to represent the rotation of a shaft.

10.3.3 Timers

A timer must be associated with a clock. That clock acts as if it provides an interrupt to each of its timers at the next instance of time at which the timer should do something. In other words, a clock fires its timer at a requested time. Timers can be modeled as counters, or as comparators.

10.3.3.1 Counter Model

In the timer model, a timer can be viewed as if every clock interrupt increments a count up to the firing count, initially given by either an instance of `RelativeTime` or computed as the difference between an instance of `AbsoluteTime` and a semantically specified “now” (using the same clock).

1. `start` is understood as defining “now” and start counting, `stop` is understood as stop counting. `start` after `stop` may be understood as start counting again from where stopped, or start from scratch after resetting the count.
2. In both cases, a delay is introduced.
3. An `RTSJ Timer`, when using the counter model, resets the count when it is restarted after being stopped.
4. When a `Timer` is created or rescheduled using a `RelativeTime` to specify the initial alarm time, the `RTSJ` keeps the specified initial trigger time as a `RelativeTime` and behaves according to the counter model.

10.3.3.2 Comparator Model

In the comparator model, a `Timer` can be viewed as if every clock interrupt forces a comparison between an absolute time and a firing time, initially given either as an instance of `AbsoluteTime` or computed as the sum of an instance of `RelativeTime` and a semantically specified “now” (using the same clock).

1. In this model, `start` is understood as start comparing, and possibly the first `start` is understood as defining “now”. `stop` is understood as stop comparing. `start` after `stop` may be understood as start comparing again.
2. In this case, no delay is introduced.
3. When a `Timer` is created or rescheduled using an `AbsoluteTime` to specify the initial triggering time, the `RTSJ` keeps the specified initial firing time as an `AbsoluteTime` and uses the comparator model.

10.3.3.3 Triggering

A clock signals to the associated timetable that its alarm time has been reached by triggering the dispatcher associated with the timetable. This trigger causes the dispatcher to fire the associated timer. When the timer is active, it releases its handlers and is said to be fired. When the timer is inactive, nothing happens and it is said to be skipped. A stopped timer is never triggered. For this it must be running.

10.3.3.4 Behavior of Timers

There are two kinds of timers defined: `OneShotTimer` and `PeriodicTimer`. As their names imply, the first is used to mark a single time interval and the second is to mark a regularly repeating time interval.

The `OneShotTimer` class shall ensure that each instance is fired at most once at the time specified unless restarted after expiration.

The `PeriodicTimer` class shall enable the period of a timer to be expressed in terms of a `RelativeTime`. The initial firing of a `PeriodicTimer` occurs in response to the invocation of its `start` method, in accordance with the start time passed to its constructor. The `PhasingPolicy` class defines the relationship between the timer's start time and its first firing when the start time is in the past. This initial firing or skipping, may be rescheduled by a call to the `reschedule` method, in accordance with the time passed to that method.

Given an instance of `PeriodicTimer`, let S be the effective time, as an absolute time, at which the initial firing or skipping, of a `PeriodicTimer` is scheduled to occur:

1. when the start, or reschedule, time was given as an absolute time, A , and that time is in the future when the timer is made active, then S equals A , otherwise
2. when the absolute time has passed when the timer is made active, then S depends on the phasing mode of that instance of `PeriodicTimer`.

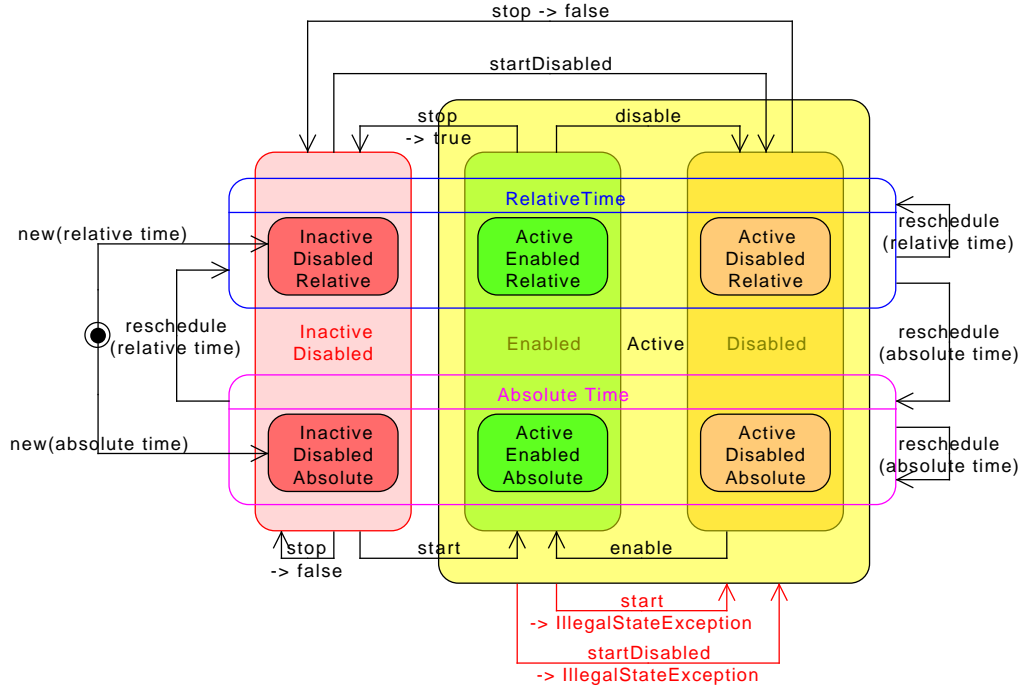
The firings of a `PeriodicTimer` are scheduled to occur according to $S + nT$, for $n = 0, 1, 2, \dots$ where S is as just specified, and T is the interval of the periodic timer.

For all timers, when the start or reschedule time is given as a relative time, R , S equals the time at which the *counting time*, started when the timer was made *active*, equals R . The transition to *not-active* by this timer causes the *counting time* to reset, effectively preventing this kind of timer from firing immediately, unless given a time value of 0.

When in a *not-active* state a `Timer` retains the parameters given at construction time or the parameters it had at de-activation time. Those are the parameters that will be used upon invocation of `start` while in that state, unless the parameters are explicitly changed before that, using `reschedule` and `setInterval` as appropriate.

When a `Timer` object is allocated in a scoped memory area, then it will increment the reference count associated with that area. Such a reference count will only be decremented when the `Timer` object is destroyed. (See semantics in the *Memory* chapter for details.) A `Timer` object will not fire before its due time.

The states of a `Timer` are essentially the same as for an `ActiveEvent` as depicted in Figure 8.3. The main difference is that the time used for the next fire may be either an absolute time or a relative time. Figure 10.3 reflects this difference in a UML state diagram.

Figure 10.3: States of a Timer¹

10.3.3.5 Phasing

Phasing comes into play only when a periodic timer (with period T) starts after its initial time. This can happen when an absolute start time (A) is specified and the start method is called after that time. It is used to determine the effective start time S :

1. S is the next multiple of $A + nT$, when phasing is `ADJUST_FORWARD`,
2. S is the most recent multiple of $A + nT$, when phasing is `ADJUST_BACKWARD`,
3. S is “now,” when phasing is `ADJUST_TO_START`, and
4. S is undefined and an exception is thrown when phasing is `STRICT_PHASING`.

The default phasing is `ADJUST_TO_START`.

¹Note that the semantics of the fire transition differ among the subclasses of `Timer`.

10.4 Package javax.realtime

10.4.1 Interfaces

10.4.1.1 AsyncTimable

Interfaces

`javax.realtime.Timable`

Description

A common type for `Timer`² and `RealtimeThread`³ to indicate that they can be associated with a `Clock`⁴ and be suspended waiting for time events based on that clock.

Available since RTSJ 2.0

10.4.1.1.1 Methods

fire

Signature

```
public  
void fire()
```

Description

Called by the dispatcher associated with `this` to indicate that a time event has occurred.

Available since RTSJ 2.0

²Section [10.4.2.6](#)

³Section [5.4.2.2](#)

⁴Section [10.4.2.1](#)

10.4.1.2 Chronograph

Description

The interface for all devices that support the measurement of time with great accuracy.

Available since RTSJ 2.0

10.4.1.2.1 Methods

getEpochOffset

Signature

```
public  
    javax.realtime.RelativeTime getEpochOffset()
```

Description

Determines the time on the realtime clock when this chronograph was zero.

Throws

`UnsupportedOperationException` when the chronograph does not have the concept of date.

Returns

A newly allocated `RelativeTime`⁵ object in the current execution context with the realtime clock as its chronograph and containing time when this chronograph was zero.

getTime

Signature

```
public  
    javax.realtime.AbsoluteTime getTime()
```

Description

⁵Section 9.4.1.3

Determines the current time. This method returns an absolute time value representing the chronograph's notion of absolute time. For chronographs that do not measure calendar time, this absolute time may not represent a wall clock time.

Returns

A newly allocated instance of [AbsoluteTime](#)⁶ in the current allocation context, representing the current time. The returned object has `this` its chronograph.

getTime(AbsoluteTime)

Signature

```
public  
javax.realtime.AbsoluteTime getTime(AbsoluteTime dest)
```

Description

Obtain the current time. The time represented by the given [AbsoluteTime](#)⁷ is changed at some time between the invocation of the method and the return of the method. This method will return an absolute time value that represents this chronograph's notion of the absolute time. For chronographs that do not measure calendar time, this absolute time may not represent a wall clock time.

Parameters

dest The instance of [AbsoluteTime](#)⁸ object which will be updated in place.

Returns

The instance of [AbsoluteTime](#)⁹ passed as parameter, or a new object when **dest** is null. The returned object represents the current time and is associated with `this` chronograph.

getQueryPrecision

Signature

```
public  
javax.realtime.RelativeTime getQueryPrecision()
```

Description

⁶Section [9.4.1.1](#)

⁷Section [9.4.1.1](#)

⁸Section [9.4.1.1](#)

⁹Section [9.4.1.1](#)

Obtain the precision with which time can be read, i.e., the nominal interval between ticks. It is the same as calling `getQueryPrecision(RelativeTime)`¹⁰ with `null` as an argument.

Returns

a newly allocated time value holding the read precision.

getQueryPrecision(RelativeTime)

Signature

```
public  
javax.realtime.RelativeTime getQueryPrecision(RelativeTime dest)
```

Description

Obtain the precision with which time can be read, i.e., the nominal interval between ticks.

Parameters

dest is a time object in which to return the results.

Returns

the read precision in **dest**, when **dest** is not `null`, or in a newly created object otherwise.

10.4.1.3 Timable

Interfaces

`javax.realtime.Releasable`

Description

A type for all classes that can use a `Clock`¹¹ for timing, either for sleeping or for being released at a given time.

10.4.1.3.1 Methods

¹⁰Section 10.4.1.2.1

¹¹Section 10.4.2.1

getDispatcher

Signature

```
public  
    javax.realtime.TimeDispatcher getDispatcher()
```

Description

Get the dispatcher associated with this Timable.

Available since RTSJ 2.0

10.4.2 Classes

10.4.2.1 Clock

Inheritance

```
java.lang.Object  
    javax.realtime.Clock
```

Interfaces

```
    javax.realtime.Chronograph
```

Description

A clock marks the passing of time. It has a concept of now that can be queried through `Clock.getTime()`, and it can have events queued on it which will be fired when their appointed time is reached.

Note that while all `Clock` implementations use representations of time derived from `HighResolutionTime`, which expresses its time in milliseconds and nanoseconds, a particular `Clock` may track time that is not delimited in seconds or not related to wall clock time in any particular fashion (*e.g.*, revolutions or event detections). In this case, the `Clock`'s timebase should be mapped to milliseconds and nanoseconds in a manner that is computationally appropriate.

10.4.2.1.1 Constructors

Clock

Signature

```
public  
Clock()
```

Description

Constructor for the abstract class.

10.4.2.1.2 Methods

getRealtimeClock

Signature

```
public static  
javax.realtime.Clock getRealtimeClock()
```

Description

There is always at least one clock object available: the system realtime clock. This is the default `Clock`.

Returns

The singleton instance of the default `Clock`

getEpochOffset

Signature

```
public final  
javax.realtime.RelativeTime getEpochOffset()  
throws UnsupportedOperationException
```

Description

Determines the time on the realtime clock when this chronograph was zero.

Throws

`UnsupportedOperationException` `UnsupportedOperationException` when the chronograph does not have the concept of date.

Available since RTSJ 1.0.1

getTime

Signature

```
public final  
    javax.realtime.AbsoluteTime getTime()
```

Description

Determines the current time. This method returns an absolute time value representing the chronograph's notion of absolute time. For chronographs that do not measure calendar time, this absolute time may not represent a wall clock time.

Returns

A newly allocated instance of [AbsoluteTime](#)¹² in the current allocation context, representing the current time. The returned object has `this` its chronograph.

getTime(AbsoluteTime)

Signature

```
public abstract  
    javax.realtime.AbsoluteTime getTime(AbsoluteTime dest)
```

Description

Obtain the current time. The time represented by the given [AbsoluteTime](#)¹³ is changed at some time between the invocation of the method and the return of the method. This method will return an absolute time value that represents this chronograph's notion of the absolute time. For chronographs that do not measure calendar time, this absolute time may not represent a wall clock time.

Parameters

dest dest The instance of [AbsoluteTime](#)¹⁴ object which will be updated in place.

Returns

¹²Section 9.4.1.1

¹³Section 9.4.1.1

¹⁴Section 9.4.1.1

The instance of `AbsoluteTime`¹⁵ passed as parameter, or a new object when `dest` is `null`. The returned object represents the current time and is associated with `this` chronograph.

Available since RTSJ 1.0.1 The return value is updated from void to `AbsoluteTime`.

Available since RTSJ 2.0 When `dest` is `null`, a new object is allocated, when not `chronograph` is overwritten with `this`.

`getQueryPrecision`

Signature

```
public abstract  
javax.realtime.RelativeTime getQueryPrecision()
```

Description

Obtain the precision with which time can be read, i.e., the nominal interval between ticks. It is the same as calling `getQueryPrecision(RelativeTime)`¹⁶ with `null` as an argument.

Returns

a newly allocated time value holding the read precision.

Available since RTSJ 2.0

`getQueryPrecision(RelativeTime)`

Signature

```
public abstract  
javax.realtime.RelativeTime getQueryPrecision(RelativeTime dest)
```

Description

Obtain the precision with which time can be read, i.e., the nominal interval between ticks.

Parameters

dest `dest` is a time object in which to return the results.

¹⁵Section 9.4.1.1

¹⁶Section 10.4.2.1.2

Returns

the read precision in `dest`, when `dest` is not `null`, or in a newly created object otherwise.

Available since RTSJ 2.0

getDrivePrecision

Signature

```
public abstract  
javax.realtime.RelativeTime getDrivePrecision()
```

Description

Gets the precision of the clock for driving events, the nominal interval between ticks that can trigger an event. It is the same as calling `getDrivePrecision(RelativeTime)`¹⁷ with `null` as its argument.

Returns

a value representing the drive precision.

Available since RTSJ 2.0

getDrivePrecision(RelativeTime)

Signature

```
public abstract  
javax.realtime.RelativeTime getDrivePrecision(RelativeTime dest)
```

Description

Gets the precision of the clock for driving events, the nominal interval between ticks that can trigger an event. The result may be larger than that of `getQueryPrecision(RelativeTime)`¹⁸.

Parameters

`dest` return the relative time value in `dest`. When `dest` is `null`, it allocates a new `RelativeTime`¹⁹ instance to hold the returned value.

Returns

¹⁷Section 10.4.2.1.2

¹⁸Section 10.4.2.1.2

¹⁹Section 9.4.1.3

`dest` set to values representing the drive precision.

Available since RTSJ 2.0

setResolution(RelativeTime)

Signature

```
public abstract  
void setResolution(RelativeTime resolution)
```

Description

Set the resolution of `this`. For some hardware clocks setting resolution is impossible and when this method is called on those clocks, then an `UnsupportedOperationException` is thrown.

Parameters

resolution The new resolution of `this`, when the requested value is supported by `this` clock. When **resolution** is smaller than the minimum resolution supported by `this` clock then it throws `IllegalArgumentException`. When the requested **resolution** is not available and it is larger than the minimum resolution, then the clock will be set to the closest resolution that the clock supports, via truncation. The value of the **resolution** parameter is not altered. The clock association of the **resolution** parameter is ignored.

Throws

`IllegalArgumentException` when **resolution** is `null`, or when the requested **resolution** is smaller than the minimum resolution supported by this clock.
`UnsupportedOperationException` when the clock does not support setting its resolution.

Deprecated since RTSJ version since RTSJ 2.0

triggerAlarm

Signature

```
protected final  
void triggerAlarm()
```

Description

Code in the abstract base `Clock` is called by a subclass to signal that the time of the next alarm has been reached. It will trigger a `TimeDispatcher`²⁰, which in turn will cause a fire on an associated `AsyncTimable`²¹

This method should be implemented with a runtime complexity not exceeding $O(1)$. Implementations exceeding this bound shall explicitly document the complexity their implementation. **Available since RTSJ 2.0**

setAlarm(long, int)

Signature

```
protected abstract  
void setAlarm(long milliseconds,  
               int nanoseconds)
```

Description

Implemented by subclasses to set the time for the next alarm. When there is an alarm outstanding when called, the subclass must override the old time. This should never be called from application or library code. It is intended to be called only from the `javax.realtime` package.

Parameters

`milliseconds` of the next alarm.
`nanoseconds` of the next alarm.

Available since RTSJ 2.0

clearAlarm

Signature

```
protected abstract  
void clearAlarm()
```

Description

Implemented by subclasses to cancel the current outstanding alarm.

Available since RTSJ 2.0

²⁰Section 10.4.2.4

²¹Section 10.4.1.1

10.4.2.2 OneShotTimer

Inheritance

```

java.lang.Object
  javax.realtime.AsyncBaseEvent
    javax.realtime.AsyncEvent
      javax.realtime.Timer
        javax.realtime.OneShotTimer

```

Description

A timed [AsyncEvent](#)²² that is driven by a [Clock](#)²³. It will fire once, when the clock time reaches the time-out time, unless restarted after expiration. When the timer is *disabled* at the expiration of the indicated time, the firing is lost (*skipped*). After expiration, the **OneShotTimer** becomes *not-active* and *disabled*. When the clock time has already passed the time-out time, it will fire immediately after it is started or after it is rescheduled while *active*.

Semantics details are described in the [Timer](#)²⁴ pseudocode and compact graphic representation of state transitions.

Caution: This class is explicitly unsafe for multithreading when being changed. Code that mutates instances of this class should synchronize at a higher level.

10.4.2.2.1 Constructors

OneShotTimer(HighResolutionTime, AsyncEventHandler, TimeDispatcher)

Signature

```

public
OneShotTimer(javax.realtime.HighResolutionTime<?> time,
              AsyncEventHandler handler,
              TimeDispatcher dispatcher)

```

²²Section [8.4.3.4](#)

²³Section [10.4.2.1](#)

²⁴Section [10.4.2.6](#)

throws `IllegalArgumentException`,
`UnsupportedOperationException`,
`IllegalAssignmentError`

Description

Create an instance of `OneShotTimer`²⁵, based on the `Clock`²⁶ associated with the `time` parameter, that will execute its `fire` method according to the given time.

Available since RTSJ 2.0

Parameters

`time` The time used to determine when to fire the event. A `time` value of `null` is equivalent to a `RelativeTime` of 0, and in this case the `Timer` fires immediately upon a call to `start()`.

`handler` The `AsyncEventHandler`²⁷ that will be released when `fire` is invoked. When `null`, no handler is associated with this `Timer` and nothing will happen when this event fires unless a handler is subsequently associated with the timer using the `addHandler()` or `setHandler()` method.

`dispatcher` The `TimeDispatcher`²⁸ to use for triggering this event.

Throws

`IllegalArgumentException` when `time` is a `RelativeTime` instance less than zero.

`UnsupportedOperationException` when the `Chronograph`²⁹ associated with `time` is not a `Clock`³⁰.

`IllegalAssignmentError` when this `OneShotTimer` cannot hold a reference to handler.

OneShotTimer(HighResolutionTime, AsyncEventHandler)

Signature

```
public
OneShotTimer(javax.realtime.HighResolutionTime<?> time,
              AsyncEventHandler handler)
```

²⁵Section 10.4.2.2

²⁶Section 10.4.2.1

²⁷Section 8.4.3.5

²⁸Section 10.4.2.4

²⁹Section 10.4.1.2

³⁰Section 10.4.2.1

Description

The equivalent of calling `OneShotTimer(HighResolutionTime, AsyncEventHandler, TimeDispatcher)`³¹ with arguments `time`, `handler`, `null`.

Parameters

`time` is the time to release its handlers.

`handler` is the hanndler to release.

10.4.2.2.2 Methods

fire*Signature*

```
public  
void fire()
```

Description

This should not be called for application code, except for emulation. The `fire` method is reserved for the use of the system. When `this` is enabled, it releases all handlers and then calls `Timer.stop()`³². When distabled, but active, it only calls `Timer.stop()`. Otherwise it does nothing.

Available since RTSJ 2.0 moved here from `Timer`, since `OneShotTimer` and `PeriodicTimer` have slightly different semantics.

10.4.2.3 PeriodicTimer

Inheritance

```
java.lang.Object  
  javax.realtime.AsyncBaseEvent  
    javax.realtime.AsyncEvent  
      javax.realtime.Timer  
        javax.realtime.PeriodicTimer
```

³¹Section 10.4.2.2.1

³²Section 10.4.2.6.2

Description

An `AsyncEvent`³³ whose `fire` method is executed periodically according to the given parameters. The clock associated with the `Timer` start time must be identical to the the clock associated with the `Timer` `interval`

The first firing is at the beginning of the first interval.

When an interval greater than 0 is given, the timer will fire periodically. When an interval of 0 is given, the `PeriodicTimer` will only fire once, unless restarted after expiration, behaving like a `OneShotTimer`. In all cases, when the timer is *disabled* when the firing time is reached, that particular firing is lost (*skipped*). When *enabled* at a later time, it will fire at its next scheduled time.

When the clock time has already passed the beginning of the first period, the `PeriodicTimer` will first fire according to the `PhasingPolicy`³⁴.

Semantics details are described in the `Timer`³⁵ pseudo-code and compact graphic representation of state transitions.

Caution: This class is explicitly unsafe for multithreading when being changed. Code that mutates instances of this class should synchronize at a higher level.

10.4.2.3.1 Constructors**PeriodicTimer(HighResolutionTime, RelativeTime, AsyncEventHandler)***Signature*

```
public
PeriodicTimer(javax.realtime.HighResolutionTime<?> start,
               RelativeTime interval,
               AsyncEventHandler handler)
throws IllegalArgumentException,
       IllegalAssignmentError
```

Description

Create a timer that executes its `fire` method periodically. Equivalent to `PeriodicTimer(start, interval, handler, null)`.

³³Section 8.4.3.4

³⁴Section 5.4.1.1

³⁵Section 10.4.2.6

PeriodicTimer(HighResolutionTime, RelativeTime, AsyncEventHandler, TimeDispatcher)

Signature

```
public
PeriodicTimer(javax.realtime.HighResolutionTime<?> start,
               RelativeTime interval,
               AsyncEventHandler handler,
               TimeDispatcher dispatcher)
throws IllegalArgumentException,
       IllegalAssignmentError,
       UnsupportedOperationException
```

Description

Create a timer that executes its fire method periodically.

Available since RTSJ 2.0

Parameters

start The time that specifies when the first interval begins, based on the clock associated with it. The first firing of the timer is modified according the *PhasingPolicy* when the timer is started. A **start** value of **null** is equivalent to a *RelativeTime* of 0.

interval The period of the timer. Its usage is based on the clock specified by the **clock** parameter. When **interval** is zero or **null**, the period is ignored and the firing behavior of the *PeriodicTimer* is that of a *OneShotTimer*³⁶.

handler The *AsyncEventHandler*³⁷ that will be released when **fire** is invoked. When **null**, no handler is associated with this *Timer* and nothing will happen when this event fires unless a handler is subsequently associated with the timer using the **addHandler()** or **setHandler()** method.

dispatcher is the dispatcher to use for triggering this event.

Throws

IllegalArgumentException when **start** or **interval** is a *RelativeTime* instance with a value less than zero; or the clocks associated with **start** and **interval** are not the identical.

IllegalAssignmentError when this *PeriodicTimer* cannot hold references to **handler**, **clock** and **interval**.

³⁶Section 10.4.2.2

³⁷Section 8.4.3.5

UnsupportedOperationException when the [Chronograph](#)³⁸ associated with time is not a [Clock](#)³⁹.

10.4.2.3.2 Methods

addHandler(AsyncBaseEventHandler)

Signature

```
public  
void addHandler(AsyncBaseEventHandler handler)  
throws IllegalArgumentException,  
        IllegalAssignmentError
```

Description

Add a handler to the set of handlers associated with this event. It overrides the method in [AsyncBaseEvent](#)⁴⁰ to allow the use of handlers with [PeriodicParameters](#)⁴¹, but these parameters must match the period of this timer, otherwise [IllegalArgumentException](#) is thrown.

Parameters

handler a new handler to add to the list of handlers already associated with **this**. When **handler** is already associated with the event, the call has no effect.

Throws

[IllegalArgumentException](#) when **handler** is null or the handler has [PeriodicParameters](#)⁴² with a period that does not match the period of **this**.
[IllegalAssignmentError](#) when this [AsyncEvent](#) cannot hold a reference to **handler**.

Available since RTSJ 2.0

³⁸Section [10.4.1.2](#)

³⁹Section [10.4.2.1](#)

⁴⁰Section [8.4.3.2](#)

⁴¹Section [6.4.3.6](#)

⁴²Section [6.4.3.6](#)

setHandler(AsyncBaseEventHandler)

Signature

```
public  
void setHandler(AsyncBaseEventHandler handler)  
throws IllegalArgumentException,  
       IllegalAssignmentError
```

Description

Associate a new handler with this event and remove all existing handlers. It overrides the method in [AsyncBaseEvent](#)⁴³ to allow the use of handlers with [PeriodicParameters](#)⁴⁴, but these parameters must match the period of this timer, otherwise `IllegalArgumentException` is thrown.

Parameters

handler The instance of [AsyncBaseEventHandler](#)⁴⁵ to be associated with `this`. When **handler** is `null`, no handler will be associated with `this`, i.e., behave effectively as when `setHandler(null)` invokes `removeHandler(AsyncBaseEventHandler)` for each associated handler.

Throws

`IllegalArgumentException` when **handler** has [PeriodicParameters](#)⁴⁶ with a period that does not match the period of `this`.

`IllegalAssignmentError` when this `AsyncEvent` cannot hold a reference to **handler**.

Available since RTSJ 2.0

start(PhasingPolicy)

Signature

```
public  
void start(PhasingPolicy phasingPolicy)  
throws LateStartException,  
       IllegalArgumentException
```

Description

⁴³Section [8.4.3.2](#)

⁴⁴Section [6.4.3.6](#)

⁴⁵Section [8.4.3.3](#)

⁴⁶Section [6.4.3.6](#)

Start the timer with the specified `PhasingPolicy`⁴⁷.

Parameters

`phasingPolicy` determines what happens when the start is too late.

Throws

`LateStartException` when this method is called after its absolute start time and the `phasingPolicy` is `PhasingPolicy.STRICT_PHASING`⁴⁸.

`IllegalArgumentException` when the start time of this timer is not an absolute time, or `phasingPolicy` is null.

Available since RTSJ 2.0

start(boolean, PhasingPolicy)

Signature

```
public
void start(boolean disabled,
           PhasingPolicy phasingPolicy)
throws LateStartException,
       IllegalArgumentException
```

Description

Start the timer with the specified `PhasingPolicy`⁴⁹ and the specified disabled state.

Parameters

`disabled` determine the mode of start: `true` for enabled and `false` for disabled for consistency with `Timer.start(boolean)`⁵⁰.

`phasingPolicy` determines what happens when the start is too late.

Throws

`LateStartException` when this method is called after its absolute start time and the `phasingPolicy` is `PhasingPolicy.STRICT_PHASING`⁵¹.

`IllegalArgumentException` when the start time of this timer is not an absolute time, or `phasingPolicy` is null.

Available since RTSJ 2.0

⁴⁷Section 5.4.1.1

⁴⁸Section 5.4.1.1.1

⁴⁹Section 5.4.1.1

⁵⁰Section 10.4.2.6.2

⁵¹Section 5.4.1.1.1

getClock

Signature

```
public  
    javax.realtime.Clock getClock()  
    throws IllegalStateException
```

Description

Each instance can only be associated with a single clock, which this method can obtain.

Throws

`IllegalStateException` when `this` has been destroyed.

Returns

the instance of `Clock`⁵² that is associated with `this`.

Available since RTSJ 1.0.1

createReleaseParameters

Signature

```
public  
    javax.realtime.ReleaseParameters createReleaseParameters()
```

Description

Create a release parameters object with new objects containing copies of the values corresponding to this timer. When the `PeriodicTimer` interval is greater than 0, create a `PeriodicParameters`⁵³ object with a start time and period that correspond to the next firing (or skipping) time, and interval, of this timer. When the interval is 0, create an `AperiodicParameters`⁵⁴ object, since in this case the timer behaves like a `OneShotTimer`⁵⁵.

When this timer is active, then the start time is the next firing (or skipping) time returned as an `AbsoluteTime`⁵⁶. Otherwise, the start time is the initial firing (or skipping) time, as set by the last call to `Timer.reschedule`⁵⁷, or when there was no such call, by the constructor of this timer.

⁵²Section 10.4.2.1

⁵³Section 6.4.3.6

⁵⁴Section 6.4.3.2

⁵⁵Section 10.4.2.2

⁵⁶Section 9.4.1.1

⁵⁷Section 10.4.2.6.2

Throws

`IllegalStateException` when this `Timer` has been *destroyed*.

Returns

A new release parameters object with new objects containing copies of the values corresponding to this timer. When the interval is greater than zero, return a new instance of `PeriodicParameters`⁵⁸. When the interval is zero return a new instance of `AperiodicParameters`⁵⁹.

getFireTime

Signature

```
public  
java.xml.realtime.AbsoluteTime getFireTime()  
throws ArithmeticException,  
        IllegalStateException
```

Description

Get the time at which this `PeriodicTimer` is next expected to fire or to skip. When the `PeriodicTimer` is *disabled*, the returned time is that of the skipping of the firing. When the `PeriodicTimer` is *not-active* it throws `IllegalStateException`.

Throws

`ArithmeticException` when the result does not fit in the normalized format.
`IllegalStateException` when this `Timer` has been *destroyed*, or when it is *not-active*.

Returns

The absolute time at which `this` is next expected to fire or to skip, in a newly allocated `AbsoluteTime`⁶⁰ object. When the timer has been created or re-scheduled (see `Timer.reschedule(HighResolutionTime)`⁶¹) using an instance of `RelativeTime` for its time parameter then it will return the sum of the current time and the `RelativeTime` remaining time before the timer is expected to fire/skip. Within a periodic timer activation, the returned time is associated with the start clock before the first fire (or skip) time, and associated with the interval clock otherwise.

⁵⁸Section 6.4.3.6

⁵⁹Section 6.4.3.2

⁶⁰Section 9.4.1.1

⁶¹Section 10.4.2.6.2

getFireTime(AbsoluteTime)

Signature

```
public  
    javafx.realtime.AbsoluteTime getFireTime(AbsoluteTime dest)
```

Description

Get the time at which this `PeriodicTimer` is next expected to fire or to skip. When the `PeriodicTimer` is *disabled*, the returned time is that of the skipping of the firing. When the `PeriodicTimer` is *not-active* it throws `IllegalStateException`.

Parameters

dest The instance of `AbsoluteTime`⁶² which will be updated in place and returned. The clock association of the **dest** parameter is ignored. When **dest** is `null` a new object is allocated for the result.

Throws

`ArithmeticException` when the result does not fit in the normalized format.
`IllegalStateException` when this `Timer` has been *destroyed*, or when it is *not-active*.

Returns

The instance of `AbsoluteTime`⁶³ passed as parameter, with time values representing the absolute time at which **this** is expected to fire or to skip. When the **dest** parameter is `null` the result is returned in a newly allocated object. When the timer has been created or re-scheduled (see `Timer.reschedule(HighResolutionTime)`⁶⁴) using an instance of `RelativeTime` for its time parameter then it will return the sum of the current time and the `RelativeTime` remaining time before the timer is expected to fire/skip. Within a periodic timer activation, the returned time is associated with the start clock before the first fire (or skip) time, and associated with the interval clock otherwise.

Available since RTSJ 1.0.1

getInterval

Signature

⁶²Section 9.4.1.1

⁶³Section 9.4.1.1

⁶⁴Section 10.4.2.6.2


```
public  
    javax.realtime.RelativeTime getInterval()
```

Description

Gets the interval of this Timer.

Throws

`IllegalStateException` when this Timer has been *destroyed*.

Returns

The `RelativeTime` instance assigned as this periodic timer's interval by the constructor or `setInterval(RelativeTime)`⁶⁵.

setInterval(RelativeTime)

Signature

```
public  
    void setInterval(RelativeTime interval)
```

Description

Reset the interval value of this.

Parameters

interval A `RelativeTime`⁶⁶ object which is the interval used to reset this Timer. A null interval is interpreted as `RelativeTime(0,0)`.

The **interval** does not affect the first firing (or skipping) of a timer's activation. At each firing (or skipping), the next fire (or skip) time of an *active* periodic timer is established based on the **interval** currently in use. Resetting the **interval** of an *active* periodic timer only effects future fire (or skip) times after the next.

Throws

`IllegalArgumentException` when **interval** is a `RelativeTime` instance with a value less than zero, or the clock associated with **interval** is different to the clock associated with **this**.

`IllegalAssignmentError` when this `PeriodicTimer` cannot hold a reference to **interval**.

`IllegalStateException` when this Timer has been *destroyed*.

⁶⁵Section 10.4.2.3.2

⁶⁶Section 9.4.1.3

fire

Signature

```
public  
void fire()
```

Description

This should not be called for application code, except for emulation. The fire method is reserved for the use of the system. When `this` is enabled, it releases all handlers and then reschedules itself for the next period without changing state. When disabled, but active, it simply reschedules itself. Otherwise it does nothing.

Available since RTSJ 2.0 moved here from `Timer`, since `OneShotTimer` and `PeriodicTimer` have slightly different semantics.

10.4.2.4 TimeDispatcher

Inheritance

```
java.lang.Object  
  javax.realtime.ActiveEventDispatcher  
    javax.realtime.TimeDispatcher
```

Description

A dispatcher for time events: `Timer`⁶⁷ and `RealtimeThread.sleep`⁶⁸.

Available since RTSJ 2.0

10.4.2.4.1 Constructors

TimeDispatcher(SchedulingParameters, SchedulingGroup)

Signature

⁶⁷Section 10.4.2.6

⁶⁸Section 5.4.2.2.2

```
public
TimeDispatcher(SchedulingParameters schedule,
               SchedulingGroup group)
```

Description

Create a new dispatcher, whose dispatching thread runs with the given scheduling parameters.

Parameters

`schedule` give the parameters for scheduling this dispatcher

TimeDispatcher(SchedulingParameters)

Signature

```
public
TimeDispatcher(SchedulingParameters schedule)
```

Description

Create a new dispatcher, whose dispatching thread runs with the given scheduling parameters.

Parameters

`schedule` give the parameters for scheduling this dispatcher

10.4.2.4.2 Methods

register(Timable)

Signature

```
public
void register(Timable target)
throws RegistrationException,
       IllegalStateException,
       IllegalArgumentException
```

Description

Register a `AsyncTimable`⁶⁹ with this dispatcher.

Parameters

`target` to register

Throws

`RegistrationException` when `target` is already registered.

`IllegalStateException` when this object has been destroyed.

`IllegalArgumentException` when `target` is not stopped.

unregister(Timable)

Signature

```
public
void unregister(Timable target)
throws DeregistrationException,
       IllegalStateException,
       IllegalArgumentException
```

Description

Deregister a `AsyncTimable`⁷⁰ from this dispatcher.

Parameters

`target` to deregister

Throws

`DeregistrationException` when `target` is not already registered.

`IllegalStateException` when this object has been destroyed.

`IllegalArgumentException` when `target` is not stopped.

destroy

Signature

```
public
void destroy()
throws IllegalStateException
```

Description

Release all resources thereby making the dispatcher unusable.

⁶⁹Section 10.4.1.1

⁷⁰Section 10.4.1.1

Throws

`IllegalStateException` when called on a dispatcher that has one or more registered `AsyncTimable`⁷¹ objects.

10.4.2.5 `TimeDispatcher.Runner`

Inheritance

```
java.lang.Object
  java.lang.Thread
    javax.realtime.RealtimeThread
      javax.realtime.TimeDispatcher.Runner
```

Description

10.4.2.5.1 `Methods`

run*Signature*

```
public
void run()
```

Description

10.4.2.6 `Timer`

Inheritance

```
java.lang.Object
  javax.realtime.AsyncBaseEvent
    javax.realtime.AsyncEvent
      javax.realtime.Timer
```

Interfaces

⁷¹Section 10.4.1.1

`javax.realtime.AsyncTimable`

`javax.realtime.ActiveEvent`

Description

A *timer* is a timed event that measures time according to a given `Clock`⁷². This class defines basic functionality available to all timers. Applications will generally use either `PeriodicTimer`⁷³ to create an event that is fired repeatedly at regular intervals, or `OneShotTimer`⁷⁴ for an event that just fires once at a specific time. A timer is always associated with at least one `Clock`⁷⁵, which provides the basic facilities of something that ticks along following some time line (realtime, CPU-time, user-time, simulation-time, etc.). All timers are created *disabled* and do nothing until `start()` is called.

10.4.2.6.1 Constructors

Timer(HighResolutionTime, AsyncEventHandler, TimeDispatcher)

Signature

```
protected
Timer(javax.realtime.HighResolutionTime<?> time,
      AsyncEventHandler handler,
      TimeDispatcher dispatcher)
throws IllegalArgumentException,
      UnsupportedOperationException,
      IllegalAssignmentError
```

Description

Create a timer that fires according to the given `time`, based on the `Clock`⁷⁶ clock and is handled by the specified `AsyncEventHandler`⁷⁷ handler.

⁷²Section 10.4.2.1

⁷³Section 10.4.2.3

⁷⁴Section 10.4.2.2

⁷⁵Section 10.4.2.1

⁷⁶Section 10.4.2.1

⁷⁷Section 8.4.3.5

Available since version 2.0*Parameters*

time The time used to determine when to fire the event. A **time** value of **null** is equivalent to a **RelativeTime** of 0, and in this case the **Timer** fires immediately upon a call to **start()**.

handler The default **handler** to use for this event. When **null**, no **handler** is associated with the timer and nothing will happen when this event fires unless a **handler** is subsequently associated with the timer using the **addHandler()** or **setHandler()** method.

dispatcher The **dispatcher** used to interface between this **timer** and its associated clock. When **null**, the system default dispatcher is used.

Throws

IllegalArgumentException when **time** is a negative **RelativeTime** value.

UnsupportedOperationException when **time** has a **Chronograph**⁷⁸ is not a clock.

IllegalAssignmentError when this **Timer** cannot hold references to **handler** and clock.

10.4.2.6.2 Methods

getClock*Signature*

```
public  
javax.realtime.Clock getClock()  
throws IllegalStateException
```

Description

Return the instance of **Clock**⁷⁹ on which this **timer** is based.

Throws

IllegalStateException when this **Timer** has been *destroyed*.

Returns

⁷⁸Section 10.4.1.2

⁷⁹Section 10.4.2.1

The instance of `Clock`⁸⁰ associated with this `Timer`.

getStart

Signature

```
public  
javax.realtime.HighResolutionTime<?> getStart()
```

Description

Get the start time of this `Timer`. Note that the start time uses copy semantics, so changes made to the value returned by this method do not effect the start time of this `Timer`.

Returns

a reference to the time (or start) parameter used when constructing this `Timer`, ensuring the content has the original values. Since RTSJ 2.0

getEffectiveStartTime

Signature

```
public  
javax.realtime.AbsoluteTime getEffectiveStartTime()  
throws IllegalStateException,  
        ArithmeticException
```

Description

Return a newly-created time representing the time the timer actually started, or when the timer has been rescheduled, the effective start time after the reschedule.

Throws

`IllegalStateException` when the timer is not active or has been destroyed.
`ArithmeticException` when the result does not fit in the normalized format.

Returns

the time `this` actually started.

Available since RTSJ 2.0

⁸⁰Section 10.4.2.1

getEffectiveStartTime(AbsoluteTime)

Signature

```
public  
javax.realtime.AbsoluteTime getEffectiveStartTime(AbsoluteTime dest)  
throws IllegalStateException,  
        ArithmeticException
```

Description

Update **dest** to represent the time the timer actually started, or when the timer has been rescheduled, the effective start time after the reschedule. When **dest** is **null**, behave as if `getEffectiveStartTime()`⁸¹ had been called.

Parameters

dest a place to store the time **this** actually started.

Throws

`IllegalStateException` when the timer is not active or has been destroyed.

`ArithmeticException` when the result does not fit in the normalized format.

Returns

The time the timer actually started, or when it has been rescheduled, the effective start time after the reschedule.

Available since RTSJ 2.0

getLastReleaseTime

Signature

```
public final  
javax.realtime.AbsoluteTime getLastReleaseTime()
```

Description

Get the last release time of this timer.

Throws

`IllegalStateException` when this timer has not been released since it was last started.

Returns

⁸¹Section 10.4.2.6.2

a reference to a newly-created [AbsoluteTime](#)⁸² object representing this timer's last release time. When the timer has not been released since it was last started, throw an exception.

Available since RTSJ 2.0

getLastReleaseTime(AbsoluteTime)

Signature

```
public  
javax.realtime.AbsoluteTime getLastReleaseTime(AbsoluteTime dest)
```

Description

Returns

When **dest** is **null**, return a reference to a newly-created [AbsoluteTime](#)⁸³ object representing this timer's last release time. When **dest** is non-null, set **dest** to this timer's last release time. When the timer has not been released, return **null**. Since RTSJ 2.0

getFireTime

Signature

```
public  
javax.realtime.AbsoluteTime getFireTime()  
throws IllegalStateException,  
        ArithmeticException
```

Description

Get the time at which this **Timer** is expected to fire. When the **Timer** is *disabled*, the returned time is that of the skipping of the firing. When the **Timer** is *not-active* it throws **IllegalStateException**.

Throws

ArithmeticException when the result does not fit in the normalized format.
IllegalStateException when this **Timer** has been *destroyed*, or when it is *not-active*.

⁸²Section [9.4.1.1](#)

⁸³Section [9.4.1.1](#)

Returns

The absolute time at which `this` is expected to fire (release handlers or skip), in a newly allocated `AbsoluteTime`⁸⁴ object. When the timer has been created or re-scheduled (see `Timer.reschedule`⁸⁵) using an instance of `RelativeTime` for its time parameter then it will return the sum of the current time and the `RelativeTime` remaining time before the timer is expected to fire/skip. The clock association of the returned time is the clock on which `this` timer is based.

getFireTime(AbsoluteTime)

Signature

```
public
javax.realtime.AbsoluteTime getFireTime(AbsoluteTime dest)
throws IllegalStateException,
    ArithmeticException
```

Description

Get the time at which this `Timer` is expected to fire. When the `Timer` is *disabled*, the returned time is that of the skipping of the firing. When the `Timer` is *not-active* it throws `IllegalStateException`.

Parameters

`dest` The instance of `AbsoluteTime`⁸⁶ which will be updated in place and returned. The clock association of the `dest` parameter is ignored. When `dest` is `null` a new object is allocated for the result.

Throws

`ArithmeticException` when the result does not fit in the normalized format.
`IllegalStateException` when this `Timer` has been *destroyed*, or when it is *not-active*.

Returns

The instance of `AbsoluteTime`⁸⁷ passed as parameter, with time values representing the absolute time at which `this` is expected to fire (release its handlers or skip). When the `dest` parameter is `null` the result is returned in a newly allocated object. When the timer has been created or rescheduled

⁸⁴Section 9.4.1.1

⁸⁵Section 10.4.2.6.2

⁸⁶Section 9.4.1.1

⁸⁷Section 9.4.1.1

(see `Timer.reschedule`⁸⁸) using an instance of `RelativeTime` for its time parameter then it will return the sum of the current time and the `RelativeTime` remaining time before the timer is expected to fire. The clock association of the returned time is the clock on which `this` timer is based.

Available since RTSJ 1.0.1

getDispatcher

Signature

```
public  
javax.realtime.TimeDispatcher getDispatcher()
```

Description

Get the dispatcher associated with this Timable.

Available since RTSJ 2.0

isActive

Signature

```
public  
boolean isActive()
```

Description

Determine the activation state of this happening, i.e., it has been started.

Returns

`true` when active, `false` otherwise.

isRunning

Signature

```
public  
boolean isRunning()  
throws IllegalStateException
```

⁸⁸Section 10.4.2.6.2

Description

Determines if `this` is *active* and is *enabled* such that when the given time occurs it will fire the event. Given the `Timer` current state it answer the question *"Is firing expected?"*.

Throws

`IllegalStateException` when this `Timer` has been *destroyed*.

Returns

`true` when the timer is *active* and *enabled*; otherwise `false`, when the timer has either not been *started*, it has been *started* but it is *disabled*, or it has been *started* and is now *stopped*.

`handledBy(AsyncEventHandler)`

Signature

```
public  
boolean handledBy(AsyncEventHandler handler)  
throws IllegalStateException
```

Description

Replaced by `AsyncBaseEvent.handledBy(AsyncBaseEventHandler)`⁸⁹

Parameters

`handler` to add to the `Timer`

Throws

`IllegalStateException` when this `Timer` has been *destroyed*.

Returns

`true` when `handler` is associated with `this`, otherwise `false`.

Available since RTSJ 1.0.1

`createReleaseParameters`

Signature

```
public  
javax.realtime.ReleaseParameters createReleaseParameters()  
throws IllegalStateException
```

⁸⁹Section 8.4.3.2.1

Description

Create a `ReleaseParameters`⁹⁰ object appropriate to the timing characteristics of this event. The default is the most pessimistic: `AperiodicParameters`⁹¹. This is typically called by code that is setting up a `handler` for this event that will fill in the parts of the release parameters for which it has values, e.g. `cost`.

Throws

`IllegalStateException` when this `Timer` has been *destroyed*.

Returns

A newly created `ReleaseParameters`⁹² object.

addHandler(AsyncEventHandler)

Signature

```
public
void addHandler(AsyncEventHandler handler)
throws IllegalStateException,
       IllegalAssignmentError
```

Description

Add a handler to release upon fire.

Parameters

`handler` to add to the `Timer`

Throws

`IllegalStateException` when this `Timer` has been *destroyed*.

`IllegalAssignmentError` null

Available since RTSJ 1.0.1

setHandler(AsyncEventHandler)

Signature

```
public
void setHandler(AsyncEventHandler handler)
```

⁹⁰Section 6.4.3.10

⁹¹Section 6.4.3.2

⁹²Section 6.4.3.10

throws `IllegalStateException`,
`IllegalAssignmentError`

Description

Set a handler and remove all others.

Parameters

handler to add to the Timer

Throws

`IllegalStateException` when this Timer has been *destroyed*.

`IllegalAssignmentError` null

Available since RTSJ 1.0.1

removeHandler(AsyncEventHandler)

Signature

```
public  
void removeHandler(AsyncEventHandler handler)  
throws IllegalStateException
```

Description

Remove the given handler.

Parameters

handler to add to the Timer

Throws

`IllegalStateException` when this Timer has been *destroyed*.

Available since RTSJ 1.0.1

enable

Signature

```
public  
void enable()  
throws IllegalStateException
```

Description

Re-enable this timer after it has been *disabled*. (See `Timer.disable()`⁹³.) When the `Timer` is already *enabled*, this method does nothing. When the `Timer` is *not-active*, this method does nothing.

Throws

`IllegalStateException` when this `Timer` has been *destroyed*.

disable

Signature

```
public
void disable()
throws IllegalStateException
```

Description

Disable this timer, preventing it from firing. It may subsequently be re-*enabled*. When the timer is *disabled* when its fire time occurs then it will not release its handlers. However, a *disabled* timer created using an instance of `RelativeTime` for its time parameter continues to count while it is *disabled*, and no changes take place in a *disabled* timer created using an instance of `AbsoluteTime`, in both cases the potential firing is simply masked, or skipped. When the timer is subsequently re-*enabled* before its fire time and it is *enabled* when its fire time occurs, then it will fire. It is important to note that this method does not delay the time before a possible firing. For example, when the timer is set to fire at time 42 and the `disable()` is called at time 30 and `enable()` is called at time 40 the firing will occur at time 42 (not time 52). These semantics imply also that firings are not queued. Using the above example, when `enable` was called at time 43 no firing will occur, since at time 42 `this` was *disabled*. When the `Timer` is already *disabled*, whether it is *active* or *inactive*, this method does nothing.

Throws

`IllegalStateException` when this `Timer` has been *destroyed*.

start

Signature

```
public
void start()
```

⁹³Section 10.4.2.6.2

throws `IllegalStateException`

Description

Start this timer. A timer starts measuring time from when it is started; this method makes the timer *active* and *enabled*.

Throws

`IllegalStateException` when this `Timer` has been *destroyed*, or when this timer is already *active*.

start(boolean)

Signature

```
public  
void start(boolean disabled)  
throws IllegalStateException
```

Description

Start this timer. A timer starts measuring time from when it is started. When `disabled` is `true` start the timer making it *active* in a *disabled* state. When `disabled` is `false` this method behaves like the `start()` method.

Parameters

`disabled` When `true`, the timer will be *active* but *disabled* after it is started. When `false` this method behaves like the `start()` method.

Throws

`IllegalStateException` when this `Timer` has been *destroyed*, or when this timer is *active*.

Available since RTSJ 1.0.1

stop

Signature

```
public  
boolean stop()  
throws IllegalStateException
```

Description

Stops a timer when it is *active* and changes its state to *inactive* and *disabled*.

Throws

`IllegalStateException` when this `Timer` has been *destroyed*.

Returns

`true` when this was *enabled* and `false` otherwise.

reschedule(HighResolutionTime)*Signature*

```
public  
void reschedule(javax.realtime.HighResolutionTime<?> time)  
throws IllegalStateException,  
       IllegalArgumentException
```

Description

Change the scheduled time for this event. This method can take either an `AbsoluteTime` or a `RelativeTime` for its argument, and the `Timer` will behave as if created using that type for its `time` parameter. The rescheduling will take place between the invocation and the return of the method.

NOTE: While the scheduled time is changed as described above, the rescheduling itself is applied only on the first firing (or on the first skipping when *disabled*) of a timer's activation. When `reschedule` is invoked after the current activation timer's firing, then the rescheduled `time` will be effective only upon the next `start` or `startDisabled` command (which may need to be preceded by a `stop` command).

When `reschedule` is invoked with a `RelativeTime` `time` on an *active* timer before its first firing/skipping, then the rescheduled firing/skipping `time` is relative to the time of invocation.

Parameters

`time` The time to reschedule for this event firing. When `time` is `null`, the previous time is still the time used for the `Timer` firing.

Throws

`IllegalArgumentException` when `time` is a negative `RelativeTime` value.
`IllegalStateException` when this `Timer` has been *destroyed*.

10.5 Rationale

Clocks differ because of monotonicity, synchronization, jitter, stability, accuracy, precision, and resolution. There are many possible subclasses of clocks: realtime

clocks, user time clocks, simulation time clocks, wall clocks.

The idea of using multiple clocks may at first seem unusual, but it enables the accommodation of different kinds of clocks and as a possible resource allocation strategy. Consider a realtime system where the natural events of the system have different tolerances for jitter. Assume the system functions properly if event *A* is triggered within plus or minus 100 seconds of the actual time it should occur but event *B* must be triggered within 100 microseconds of its actual time. Further assume, without loss of generality, that events *A* and *B* are periodic. An application could then create two instances of `PeriodicTimer` based on two clocks. The timer for event *B* should be based on a `Clock` which checks its queue at least every 100 microseconds but the timer for event *A* could be based on a `Clock` that checked its queue only every 100 seconds. This use of two clocks reduces the queue size of the accurate clock and thus queue management overhead is reduced.

The importance of the use of one-shot timers for time-out behavior and the vagaries in the execution of code prior to starting the timer for short time-outs dictate that the triggering of the timer should be guaranteed. The problem is exacerbated for periodic timers where the importance of the periodic triggering outweighs the precision of the start time. In such cases, it is also convenient to allow, for example, a relative time of zero to be used as the start time.

Clock resolution is a complicated topic, and clock implementations may have differing precision for different purposes. For example, a clock for interacting with humans need much less precision than for controlling the opening and closing of valves on an internal combustion engine. In this case, their relationship to wall clock time may vary as well.

The precision of time returned by a hardware clock device when queried may be greater than the precision at which that device can supply interrupts. (Consider, for example, a high precision off-chip realtime clock device connected via a shared serial bus.) A different device may provide pulse-per-second interrupts of very high precision, but be unable to interrupt on any other interval. The `RTSJ Clock` class provides two representation of precision: `getDrivePrecision()` and `getQueryPrecision()` inherited from `Chronograph`. Clocks should behave as if their tick (`setAlarm()`) precision is the same as returned by `getResolution()`.

Chapter 11

Alternative Memory Areas

11.1 Overview

Open issue 11.1.1 (elb)

Rationalize terminology for the various memory area concepts and make sure that the spec is consistent and uses clear language in this respect.

End of issue 11.1.1

Conventional Java uses a single heap for storing all objects. The thread stacks hold only primitive objects and references to objects. This is fine for desktop and server systems, where there are no realtime, locality, or isolation requirements. For most realtime systems, a single heap with a deterministic garbage collector is usually also sufficient. For other situations, this specification defines classes directly related to memory and memory management. These classes provide a more generalized means of memory management than available in a conventional Java VM.

In conventional Java, all of the memory needed for the allocation of an object is taken from a garbage-collected heap. The RTSJ generalizes the concept of a heap to that of a *memory area*. A memory area consists of two components: a Java object that manages the memory area and the *backing memory*, which is the actual region of memory from which objects are allocated. Every thread and schedulable has a *current allocation context*. This context is the memory area which is managing the backing memory that will be used when the thread/schedulable requests memory allocation using the Java “new” operator.

There are three types of memory area, distinguished by object lifetime semantics, defined by the RTSJ.

- Heap memory—the Java heap. Unreachable objects are collected by a garbage collector. Individual schedulables can specify their rate of allocation of objects on the heap.
- Immortal memory—an area defined by the JVM in which allocated objects

might never be collected. Access to the memory area must be independent of garbage collection activity. Individual schedulables can specify the maximum amount of memory they need in immortal memory.

- Scoped memory—multiple areas that can be created by the application; objects are collected in scoped memory when there are no schedulables currently active in that area and it is not pinned. These allow objects with well-defined lifetimes to be created and efficiently collected in an easily identified group.

Given that objects can now be created in multiple memory areas, it is necessary to ensure that an object cannot reference another object that might be collected at an earlier time. For example, an object in immortal memory (that is never collected) must not be allowed to reference an object in scoped memory. This is because the scoped memory object that is not pinned will be collected when there is no schedulable active in its associated backing memory, rendering the immortal object's reference to the scoped memory object invalid. For this reason, the RTSJ defines some memory assignment rules that are checked by the JVM on every object assignment. If the program violates the assignment rules, an exception is thrown.

11.1.1 Physical Memory

In embedded systems it is often the case that multiple directly addressable memory types are available to the application. For example, SRAM, DRAM, and Flash memory may all fall within the processor address space. Moreover, as the JVM implementer may require the VM to be portable between systems within the same processor family, the VM itself may not have detailed knowledge of the underlying memory architecture. The RTSJ therefore provides a framework with which the embedded systems integrator can define memory characteristics and specify ranges of physical addresses that support those memory characteristics. These physical memory regions can be allocated as either immortal or scoped memory areas.

11.1.2 Stacked Memory

RTSJ 2.0, adds a new type of scoped memory called *stacked memory*. Stacked memory enables systems to maintain predictable memory performance over a long period of time while still releasing memory at runtime. The older scoped memory interfaces left sufficient ambiguity in the specification that the user may not have been able to sufficiently characterize internal and external fragmentation upon creating or destroying scoped memory areas. The `StackedMemory` class provides a safe interface for creating and releasing scopes with a set of rules under which the VM must guarantee fragmentation-free behavior with predictable memory overhead. These guarantees are provided by constraining the order in which an application may enter

StackedMemory areas, as well as the manner in which they may be arranged on the scope stack. These constraints are enforced by the implementation.

11.1.3 Summary

In summary, the classes and interfaces defined in this chapter enable

1. the definition of regions of memory outside of the conventional Java heap;
2. the definition of regions of scoped memory, that is, memory regions with a limited lifetime;
3. the definition of regions of memory containing objects whose lifetime matches that of the application;
4. the definition of regions of memory mapped to specific physical addresses with specific virtual memory characteristics;
5. the specification of maximum memory area consumption and maximum allocation rates for individual schedulables;
6. the programmer to query information characterizing the behavior of the garbage collection algorithm, and to some limited ability, alter the behavior of that algorithm.

11.2 Definitions

Allocation Context — the place where a given task allocated new object. In conventional Java, this is the Java heap. This is just one type of **MemoryArea**, the base class representing all allocation contexts in the RTSJ.

Current allocation context — the memory area which will be used when object allocation is requested.

Backing store or backing memory — the area of memory that is managed by a **MemoryArea** and is logically separate from the Java heap.

Firable asynchronous event handler — An **AsyncBaseEventHandler** is *firable* whenever there is an agent that can release it. This includes cases when the **AsyncBaseEventHandler** is

1. a miss handler, or overrun handler of a **RealtimeThread** instance that has been started but not yet terminated;
2. a handler associated with an **AsyncEvent** that can be fired;
3. a miss handler or overrun handler for an instance of **AsyncBaseEventHandler**.

It excludes the final stage of scoped memory wrap-up.

Execution context — the memory area upon which execution is dependent. This includes the area a **Schedulable** or **ActiveEvent** is allocated. In order to prevent references from becoming invalid, the memory of an execution context

may not be reclaimed. A memory area containing one of the following is such a context:

1. **Thread** instances that have been started and have not terminated (including the **RealtimeThread** instances contained by **ActiveEventDispatcher** instances),
2. **AsyncBaseEvent** instances that have a least one associated **AsyncBaseEventHandler**,
3. **ActiveEvent** instances that are active,
4. Firable **AsyncBaseEventHandler** instance, and
5. active threads of control which have the memory area enter on their stack.

Default initial memory area — The initial memory area for a schedulable is *default* when it is the memory area where the schedulable was created.

Portal — A reference inside a **ScopedMemory** instance settable on that instance which may reference an object in that area. A portal can be used to pass information between instances of **Schedulable** executing in a given area.

Scope stack — A stack of the memory areas the current **Schedulable** instance has entered in order of entry.

11.3 Semantics

The classes **MemoryArea**, **HeapMemory**, and **ImmortalMemory** are part of the base module and the semantics below that apply to those modules must be fulfilled by all RTSJ implementations. The rest of the features described here belong to the Alternate Memory Area Module introduced in Section 3.3.2.3 and are only required for implementations that include that module. The following lists define the general semantics of the classes of this section. Semantics of particular classes, constructors, methods, and fields are the class description and the constructor, method, and field detail sections further on.

11.3.1 Allocation Execution Time

The following two requirements apply to allocation in any memory area, including the heap.

1. Some **MemoryArea** classes are required to have linear (in object size) allocation time. The linear time attribute requires that, ignoring performance variations due to hardware caches or similar optimizations and ignoring execution time of any static initializers, the execution time of **new** must be bounded by a polynomial, $f(n)$, where n is the size of the object and for all $n > 0$, $f(n) \leq Cn$ for some constant C .

2. Execution time of object constructors, and time spent in class loading and static initialization are not governed by bounds on object allocation in this specification, but setting default initial values for fields in the instance (as specified in *The Java Virtual Machine Specification*, Second Edition, section 2.5.1, “Each class variable, instance variable, and array component is initialized with a default value when it is created.”) is considered part of object allocation and included in the time bound.

11.3.2 Allocation Context

The following requirements apply to the allocation context represented by a memory area.

3. A memory area is represented by an instance of a subclass of the `MemoryArea` class. When a memory area, *m*, is entered by calling `m.enter` (or another method from the family of enter-like methods defined in `MemoryArea` or its subclasses), *m* becomes the *allocation context* of the current schedulable object. When control returns from the `enter` method, the allocation context is restored to the value it had immediately before `enter` was called.
4. When a memory area, *m*, is entered by calling *m*’s `executeInArea` method, *m* becomes the current allocation context of the current schedulable. When control returns from the `executeInArea` method, the allocation context is restored to the value it had before `executeInArea` was called.
5. The initial allocation context for a schedulable is the memory area that was designated the *initial memory area* when the schedulable was constructed. This initial allocation context becomes the current allocation context for that schedulable when the schedulable object first becomes eligible for execution. For instances of `AsyncBaseEventHandler`, the initial allocation context is the same on each release; for realtime threads, in releases subsequent to the first, the allocation context is the same as it was when the realtime thread became *blocked-for-release-event*.
6. All object allocation through the `new` keyword will use the current allocation context, but note that allocation can be performed in a specific memory area using the `newInstance` and `newArray` methods.
7. Instances of `schedulables` behave as if they stored their memory area context in a structure called the *scope stack*. This structure is manipulated by the instantiation of a schedulables, and the following methods from `MemoryArea` and its subclasses: all the `enter` and `joinAndEnter` methods, `executeInArea`, and both `newInstance` methods. See the semantics in Maintaining the Scope Stack for details.
8. The scope stack is accessible through a set of static methods on `RealtimeThread`. These methods allow outer allocation contexts to be accessed by their

index number. Memory areas on a scope stack may be referred to as *inner* or *outer* relative to other entries in that scope stack. An “outer scope” is further from the current allocation context on the current scope stack and has a lower index.

9. The `executeInArea`, `newInstance` and `newArray` methods, when invoked on an instance of `ScopedMemory` require that instance to be an outer allocation context on the current schedulable object’s current scope stack.
10. An instance of `ScopedMemory` is said to be *in use* if it has a non-zero reference count as defined by semantic 17 below.

11.3.3 The Parent Scope

The following requirements apply to a scope’s parent.

11. Instances of `ScopedMemory` have special semantics including definition of *parent*. If a `ScopedMemory` object is neither in use nor the initial memory area for a schedulable, it has no *parent* scope.
 - (a) When a `ScopedMemory` object becomes in use, its parent is the nearest `ScopedMemory` object outside it on the current scope stack. If there is no outside `ScopedMemory` object in the current scope stack, the parent is the *primordial scope* which is not actually a memory area, but only a marker that constrains the parentage of `ScopedMemory` objects.
 - (b) At construction of a schedulable, if the initial memory area has no parent, the initial memory area is assigned the parent it will have when the schedulable is in execution. This rule determines the initial memory area’s parent until the schedulable object is de-allocated or, in the case of a `RealtimeThread`, it completes execution.
12. Instances of `ScopedMemory` must satisfy the *single parent rule* which requires that each scoped memory has a unique parent as defined in semantic 11.

11.3.4 Memory Areas and Schedulables

The following requirements govern the relationship between memory and execution.

13. Pushing a scoped memory onto a scope stack is always subject to the single parent rule.
14. Each schedulable has an initial memory area which is that object’s initial allocation context. The default initial memory area is the current allocation context in effect during execution of the schedulable’s constructor, but schedulables may supply constructors that override the default.
15. A Java thread cannot have a scope stack; consequently it can only be created and execute within heap or immortal memory. The thread starts execution with its allocation context set to the memory area containing the `Thread`

object. An attempt to create a Java thread in a scoped memory area throws `IllegalAssignmentError`.

16. A Java thread may use `executeInArea`, and the `newInstance` and `newArray` methods from the `ImmortalMemory` and `HeapMemory` classes. These methods allow it to execute with an immortal current allocation context, but semantic 15 applies even during execution of these methods.

11.3.5 Scoped Memory Reference Counting

The following requirements apply to references to scoped memory.

17. Each instance of the class `ScopedMemory` or its subclasses must maintain a reference count which is greater than zero if and only if either:
 - (a) the scoped memory area is the current allocation context or an outer allocation context for one or more *execution contexts*; or else
 - (b) the scoped memory area contains the *fireable* `AsyncEventHandler` that was created with the `pinInitialMemoryArea` flag set to `True`.
18. Each instance of the `PinnableMemory` class must support a pinned count. This count is incremented for each call of the `pin` method and decremented for each call of the `unpin` method. The count is always greater than or equal to zero (that is, calling the `unpin` method has no effect if the count equals zero).
19. When the reference count for an instance of the class `ScopedMemory` is ready to be decremented from one to zero and the pinned count (if present) is equal to zero, all unfinalized objects within that area are considered ready for finalization. If after the finalizers for all such unfinalized objects in the scoped memory area run to completion, the reference count for the memory area is still ready to be decremented to zero and the pinned count is still equal to zero, any newly created unfinalized objects are considered ready for finalization and the process is repeated until no new objects are created or the scoped memory's reference count is no longer ready to be decremented from one to zero. When the scope contains no unfinalized objects and its reference count is ready to be decremented from one to zero and the pinned count is equal to zero, any async event in the scope is no longer treated as a source of fireability for async event handlers. If that action causes object creation in the scope the finalization process resumes from the beginning, if the reference count is no longer ready to be decremented to zero the finalization process terminates, otherwise, the reference count is decremented to zero and the memory scope is emptied of all objects. The process of scope finalization starts when the scope's reference count is about to go to zero with a zero pin count and continues until the scope is emptied or the process is terminated because the reference count is no longer about to go to zero. The RTSJ implementation must behave effectively as if during the finalization process the SO executing the finalization of a scope held

a synchronized lock that must also be acquired to increase the reference count when entering the scope, to increase the reference count during startup for a thread with the finalizing scope as its non-default initial memory area, and to increase the reference count while making firable an AEH with the scope as its non-default initial memory area. Although the steps in scope finalization are ordered no order is specified for finalization of objects or for disarming fireability of AEHs. The objects may be processed in any order or concurrently, but at no time may a scope's reference count be reduced to zero while it has one or more child scopes. (This semantic is a special case of the finalization implementation specified in *The Java Language Specification*, second edition, section 12.6.1.)

20. When the pinned count is ready to go to zero and the reference count is zero, all unfinalized objects within that area are considered ready for finalization, and the same semantics as 19 above applies.
21. Finalization may start when all unfinalized objects in the scope are ready for finalization. Finalizers are executed with the current allocation context set to the finalizing scope and are executed by the schedulable in control of the scope when its reference count is ready to be decremented from one to zero. If finalizers are executed because a realtime thread terminates or an `AsyncEventHandler` becomes unfirable, that realtime thread or `AsyncEventHandler` is considered in control of the scope and must execute the finalizers.
22. From the time objects in a scope are deleted until the portal on the scope is successfully set to a non-null value with `setPortal`, the value returned by `getPortal` on that scoped memory object must be `null`.

11.3.6 Immortal Memory

The following requirements apply to immortal memory.

23. Objects created in any immortal memory area are unexceptionally referencable from all Java threads, and all schedulables, and the allocation and use of objects in immortal memory is never subject to garbage collection delays.
24. An implementation may execute finalizers for immortal objects when it determines that the application has terminated. Finalizers will be executed by a thread or schedulable whose current allocation context is not scoped memory. Regardless of any call to `runFinalizersOnExit`, except as required to support the base Java platform, the system need not execute finalizers for immortal objects that remain unfinalized when the JVM begins termination.
25. Class objects, the associated static memory, and interned Strings behave effectively as if they were allocated in immortal memory with respect to reference rules, assignment rules, and preemption delays by schedulables which may not access the heap. Static initializers are executed effectively as if the

current thread performed `ImmutableMemory.instance().executeInArea(r)` where `r` is a `Runnable` that executes the `<clinit>` method of the class being initialized.

11.3.7 Maintaining Referential Integrity

The following rules apply to references to objects in scoped memory.

26. Assignment rules placed on reference assignments prevent the creation of dangling references, and thus maintain the referential integrity of the Java runtime. The restrictions are listed in the following table:

Stored in Area	Reference to Object in Heap	Reference to Object in Immortal	Reference to Object in Scoped	null
Heap	Permit	Permit	Forbid	Permit
Immortal	Permit	Permit	Forbid	Permit
Scoped	Permit	Permit	Permit from same or less deeply nested scope	Permit
Local Variable	Permit	Permit	Permit	Permit

For this table, `ImmutableMemory` and `ImmutablePhysicalMemory` are equivalent, and all sub-classes of `ScopedMemory` are equivalent.

27. An implementation must ensure that the above checks are performed for each assignment statement before the statement is executed, either by runtime checks or by static analysis of the application logic. Checks for operations on local variables are not required because a potentially invalid reference would be captured by the other checks before it reached a local variable.

11.3.8 Object Initialization

The following requirements apply to object initialization.

28. Static initializers run with the immortal memory area as their allocation context.
29. The current allocation context in a constructor for an object is the memory area in which the object is allocated. For `new`, this is the current allocation context when `new` was called. For members of the `m.newInstance` family, the current allocation context is memory area *m*.

11.3.9 Maintaining the Scope Stack

This section describes maintenance of a data structure that is called the *scope stack*. Implementations are not required to use a stack or implement the algorithms

given here. It is only required that an implementation behave with respect to the ordering and accessibility of memory scopes effectively as if it implemented these algorithms. The scope stack is implicitly visible through the assignment rules, and the stack is explicitly visible through the static method `getOuterMemoryArea(int)` on `RealtimeThread`.

Four operations affect the scope stack: the `enter` methods defined in `MemoryArea` and its subclasses, instantiation of a new `Schedulable`, the `executeInArea` method in `MemoryArea`, and the new instance methods in `MemoryArea`.

1. The memory area at the top of a schedulable object's scope stack is the schedulable's current allocation context.
2. When a schedulable, t , creates a schedulable object, n_t , in a `ScopedMemory` object's allocation area, n_t acquires a copy of the scope stack associated with t at the time n_t is constructed including all entries from up to and including the memory area containing n_t . If n_t is created in heap, immortal, or immortal physical memory, n_t is created with a scope stack containing only heap, immortal, or immortal physical memory respectively. If n_t has a non-default initial memory area, ima , then ima is pushed on n_t 's newly-created scope stack.
3. When a memory area, ma is entered by calling a `ma.enter` method, ma is pushed on the scope stack and becomes the *allocation context* of the current schedulable object. When control returns from the `enter` method, the allocation context is popped from the scope stack
4. When a memory area, m , is entered by calling `m's executeInArea` method or one of the `m.newInstance` methods, the scope stack before the method call is preserved and replaced with a scope stack constructed as follows:
 - (a) when ma is a scoped memory area, the new scope stack is a copy of the schedulable's previous scope stack up to and including ma , and
 - (b) when ma is not a scoped memory area, the new scope stack includes only ma .

When control returns from the `executeInArea` method, the scope stack is restored to the value it had before `ma.executeInArea` or `ma.newInstance` was called.

For the purposes of these algorithms, stacks grow *up*. One should also note that the representative algorithms ignore important issues like freeing objects in scopes.

1. In every case, objects in a scoped memory area are eligible to be freed when the reference count for the area is zero after finalizers for that scope are run.
2. Informally, any objects in a scoped memory area *must* be freed and their finalizers run before the reference count for the memory area is incremented from zero to one.

11.3.10 The enter Method

For `ma.enter(logic)`:

```

1  push ma on the scope stack belonging to the current schedulable
2  -- which may throw ScopedCycleException
3  execute logic.run method
4  pop ma from the scope stack

```

11.3.11 The executeInArea or newInstance Methods

For `ma.executeInArea(logic)`, `ma.newInstance()`, or `ma.newArray()`:

```

1  when ma is an instance of heap immortal or ImmortalPhysicalMemory,
2    start a new scope stack containing only ma.
3    make the new scope stack the scope stack for the current
4    schedulable.
5  else if ma is in the scope stack for the current schedulable,
6    start a new scope stack containing ma and all
7    scopes below ma on the scope stack.
8    make the new scope stack the scope stack for the current
9    schedulable.
10 else
11   throw InaccessibleAreaException, execute logic.run,
12   or construct the object.
13   restore the previous scope stack for the current schedulable.
14   discard the new scope stack.
15 end

```

11.3.12 Constructor Methods for Schedulables

For construction of a schedulable in memory area `cma` with initial memory area of `ima`:

```

1  if cma is heap, immortal or ImmortalPhysicalMemory,
2    create a new scope stack containing cma.
3  else
4    start a new scope stack containing the entire
5    current scope stack.
6
7  if ima != cma
8    push ima on the new scope stack
9    -- which may throw ScopedCycleException.

```

The above pseudocode illustrates a straightforward implementation of this specification's semantics, but any implementation that behaves effectively like this one with respect to reference count values of zero and one is permissible. An implementation may be eager or lazy in maintenance of its reference count provided that it correctly implements the semantics for reference counts of zero and one.

11.3.13 The Single Parent Rule

Every push of a scoped memory type on a scope stack requires reference to the single parent rule, this enforces the invariant that every scoped memory area has no more than one parent.

The parent of a scoped memory area is identified by the following rules:

1. when the memory area is not currently on any scope stack, it has no parent;
2. when the memory area is the first scoped memory area on a scope stack, i.e., was entered from `ImmortalMemory` or `Heap`, its parent is the *primordial scope*,
3. otherwise, the parent is the first scoped memory area outside it on the scope stack, i.e., the scope from which this scope was entered.

Except for the primordial scope, which represents heap, immortal and immortal physical memory, only scoped memory areas are visible to the single parent rule.

The operational effect of the single parent rule is that when a scoped memory area has a parent, the only legal change to that value is to “no parent.” Thus an ordering imposed by the first assignments of parents of a series of nested scoped memory areas is the only nesting order allowed until control leaves the scopes; then a new nesting order is possible. Thus, a schedulable attempting to enter a scope can only do so by entering in the established nesting order.

11.3.14 Scope Tree Maintenance

The single parent rule is enforced effectively as if there were a tree with the primordial scope (representing heap, immortal, and immortal physical memory) at its root, and other nodes corresponding to every scoped memory area that is currently on any schedulable's scope stack.

Each scoped memory has a reference to its parent memory area, `ma.parent`. The parent reference may indicate a specific scoped memory area, no parent, or the primordial parent.

If a scoped memory area is the non-default initial memory area of an async event handler, or the non-default initial memory area of a realtime thread that has not terminated, it is referred to as *pinned*.

11.3.14.1 On Scope Stack Push of MA

The following procedure could be used to maintain the scope tree and ensure that push operations on a schedulable's scope stack do not violate the single parent rule.

```

1 precondition: ma.parent is set to the correct parent (either a scoped
2   memory area or the primordial scope) or to noParent.
3
4   t.scopeStack is the scope stack of the current schedulable
5
6   if ma is scoped,
7     parent = findFirstScope(t.scopeStack)
8   if ma.parent == noParent
9     ma.parent = parent.
10  else if ma.parent != parent
11    throw ScopedCycleException.
12  else
13    t.scopeStack.push(ma).
```

`findFirstScope` is a convenience function that looks down the scope stack for the next entry that is a reference to an instance of `ScopedMemoryArea`.

```

1 findFirstScope(scopeStack)
2 {
3   for s = top of scope stack to bottom of scope stack
4     if s is an instance of ScopedMemory
5       return s return primordial scope
6 }
```

11.3.14.2 On Scope Stack Pop of ma

```

1 ma = t.scopeStack.pop.
2 if ma is scoped
3   if !(ma.in_use || ma.pinned)
4     ma.parent = noParent
```

11.3.15 Physical Memory

Physical memory provides a means of allocating Java objects in specific areas of a system's physical address space. This is accomplished by creating a memory area that resides in the desired address range. The memory area can be any of the memory areas defined by this specification other than heap. A physical memory area is not type distinct from a normal memory area; it is just created by a different means.

1. Physical immortal memory—an immortal memory area that can be created by the application such that their associated backing memory areas have specified physical and virtual memory characteristics. For example, the application could specify that the physical characteristics of the backing store should be Static RAM (SRAM) and that it should be mapped by the JVM into virtual memory that is never paged out to disk.
2. Physical scoped memory—a scoped memory area, that can be created by the application such that their associated backing store has specified physical and virtual memory characteristics.

This physical memory model is based on two constraints.

1. Java objects can only be allocated in a memory area when the physical backing memory supports the Java Memory Model (JMM) without the JVM having to perform any operation additional to those that it performs when accessing the main RAM for the host machine.
 - (a) No extra compiler or JVM interactions shall be required. Hence memory regions (such as EEPROM) that potentially require special hardware instructions to perform write operations cannot be used as the backing store for physical memory areas.
 - (b) Similarly, non-volatile memory cannot be used, as object lifetimes in such an area may be longer than the lifetime of the VM.

Although memory having such characteristics incompatible with the JMM are prohibited from being used as backing stores for object allocation, they can contain objects of primitive Java types and be accessed via the RTSJ Raw Memory facilities (see Section 12.3.1).

2. Any API must delegate detailed knowledge of the memory architecture to the programmer/integrator of the specific embedded system to be implemented. The model assumes that the programmer is aware of the memory map, either through some native operating system interface¹ or from some property file read at program initialization time.

The RTSJ defines a *physical memory factory*, which maintains a mapping between physical memory characteristics and the associated physical addresses of memory that support those characteristics. The physical memory factory has no knowledge of the meaning of the physical characteristics. It only provides a look-up service and keeps track of which physical memory has been associated with a physical memory range by the application. The physical memory factory does, however, have detailed knowledge of the types of virtual memory it can support. It advertises this knowledge to the application. For example, it knows if the VM can lock memory pages into

¹For example, the *Advanced Configuration and Power Interface* (ACPI) specification is an open standard for device configuration and power management by the operating system. The ACPI defines platform-independent interfaces for hardware discovery, configuration, power management and monitoring. See <http://www.acpi.info/>

memory to ensure that they are never swapped out to disk. The application can then request that the physical memory manager create an association between physical memory with certain characteristics and a virtual memory type (for example, SRAM that is permanently resident in memory).

11.3.16 Stacked Memory

A **StackedMemory** area represents both a backing memory providing **ScopedMemory** semantics and a *backing memory container* from which the backing memory is drawn. The backing memory container may be further subdivided into additional backing memories and backing memory containers. Such divisions behave as if new containers are allocated contiguously from the bottom of the container, while new backing memories are allocated contiguously from the top, with containers and backing memories meeting when the container is completely occupied.

StackedMemory backing memory containers are explicitly created and sized, and have well-defined lifetimes similar to objects in a **ScopedMemory** area. A **StackedMemory** object can be created as either a *host*, which has its own backing memory container, or a *guest*, which draws its backing memory directly from its parent's backing memory container. When a **StackedMemory** object is created in an allocation context other than **StackedMemory**, it is necessarily a host and is called a *root StackedMemory*. In this case, its backing memory container is drawn from a notional global backing memory container. Applications should assume that a root **StackedMemory**'s object is immortal, and implementations need not release it even if it is finalized. When a **StackedMemory** object is created in another **StackedMemory**'s allocation context, it may be created as either a host or guest, as illustrated in Figure 11.1. When it is created as a host, its backing memory container is drawn from its parent area's container, and its backing memory is created in the newly-divided container. When it is created as a guest, its backing memory is created in its parent's backing memory container.

Open issue 11.3.1 (elb)

StackedMemory semantics need to change WRT guest areas; a guest area should claim the remaining unused backing store of its host parent to avoid stack fragmentation. JTRES 2015

To avoid fragmentation, a guest should not claim the remaining unused backing store if its host, but for a **StackedMemory** may only hold one guest **StackedMemory**.
-jjh

End of issue 11.3.1

Object lifetimes for objects allocated in **StackedMemory** backing memories are the same as those in **ScopedMemory** allocation areas. When a **StackedMemory** object itself is finalized, its backing memory is returned to the container from which it was drawn, and in the case of host **StackedMemory** areas, the associated backing memory

container is also returned to the parent's container. As previously mentioned, root **StackedMemory** backing memory containers are effectively immortal. Additionally, the backing memory of a **StackedMemory** can be resized under certain conditions. These semantics allow the memory represented by a root **StackedMemory** backing memory container to be partitioned and re-partitioned as the application requires, without danger of fragmentation and without requiring memory allocation external to the container to track the partitioning.

Open issue 11.3.2 (elb)

The backing store of a root **StackedMemory** should be collected when the object representing the area is collected, so the term effectively immortal is misleading. –jjh

End of issue 11.3.2

In order to preserve the fragmentation-free nature of this contract, certain rules are enforced, and certain additional rules must be observed by the application. The rules that are enforced by the **StackedMemory** infrastructure are

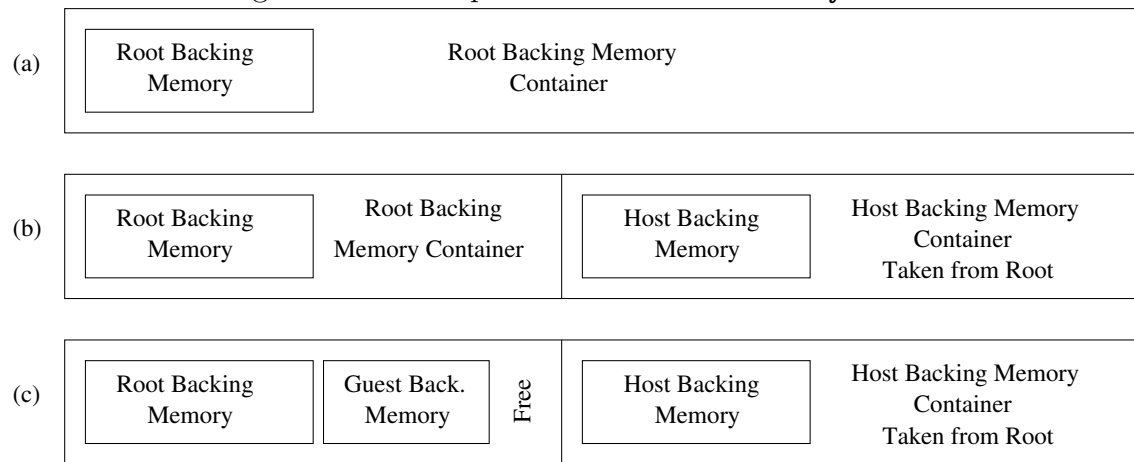
1. a nonroot **StackedMemory** area can only be entered by a schedulable when its allocation context is the same as the allocation context in which that **StackedMemory** area's object was created;
2. a **StackedMemory** area may have at most one direct child in the scope stack that is a guest **StackedMemory** area;
3. a **StackedMemory** object cannot be created from another **StackedMemory** allocation context unless it is allocated from that area's backing memory; and
4. a **StackedMemory**'s backing memory cannot be resized if there are unfinalized guest **StackedMemory** backing memories placed after it in the same backing memory container.

The additional rules that are not enforced by the infrastructure are not enforced because it may be desirable for an application to temporarily violate them, *e.g.*, when joining child threads in completion order, rather than creation order. They nevertheless must be observed at critical times in order to preserve fragmentation-free allocation. They are that, when a new **StackedMemory** is created as either a host or guest in a particular container, one of the following conditions must be met:

1. The new **StackedMemory** area is a host, and there are existing unfinalized host **StackedMemory** descendants in the parent backing memory, but all such descendants were *created after* all unfinalized host descendants. (That is, effectively last-in first-out finalization.)
2. The new **StackedMemory** area is a host, and there are no existing unfinalized host **StackedMemory** descendants in the parent backing memory.
3. The new **StackedMemory** area is a guest.

Note that the first bullet point effectively can be violated only if the parent has *both* host and guest children.

Figure 11.1 graphically depicts the behavior of **StackedMemory** backing memory

Figure 11.1: Manipulation of `StackedMemory` Areas

containers and backing memories for a root `StackedMemory` as well as one host and one guest child `StackedMemory` under that root. A code fragment that could create the stack topology in Figure 11.1 is as follows. Assume that this fragment executes in an allocation context other than a `StackedMemory`, and that zero overhead is required for memory area creation. (Implementations may require a constant amount of backing memory overhead for each `StackedMemory` area created in the store.)

```

1 // Create a StackedMemory with a 10 kB backing memory container and
2 // 2 kB backing memory
3 rootArea = new StackedMemory(2048, 10240); // (a)
4 rootArea.enter(new Runnable()
5 {
6     public void run()
7     {
8         // Create a host area with a 6 kB backing memory container and
9         // 2 kB backing memory
10        hostArea = new StackedMemory(2048, 6144); // (b)
11        // Create a guest area with a 2 kB backing memory
12        guestArea = new StackedMemory(1536); // (c)
13    }
14 });

```

Commented points (a), (b), and (c) correspond to their respective subfigures in Figure 11.1. At point (a), a root `StackedMemory` has been created with its 10 kB backing memory container drawn from the notional global container. It contains a 2 kB backing memory, which is then entered. With that backing memory as the current allocation context, a new host `StackedMemory` is created at (b), reserving 6 kB of the root `StackedMemory`'s backing memory container for its own use and

creating a second 2 kB backing memory within that reservation. A new guest **StackedMemory** is then created at (c) in the root area (without entering the host child), occupying 1.5 kB of the remaining free 2 kB of the container in the root area. At this point, the root area's backing memory container is almost entirely occupied, with one 2 kB backing memory, one 1.5 kB backing memory, and a 6 kB host area backing memory container reservation, and 512 B of free backing memory container in between. The host **StackedMemory** created at (b) has 4 kB of its backing memory container remaining unoccupied in its reservation, which could be allocated to additional host or guest **StackedMemory** areas beneath it in the stack.

11.4 Package javax.realtime

11.4.1 Interfaces

11.4.1.1 MemoryAreaVisitor

Description

This interface is used to visit memory areas. For example, the method `MemoryArea.visitNestedMemory`² uses this visitor to process all memory areas nested the area upon which it is called.

11.4.1.1.1 Methods

visit(MemoryArea)

Signature

```
public  
R visit(MemoryArea memory)
```

Description

Visit the members of a collection of memory areas. It provides a means of accessing all live scopes contained in a memory area, even those to which no reference exists, such a `javax.realtime.memory.PinnableMemory`³ that is pinned or another `ScopedMemory` that contains a `Schedulable`. The set may be concurrently modified by other tasks, but the view seen by the visitor may not be updated to reflect those changes.

Parameters

memory The memory area being visited.

Returns

Any object declared by the application or `null`. When `visit` returns an object, no more memory areas are visited and the `MemoryArea.visitNestedMemory`⁴ method returns the object returned by `visit(MemoryArea)`⁵.

²Section 11.4.2.3.2

³Section 11.5.3.5

⁴Section 11.4.2.3.2

⁵Section 11.4.1.1.1

11.4.2 Classes

11.4.2.1 HeapMemory

Inheritance

java.lang.Object
 javax.realtime.MemoryArea
 javax.realtime.HeapMemory

Description

The `HeapMemory` class is a singleton object that allows logic with a non-heap allocation context to allocate objects in the Java heap.

11.4.2.1.1 Methods

enter

Signature

```
public  
void enter()
```

Description

Associate this memory area with the current schedulable for the duration of the execution of the `run()` method of the instance of `Runnable` given in the constructor. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected (using `enter`, or `executeInArea`⁶) or the `enter` method exits.

Throws

`IllegalThreadStateException` when the caller is a Java thread.

`IllegalArgumentException` `IllegalArgumentException` when the caller is a schedulable and a `null` value for `logic` was supplied when the memory area was constructed.

`MemoryAccessError` when caller is a schedulable which may not use the heap.

⁶Section 11.4.2.1.1

enter(Runnable)

Signature

```
public  
void enter(Runnable logic)
```

Description

Associate this memory area with the current schedulable for the duration of the execution of the `run()` method of the given `Runnable`. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected (using `enter`, or `executeInArea`⁷) or the `enter` method exits.

Parameters

`logic` The `Runnable` object whose `run()` method should be invoked.

Throws

`MemoryAccessError` when caller is a schedulable which may not use the heap.

`IllegalThreadStateException` `IllegalThreadStateException` when the caller is a Java thread.

`IllegalArgumentException` `IllegalArgumentException` when the caller is a schedulable and `logic` is `null`.

instance

Signature

```
public static  
java.xml.realtime.HeapMemory instance()
```

Description

Returns a reference to the singleton instance of `HeapMemory`⁸ representing the Java heap. The singleton instance of this class shall be allocated in the `ImmortalMemory`⁹ area.

Returns

The singleton `HeapMemory`¹⁰ object.

⁷Section 11.4.2.1.1

⁸Section 11.4.2.1

⁹Section 11.4.2.2

¹⁰Section 11.4.2.1

executeInArea(Runnable)

Signature

```
public  
void executeInArea(Runnable logic)
```

Description

Execute the run method from the `logic` parameter using heap as the current allocation context. For a schedulable, this saves the current scope stack and replaces it with one consisting only of the `HeapMemory` instance; restoring the original scope stack upon completion.

Parameters

`logic` The runnable object whose `run()` method should be executed.

Throws

`IllegalArgumentException` when `logic` is null.

`MemoryAccessError` when caller is a schedulable which may not use the heap.

newArray(Class, int)

Signature

```
public  
java.lang.Object newArray(java.lang.Class<?> type,  
                           int number)
```

Description

Allocate an array of the given type in this memory area. This method may be concurrently used by multiple threads.

Parameters

`type` `type` The class of the elements of the new array. To create an array of a primitive type use a `type` such as `Integer.TYPE` (which would call for an array of the primitive `int` type.)

`number` `number` The number of elements in the new array.

Throws

`MemoryAccessError` when caller is a schedulable which may not use the heap.

`IllegalArgumentException` `IllegalArgumentException` when `number` is less than zero, `type` is null, or `type` is `java.lang.Void.TYPE`.

`OutOfMemoryError` `OutOfMemoryError` when space in the memory area is exhausted.

Returns

A new array of class type, of number elements.

newInstance(Class)*Signature*

```
public
java.lang.Object newInstance(java.lang.Class type)
throws IllegalAccessException,
    InstantiationException
```

Description

Allocate an object in this memory area. This method may be concurrently used by multiple threads.

Parameters

type type The class of which to create a new instance.

Throws

MemoryAccessError when caller is a schedulable which may not use the heap.
IllegalAccessException IllegalAccessException The class or initializer is inaccessible.

IllegalArgumentException IllegalArgumentException when **type** is null.

ExceptionInInitializerError ExceptionInInitializerError when an unexpected exception has occurred in a static initializer

OutOfMemoryError OutOfMemoryError when space in the memory area is exhausted.

InstantiationException InstantiationException when the specified class object could not be instantiated. Possible causes are: it is an interface, it is abstract, it is an array, or an exception was thrown by the constructor.

Returns

A new instance of class **type**.

newInstance(Constructor, Object)*Signature*

```
public
java.lang.Object newInstance(java.lang.reflect.Constructor c,
                             java.lang.Object[] args)
```

throws `IllegalAccessException`,
 `InstantiationException`,
 `InvocationTargetException`

Description

Allocate an object in this memory area. This method may be concurrently used by multiple threads.

Parameters

c `Tc` The constructor for the new instance.
args `args` An array of arguments to pass to the constructor.

Throws

MemoryAccessError when caller is a schedulable which may not use the heap.
IllegalAccessException `IllegalAccessException` when the class or initializer is inaccessible under Java access control.
InstantiationException `InstantiationException` when the specified class object could not be instantiated. Possible causes are: it is an interface, it is abstract, it is an array.
OutOfMemoryError `OutOfMemoryError` when space in the memory area is exhausted.
IllegalArgumentException `IllegalArgumentException` when **c** is `null`, or the **args** array does not contain the number of arguments required by **c**. A `null` value of **args** is treated like an array of length 0.
InvocationTargetException `InvocationTargetException` when the underlying constructor throws an exception.

Returns

A new instance of the object constructed by **c**.

visitNestedMemory(MemoryAreaVisitor)

Signature

```
public  
R visitNestedMemory(javax.realtime.MemoryAreaVisitor<R> visitor)
```

Description

Visit each scoped memory area who's parent is the primordial scope and was created in heap memory.

Parameters

`visitor` invoke the `MemoryAreaVisitor.visit(MemoryArea)`¹¹ method for each member of the set of scoped memory areas that was created in heap memory and has the primordial scope as its parent.

Throws

`IllegalArgumentException` `IllegalArgumentException` when `visitor` is `null`.

Returns

`null` when all elements were visited and some object of type `R` when the visit is forced to terminate at the end of visiting that element.

11.4.2.2 `ImmutableMemory`

Inheritance

```
java.lang.Object
  javax.realtime.MemoryArea
    javax.realtime.ImmutableMemory
```

Description

`ImmutableMemory` is a memory resource that is unexceptionally available to all schedulables and Java threads for use and allocation.

An immortal object may not contain references to any form of scoped memory, e.g., `javax.realtime.memory.LTMemory`¹², `javax.realtime.memory.StackedMemory`¹³, or `javax.realtime.memory.PinnableMemory`¹⁴.

Objects in immortal have the same states with respect to finalization as objects in the standard Java heap, but there is no assurance that immortal objects will be finalized even when the JVM is terminated.

Methods from `ImmutableMemory` should be overridden only by methods that use `super`.

11.4.2.2.1 Methods

¹¹Section 11.4.1.1.1

¹²Section 11.5.3.1

¹³Section 11.5.3.7

¹⁴Section 11.5.3.5

instance

Signature

```
public static  
    javax.realtime.ImmutableMemory instance()
```

Description

Returns a pointer to the singleton `ImmutableMemory`¹⁵ object.

Returns

The singleton `ImmutableMemory`¹⁶ object.

executeInArea(Runnable)

Signature

```
public  
    void executeInArea(Runnable logic)
```

Description

Execute the run method from the `logic` parameter using this memory area as the current allocation context. For a schedulable, this saves the current scope stack and replaces it with one consisting only of the `ImmutableMemory` instance; restoring the original scope stack upon completion.

Parameters

`logic` The runnable object whose `run()` method should be executed.

Throws

`IllegalArgumentException` when `logic` is null.

visitNestedMemory(MemoryAreaVisitor)

Signature

```
public  
    R visitNestedMemory(javax.realtime.MemoryAreaVisitor<R> visitor)
```

Description

Visit each scoped memory area who's parent is the primordial scope and was created in this memory area.

¹⁵Section 11.4.2.2

¹⁶Section 11.4.2.2

Parameters

`visitor` invoke the `MemoryAreaVisitor.visit(MemoryArea)`¹⁷ method for each member of the set of scoped memory areas that was created in this immortal memory area and has the primordial scope as its parent.

Throws

`IllegalArgumentException` `IllegalArgumentException` when `visitor` is `null`.

Returns

`null` when all elements where visited and some object of type `R` when the visit is forced to terminate at the end of visiting that element.

11.4.2.3 MemoryArea

Inheritance

`java.lang.Object`
`javax.realtime.MemoryArea`

Description

`MemoryArea` is the abstract base class of all classes dealing with the representations of allocatable memory areas, including the immortal memory area, physical memory and scoped memory areas. This is an abstract class, but no method in this class is abstract. An application should not subclass `MemoryArea` without complete knowledge of its implementation details.

11.4.2.3.1 Constructors

MemoryArea(long)

Signature

```
protected  
MemoryArea(long size)  
throws IllegalArgumentException,  
        OutOfMemoryError
```

Description

¹⁷Section [11.4.1.1.1](#)

Create an instance of `MemoryArea`.

Parameters

size The size of `MemoryArea` to allocate, in bytes.

Throws

`IllegalArgumentException` when **size** is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `MemoryArea` object or for the backing memory.

`MemoryArea(SizeEstimator)`

Signature

```
protected  
MemoryArea(SizeEstimator size)  
throws IllegalArgumentException,  
        OutOfMemoryError
```

Description

Create an instance of `MemoryArea`.

Parameters

size A `SizeEstimator`¹⁸ object which indicates the amount of memory required by this `MemoryArea`.

Throws

`IllegalArgumentException` when the **size** parameter is null, or **size.getEstimate()** is negative.

`OutOfMemoryError` when there is insufficient memory for the `MemoryArea` object or for the backing memory.

`MemoryArea(long, Runnable)`

Signature

```
protected  
MemoryArea(long size,  
            Runnable logic)
```

¹⁸Section 11.4.2.5

throws `IllegalArgumentException`,
`OutOfMemoryError`,
`IllegalAssignmentError`

Description

Create an instance of `MemoryArea`.

Parameters

size The size of `MemoryArea` to allocate, in bytes.

logic The `run()` method of this object will be called whenever `enter()`¹⁹ is called. When `logic` is null, this constructor is equivalent to `MemoryArea(long size)`.

Throws

`IllegalArgumentException` when the `size` parameter is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `MemoryArea` object or for the backing memory.

`IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

MemoryArea(SizeEstimator, Runnable)

Signature

protected
`MemoryArea(SizeEstimator size,`
 `Runnable logic)`
throws `IllegalArgumentException`,
`OutOfMemoryError`,
`IllegalAssignmentError`

Description

Create an instance of `MemoryArea`.

Parameters

size A `SizeEstimator` object which indicates the amount of memory required by this `MemoryArea`.

¹⁹Section 11.4.2.3.2

`logic` The `run()` method of this object will be called whenever `enter()`²⁰ is called. When `logic` is `null`, this constructor is equivalent to `MemoryArea(SizeEstimator size)`.

Throws

`IllegalArgumentException` when `size` is `null` or `size.getEstimate()` is negative.

`OutOfMemoryError` when there is insufficient memory for the `MemoryArea` object or for the backing memory.

`IllegalAssignmentError` when storing `logic` in this would violate the assignment rules.

11.4.2.3.2 Methods

enter

Signature

```
public
void enter()
throws IllegalArgumentException,
    OutOfMemoryError,
    IllegalAssignmentError,
    MemoryAccessError
```

Description

Associate this memory area with the current schedulable for the duration of the execution of the `run()` method of the instance of `Runnable` given in the constructor. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected (using `enter`, or `executeInArea`²¹) or the `enter` method exits.

Throws

`IllegalThreadStateException` when the caller is a Java thread.

`IllegalArgumentException` when the caller is a schedulable and a `null` value for `logic` was supplied when the memory area was constructed.

²⁰Section 11.4.2.3.2

²¹Section 11.4.2.3.2

ThrowBoundaryError Thrown when the JVM needs to propagate an exception allocated in **this** scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an **IllegalAssignmentError**²², so the JVM cannot be permitted to deliver the exception. The **ThrowBoundaryError**²³ instance is preallocated by the VM to avoid cascading creation of **ThrowBoundaryError**²⁴.

MemoryAccessError when caller is a schedulable that may not use the heap and this memory area's logic value is allocated in heap memory.

enter(Runnable)

Signature

```
public  
void enter(Runnable logic)
```

Description

Associate this memory area with the current schedulable for the duration of the execution of the `run()` method of the given **Runnable**. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected (using **enter**, or **executeInArea**²⁵) or the **enter** method exits.

Parameters

logic The **Runnable** object whose `run()` method should be invoked.

Throws

IllegalThreadStateException when the caller is a Java thread.

IllegalArgumentException when the caller is a schedulable and **logic** is **null**.

ThrowBoundaryError Thrown when the JVM needs to propagate an exception allocated in **this** scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an **IllegalAssignmentError**²⁶, so the JVM cannot be permitted to deliver the exception. The **ThrowBoundaryError**²⁷ instance is preallocated by the VM to avoid cascading creation of **ThrowBoundaryError**.

²²Section 15.3.3.2

²³Section 15.3.3.8

²⁴Section 15.3.3.8

²⁵Section 11.4.2.3.2

²⁶Section 15.3.3.2

²⁷Section 15.3.3.8

enter(Supplier)

Signature

```
public  
T enter(java.util.function.Supplier<T> logic)
```

Description

Same as `enter(Runnable)`²⁸ except that the executed method is called `get` and an object is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

enter(BooleanSupplier)

Signature

```
public  
boolean enter(BooleanSupplier logic)
```

Description

Same as `enter(Runnable)`²⁹ except that the executed method is called `get` and a `boolean` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

enter(IntSupplier)

Signature

```
public  
int enter(IntSupplier logic)
```

Description

²⁸Section 11.4.2.3.2

²⁹Section 11.4.2.3.2

Same as `enter(Runnable)`³⁰ except that the executed method is called `get` and an `int` is returned.

Parameters

`logic` the object who's get method will be executed.

Returns

a result from the computation.

enter(LongSupplier)

Signature

```
public  
long enter(LongSupplier logic)
```

Description

Same as `enter(Runnable)`³¹ except that the executed method is called `get` and a `long` is returned.

Parameters

`logic` the object who's get method will be executed.

Returns

a result from the computation.

enter(DoubleSupplier)

Signature

```
public  
double enter(DoubleSupplier logic)
```

Description

Same as `enter(Runnable)`³² except that the executed method is called `get` and a `double` is returned.

Parameters

`logic` the object who's get method will be executed.

Returns

a result from the computation.

³⁰Section 11.4.2.3.2

³¹Section 11.4.2.3.2

³²Section 11.4.2.3.2

getMemoryArea(Object)

Signature

```
public static  
    javax.realtime.MemoryArea getMemoryArea(Object object)
```

Description

Gets the `MemoryArea` in which the given object is located.

Throws

`IllegalArgumentException` when the value of `object` is `null`.

Returns

The instance of `MemoryArea` from which `object` was allocated.

memoryConsumed

Signature

```
public  
    long memoryConsumed()
```

Description

For memory areas where memory is freed under program control this returns an exact count, in bytes, of the memory currently used by the system for the allocated objects. For memory areas (such as heap) where the definition of "used" is imprecise, this returns the best value it can generate in constant time.

Returns

The amount of memory consumed in bytes.

memoryRemaining

Signature

```
public  
    long memoryRemaining()
```

Description

An approximation to the total amount of memory currently available for future allocated objects, measured in bytes.

Returns

The amount of remaining memory in bytes.

newArray(Class, int)

Signature

```
public
java.lang.Object newArray(java.lang.Class<?> type,
                           int number)
throws IllegalArgumentException,
       OutOfMemoryError,
       SecurityException
```

Description

Allocate an array of the given type in this memory area. This method may be concurrently used by multiple threads.

Parameters

type The class of the elements of the new array. To create an array of a primitive type use a **type** such as `Integer.TYPE` (which would call for an array of the primitive `int` type.)

number The number of elements in the new array.

Throws

`IllegalArgumentException` when **number** is less than zero, **type** is `null`, or **type** is `java.lang.Void.TYPE`.

`OutOfMemoryError` when space in the memory area is exhausted.

`SecurityException` when the caller does not have permission to create a new instance.

Returns

A new array of class **type**, of **number** elements.

newInstance(Class)

Signature

```
public
T newInstance(java.lang.Class<T> type)
throws IllegalAccessException,
       IllegalArgumentException,
       InstantiationException,
       OutOfMemoryError,
       ExceptionInInitializerError,
       SecurityException
```

Description

Allocate an object in this memory area. This method may be concurrently used by multiple threads.

Parameters

type The class of which to create a new instance.

Throws

IllegalAccessException The class or initializer is inaccessible.

IllegalArgumentException when **type** is null.

InstantiationException when the specified class object could not be instantiated. Possible causes are: it is an interface, it is abstract, it is an array, or an exception was thrown by the constructor.

OutOfMemoryError when space in the memory area is exhausted.

ExceptionInInitializerError when an unexpected exception has occurred in a static initializer

SecurityException when the caller does not have permission to create a new instance.

Returns

A new instance of class **type**.

newInstance(Constructor, Object)*Signature*

```
public
T newInstance(java.lang.reflect.Constructor<T> c,
              java.lang.Object[] args)
throws ExceptionInInitializerError,
       IllegalAccessException,
       IllegalArgumentException,
       InstantiationException,
       InvocationTargetException,
       OutOfMemoryError,
       SecurityException
```

Description

Allocate an object in this memory area. This method may be concurrently used by multiple threads.

Parameters

c The constructor for the new instance.

args An array of arguments to pass to the constructor.

Throws

ExceptionInInitializerError when an unexpected exception has occurred in a static initializer

IllegalAccessException when the class or initializer is inaccessible under Java access control.

IllegalArgumentException when **c** is **null**, or the **args** array does not contain the number of arguments required by **c**. A **null** value of **args** is treated like an array of length 0.

InstantiationException when the specified class object could not be instantiated. Possible causes are: it is an interface, it is abstract, it is an array.

InvocationTargetException when the underlying constructor throws an exception.

OutOfMemoryError when space in the memory area is exhausted.

SecurityException when the caller does not have permission to create a new instance.

Returns

A new instance of the object constructed by **c**.

size

Signature

```
public  
long size()
```

Description

Query the size of the memory area. The returned value is the current size. Current size may be larger than initial size for those areas that are allowed to grow.

Returns

The size of the memory area in bytes.

executeInArea(Runnable)

Signature

```
public
void executeInArea(Runnable logic)
throws IllegalArgumentException
```

Description

Execute the run method from the `logic` parameter using this memory area as the current allocation context. The effect of `executeInArea` on the scope stack is specified in the subclasses of `MemoryArea`.

Parameters

`logic` The runnable object whose `run()` method should be executed.

Throws

`IllegalArgumentException` when `logic` is null.

executeInArea(Supplier)

Signature

```
public
T executeInArea(java.util.function.Supplier<T> logic)
```

Description

Same as `executeInArea(Runnable)`³³ except that the executed method is called `get` and an object is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

executeInArea(BooleanSupplier)

Signature

```
public
boolean executeInArea(BooleanSupplier logic)
```

Description

Same as `executeInArea(Runnable)`³⁴ except that the executed method is called `get` and a `boolean` is returned.

³³Section 11.4.2.3.2

³⁴Section 11.4.2.3.2

Parameters

`logic` the object who's get method will be executed.

Returns

a result from the computation.

executeInArea(IntSupplier)

Signature

```
public  
int executeInArea(IntSupplier logic)
```

Description

Same as `executeInArea(Runnable)`³⁵ except that the executed method is called `get` and an `int` is returned.

Parameters

`logic` the object who's get method will be executed.

Returns

a result from the computation.

executeInArea(LongSupplier)

Signature

```
public  
long executeInArea(LongSupplier logic)
```

Description

Same as `executeInArea(Runnable)`³⁶ except that the executed method is called `get` and a `long` is returned.

Parameters

`logic` the object who's get method will be executed.

Returns

a result from the computation.

³⁵Section 11.4.2.3.2

³⁶Section 11.4.2.3.2

executeInArea(DoubleSupplier)

Signature

```
public  
double executeInArea(DoubleSupplier logic)
```

Description

Same as `executeInArea(Runnable)`³⁷ except that the executed method is called `get` and a `double` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

visitNestedMemory(MemoryAreaVisitor)

Signature

```
public  
R visitNestedMemory(javax.realtime.MemoryAreaVisitor<R> visitor)  
throws IllegalArgumentException
```

Description

A means of accessing all live nested memory areas contained in this memory area, even those to which no reference exists, such as a `javax.realtime.memory.PinnableMemory`³⁸ that is pinned or another `javax.realtime.memory.ScopedMemory` that contains a `Schedulable`. The set may be concurrently modified by other tasks, but the view seen by the visitor may not be updated to reflect those changes. The following is guaranteed even when the set is disturbed by other tasks:

- the visitor shall visit no member more than once,
- it shall visit only scopes that were a member of the set at some time during the enumeration of the set, and
- it shall visit all the scopes that are not deleted during the execution of the visitor.

Perform an action on all children scopes of this memory area, so long as the `MemoryAreaVisitor.visit(MemoryArea)`³⁹ method returns `null`. When that

³⁷Section 11.4.2.3.2

³⁸Section 11.5.3.5

³⁹Section 11.4.1.1.1

method returns an object, the visit is terminated and that object is returned by this method,

When execution of the visitor's visit method terminated abruptly by throwing an exception, then execution of visitScopedChildren also terminates abruptly by throwing the same exception.

Parameters

visitor determines the action to be performed on each of the children scopes.

Throws

IllegalArgumentException when visitor is **null**.

Returns

null when all elements where visited and some object of type **R** when the visit is forced to terminate at the end of visiting that element.

mayHoldReferenceTo

Signature

```
public  
boolean mayHoldReferenceTo()
```

Description

Determine whether an object **A** allocated in the memory area represented by **this** can hold a reference to an object **B** allocated in the current memory area.

Returns

true when **B** can be assigned to a field of **A**, otherwise **false**.

mayHoldReferenceTo(Object)

Signature

```
public  
boolean mayHoldReferenceTo(Object value)
```

Description

Determine whether an object **A** allocated in the memory area represented by **this** can hold a reference to the object **value**.

Parameters

value is the object to test.

Returns

true when **value** can be assigned to a field of **A**, otherwise **false**.

11.4.2.4 MemoryParameters

Inheritance

java.lang.Object
 javax.realtime.MemoryParameters

Interfaces

Cloneable
Serializable

Description

Memory parameters can be given on the constructor of `RealtimeThread`⁴⁰ and `AsyncEventHandler`⁴¹. These can be used both for the purposes of admission control by the scheduler and for the purposes of pacing the garbage collector (if any) to satisfy all of the schedulable memory allocation rates.

The limits in a `MemoryParameters` instance are enforced when a schedulable creates a new object, e.g., uses the `new` operation. When a schedulable exceeds its allocation or allocation rate limit, the error is handled as if the allocation failed because of insufficient memory. The object allocation throws an `OutOfMemoryError`.

When a reference to a `MemoryParameters` object is given as a parameter to a constructor, the `MemoryParameters` object becomes bound to the object being created. Changes to the values in the `MemoryParameters` object affect the constructed object. When given to more than one constructor, then changes to the values in the `MemoryParameters` object affect *all* of the associated objects. Note that this is a one-to-many relationship and *not* a many-to-many.

A `MemoryParameters` object may be shared, but that does not cause the memory budgets reflected by the parameter to be shared among the schedulables that are associated with the parameter object.

Caution: This class is explicitly unsafe for multithreading when being changed. Code that mutates instances of this class should synchronize at a higher level.

11.4.2.4.1 Fields

NO_MAX

⁴⁰Section 5.4.2.2

⁴¹Section 8.4.3.5

```
public static final NO_MAX
```

Description

Specifies no maximum limit.

11.4.2.4.2 Constructors

`MemoryParameters(boolean)`

Signature

```
public  
MemoryParameters(boolean mayUseHeap)
```

Description

Create a `MemoryParameters` object with the given values.

Available since RTSJ 2.0

Parameters

`mayUseHeap` indicates whether or not the schedulable may use the heap. The default is `true` when an instance of this class is not provided.

`MemoryParameters(long, long, boolean)`

Signature

```
public  
MemoryParameters(long maxMemoryArea,  
                  long maxImmortal,  
                  boolean mayUseHeap)
```

Description

Create a `MemoryParameters` object with the given values.

Available since RTSJ 2.0

Parameters

maxMemoryArea A limit on the amount of memory the schedulable may allocate in its initial memory area. Units are in bytes. When zero, no allocation allowed in the memory area. To specify no limit, use **NO_MAX**.

maxImmortal A limit on the amount of memory the schedulable may allocate in the immortal area. Units are in bytes. When zero, no allocation allowed in immortal. To specify no limit, use **NO_MAX**.

mayUseHeap indicates whether or not the schedulable may use the heap. The default is **true** when an instance of this class is not provided.

Throws

IllegalArgumentException when any value other than positive. zero, or **NO_MAX** is passed as the value of **maxMemoryArea** or **maxImmortal**.

MemoryParameters(long, long)

Signature

```
public
MemoryParameters(long maxMemoryArea,
                  long maxImmortal)
```

Description

Create a **MemoryParameters** object with the given values and **mayUseHeap**⁴² returns **false**.

Parameters

maxMemoryArea A limit on the amount of memory the schedulable may allocate in its initial memory area. Units are in bytes. When zero, no allocation allowed in the memory area. To specify no limit, use **NO_MAX**.

maxImmortal A limit on the amount of memory the schedulable may allocate in the immortal area. Units are in bytes. When zero, no allocation allowed in immortal. To specify no limit, use **NO_MAX**.

Throws

IllegalArgumentException when any value other than positive. zero, or **NO_MAX** is passed as the value of **maxMemoryArea** or **maxImmortal**.

MemoryParameters(long, long, long)

⁴²Section 11.4.2.4.3

Signature

```
public
MemoryParameters(long maxMemoryArea,
                  long maxImmortal,
                  long allocationRate)
```

Description

Create a `MemoryParameters` object with the given values and `mayUseHeap`⁴³ returns `true`.

Parameters

maxMemoryArea A limit on the amount of memory the schedulable may allocate in its initial memory area. Units are in bytes. When zero, no allocation allowed in the memory area. To specify no limit, use `NO_MAX`.

maxImmortal A limit on the amount of memory the schedulable may allocate in the immortal area. Units are in bytes. When zero, no allocation allowed in immortal. To specify no limit, use `NO_MAX`.

allocationRate A limit on the rate of allocation in the heap. Units are in bytes per second of wall clock time. When `allocationRate` is zero, no allocation is allowed in the heap. To specify no limit, use `NO_MAX`. Measurement starts when the schedulable is first released for execution (not when it is constructed.) Enforcement of the allocation rate is an implementation option. When the implementation does not enforce allocation rate limits, it treats all non-zero allocation rate limits as `NO_MAX`.

Throws

`IllegalArgumentException` when any value other than positive. zero, or `NO_MAX` is passed as the value of `maxMemoryArea` or `maxImmortal`, or `allocationRate`.

11.4.2.4.3 Methods

clone

Signature

```
public
java.lang.Object clone()
```

⁴³Section 11.4.2.4.3

Description

Return a clone of `this`. This method should behave effectively as if it constructed a new object with the visible values of `this`.

- The new object is in the current allocation context.
- `clone` does not copy any associations from `this` and it does not implicitly bind the new object to a SO.
-

Available since RTSJ 1.0.1

getAllocationRate

Signature

```
public  
long getAllocationRate()
```

Description

Gets the limit on the rate of allocation in the heap. Units are in bytes per second.

Returns

The allocation rate in bytes per second. When zero, no allocation is allowed in the heap. When the returned value is `NO_MAX`⁴⁴ then the allocation rate on the heap is uncontrolled.

getMaxImmortal

Signature

```
public  
long getMaxImmortal()
```

Description

Gets the limit on the amount of memory the schedulable may allocate in the immortal area. Units are in bytes.

Returns

The limit on immortal memory allocation. When zero, no allocation is allowed in immortal memory. When the returned value is `NO_MAX`⁴⁵ then there is no limit for allocation in immortal memory.

⁴⁴Section 11.4.2.4.1

⁴⁵Section 11.4.2.4.1

getMaxMemoryArea

Signature

```
public  
long getMaxMemoryArea()
```

Description

Gets the limit on the amount of memory the schedulable may allocate in its initial memory area. Units are in bytes.

Returns

The allocation limit in the schedulable's initial memory area. When zero, no allocation is allowed in the initial memory area. When the returned value is `NO_MAX`⁴⁶ then there is no limit for allocation in the initial memory area.

mayUseHeap

Signature

```
public  
boolean mayUseHeap()
```

Description

Determine whether or not this parameter object specifies that the heap may be used.

Returns

`true` when heap may be used and `false` otherwise.

setAllocationRate(long)

Signature

```
public  
void setAllocationRate(long allocationRate)
```

Description

Sets the limit on the rate of allocation in the heap.

Parameters

⁴⁶Section 11.4.2.4.1

allocationRate Units are in bytes per second of wall-clock time. When **allocationRate** is zero, no allocation is allowed in the heap. To specify no limit, use **NO_MAX**. Measurement starts when the schedulable starts (not when it is constructed.) Enforcement of the allocation rate is an implementation option. When the implementation does not enforce allocation rate limits, it treats all non-zero allocation rate limits as **NO_MAX**.

Throws

IllegalArgumentException when any value other than positive, zero, or **NO_MAX** is passed as the value of **allocationRate**.

11.4.2.5 SizeEstimator

Inheritance

java.lang.Object
 javax.realtime.SizeEstimator

Description

This class maintains an estimate of the amount of memory required to store a set of objects.

SizeEstimator is a floor on the amount of memory that should be allocated. Many objects allocate other objects when they are constructed. **SizeEstimator** only estimates the memory requirement of the object itself, it does not include memory required for any objects allocated at construction time. When the instance itself is allocated in several parts (when for instance the object and its monitor are separate), the size estimate shall include the sum of the sizes of all the parts that are allocated from the same memory area as the instance. Alignment considerations, and possibly other order-dependent issues may cause the allocator to leave a small amount of unusable space, consequently the size estimate cannot be seen as more than a close estimate.

See Section [MemoryArea.MemoryArea\(SizeEstimator\)](#)

See Section [LTMemory.LTMemory\(SizeEstimator\)](#)

11.4.2.5.1 Constructors

SizeEstimator

Signature

```
public  
SizeEstimator()
```

Description

11.4.2.5.2 Methods

reserve(Class, int)

Signature

```
public  
void reserve(java.lang.Class c,  
             int number)
```

Description

Take into account additional `number` instances of Class `c` when estimating the size of the `MemoryArea`⁴⁷.

Parameters

`c` The class to take into account.

`number` The number of instances of `c` to estimate.

Throws

`IllegalArgumentException` when `c` is `null`.

reserve(SizeEstimator, int)

Signature

```
public  
void reserve(SizeEstimator estimator,  
             int number)
```

⁴⁷Section 11.4.2.3

Description

Take into account additional `number` instances of `SizeEstimator` `size` when estimating the size of the `MemoryArea`⁴⁸.

Parameters

`estimator` The given instance of `SizeEstimator`⁴⁹.

`number` The number of times to reserve the size denoted by `estimator`.

Throws

`IllegalArgumentException` when `estimator` is `null`.

reserve(SizeEstimator)*Signature*

```
public  
void reserve(SizeEstimator size)
```

Description

Take into account an additional instance of `SizeEstimator` `size` when estimating the size of the `MemoryArea`⁵⁰.

Parameters

`size` The given instance of `SizeEstimator`.

Throws

`IllegalArgumentException` when `size` is `null`.

reserveArray(int)*Signature*

```
public  
void reserveArray(int length)
```

Description

Take into account an additional instance of an array of `length` reference values when estimating the size of the `MemoryArea`⁵¹.

Parameters

⁴⁸Section 11.4.2.3

⁴⁹Section 11.4.2.5

⁵⁰Section 11.4.2.3

⁵¹Section 11.4.2.3

length The number of entries in the array.

Throws

`IllegalArgumentException` when **length** is negative.

Available since RTSJ 1.0.1

reserveArray(int, Class)

Signature

```
public
void reserveArray(int length,
                  java.lang.Class type)
```

Description

Take into account an additional instance of an array of **length** primitive values when estimating the size of the `MemoryArea`⁵².

Class values for the primitive types are available from the corresponding class types; e.g., `Byte.TYPE`, `Integer.TYPE`, and `Short.TYPE`.

Parameters

length The number of entries in the array.

type The class representing a primitive type. The reservation will leave room for an array of **length** of the primitive type corresponding to **type**.

Throws

`IllegalArgumentException` when **length** is negative, or **type** does not represent a primitive type.

Available since RTSJ 1.0.1

getEstimate

Signature

```
public
long getEstimate()
```

Description

Gets an estimate of the number of bytes needed to store all the objects reserved.

⁵²Section 11.4.2.3

Returns

The estimated size in bytes.

11.5 Package javax.realtime.memory

11.5.1 Interfaces

11.5.1.1 PhysicalMemoryCharacteristic

Description

A tagging interface used to identify physical memory characteristics. Applications can give names to regions of memory that are described by `PhysicalMemoryRegion`⁵³. The names are defined by creating instances of this interface. For example, final static `PhysicalMemoryCharacteristic STATIC_RAM = ...`;

Available since RTSJ 2.0

11.5.1.2 VirtualMemoryCharacteristic

Description

A tagging interface used to identify virtual memory characteristics. The `PhysicalMemoryFactory` defines static public objects that implement this interface. Each instant represent a particular virtual memory characteristics supported by the hosting machine.

For example, public final static `VirtualMemoryCharacteristic PERMANENTLY_RESIDENT`

Available since RTSJ 2.0

11.5.1.2.1 Methods

apply(long, long)

Signature

⁵³Section 11.5.3.3

```
public
void apply(long base,
           long size)
```

Description

Apply the Characteristic to a given memory area.

Parameters

base is the physical start of the memory
size is the length of the memory in bytes.

unapply(long, long)*Signature*

```
public
void unapply(long base,
             long size)
```

Description

Unapply the Characteristic to a given memory area.

Parameters

base is the physical start of the memory
size is the length of the memory in bytes.

11.5.2 Enumerations**11.5.2.1 PhysicalMemorySelector.CachingBehavior****Inheritance**

```
java.lang.Object
  java.lang.Enum
    javax.realtime.memory.PhysicalMemorySelector.CachingBehavior
```

Description

Marker for standard caching behaviors. Not all need be supported. For example, a VM running in Kernel mode might only support DISABLED.

11.5.2.1.1 Enumeration Constants

DISABLED

```
public static final DISABLED
```

Description

WRITE_THROUGH

```
public static final WRITE_THROUGH
```

Description

WRITE_BACK

```
public static final WRITE_BACK
```

Description

11.5.2.1.2 Methods

values

Signature

```
public static  
    javax.realtime.memory.PhysicalMemorySelector.CachingBehavior[] values()
```

Description

valueOf(String)*Signature*

```
public static
javax.realtime.memory.PhysicalMemorySelector.CachingBehavior valueOf(String name)
```

*Description***11.5.2.2 PhysicalMemorySelector.PagingBehavior**

Inheritance

```
java.lang.Object
  java.lang.Enum
    javax.realtime.memory.PhysicalMemorySelector.PagingBehavior
```

Description

Marker for standard paging behaviors. Not all need be supported. For example, a VM running in Kernel mode might only support DIRECT.

11.5.2.2.1 Enumeration Constants

DIRECT

```
public static final DIRECT
```

*Description***FIXED**

```
public static final FIXED
```

Description

SWAPPABLE

```
public static final SWAPPABLE
```

Description

11.5.2.2.2 Methods

values

Signature

```
public static  
    javax.realtime.memory.PhysicalMemorySelector.PagingBehavior[] values()
```

Description

valueOf(String)

Signature

```
public static  
    javax.realtime.memory.PhysicalMemorySelector.PagingBehavior valueOf(String name)
```

Description

11.5.3 Classes

11.5.3.1 LTMemory

Inheritance

```
java.lang.Object  
    javax.realtime.MemoryArea  
        javax.realtime.memory.ScopedMemory
```

`javax.realtime.memory.LTMemory`

Description

LTMemory represents a memory area guaranteed by the system to have linear time allocation when memory consumption from the memory area is less than the memory area's *initial* size. Execution time for allocation is allowed to vary when memory consumption is between the initial size and the maximum size for the area. Furthermore, the underlying system is not required to guarantee that memory between initial and maximum will always be available.

The memory area described by a **LTMemory** instance does not exist in the Java heap, and is not subject to garbage collection. Thus, it is safe to use a **LTMemory** object as the initial memory area for a `javax.realtime.Schedulable`⁵⁴ instance which may not use the `javax.realtime.HeapMemory`⁵⁵ or to enter the memory area using the `ScopedMemory.enter`⁵⁶ method within such an instance.

Enough memory must be committed by the completion of the constructor to satisfy the initial memory requirement. (Committed means that this memory must always be available for allocation). The initial memory allocation must behave, with respect to successful allocation, as if it were contiguous; i.e., a correct implementation must guarantee that any sequence of object allocations that could ever succeed without exceeding a specified initial memory size will always succeed without exceeding that initial memory size and succeed for any instance of **LTMemory** with that initial memory size. (Note: to ensure that all requested memory is available set initial and maximum to the same value) Methods from **LTMemory** should be overridden only by methods that use `super`.

See Section `javax.realtime.MemoryArea`

See Section `ScopedMemory`

See Section `javax.realtime.Schedulable`

Available since RTSJ 2.0 moved to this package.

11.5.3.1.1 Constructors

⁵⁴Section 6.4.1.3

⁵⁵Section 11.4.2.1

⁵⁶Section 11.5.3.6.2

LTMemory(long, long)

Signature

```
public
LTMemory(long initial,
          long maximum)
```

Description

Create an LTMemory of the given size.

Parameters

initial The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

maximum The size in bytes of the memory to allocate for this area.

Throws

`IllegalArgumentException` when **initial** is greater than **maximum**, or when **initial** or **maximum** is less than zero.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory for the LTMemory object or for the backing memory.

LTMemory(long, long, Runnable)

Signature

```
public
LTMemory(long initial,
          long maximum,
          Runnable logic)
```

Description

Create an LTMemory of the given size.

Parameters

initial The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

maximum The size in bytes of the memory to allocate for this area.

logic The `run()` of the given `Runnable` will be executed using `this` as its initial memory area. When `logic` is `null`, this constructor is equivalent to `LTMemory(long initial, long maximum)`⁵⁷.

Throws

`IllegalArgumentException` when `initial` is greater than `maximum`, or when `initial` or `maximum` is less than zero.

`javafx.runtime.StaticOutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

`javafx.runtime.IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

LTMemory(SizeEstimator, SizeEstimator)

Signature

```
public
LTMemory(SizeEstimator initial,
         SizeEstimator maximum)
```

Description

Create an `LTMemory` of the given size.

Parameters

`initial` An instance of `javafx.runtime.SizeEstimator`⁵⁸ used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

`maximum` An instance of `javafx.runtime.SizeEstimator`⁵⁹ used to give an estimate for the maximum bytes to allocate for this area.

Throws

`IllegalArgumentException` when `initial` is `null`, `maximum` is `null`, `initial.getEstimate()` is greater than `maximum.getEstimate()`, or when `initial.getEstimate()` is less than zero.

`javafx.runtime.StaticOutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

⁵⁷Section 11.5.3.1.1

⁵⁸Section 11.4.2.5

⁵⁹Section 11.4.2.5

LTMemory(SizeEstimator, SizeEstimator, Runnable)

Signature

```
public
LTMemory(SizeEstimator initial,
          SizeEstimator maximum,
          Runnable logic)
```

Description

Create an LTMemory of the given size.

Parameters

initial An instance of `javax.realtime.SizeEstimator`⁶⁰ used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

maximum An instance of `javax.realtime.SizeEstimator`⁶¹ used to give an estimate for the maximum bytes to allocate for this area.

logic The `run()` of the given `Runnable` will be executed using `this` as its initial memory area. When `logic` is `null`, this constructor is equivalent to `LTMemory(SizeEstimator initial, SizeEstimator maximum)`⁶².

Throws

`IllegalArgumentException` when `initial` is `null`, `maximum` is `null`, `initial.getEstimate()` is greater than `maximum.getEstimate()`, or when `initial.getEstimate()` is less than zero.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory for the LTMemory object or for the backing memory.

`javax.realtime.IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

LTMemory(long)

Signature

```
public
LTMemory(long size)
```

⁶⁰Section 11.4.2.5

⁶¹Section 11.4.2.5

⁶²Section 11.5.3.1.1

Description

Create an LTMemory of the given size. This constructor is equivalent to LTMemory(size, size)

Available since RTSJ 1.0.1

Parameters

size The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

Throws

IllegalArgumentException when **size** is less than zero.

javax.realtime.StaticOutOfMemoryError when there is insufficient memory for the LTMemory object or for the backing memory.

LTMemory(long, Runnable)

Signature

```
public
LTMemory(long size,
          Runnable logic)
```

Description

Create an LTMemory of the given size. This constructor is equivalent to LTMemory(size, size, logic).

Available since RTSJ 1.0.1

Parameters

size The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

logic The run() of the given Runnable will be executed using **this** as its initial memory area. When **logic** is null, this constructor is equivalent to LTMemory(long size)⁶³.

Throws

IllegalArgumentException when **size** is less than zero.

javax.realtime.StaticOutOfMemoryError when there is insufficient memory for the LTMemory object or for the backing memory.

⁶³Section 11.5.3.1.1

`javax.realtime.IllegalAssignmentError` when storing logic in this would violate the assignment rules.

LTMemory(SizeEstimator)

Signature

```
public  
LTMemory(SizeEstimator size)
```

Description

Create an LTMemory of the given size. This constructor is equivalent to `LTMemory(size, size)`.

Available since RTSJ 1.0.1

Parameters

size An instance of `javax.realtime.SizeEstimator`⁶⁴ used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

Throws

`IllegalArgumentException` when `size` is null, or `size.getEstimate()` is less than zero.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory for the LTMemory object or for the backing memory.

LTMemory(SizeEstimator, Runnable)

Signature

```
public  
LTMemory(SizeEstimator size,  
          Runnable logic)
```

Description

Create an LTMemory of the given size.

⁶⁴Section 11.4.2.5

Available since RTSJ 1.0.1*Parameters*

size An instance of `javax.realtime.SizeEstimator`⁶⁵ used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

logic The `run()` of the given `Runnable` will be executed using `this` as its initial memory area. When `logic` is null, this constructor is equivalent to `LMemory(SizeEstimator initial)`⁶⁶.

Throws

`IllegalArgumentException` when `size` is null, or `size.getEstimate()` is less than zero.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory for the `LMemory` object or for the backing memory.

`javax.realtime.IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

11.5.3.1.2 Methods

toString*Signature*

```
public
java.lang.String toString()
```

Description

Create a string representation of this object. The string is of the form (LMemory) Scoped memory # num where `num` uniquely identifies the `LMemory` area.

Returns

A string representing the value of `this`.

⁶⁵Section 11.4.2.5

⁶⁶Section 11.5.3.1.1

11.5.3.2 PhysicalMemoryFactory

Inheritance

```
java.lang.Object
  javax.realtime.memory.PhysicalMemoryFactory
```

Description

Both associate memory ranges, in the form of **PhysicalMemoryRegion**⁶⁷ instances with physical memory characteristics in the form of **PhysicalMemoryCharacteristic**⁶⁸ instances, and create memory areas in those modules.

Each physical memory module can have more than one physical memory characteristic. A physical memory characteristic can apply to many physical memory modules. The range of physical addresses of modules shall not overlap. A memory that spans more than one physical memory module may not be create.

The **PhysicalMemoryFactory** determines the physical addresses from the modules and keeps a relation between instances of **PhysicalMemoryRegion** and Physical Memory Addresses. The range of physical addresses of modules shall not overlap. A created memory are may not span more than one physical memory module. To find a memory range that supports PMC A and PMC B uses set intersection modules(A) \$ cap\$ modules(B)

Available since RTSJ 2.0

11.5.3.2.1 Constructors

PhysicalMemoryFactory

Signature

```
public
PhysicalMemoryFactory()
```

Description

⁶⁷Section 11.5.3.3

⁶⁸Section 11.5.1.1

11.5.3.2.2 Methods

associate(PhysicalMemoryCharacteristic, PhysicalMemoryRegion)

Signature

```
public static
void associate(PhysicalMemoryCharacteristic name,
               PhysicalMemoryRegion module)
throws IllegalArgumentException,
       IllegalStateException
```

Description

Associates a programmer-defined name with a physical address range.

Parameters

name is the physical memory characteristic. e.g STATIC_RAM.
module is the object representing a range of contiguous physical addresses

Throws

IllegalArgumentException when either name or module is null
 IllegalStateException when module overlaps a previously associated PhysicalMemoryRegion instance.

associate(PhysicalMemoryCharacteristic[], PhysicalMemoryRegion)

Signature

```
public static
void associate(javax.realtime.memory.PhysicalMemoryCharacteristic[] names,
               PhysicalMemoryRegion module)
throws IllegalArgumentException,
       IllegalStateException
```

Description

Associates an array of programmer-defined names with a physical address range.

Parameters

names is the array of physical memory characteristics. e.g STATIC_RAM.

`module` is the object representing a range of contiguous physical addresses

Throws

`IllegalArgumentException` when either `names` or `module` is null

`IllegalStateException` when `module` overlaps a previously associated `PhysicalMemoryRegion` instance.

associate(PhysicalMemoryCharacteristic, PhysicalMemoryRegion)

Signature

```
public static
void associate(PhysicalMemoryCharacteristic name,
               javax.realtime.memory.PhysicalMemoryRegion[] modules)
throws IllegalArgumentException,
       IllegalStateException
```

Description

Associates a programmer-defined name with an array of physical address ranges.

Parameters

`name` is the physical memory characteristic. e.g `STATIC_RAM`.

`modules` is an array of objects each representing a range of contiguous physical addresses

Throws

`IllegalArgumentException` when either `name` or `modules` is null

`IllegalStateException` when `module` overlaps a previously associated `PhysicalMemoryRegion` instance.

createStackedMemory(PhysicalMemorySelector, long, long, Runnable)

Signature

```
public
javax.realtime.memory.StackedMemory createStackedMemory(javax.realtime.memory.P
                                                         long scopeSize,
                                                         long backingSize,
                                                         Runnable logic)
```

throws `SecurityException`,
`SizeOutOfBoundsException`,
`UnsupportedPhysicalMemoryException`,
`MemoryTypeConflictException`,
`IllegalArgumentException`

Description

Instantiate a `StackedMemory`⁶⁹ object in a `PhysicalMemoryRegion`⁷⁰ matching the `PhysicalMemoryCharacteristic`⁷¹ in `selector` and then with virtual memory parameters of `selector` applied.

Parameters

`selector` to use to choose the memory module and set the virtual mapping
`scopeSize` is the size of the scope to be created
`backingSize` is the size of the backing store to take out of the selected module
`logic` the logic to execute on entry (may be null)

Throws

`SecurityException` when the application does not have permissions to access physical memory or the given range of memory.

`javax.realtime.SizeOutOfBoundsException` when the implementation detects that `size` extends beyond a physically addressable memory module.

`javax.realtime.UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryCharacteristic`⁷² has been registered with this `PhysicalMemoryFactory`.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when `type` specifies incompatible memory attributes.

`IllegalArgumentException` when `scopeSize` or `backingSize` is less than zero.

Returns

the new memory area

createPinnableMemory(PhysicalMemorySelector, long, Runnable)

⁶⁹Section 11.5.3.7

⁷⁰Section 11.5.3.3

⁷¹Section 11.5.1.1

⁷²Section 11.5.1.1

Signature

```

public
javafx.runtime.memory.PinnableMemory createPinnableMemory(javafx.runtime.memory
                                                                    long size,
                                                                    Runnable logic)

throws SecurityException,
        SizeOutOfBoundsException,
        UnsupportedPhysicalMemoryException,
        MemoryTypeConflictException,
        IllegalArgumentException

```

Description

Instantiate a [PinnableMemory](#)⁷³ object in a [PhysicalMemoryRegion](#)⁷⁴ matching the [PhysicalMemoryCharacteristic](#)⁷⁵ in `selector` and then with virtual memory parameters of `selector` applied.

Parameters

`selector` to use to choose the memory module and set the virtual mapping
`size` is the size of memory to be taken out of the selected module
`logic` the logic to execute on entry (may be `null`)

Throws

[SecurityException](#) when the application does not have permissions to access physical memory or the given range of memory.

[javafx.runtime.SizeOutOfBoundsException](#) when the implementation detects that `size` extends beyond a physically addressable memory module.

[javafx.runtime.UnsupportedPhysicalMemoryException](#) when the underlying hardware does not support the given type, or when no matching [PhysicalMemoryCharacteristic](#)⁷⁶ has been registered with this [PhysicalMemoryFactory](#).

[MemoryTypeConflictException](#) when the specified base does not point to memory that matches the requested type, or when `type` specifies incompatible memory attributes.

[IllegalArgumentException](#) when `size` is less than zero.

Returns

⁷³Section [11.5.3.5](#)

⁷⁴Section [11.5.3.3](#)

⁷⁵Section [11.5.1.1](#)

⁷⁶Section [11.5.1.1](#)

the new memory area

createImmortalMemory(PhysicalMemorySelector, long, Runnable)

Signature

```
public
javax.realtime.ImmortalMemory createImmortalMemory(javax.realtime.memory.PhysicalMemorySelector selector,
                                                    long size,
                                                    Runnable logic)

throws SecurityException,
       SizeOutOfBoundsException,
       UnsupportedPhysicalMemoryException,
       MemoryTypeConflictException,
       IllegalArgumentException
```

Description

Instantiate a `javax.realtime.ImmortalMemory`⁷⁷ object in a `PhysicalMemoryRegion`⁷⁸ matching the `PhysicalMemoryCharacteristic`⁷⁹ in `selector` and then with virtual memory parameters of `selector` applied.

Parameters

`selector` to use to choose the memory module and set the virtual mapping
`size` is the size of memory to be taken out of the selected module
`logic` the logic to execute on entry (may be null)

Throws

`SecurityException` when the application does not have permissions to access physical memory or the given range of memory.

`javax.realtime.SizeOutOfBoundsException` when the implementation detects that `size` extends beyond a physically addressable memory module.

`javax.realtime.UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryCharacteristic`⁸⁰ has been registered with this `PhysicalMemoryFactory`.

⁷⁷Section 11.4.2.2

⁷⁸Section 11.5.3.3

⁷⁹Section 11.5.1.1

⁸⁰Section 11.5.1.1

MemoryTypeConflictException when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

IllegalArgumentException when **size** is less than zero.

Returns

the new memory area

11.5.3.3 PhysicalMemoryRegion

Inheritance

java.lang.Object

javax.realtime.memory.PhysicalMemoryRegion

Description

Enable an application to define a range of physical memory addresses.

Available since RTSJ 2.0

11.5.3.3.1 Constructors

PhysicalMemoryRegion(long, long)

Signature

```
public  
PhysicalMemoryRegion(long base,  
                      long length)
```

Description

Creates an instance representing a range of contiguous physical memory.

Parameters

base is a physical address

length is size of contiguous memory from that base

Throws

`IllegalArgumentException` when length is less than or equal to 0, or when base is less than 0 or when this module overlaps with another memory module.
`javax.realtime.SizeOutOfBoundsException` when base + length is greater than the physical address range of the processor

11.5.3.3.2 Methods

getBase

Signature

```
public  
long getBase()
```

Description

Gets the base address of the contiguous memory represented by this.

Returns

the base address

getLength

Signature

```
public  
long getLength()
```

Description

Gets the length of the contiguous memory represented by this.

Returns

the length

11.5.3.4 PhysicalMemorySelector

Inheritance

```
java.lang.Object  
  javax.realtime.memory.PhysicalMemorySelector
```

Description

Provides both characteristics both for physical memory, used to select a memory range from a memory module, and for virtual memory to be used for setting the characteristics of the mapped pages.

Available since RTSJ 2.0

11.5.3.4.1 Constructors

PhysicalMemorySelector(PhysicalMemoryCharacteristic, VirtualMemoryCharacteristic, CachingBehavior, PagingBehavior)

Signature

```
public  
PhysicalMemorySelector(javax.realtime.memory.PhysicalMemoryCharacteristic[] pmc,  
                        javax.realtime.memory.VirtualMemoryCharacteristic[] vmc,  
                        PhysicalMemorySelector.CachingBehavior caching,  
                        PhysicalMemorySelector.PagingBehavior paging)
```

Description

11.5.3.4.2 Methods

getSupportedCachingBehavior

Signature

```
public static  
javax.realtime.memory.PhysicalMemorySelector.CachingBehavior[] getSupportedCach
```

Description

Get the caching behaviors that are supported by this JVM

Returns

an array of the supported caching behaviors.

getSupportedPagingBehavior*Signature*

```
public static  
    javax.realtime.memory.PhysicalMemorySelector.PagingBehavior[] getSupportedPagingBehaviors()
```

Description

Get the paging behaviors that are supported by this JVM

Returns

an array of the supported paging behaviors.

getPhysicalMemoryCharacteristics*Signature*

```
public  
    javax.realtime.memory.PhysicalMemoryCharacteristic[] getPhysicalMemoryCharacteristics()
```

Description

A getter for the PhysicalMemoryCharacteristic list to be requested

Returns

the PhysicalMemoryCharacteristic list

getVirtualMemoryCharateristics*Signature*

```
public  
    javax.realtime.memory.VirtualMemoryCharacteristic[] getVirtualMemoryCharateristics()
```

Description

A getter for the VirtualMemoryCharacteristic list to be requested

Returns

the VirtualMemoryCharacteristic list

getCachingBehavior

Signature

```
public  
javax.realtime.memory.PhysicalMemorySelector.CachingBehavior getCachingBehavior
```

Description

A getter for the `CachingBehavior` to be requested

Returns

the `CachingBehavior`

getPagingPagingBehavior

Signature

```
public  
javax.realtime.memory.PhysicalMemorySelector.PagingBehavior getPagingPagingBeha
```

Description

A getter for the `PagingBehavior` to be requested

Returns

the `PagingBehavior`

11.5.3.5 PinnableMemory

Inheritance

```
java.lang.Object  
  javax.realtime.MemoryArea  
    javax.realtime.memory.ScopedMemory  
      javax.realtime.memory.PinnableMemory
```

Description

This class is for passing information between different threads as in the producer consumer pattern. One thread can enter an empty `PinnableMemory`, allocate some data structure, put a reference in the portal, pin the scope, exit it, and then pass it to another thread for further processing or consumption. Once the last thread is done, the memory can be unpinned, causing its contents to be freed.

Available since RTSJ 2.0

11.5.3.5.1 Constructors

PinnableMemory(long)

Signature

```
public  
PinnableMemory(long size)
```

Description

Create a scope of fixed size.

Parameters

size is the number of bytes in the memory area.

PinnableMemory(SizeEstimator)

Signature

```
public  
PinnableMemory(SizeEstimator size)
```

Description

Create a scope of fixed size.

Parameters

size is an estimator for determining the number of bytes in the memory area.

11.5.3.5.2 Methods

pin

Signature

```
public  
void pin()
```


Description

Prevent the contents from being freed.

unpin*Signature*

```
public  
void unpin()
```

Description

Allow the contents to be freed the next time no `javax.realtime.Schedulable`⁸¹ or `javax.realtime.AsyncBaseEvent`⁸² is active within the scope.

isPinned*Signature*

```
public  
boolean isPinned()
```

Description

Determine whether the scope may be cleared on last exit.

Returns

true when yes, otherwise false.

getPinCount*Signature*

```
public  
int getPinCount()
```

Description

Find out how many times the scope has been pinned, but not unpinned.

Returns

the number of outstanding pins.

⁸¹Section 6.4.1.3

⁸²Section 8.4.3.2

joinPinned

Signature

```
public  
void joinPinned()  
throws InterruptedException
```

Description

Wait until the scope has been cleared and then pin it.

joinPinned(HighResolutionTime)

Signature

```
public  
void joinPinned(javax.realtime.HighResolutionTime<T> limit)  
throws InterruptedException
```

Description

Wait until the scope has been cleared and then pin it, within a specified time frame.

Parameters

`limit` is the maximum time to wait

joinPinnedAndEnter(Runnable)

Signature

```
public  
void joinPinnedAndEnter(Runnable logic)  
throws InterruptedException,  
    ScopedCycleException
```

Description

Wait until the scope has been cleared and then pin it and enter it.

Parameters

`logic` is the logic to execute upon entry

joinPinnedAndEnter(Runnable, HighResolutionTime)

Signature

```
public
void joinPinnedAndEnter(Runnable logic,
                        javax.realtime.HighResolutionTime<T> limit)
throws InterruptedException,
    ScopedCycleException
```

Description

Wait until the scope has been cleared and then pin it and enter it, within a specified time frame.

Parameters

`logic` is the logic to execute upon entry
`limit` is the maximum time to wait.

joinPinnedAndEnter

Signature

```
public
void joinPinnedAndEnter()
throws InterruptedException,
    IllegalThreadStateException,
    ThrowBoundaryError,
    ScopedCycleException,
    MemoryAccessError
```

Description

Wait until the scope has been cleared and then pin it and enter it.

joinPinnedAndEnter(HighResolutionTime)

Signature

```
public
void joinPinnedAndEnter(javax.realtime.HighResolutionTime<T> limit)
throws InterruptedException,
    IllegalThreadStateException,
    IllegalArgumentException,
    UnsupportedOperationException,
```

ThrowBoundaryError,
 ScopedCycleException,
 MemoryAccessError

Description

Wait until the scope has been cleared and then pin it and enter it, within a specified time frame.

Parameters

`limit` is the maximum time to wait.

11.5.3.6 ScopedMemory

Inheritance

java.lang.Object
 javax.realtime.MemoryArea
 javax.realtime.memory.ScopedMemory

Description

ScopedMemory is the abstract base class of all classes dealing with representations of memory spaces which have a limited lifetime. In general, objects allocated in scoped memory are freed when (and only when) no schedulable object has access to the objects in the scoped memory.

A **ScopedMemory** area is a connection to a particular region of memory and reflects the current status of that memory. The object does not necessarily contain direct references to the region of memory. That is implementation dependent.

When a **ScopedMemory** area is instantiated, the object itself is allocated from the current memory allocation context, but the memory space that object represents (it's backing store) is allocated from memory that is not otherwise directly visible to Java code; e.g., it might be allocated with the C `malloc` function. This backing store behaves effectively as if it were allocated when the associated scoped memory object is constructed and freed at that scoped memory object's finalization.

The **ScopedMemory.enter**⁸³ method of **ScopedMemory** is one mechanism used to make a memory area the current allocation context. The other mechanism for activating a memory area is making it the initial memory area for a realtime thread or async event handler. Entry into the scope is accomplished, for example, by calling the

```
public void enter(Runnable logic)
```

⁸³Section 11.5.3.6.2

where `logic` is a instance of `Runnable` whose `run()` method represents the entry point of the code that will run in the new scope. Exit from the scope occurs between the time the `runnable.run()` method completes and the time control returns from the `enter` method. By default, allocations of objects within `runnable.run()` are taken from the backing store of the `ScopedMemory`.

`ScopedMemory` is an abstract class, but all specified methods include implementations. The responsibilities of `MemoryArea`, `ScopedMemory` and the classes that extend `ScopedMemory` are not specified. Application code should not extend `ScopedMemory` without detailed knowledge of its implementation. since RTSJ 2.0

11.5.3.6.1 Constructors

ScopedMemory(long)

Signature

```
public  
    ScopedMemory(long size)
```

Description

Create a new `ScopedMemory` area with the given parameters.

Parameters

`size` of the new `ScopedMemory` area in bytes.

Throws

`IllegalArgumentException` when `size` is less than zero.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory for the `ScopedMemory` object or for the backing memory.

ScopedMemory(long, Runnable)

Signature

```
public  
    ScopedMemory(long size,  
                  Runnable logic)
```

Description

Create a new `ScopedMemory` area with the given parameters.

Parameters

size The size of the new `ScopedMemory` area in bytes.
logic The `Runnable` to execute when this `ScopedMemory` is entered. When **logic** is `null`, this constructor is equivalent to constructing the memory area without a logic value.

Throws

`IllegalArgumentException` when **size** is less than zero.
`javax.realtime.IllegalAssignmentError` when storing **logic** in this would violate the assignment rules.
`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory for the `ScopedMemory` object or for the backing memory.

ScopedMemory(SizeEstimator)*Signature*

```
public
ScopedMemory(SizeEstimator size)
```

Description

Create a new `ScopedMemory` area with the given parameters.

Parameters

size The size of the new `ScopedMemory` area estimated by an instance of `javax.realtime.SizeEstimator`⁸⁴.

Throws

`IllegalArgumentException` when **size** is `null`, or **size.getEstimate()** is negative.
`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory for the `ScopedMemory` object or for the backing memory.

ScopedMemory(SizeEstimator, Runnable)*Signature*

⁸⁴Section 11.4.2.5

```
public
ScopedMemory(SizeEstimator size,
              Runnable logic)
```

Description

Create a new `ScopedMemory` area with the given parameters.

Parameters

size The size of the new `ScopedMemory` area estimated by an instance of `javax.realtime.SizeEstimator`⁸⁵.

logic The logic which will use the memory represented by `this` as its initial memory area. When `logic` is `null`, this constructor is equivalent to constructing the memory area without a logic value.

Throws

`IllegalArgumentException` when `size` is `null`, or `size.getEstimate()` is negative.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory for the `ScopedMemory` object or for the backing memory.

`javax.realtime.IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

11.5.3.6.2 Methods

enter

Signature

```
public
void enter()
```

Description

Associate this memory area with the current schedulable for the duration of the execution of the `run()` method of the instance of `Runnable` given in the constructor. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected (using `enter`, or `executeInArea`⁸⁶) or the `enter` method exits.

⁸⁵Section 11.4.2.5

⁸⁶Section 11.5.3.6.2

Throws

`javax.realtime.ScopedCycleException` when this invocation would break the single parent rule.

`javax.realtime.ThrowBoundaryError` Thrown when the JVM needs to propagate an exception allocated in `this` scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `javax.realtime.IllegalAssignmentError` so the JVM cannot be permitted to deliver the exception. The `javax.realtime.ThrowBoundaryError` is allocated in the current allocation context and contains information about the exception it replaces.

`IllegalThreadStateException` when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

`IllegalArgumentException` `IllegalArgumentException` when the caller is a schedulable and a `null` value for `logic` was supplied when the memory area was constructed.

`MemoryAccessError` `MemoryAccessError` when caller is a schedulable that may not use the heap and this memory area's `logic` value is allocated in heap memory.

enter(Runnable)*Signature*

```
public
void enter(Runnable logic)
```

Description

Associate this memory area with the current schedulable for the duration of the execution of the `run()` method of the given `Runnable`. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected (using `enter`, or `executeInArea`⁸⁹) or the `enter` method exits.

Parameters

`logic` `logic` The `Runnable` object whose `run()` method should be invoked.

⁸⁷Section 15.3.3.2

⁸⁸Section 15.3.3.8

⁸⁹Section 11.5.3.6.2

Throws

`javax.realtime.ScopedCycleException` when this invocation would break the single parent rule.

`javax.realtime.ThrowBoundaryError` Thrown when the JVM needs to propagate an exception allocated in `this` scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `javax.realtime.IllegalAssignment` so the JVM cannot be permitted to deliver the exception. The `javax.realtime.ThrowBoundaryError` is allocated in the current allocation context and contains information about the exception it replaces.

`IllegalThreadStateException` when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

`IllegalArgumentException` `IllegalArgumentException` when the caller is a schedulable and `logic` is `null`.

enter(Supplier)

Signature

```
public  
T enter(java.util.function.Supplier<T> logic)
```

Description

Same as `enter(Runnable)`⁹² except that the executed method is called `get` and an object is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

enter(BooleanSupplier)

Signature

⁹⁰Section 15.3.3.2

⁹¹Section 15.3.3.8

⁹²Section 11.5.3.6.2

```
public  
boolean enter(BooleanSupplier logic)
```

Description

Same as `enter(Runnable)`⁹³ except that the executed method is called `get` and a `boolean` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

enter(IntSupplier)

Signature

```
public  
int enter(IntSupplier logic)
```

Description

Same as `enter(Runnable)`⁹⁴ except that the executed method is called `get` and an `int` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

enter(LongSupplier)

Signature

```
public  
long enter(LongSupplier logic)
```

Description

Same as `enter(Runnable)`⁹⁵ except that the executed method is called `get` and a `long` is returned.

⁹³Section 11.5.3.6.2

⁹⁴Section 11.5.3.6.2

⁹⁵Section 11.5.3.6.2

Parameters

`logic` the object who's get method will be executed.

Returns

a result from the computation.

enter(DoubleSupplier)*Signature*

```
public
double enter(DoubleSupplier logic)
```

Description

Same as `enter(Runnable)`⁹⁶ except that the executed method is called `get` and a `double` is returned.

Parameters

`logic` the object who's get method will be executed.

Returns

a result from the computation.

executeInArea(Runnable)*Signature*

```
public
void executeInArea(Runnable logic)
```

Description

Execute the run method from the `logic` parameter using this memory area as the current allocation context. This method behaves as if it moves the allocation context down the scope stack to the occurrence of `this`.

Parameters

`logic` The runnable object whose `run()` method should be executed.

Throws

`IllegalThreadStateException` when the caller is a Java thread.

`InaccessibleAreaException` when the memory area is not in the schedulable's scope stack.

`IllegalArgumentException` when the caller is a schedulable and `logic` is `null`.

⁹⁶Section 11.5.3.6.2

executeInArea(Supplier)

Signature

```
public  
T executeInArea(java.util.function.Supplier<T> logic)
```

Description

Same as `executeInArea(Runnable)`⁹⁷ except that the executed method is called `get` and an object is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

executeInArea(BooleanSupplier)

Signature

```
public  
boolean executeInArea(BooleanSupplier logic)
```

Description

Same as `executeInArea(Runnable)`⁹⁸ except that the executed method is called `get` and a boolean is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

executeInArea(IntSupplier)

Signature

```
public  
int executeInArea(IntSupplier logic)
```

Description

⁹⁷Section 11.5.3.6.2

⁹⁸Section 11.5.3.6.2

Same as `executeInArea(Runnable)`⁹⁹ except that the executed method is called `get` and an `int` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

executeInArea(LongSupplier)

Signature

```
public  
long executeInArea(LongSupplier logic)
```

Description

Same as `executeInArea(Runnable)`¹⁰⁰ except that the executed method is called `get` and a `long` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

executeInArea(DoubleSupplier)

Signature

```
public  
double executeInArea(DoubleSupplier logic)
```

Description

Same as `executeInArea(Runnable)`¹⁰¹ except that the executed method is called `get` and a `double` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

⁹⁹Section 11.5.3.6.2

¹⁰⁰Section 11.5.3.6.2

¹⁰¹Section 11.5.3.6.2

getPortal

Signature

```
public  
java.lang.Object getPortal()
```

Description

Return a reference to the portal object in this instance of **ScopedMemory**.

Assignment rules are enforced on the value returned by **getPortal** as if the return value were first stored in an object allocated in the current allocation context, then moved to its final destination.

Throws

javax.realtime.IllegalAssignmentError when a reference to the portal object cannot be stored in the caller's allocation context; that is, when **this** is "inner" relative to the current allocation context or not on the caller's scope stack.

IllegalThreadStateException when the caller is a Java thread.

Returns

A reference to the portal object or **null** when there is no portal object. The portal value is always set to **null** when the contents of the memory are deleted.

getReferenceCount

Signature

```
public  
int getReferenceCount()
```

Description

Returns the reference count of this **ScopedMemory**.

Note: A reference count of 0 reliably means that the scope is not referenced, but other reference counts are subject to artifacts of lazy/eager maintenance by the implementation.

Returns

The reference count of this **ScopedMemory**.

join

Signature

```
public  
void join()  
throws InterruptedException
```

Description

Wait until the reference count of this **ScopedMemory** goes down to zero. Return immediately when the memory is unreferenced.

Throws

InterruptedException When this schedulable is interrupted by `javax.realtime.RealtimeThread` or `javax.realtime.AsynchronouslyInterruptedException.fire()`¹⁰³ while waiting for the reference count to go to zero.

IllegalThreadStateException when the caller is a Java thread.

join(HighResolutionTime)

Signature

```
public  
void join(javax.realtime.HighResolutionTime<?> time)  
throws InterruptedException
```

Description

Wait at most until the time designated by the **time** parameter for the reference count of this **ScopedMemory** to drop to zero. Return immediately when the memory area is unreferenced.

Since the time is expressed as a `javax.realtime.HighResolutionTime`¹⁰⁴, this method is an accurate timer with nanosecond granularity. The actual resolution of the timer and even the quantity it measures depends on the clock associated with **time**. The delay time may be relative or absolute. When relative, then the delay is the amount of time given by **time**, and measured by its associated clock. When absolute, then the delay is until the indicated value is reached by the clock. When the given absolute time is less than or equal to the current value of the clock, the call to **join** returns immediately.

¹⁰²Section 5.4.1

¹⁰³Section 8.4.2.1.2

¹⁰⁴Section 9.4.1.2

Parameters

time When this time is an absolute time, the wait is bounded by that point in time. When the time is a relative time (or a member of the `RationalTime` subclass of `RelativeTime`) the wait is bounded by a the specified interval from some time between the time `join` is called and the time it starts waiting for the reference count to reach zero.

Throws

`InterruptedException` When this schedulable is interrupted by `javax.realtime.RealtimeThread` or `javax.realtime.AsynchronouslyInterruptedException.fire()`¹⁰⁶ while waiting for the reference count to go to zero.

`IllegalThreadStateException` when the caller is a Java thread.

`IllegalArgumentException` when the caller is a schedulable and **time** is `null`.

`UnsupportedOperationException` when the wait operation is not supported using the clock associated with **time**.

joinAndEnter

Signature

```
public
void joinAndEnter()
throws InterruptedException
```

Description

In the error-free case, `joinAndEnter` combines `join();enter();` such that no `enter()` from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this `ScopedMemory` to reach zero, then enter the `ScopedMemory` and execute the `run` method from logic passed in the constructor. When no instance of `Runnable` was passed to the memory area's constructor, the method throws `IllegalArgumentException` immediately.

When multiple threads are waiting in `joinAndEnter` family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Note that although `joinAndEnter` guarantees that the reference count is zero when the schedulable is released for entry, it does not guarantee that the reference count will remain one for any length of time. A subsequent `enter` could raise the reference count to two.

¹⁰⁵Section 5.4.1

¹⁰⁶Section 8.4.2.1.2

Throws

InterruptedException When this schedulable is interrupted by `javax.realtime.RealtimeThread` or `javax.realtime.AsynchronouslyInterruptedException.fire()`¹⁰⁸ while waiting for the reference count to go to zero.

IllegalThreadStateException when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

javax.realtime.ThrowBoundaryError Thrown when the JVM needs to propagate an exception allocated in this scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `javax.realtime.IllegalAssignmentException` so the JVM cannot be permitted to deliver the exception. The `javax.realtime.ThrowBoundaryError` is allocated in the current allocation context and contains information about the exception it replaces.

javax.realtime.ScopedCycleException when this invocation would break the single parent rule.

IllegalArgumentException when the caller is a schedulable and no non-null logic value was supplied to the memory area's constructor.

MemoryAccessError when caller is a non-heap schedulable and this memory area's logic value is allocated in heap memory.

joinAndEnter(HighResolutionTime)*Signature*

```
public
void joinAndEnter(javax.realtime.HighResolutionTime<?> time)
throws InterruptedException
```

Description

In the error-free case, `joinAndEnter` combines `join();enter();` such that no `enter()` from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this `ScopedMemory` to reach zero, or for the current time to reach the designated time, then enter the `ScopedMemory` and execute the `run` method from `Runnable` object passed to the

¹⁰⁷Section 5.4.1

¹⁰⁸Section 8.4.2.1.2

¹⁰⁹Section 15.3.3.2

¹¹⁰Section 15.3.3.8

constructor. When no instance of `Runnable` was passed to the memory area's constructor, the method throws `IllegalArgumentException` immediately. *

When multiple threads are waiting in `joinAndEnter` family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Since the time is expressed as a `javax.realtime.HighResolutionTime`¹¹¹, this method has an accurate timer with nanosecond granularity. The actual resolution of the timer and even the quantity it measures depends on the clock associated with `time`. The delay time may be relative or absolute. When relative, then the calling thread is blocked for at most the amount of time given by `time`, and measured by its associated clock. When absolute, then the time delay is until the indicated value is reached by the clock. When the given absolute time is less than or equal to the current value of the clock, the call to `joinAndEnter` behaves effectively like `enter`¹¹².

Note that expiration of `time` may cause control to enter the memory area before its reference count has gone to zero.

Parameters

`time` The time that bounds the wait.

Throws

`javax.realtime.ThrowBoundaryError` Thrown when the JVM needs to propagate an exception allocated in `this` scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `javax.realtime.IllegalAssignmentError` so the JVM cannot be permitted to deliver the exception. The `javax.realtime.ThrowBoundaryError` is allocated in the current allocation context and contains information about the exception it replaces.

`InterruptedException` When this schedulable is interrupted by `javax.realtime.RealtimeThread` or `javax.realtime.AsynchronouslyInterruptedException`.¹¹⁶ `fire()` while waiting for the reference count to go to zero.

`IllegalThreadStateException` when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

¹¹¹Section 9.4.1.2

¹¹²Section 11.5.3.6.2

¹¹³Section 15.3.3.2

¹¹⁴Section 15.3.3.8

¹¹⁵Section 5.4.1

¹¹⁶Section 8.4.2.1.2

`javax.realtime.ScopedCycleException` when the caller is a schedulable and this invocation would break the single parent rule.

`IllegalArgumentException` when the caller is a schedulable, and `time` is `null` or no non-`null` `logic` value was supplied to the memory area's constructor.

`UnsupportedOperationException` when the wait operation is not supported using the clock associated with `time`.

`MemoryAccessError` when calling schedulable may not use the heap and this memory area's `logic` value is allocated in heap memory.

joinAndEnter(Runnable)

Signature

```
public
void joinAndEnter(Runnable logic)
throws InterruptedException
```

Description

In the error-free case, `joinAndEnter` combines `join();enter();` such that no `enter()` from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this `ScopedMemory` to reach zero, then enter the `ScopedMemory` and execute the `run` method from `logic`.

When `logic` is `null`, throw `IllegalArgumentException` immediately.

When multiple threads are waiting in `joinAndEnter` family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Note that although `joinAndEnter` guarantees that the reference count is zero when the schedulable is released for entry, it does not guarantee that the reference count will remain one for any length of time. A subsequent `enter` could raise the reference count to two.

Parameters

`logic` The `Runnable` object which contains the code to execute.

Throws

`InterruptedException` When this schedulable is interrupted by `javax.realtime.RealtimeThread.interrupt()` or `javax.realtime.AsynchronouslyInterruptedException.fire()`¹¹⁸ while waiting for the reference count to go to zero.

¹¹⁷Section 5.4.1

¹¹⁸Section 8.4.2.1.2

`IllegalThreadStateException` when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

`javax.realtime.ThrowBoundaryError` Thrown when the JVM needs to propagate an exception allocated in **this** scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `javax.realtime.IllegalAssignmentError` so the JVM cannot be permitted to deliver the exception. The `javax.realtime.ThrowBoundaryError` is allocated in the current allocation context and contains information about the exception it replaces.

`javax.realtime.ScopedCycleException` when this invocation would break the single parent rule.

`IllegalArgumentException` when the caller is a schedulable and `logic` is null.

joinAndEnter(Supplier)

Signature

```
public
T joinAndEnter(java.util.function.Supplier<T> logic)
```

Description

Same as `joinAndEnter(Runnable)`¹²¹ except that the executed method is called `get` and an object is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

joinAndEnter(BooleanSupplier)

Signature

```
public
boolean joinAndEnter(BooleanSupplier logic)
```

¹¹⁹Section 15.3.3.2

¹²⁰Section 15.3.3.8

¹²¹Section 11.5.3.6.2

Description

Same as `joinAndEnter(Runnable)`¹²² except that the executed method is called `get` and a `boolean` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

joinAndEnter(IntSupplier)

Signature

```
public  
int joinAndEnter(IntSupplier logic)
```

Description

Same as `joinAndEnter(Runnable)`¹²³ except that the executed method is called `get` and an `int` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

joinAndEnter(LongSupplier)

Signature

```
public  
long joinAndEnter(LongSupplier logic)
```

Description

Same as `joinAndEnter(Runnable)`¹²⁴ except that the executed method is called `get` and a `long` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

¹²²Section 11.5.3.6.2

¹²³Section 11.5.3.6.2

¹²⁴Section 11.5.3.6.2

joinAndEnter(DoubleSupplier)

Signature

```
public  
double joinAndEnter(DoubleSupplier logic)
```

Description

Same as `joinAndEnter(Runnable)`¹²⁵ except that the executed method is called `get` and a `double` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

joinAndEnter(Runnable, HighResolutionTime)

Signature

```
public  
void joinAndEnter(Runnable logic,  
                  javax.realtime.HighResolutionTime<?> time)  
throws InterruptedException
```

Description

In the error-free case, `joinAndEnter` combines `join();enter();` such that no `enter()` from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this `ScopedMemory` to reach zero, or for the current time to reach the designated time, then enter the `ScopedMemory` and execute the `run` method from `logic`.

Since the time is expressed as a `javax.realtime.HighResolutionTime`¹²⁶, this method is an accurate timer with nanosecond granularity. The actual resolution of the timer and even the quantity it measures depends on the clock associated with `time`. The delay time may be relative or absolute. When relative, then the delay is the amount of time given by `time`, and measured by its associated clock. When absolute, then the delay is until the indicated value is reached by the clock. When the given absolute time is less than or equal to the current value of the clock, the call to `joinAndEnter` behaves effectively like `enter(Runnable)`¹²⁷.

¹²⁵Section 11.5.3.6.2

¹²⁶Section 9.4.1.2

¹²⁷Section 11.5.3.6.2

Throws `IllegalArgumentException` immediately when `logic` is `null`.

When multiple threads are waiting in `joinAndEnter` family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Note that expiration of `time` may cause control to enter the memory area before its reference count has gone to zero.

Parameters

`logic` The `Runnable` object which contains the code to execute.

`time` The time that bounds the wait.

Throws

`InterruptedException` When this schedulable is interrupted by `javafx.realtime.RealtimeThread` or `javafx.realtime.AsynchronouslyInterruptedException.fire()`¹²⁹ while waiting for the reference count to go to zero.

`IllegalThreadStateException` when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

`javafx.realtime.ThrowBoundaryError` Thrown when the JVM needs to propagate an exception allocated in `this` scope to (or through) the memory area of the caller. Storing a reference to that exception would cause a `javafx.realtime.IllegalAssignmentException` so the JVM cannot be permitted to deliver the exception. The `javafx.realtime.ThrowBoundaryError` is preallocated and saves information about the exception it replaces.

`javafx.realtime.ScopedCycleException` when the caller is a schedulable and this invocation would break the single parent rule.

`IllegalArgumentException` when the caller is a schedulable and `time` or `logic` is `null`.

`UnsupportedOperationException` when the wait operation is not supported using the clock associated with `time`.

joinAndEnter(Supplier, HighResolutionTime)

Signature

`public`

¹²⁸Section 5.4.1

¹²⁹Section 8.4.2.1.2

¹³⁰Section 15.3.3.2

¹³¹Section 15.3.3.8

```
P joinAndEnter(java.util.function.Supplier<P> logic,
               javax.realtime.HighResolutionTime<?> time)
```

Description

Same as `joinAndEnter(Runnable, HighResolutionTime)`¹³² except that the executed method is called `get` and an object is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

joinAndEnter(BooleanSupplier, HighResolutionTime)*Signature*

```
public
boolean joinAndEnter(BooleanSupplier logic,
                     javax.realtime.HighResolutionTime<?> time)
```

Description

Same as `joinAndEnter(Runnable, HighResolutionTime)`¹³³ except that the executed method is called `get` and a `boolean` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

joinAndEnter(IntSupplier, HighResolutionTime)*Signature*

```
public
int joinAndEnter(IntSupplier logic,
                 javax.realtime.HighResolutionTime<?> time)
```

Description

¹³²Section 11.5.3.6.2

¹³³Section 11.5.3.6.2

Same as `joinAndEnter(Runnable, HighResolutionTime)`¹³⁴ except that the executed method is called `get` and an `int` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

joinAndEnter(LongSupplier, HighResolutionTime)

Signature

```
public
long joinAndEnter(LongSupplier logic,
                  javax.realtime.HighResolutionTime<?> time)
```

Description

Same as `joinAndEnter(Runnable, HighResolutionTime)`¹³⁵ except that the executed method is called `get` and a `long` is returned.

Parameters

`logic` the object who's `get` method will be executed.

Returns

a result from the computation.

joinAndEnter(DoubleSupplier, HighResolutionTime)

Signature

```
public
double joinAndEnter(DoubleSupplier logic,
                   javax.realtime.HighResolutionTime<?> time)
```

Description

Same as `joinAndEnter(Runnable, HighResolutionTime)`¹³⁶ except that the executed method is called `get` and a `double` is returned.

Parameters

`logic` the object who's `get` method will be executed.

¹³⁴Section 11.5.3.6.2

¹³⁵Section 11.5.3.6.2

¹³⁶Section 11.5.3.6.2

Returns

a result from the computation.

getParent*Signature*

```
public
  javax.realtime.MemoryArea getParent()
```

Description

Return a reference to this scopes parent scope (e.g., its parent in the single-parent-rule tree).

Returns

- a reference to the next outer scoped memory region on the caller's scope stack.
- When there is no outer scoped memory and the primordial parent is heap memory, return a reference to **this**.
- When there is no outer scoped memory and the primordial parent is immortal, or when **this** is unreferenced and unpinned, return **null**

*Problem. The single-parent tree is RTT-independent except for the primordial scope. The type of the primordial scope is RTT-dependent. What should we do about that? When called from a RTT that has entered **this**, the above rules make some sense, but what if the caller has not even entered the scope, should we throw an exception? Or just return **null**? I think the right solution is to return **this** whatever the type of the primordial scope. The app can then know that **null** means the scope is not pinned and not referenced, and **this** means the parent is either heap or immortal. At that point, the app can learn what it wants to know by just finding what memory area contains the scope object.*

Available since RTSJ 2.0

visitNestedMemory(MemoryAreaVisitor)*Signature*

```
public
  R visitNestedMemory(javax.realtime.MemoryAreaVisitor<R> visitor)
```

Description

A means of accessing all live nested memory areas contained in this memory area, even those to which no reference exists, such a `javax.realtime.memory.PinnableMemory`¹³⁷ that is pinned or another `javax.realtime.memory.ScopedMemory` that contains a `Schedulable`. The set may be concurrently modified by other tasks, but the view seen by the visitor may not be updated to reflect those changes. The following is guarantees even when the set is disturbed by other tasks:

- the visitor shall visit no member more than once,
- it shall visit only scopes that were a member of the set at some time during the enumeration of the set, and
- it shall visit all the scopes that are not deleted during the execution of the visitor.

Perform an action on all children scopes of this memory area, so long as the `MemoryAreaVisitor.visit(MemoryArea)`¹³⁸ method returns `null`. When that method returns an object, the visit is terminated and that object is returned by this method,

When execution of the visitor's visit method terminated abruptly by throwing an exception, then execution of `visitScopedChildren` also terminates abruptly by throwing the same exception.

Throws

`IllegalArgumentException` when visitor is `null`.

`newArray(Class, int)`

Signature

```
public
java.lang.Object newArray(java.lang.Class<?> type,
                           int number)
```

Description

Allocate an array of the given type in this memory area. This method may be concurrently used by multiple threads.

Parameters

type `type` The class of the elements of the new array. To create an array of a primitive type use a `type` such as `Integer.TYPE` (which would call for an array of the primitive `int` type.)

number `number` The number of elements in the new array.

¹³⁷Section 11.5.3.5

¹³⁸Section 11.4.1.1.1

Throws

`IllegalArgumentException` `IllegalArgumentException` when `number` is less than zero, `type` is null, or `type` is `java.lang.Void.TYPE`.

`javax.realtime.StaticOutOfMemoryError` null

`IllegalThreadStateException` when the caller is a Java thread.

`InaccessibleAreaException` when the memory area is not in the schedulable's scope stack.

Returns

A new array of class `type`, of `number` elements.

newInstance(Class)*Signature*

```
public
T newInstance(java.lang.Class<T> type)
throws IllegalAccessException,
    InstantiationException
```

Description

Allocate an object in this memory area. This method may be concurrently used by multiple threads.

Parameters

`type` `type` The class of which to create a new instance.

Throws

`IllegalAccessException` `IllegalAccessException` The class or initializer is inaccessible.

`IllegalArgumentException` `IllegalArgumentException` when `type` is null.

`ExceptionInInitializerError` `ExceptionInInitializerError` when an unexpected exception has occurred in a static initializer

`javax.realtime.StaticOutOfMemoryError` null

`InstantiationException` `InstantiationException` when the specified class object could not be instantiated. Possible causes are: it is an interface, it is abstract, it is an array, or an exception was thrown by the constructor.

`IllegalThreadStateException` when the caller is a Java thread.

`InaccessibleAreaException` when the memory area is not in the schedulable's scope stack.

Returns

A new instance of class `type`.

newInstance(Constructor, Object)

Signature

```
public
T newInstance(java.lang.reflect.Constructor<T> c,
              java.lang.Object[] args)
throws IllegalAccessException,
      InstantiationException,
      InvocationTargetException
```

Description

Allocate an object in this memory area. This method may be concurrently used by multiple threads.

Parameters

`c` `T c` The constructor for the new instance.

`args` `args` An array of arguments to pass to the constructor.

Throws

`IllegalAccessException` `IllegalAccessException` when the class or initializer is inaccessible under Java access control.

`InstantiationException` `InstantiationException` when the specified class object could not be instantiated. Possible causes are: it is an interface, it is abstract, it is an array.

`javax.realtime.StaticOutOfMemoryError` `null`

`IllegalArgumentException` `IllegalArgumentException` when `c` is `null`, or the `args` array does not contain the number of arguments required by `c`. A `null` value of `args` is treated like an array of length 0.

`IllegalThreadStateException` when the caller is a Java thread.

`InvocationTargetException` `InvocationTargetException` when the underlying constructor throws an exception.

`InaccessibleAreaException` when the memory area is not in the schedulable's scope stack.

Returns

A new instance of the object constructed by `c`.

setPortal(Object)

Signature

```
public  
void setPortal(Object object)
```

Description

Sets the *portal* object of the memory area represented by this instance of **ScopedMemory** to the given object. The object must have been allocated in this **ScopedMemory** instance.

Parameters

object The object which will become the portal for this. When **null** the previous portal object remains the portal object for this or when there was no previous portal object then there is still no portal object for **this**.

Throws

IllegalThreadStateException when the caller is a Java Thread.
javax.realtime.IllegalAssignmentError when the caller is a schedulable, and **object** is not allocated in this scoped memory instance and not **null**.
InaccessibleAreaException when the caller is a schedulable, **this** memory area is not in the caller's scope stack and **object** is not **null**.

toString

Signature

```
public  
java.lang.String toString()
```

Description

Returns a user-friendly representation of this **ScopedMemory** of the form "**ScopedMemory**#<num>" where <num> is a number that uniquely identifies this scoped memory area.

Returns

The string representation

11.5.3.7 StackedMemory

Inheritance

```
java.lang.Object
  javax.realtime.MemoryArea
    javax.realtime.memory.ScopedMemory
      javax.realtime.memory.StackedMemory
```

Description

StackedMemory implements a scoped memory allocation area and backing store management system. It is designed to allow for safe, fragmentation-free management of scoped allocation with certain strong guarantees provided by the virtual machine and runtime libraries.

Each **StackedMemory** instance represents a single object allocation area and additional memory associated with it in the form of a *backing store*. The backing store associated with a **StackedMemory** is a fixed-size memory area allocated at or before instantiation of the **StackedMemory**. The object allocation area is taken from the associated backing store, and the backing store may be further subdivided into additional **StackedMemory** allocation areas or backing stores by instantiating additional **StackedMemory** objects.

When a **StackedMemory** is created with a backing store, the backing store may be taken from a notional global backing store, in which case it is effectively immortal, or it may be taken from the enclosing **StackedMemory**'s backing store when the scope in which it is created is also a **StackedMemory**, in which case it is returned to its enclosing scope's backing store when the object is finalized. Implementations are not required to return the space occupied by backing stores taken from the global backing store when their associated **StackedMemory** object is finalized.

These backing store semantics divide instances of **StackedMemory** into two categories:

- *Host* — this denotes a **StackedMemory** with an object allocation area created in a new backing store, allocated either from the global store or from a parent **StackedMemory**'s backing store.
- *guest* — this in turn indicates a **StackedMemory** with an object allocation area taken directly from a parent **StackedMemory**'s backing store without creating a sub-store.

In addition, there is one distinguished status for **StackedMemory** objects, *root*. A root **StackedMemory** is a host **StackedMemory** created with a backing store drawn directly from the global backing store, created in an allocation context of some type other than **StackedMemory**.

Allocations from a **StackedMemory** object allocation area are guaranteed to run in time linear in the size of the allocation. All memory for the backing store must be reserved at object construction time.

StackedMemory memory areas have two additional stacking constraints in addition to the single parent rule, designed to enable fragmentation-free manipu-

lation:

- A **StackedMemory** that is created when another **StackedMemory** is the current allocation context can only be entered from the same allocation context in which it was created.
- A guest **StackedMemory** cannot be created from a **StackedMemory** that currently has another child area that is also a guest **StackedMemory**. (That is, a **StackedMemory** can have at most one direct child that is a guest **StackedMemory**.)

The **StackedMemory** constructor semantics also enforce the property that a **StackedMemory** cannot be created from another **StackedMemory** allocation context unless it is allocated from that context's backing store as either a host or guest area.

The backing store of a **StackedMemory** behaves as if any **StackedMemory** object allocation areas are at the “bottom” of the backing store, while the backing stores for enclosed **StackedMemory** areas are taken from the “top” of the backing store.

There may be an implementation-specific memory overhead for creating a backing store of a given size. This means that creating a **StackedMemory** with a backing store of exactly the remaining available backing store of the current **StackedMemory** may fail with an `javax.realtime.StaticOutOfMemoryError`. This overhead must be bounded by a constant.

Available since RTSJ 2.0

11.5.3.7.1 Constructors

StackedMemory(long, long)

Signature

```
public
    StackedMemory(long scopeSize,
                  long backingSize)
```

Description

Create a host **StackedMemory** with an object allocation area and backing store of the specified sizes. The backing store is allocated from the currently active

memory area when it is also a `StackedMemory`, and the global backing store otherwise. The object allocation area is allocated from the backing store.

Parameters

`scopeSize` Size of the allocation area

`backingSize` Size of the total backing store

Throws

`IllegalArgumentException` when either `scopeSize` or `backingSize` is less than zero, or when `scopeSize` is too large to be allocated from a backing store of size `backingSize`.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory available to reserve the requested backing store.

`StackedMemory(long, long, Runnable)`

Signature

```
public
StackedMemory(long scopeSize,
               long backingSize,
               Runnable logic)
```

Description

Create a host `StackedMemory` with an object allocation area and backing store of the specified sizes, bound to the specified `Runnable`. The backing store is allocated from the currently active memory area when it is also a `StackedMemory`, and the global backing store otherwise. The object allocation area is allocated from the backing store.

Parameters

`scopeSize` Size of the allocation area

`backingSize` Size of the total backing store

`logic` `Runnable` to be entered using `this` as its current memory area when `enter()`¹³⁹ is called.

Throws

`IllegalArgumentException` when either `scopeSize` or `backingSize` is less than zero, or when `scopeSize` is too large to be allocated from a backing store of size `backingSize`.

¹³⁹Section 11.5.3.7.2

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory available to reserve the requested backing store.

StackedMemory(SizeEstimator, SizeEstimator)

Signature

```
public  
StackedMemory(SizeEstimator scopeSize,  
               SizeEstimator backingSize)
```

Description

Create a host `StackedMemory` with an object allocation area and backing store of the sizes estimated by the specified `SizeEstimators`. The backing store is allocated from the currently active memory area when it is also a `StackedMemory`, and the global backing store otherwise. The object allocation area is allocated from the backing store.

Parameters

`scopeSize` `SizeEstimator` indicating the size of the object allocation area
`backingSize` `SizeEstimator` indicating the size of the total backing store

Throws

`IllegalArgumentException` when either `scopeSize` or `backingSize` is less than zero, or when `scopeSize` is too large to be allocated from a backing store of size `backingSize`.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory available to reserve the requested backing store.

StackedMemory(SizeEstimator, SizeEstimator, Runnable)

Signature

```
public  
StackedMemory(SizeEstimator scopeSize,  
               SizeEstimator backingSize,  
               Runnable logic)
```

Description

Create a host **StackedMemory** with an object allocation area and backing store of the sizes estimated by the specified **SizeEstimators**, bound to the specified **Runnable**. The backing store is allocated from the currently active memory area when it is also a **StackedMemory**, and the global backing store otherwise. The object allocation area is allocated from the backing store.

Parameters

scopeSize **SizeEstimator** indicating the size of the object allocation area
backingSize **SizeEstimator** indicating the size of the total backing store
logic **Runnable** to be entered using **this** as its current memory area when **enter()**¹⁴⁰ is called.

Throws

IllegalArgumentException when either **scopeSize** or **backingSize** is less than zero, or when **scopeSize** is too large to be allocated from a backing store of size **backingSize**.
javafx.runtime.StaticOutOfMemoryError when there is insufficient memory available to reserve the requested backing store.

StackedMemory(long)

Signature

```
public  
StackedMemory(long scopeSize)
```

Description

Create a guest **StackedMemory** with an object allocation area of the specified size. The object allocation area is drawn from the same backing store as the parent scope's object allocation area. The parent scope must be a **StackedMemory**.

Parameters

scopeSize Size of the allocation area

Throws

IllegalStateException when the parent memory area is not a **StackedMemory**, or when the parent **StackedMemory** already has a child that is also a guest **StackedMemory**.
IllegalArgumentException when **scopeSize** is less than zero.

¹⁴⁰Section 11.5.3.7.2

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory available in the backing store of the parent `StackedMemory`'s object allocation area to reserve the requested object allocation area.

StackedMemory(SizeEstimator)

Signature

```
public  
StackedMemory(SizeEstimator scopeSize)
```

Description

Create a guest `StackedMemory` with an object allocation area of the size estimated by the specified `SizeEstimator`. The object allocation area is drawn from the same backing store as the parent scope's object allocation area. The parent scope must be a `StackedMemory`.

Parameters

`scopeSize` `SizeEstimator` indicating the size of the object allocation area

Throws

`IllegalStateException` when the parent memory area is not a `StackedMemory`, or when the parent `StackedMemory` already has a child that is also a guest `StackedMemory`.

`IllegalArgumentException` when `scopeSize` is less than zero.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory available in the backing store of the parent `StackedMemory`'s object allocation area to reserve the requested object allocation area.

StackedMemory(long, Runnable)

Signature

```
public  
StackedMemory(long scopeSize,  
               Runnable logic)
```

Description

Create a guest `StackedMemory` with an object allocation area of the specified size, bound to the specified `Runnable`. The object allocation area is drawn from

the same backing store as the parent scope's object allocation area. The parent scope must be a `StackedMemory`.

Parameters

`scopeSize` `Size` of the allocation area
`logic` `Runnable` to be entered using `this` as its current memory area when `enter()`¹⁴¹ is called.

Throws

`IllegalStateException` when the parent memory area is not a `StackedMemory`, or when the parent `StackedMemory` already has a child that is also a guest `StackedMemory`.

`IllegalArgumentException` when `scopeSize` is less than zero.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory available in the backing store of the parent `StackedMemory`'s object allocation area to reserve the requested object allocation area.

`StackedMemory(SizeEstimator, Runnable)`

Signature

```
public  
StackedMemory(SizeEstimator scopeSize,  
               Runnable logic)
```

Description

Create a guest `StackedMemory` with an object allocation area of the size estimated by the specified `SizeEstimator`, bound to the specified `Runnable`. The object allocation area is drawn from the same backing store as the parent scope's object allocation area. The parent scope must be a `StackedMemory`.

Parameters

`scopeSize` `SizeEstimator` indicating the size of the object allocation area
`logic` `Runnable` to be entered using `this` as its current memory area when `enter()`¹⁴² is called.

Throws

`IllegalStateException` when the parent memory area is not a `StackedMemory`, or when the parent `StackedMemory` already has a child that is also a guest `StackedMemory`.

¹⁴¹Section 11.5.3.7.2

¹⁴²Section 11.5.3.7.2

`IllegalArgumentException` when `scopeSize` is less than zero.

`javax.realtime.StaticOutOfMemoryError` when there is insufficient memory available in the backing store of the parent `StackedMemory`'s object allocation area to reserve the requested object allocation area.

11.5.3.7.2 Methods

resize(long)

Signature

```
public  
void resize(long scopeSize)
```

Description

Change the size of the object allocation area for this scope. This method may be used to either grow or shrink the allocation area when there are no objects allocated in the scope and no `Schedulable` object has this area as its current allocation context. It may be used to shrink the allocation area down to the size of its current usage when the calling `Schedulable` object is the only object that has this area on its scope stack and there are no guest `StackedMemory` object allocation areas created after this area in the same backing store but not yet finalized.

Parameters

scopeSize The new allocation area size for this scope

Throws

`IllegalStateException` when the caller is not permitted to perform the requested adjustment or there are additional guest `StackedMemory` allocation areas after this one in the backing store.

`javax.realtime.StaticOutOfMemoryError` when the remaining backing store is insufficient for the requested adjustment.

getMaximumSize

Signature

```
public  
long getMaximumSize()
```

Description

Get the maximum size this memory area can attain. The value returned by this function is the maximum size that can currently be passed to `resize(long)`¹⁴³ without triggering an `OutOfMemoryException`.

Returns

The maximum size attainable.

enter*Signature*

```
public  
void enter()
```

Description

Associate this memory area with the current `Schedulable` object for the duration of the `run()` method of the instance of `Runnable` given in this object's constructor. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected.

This method may only be called from the memory area in which this scope was created.

Throws

`IllegalStateException` when the currently active memory area is a `StackedMemory` and is not the area in which this scope was created, or the current memory area is not a `StackedMemory` and this `StackedMemory` is not a root area.

`ThrowBoundaryError` null

`IllegalThreadStateException` `IllegalThreadStateException` when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

`MemoryAccessError` `MemoryAccessError` `MemoryAccessError` when caller is a schedulable that may not use the heap and this memory area's logic value is allocated in heap memory.

See Section [ScopedMemory.enter\(\)](#)

¹⁴³Section [11.5.3.7.2](#)

enter(Runnable)

Signature

```
public  
void enter(Runnable logic)
```

Description

Associate this memory area with the current **Schedulable** object for the duration of the **run()** method of the given **Runnable**. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected.

This method may only be called from the memory area in which this scope was created.

Throws

IllegalStateException when the currently active memory area is a **StackedMemory** and is not the area in which this scope was created, or the current memory area is not a **StackedMemory** and this **StackedMemory** is not a root area.

ThrowBoundaryError null

IllegalThreadStateException **IllegalThreadStateException** when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

MemoryAccessError null

See Section [ScopedMemory.enter\(Runnable\)](#)

joinAndEnter

Signature

```
public  
void joinAndEnter()
```

Description

In the error-free case, **joinAndEnter** combines **join();enter();** such that no **enter()** from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this **ScopedMemory** to reach zero, then enter the **ScopedMemory** and execute the **run** method from

logic passed in the constructor. When no instance of `Runnable` was passed to the memory area's constructor, the method throws `IllegalArgumentException` immediately.

When multiple threads are waiting in `joinAndEnter` family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Note that although `joinAndEnter` guarantees that the reference count is zero when the schedulable is released for entry, it does not guarantee that the reference count will remain one for any length of time. A subsequent `enter` could raise the reference count to two.

Throws

`InterruptedException` When this schedulable is interrupted by `javafx.runtime.RealtimeThread.interrupt()` or `javafx.runtime.AsynchronouslyInterruptedException.fire()`¹⁴⁵ while waiting for the reference count to go to zero.

`IllegalThreadStateException` when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

`javafx.runtime.ThrowBoundaryError` Thrown when the JVM needs to propagate an exception allocated in *this* scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `javafx.runtime.IllegalAssignmentException` so the JVM cannot be permitted to deliver the exception. The `javafx.runtime.ThrowBoundaryError` is allocated in the current allocation context and contains information about the exception it replaces.

`javafx.runtime.ScopedCycleException` when this invocation would break the single parent rule.

`IllegalArgumentException` when the caller is a schedulable and no non-null logic value was supplied to the memory area's constructor.

`MemoryAccessError` when caller is a non-heap schedulable and this memory area's logic value is allocated in heap memory.

joinAndEnter(HighResolutionTime)

Signature

¹⁴⁴Section 5.4.1

¹⁴⁵Section 8.4.2.1.2

¹⁴⁶Section 15.3.3.2

¹⁴⁷Section 15.3.3.8

```

public
void joinAndEnter(javax.realtime.HighResolutionTime<?> time)
throws InterruptedException

```

Description

In the error-free case, `joinAndEnter` combines `join();enter();` such that no `enter()` from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this `ScopedMemory` to reach zero, or for the current time to reach the designated time, then enter the `ScopedMemory` and execute the `run` method from `Runnable` object passed to the constructor. When no instance of `Runnable` was passed to the memory area's constructor, the method throws `IllegalArgumentException` immediately. *

When multiple threads are waiting in `joinAndEnter` family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Since the time is expressed as a `javax.realtime.HighResolutionTime`¹⁴⁸, this method has an accurate timer with nanosecond granularity. The actual resolution of the timer and even the quantity it measures depends on the clock associated with `time`. The delay time may be relative or absolute. When relative, then the calling thread is blocked for at most the amount of time given by `time`, and measured by its associated clock. When absolute, then the time delay is until the indicated value is reached by the clock. When the given absolute time is less than or equal to the current value of the clock, the call to `joinAndEnter` behaves effectively like `enter`¹⁴⁹.

Note that expiration of `time` may cause control to enter the memory area before its reference count has gone to zero.

Parameters

`time` The time that bounds the wait.

Throws

`javax.realtime.ThrowBoundaryError` Thrown when the JVM needs to propagate an exception allocated in `this` scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `javax.realtime.IllegalAssignmentError` so the JVM cannot be permitted to deliver the exception. The `javax.realtime.ThrowBoundaryError` is allocated in the current allocation context and contains information about the exception it replaces.

¹⁴⁸Section 9.4.1.2

¹⁴⁹Section 11.5.3.7.2

¹⁵⁰Section 15.3.3.2

¹⁵¹Section 15.3.3.8

InterruptedException When this schedulable is interrupted by `javax.realtime.RealtimeThread` or `javax.realtime.AsynchronouslyInterruptedException.fire()`¹⁵³ while waiting for the reference count to go to zero.

IllegalThreadStateException when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

javax.realtime.ScopedCycleException when the caller is a schedulable and this invocation would break the single parent rule.

IllegalArgumentException when the caller is a schedulable, and `time` is `null` or no non-`null` `logic` value was supplied to the memory area's constructor.

UnsupportedOperationException when the wait operation is not supported using the clock associated with `time`.

MemoryAccessError when calling schedulable may not use the heap and this memory area's `logic` value is allocated in heap memory.

joinAndEnter(Runnable)

Signature

```
public
void joinAndEnter(Runnable logic)
throws InterruptedException
```

Description

In the error-free case, `joinAndEnter` combines `join();enter();` such that no `enter()` from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this `ScopedMemory` to reach zero, then enter the `ScopedMemory` and execute the `run` method from `logic`

When `logic` is `null`, throw `IllegalArgumentException` immediately.

When multiple threads are waiting in `joinAndEnter` family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Note that although `joinAndEnter` guarantees that the reference count is zero when the schedulable is released for entry, it does not guarantee that the reference

¹⁵²Section 5.4.1

¹⁵³Section 8.4.2.1.2

count will remain one for any length of time. A subsequent **enter** could raise the reference count to two.

Parameters

logic The Runnable object which contains the code to execute.

Throws

InterruptedException When this schedulable is interrupted by `javax.realtime.RealtimeThread` or `javax.realtime.AsynchronouslyInterruptedException`.¹⁵⁵ while waiting for the reference count to go to zero.

IllegalThreadStateException when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

javax.realtime.ThrowBoundaryError Thrown when the JVM needs to propagate an exception allocated in this scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `javax.realtime.IllegalAssignmentError` so the JVM cannot be permitted to deliver the exception. The `javax.realtime.ThrowBoundaryError` is allocated in the current allocation context and contains information about the exception it replaces.

javax.realtime.ScopedCycleException when this invocation would break the single parent rule.

IllegalArgumentException when the caller is a schedulable and **logic** is null.

joinAndEnter(Runnable, HighResolutionTime)

Signature

```
public
void joinAndEnter(Runnable logic,
                  javax.realtime.HighResolutionTime<?> time)
throws InterruptedException
```

Description

In the error-free case, **joinAndEnter** combines **join()**; **enter()**; such that no **enter()** from another schedulable can intervene between the two method invoca-

¹⁵⁴Section 5.4.1

¹⁵⁵Section 8.4.2.1.2

¹⁵⁶Section 15.3.3.2

¹⁵⁷Section 15.3.3.8

tions. The resulting method will wait for the reference count on this `ScopedMemory` to reach zero, or for the current time to reach the designated time, then enter the `ScopedMemory` and execute the `run` method from `logic`.

Since the time is expressed as a `javax.realtime.HighResolutionTime`¹⁵⁸, this method is an accurate timer with nanosecond granularity. The actual resolution of the timer and even the quantity it measures depends on the clock associated with `time`. The delay time may be relative or absolute. When relative, then the delay is the amount of time given by `time`, and measured by its associated clock. When absolute, then the delay is until the indicated value is reached by the clock. When the given absolute time is less than or equal to the current value of the clock, the call to `joinAndEnter` behaves effectively like `enter(Runnable)`¹⁵⁹.

Throws `IllegalArgumentException` immediately when `logic` is `null`.

When multiple threads are waiting in `joinAndEnter` family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Note that expiration of `time` may cause control to enter the memory area before its reference count has gone to zero.

Parameters

`logic` The `Runnable` object which contains the code to execute.

`time` The time that bounds the wait.

Throws

`InterruptedException` When this schedulable is interrupted by `javax.realtime.RealtimeThread` or `javax.realtime.AsynchronouslyInterruptedException.fire()`¹⁶¹ while waiting for the reference count to go to zero.

`IllegalThreadStateException` when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

`javax.realtime.ThrowBoundaryError` Thrown when the JVM needs to propagate an exception allocated in `this` scope to (or through) the memory area of the caller. Storing a reference to that exception would cause a `javax.realtime.IllegalAssignment` so the JVM cannot be permitted to deliver the exception. The `javax.realtime.ThrowBoundaryError` is preallocated and saves information about the exception it replaces.

¹⁵⁸Section 9.4.1.2

¹⁵⁹Section 11.5.3.7.2

¹⁶⁰Section 5.4.1

¹⁶¹Section 8.4.2.1.2

¹⁶²Section 15.3.3.2

¹⁶³Section 15.3.3.8

`javafx.runtime.ScopedCycleException` when the caller is a schedulable and this invocation would break the single parent rule.

`IllegalArgumentException` when the caller is a schedulable and `time` or `logic` is null.

`UnsupportedOperationException` when the wait operation is not supported using the clock associated with `time`.

11.6 The Rationale

11.6.1 The Scoped Memory Model

Languages that employ automatic reclamation of blocks of memory allocated in what is conventionally called the heap by program logic also typically use an algorithm called a garbage collector. Garbage collection algorithms and implementations vary in the amount of non-determinacy they add to the execution of program logic. Rather than require a garbage collector, and require it to meet realtime constraints that would necessarily be a compromise, this specification constructs alternative systems for “safe” management of memory. The scoped and immortal memory areas allow program logic to allocate objects in a Java-like style, ignore the reclamation of those objects, and not incur the latency of the implemented garbage collection algorithm.

The term *scope stack* might mislead a reader to infer that it contains only scoped memory areas. This is incorrect. Although the scope stack may contain scoped memory references, it may also contain heap and immortal memory areas. Also, although the scope stack’s behavior is specified as a stack, an implementation is free to use any data structure that preserves the stack semantics.

This specification does not specifically address the lifetime of objects allocated in immortal memory areas. If they were reclaimed while they were still referenced, the referential integrity of the JVM would be compromised which is not permissible. Recovering immortal objects only at the termination of the application, or never recovering them under any circumstances is consistent with this specification.

If a scoped memory area is used by both heap and non-heap SOs, there could be cases where a finalizer executed in non-heap context could attempt to use a heap reference left by a heap-using SO. The code in the finalizer would throw a memory access error. If that exception is not caught in the finalizer, it will be handled by the implementation so finalization will continue undisturbed, but the problem in finalizer that caused the illegal memory access could be hard to locate. So, catch clauses in finalizers for objects allocated in scoped memory are even more useful than they are for normal finalizers.

Support for scoped non-default initial memory areas (SNDIMAs) for schedulables has repercussions. These repercussions include:

1. The SNDIMA's parent is set when the SO is constructed, but its reference count is not incremented until the realtime thread is started or the async event handler becomes firable. This lets a scope with a zero reference count have a parent. This may cause unexpected scoped cycle exceptions. The most surprising are from the `joinAndEnter` family of methods.
2. Finalization of a scoped memory (when its reference count goes to zero) can cause finalization of SNDIMAs of AEHs whose AEs are in the finalizing scope. This can cause finalization of one scope to trigger finalization of numerous other scopes including scopes that are descendants of the scope whose finalization started the process.
3. Any action that makes an AEH non-firable (directly disassociating it from all AEs, or indirectly disassociating it by finalizing the scopes containing those AEs) must block until all the resulting finalization completes.
4. Any action that makes an AEH firable must block until any ongoing finalization of its SNDIMA completes.

11.6.2 The Physical Memory Model

Embedded systems may have many different types of directly addressable memory available to them. Each type has its own characteristics [2] that determine whether it is

1. volatile – whether it maintains its state when the power is turned off;
2. writable – whether it can be written at all, written once or written many times and whether writing is under program control,
3. synchronous or asynchronous – whether the memory is synchronized with the system bus,
4. erasable at the byte level – if the memory can be overwritten whether this is done at the byte level or whether whole sectors of the memory need to be erased,
5. fast to access – both for reading and writing.

Examples include the following [2]:

1. *Dynamic Random Access Memory* (DRAM) and *Static Random Access Memory* (SRAM) – these are volatile memory types that are usually writable at the byte level. There are no limits on the number of times the memory contents can be written. From the embedded systems designer's view point, the main differences between the two are their access times and their costs per byte. SRAM has faster access times and is more expensive. Both DRAM and SRAM are example of asynchronous memory, SDRAM and SSRAM are their synchronized counterparts. Another important difference is that DRAM requires periodic refresh operations, which may interfere with execution time determinism.
2. Read-Only Memory (for example, *Erasable Programmable Read-Only Memory*

- (EPROM)) – these are nonvolatile memory types that once initialized with data can not be overwritten by the program (without recourse to some external effect, usually ultraviolet light as in EPROM). They are fast to access and cost less per byte than DRAM.
3. Hybrid Memory (for example, *Electrically Erasable Programmable Read-Only Memory* (EEPROM), and Flash) – these have some properties of both random access and read-only memory.
 - (a) EEPROM – this is nonvolatile memory that is writable at the byte level. However, there are typically limits on how many time the same location can be overwritten. EEPROMs are expensive to manufacture, fast to read but slow to write.
 - (b) FLASH memory – this is nonvolatile that is writable at the sector level. Like EEPROM there are limits on how many times the same location can be overwritten and they are fast to read but slow to write. Flash memory is cheaper to manufacture than EEPROM.

Some embedded systems may have multiple types of random-access memory, and multiple ways of accessing memory. For instance, there may be a small amount of very fast RAM on the processor chip, memory that is on the same board as the processor, memory that may be added and removed from the system dynamically, memory that is accessed across a bus, access to memory that is mediated by a cache, access where the cache is partially disabled so all stores are “write through”, memory that is demand paged, and other types of memory and memory-access attributes only limited by physics and the imagination of electrical engineers. Some of these memory types will have no impact on the programmer, others will.

Individual computers are often targeted at a particular application domain. This domain will often dictate the cost and performance requirements, and therefore, the memory type used. Some embedded systems are highly optimized and need to explore different options in memory to meet their performance requirements. Here are five example scenarios.

1. Ninety percent of performance-critical memory access is to a set of objects that could fit in a half the total memory.
2. The system enables the locking of a small amount of data in the cache, and a small number of pages in the translation lookaside buffer (TLB). A few very frequently accessed objects are to be locked in the cache and a larger number of objects that have jitter requirements can be TLB-locked to avoid TLB faults.
3. The boards accept added memory on daughter boards, but that memory is not accessible to DMA from the disk and network controllers and it cannot be used for video buffers. Better performance is obtained if one ensures that all data that might interact with disk, network, or video is not stored on the daughter board.

4. Improved video performance can be obtained by using an array as a video buffer. This will only be effective if a physically contiguous, unpagable, DMA-accessible block of RAM is used for the buffer and all stores forced to write through the cache. Of course, such an approach is dependent on the way the JVM lays out arrays in memory, and it breaks the JVM abstraction by depending on that layout.
5. The system has banks of SRAM and saves power by automatically putting them to “sleep” whenever they stay unused for 100 ms or so. To exploit this, the objects used by each phase of our program can be collected in a separate bank of this special memory.

To be clear, few embedded systems are this aggressive in their hardware optimization. The majority of embedded systems have only ROM, RAM, and maybe flash memory. Configuration-controlled memory attributes (such as page locking, and TLB behavior) are more common.

As well as having different types of memory, many computers map input and output devices so that their registers can be accessed as if they were resident within the computer memory (see Section 12.3.1). Hence, some parts of the processor’s address space map to real memory and other parts map to device registers. Logically, even a device’s memory can be considered part of the memory hierarchy, even where the device’s interface is accessed through special assembly instructions. Multiprocessor systems add a further dimension to the problem of memory access. Memory may be local to a CPU, tightly shared between CPUs, or remotely accessible from the CPU (but with a delay).

Traditionally, Java programmers are not concerned with these low-level issues; they program at a higher level of abstraction and assume the JVM makes judicious use of the underlying resources provided by the execution platform¹⁶⁴. Embedded systems programmers cannot afford this luxury. Consequently, any Java environment that wishes to facilitate the programming of embedded systems must enable the programmer to exercise more control over memory.

11.6.2.1 Problems with the RTSJ 1.0 Physical Memory Framework

The RTSJ 1.0 supported three ways to allocate objects that can be placed in particular types of memory:

1. `ImmortalPhysicalMemory` allocates immortal objects in memory with specified characteristics.
2. `LTPhysicalMemory` allocates scoped memory objects in a memory with specified characteristics using a linear time memory allocation algorithm.

¹⁶⁴This is reflected by the OS support provided. For example, most POSIX systems only offer programs a choice of demand paged or page-locked memory.

3. `VTPhysicalMemory` allocates scoped memory objects in memory with specified characteristics using an algorithm that may be worse than linear time but could offer extra services (such as extensibility).

The only difference between the physical memory classes and the corresponding non-physical classes is that the ordinary memory classes give access to normal system RAM and the physical memory classes offer access to particular types of memory.

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Update this for 2.0; remove filters, etc. JTRES 2015

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The RTSJ 1.0 supports access to physical memory via a memory manager and one or more memory filters. The goal of the memory manager is to provide a single interface with which the programmer can interact in order to access memory with a particular characteristic. A memory filter enables access to a particular type of physical memory. Memory filters may be dynamically added and removed from the system, and there can only be a single filter for each memory type. The memory manager is unaware of the physical addresses of each type of memory. This is encapsulated by the filters. The filters also know the virtual memory characteristics that have been allocated to their memory type. For example, whether the memory is readable or writable.

In theory, any developer can create a new physical memory filter and register it with the PMM. However, the programming of filters is difficult for the following reasons.

1. Physical memory type filters include a memory allocation function that must respond to allocation requests with whether a requested range of physical memory is free and if it is not, the physical address of the next free physical memory of the requested type. This is complex because requests for compound types of physical memory must find a free segment that satisfies all attributes of the compound type.
2. The Java runtime must continue to behave correctly under the Java memory model when it is using physical memory. This is not a problem when a memory type behaves like the system's normal RAM with respect to the properties addressed by the memory model, or is more restricted than normal RAM (as, for instance, write-through cache is more restricted than copy-back cache). If a new memory type does not obey the memory model using the same instruction sequences as normal RAM, the memory filter must cooperate with the interpreter, the JIT, and any ahead-of-time compilation to modify those instruction sequences when accessing the new type of memory. That task is difficult for someone who can easily modify the Java runtime and nearly impossible for anyone else.

Hence, the utility of the physical memory filter framework at Version 1.0 is questionable, and hence is replaced in 2.0 with an easier to use framework.

11.6.2.2 The RTSJ 2.0 Physical Memory Framework

The main problem with the 1.0 framework is that it places too great a burden on the JVM implementer. Even for embedded systems, the JVM implementer requires the VM to be portable between systems within the same processor family. It, therefore, cannot have detailed knowledge of the underlying memory architecture. It is only concerned with the standard RAM provided to it by the host operating system.

The design of 2.0 model is based on two constraints.

1. Java objects can only be allocated in a memory area if the physical backing store supports the Java Memory Model without the JVM having to perform any operation addition to those that it performs when accessing as the main RAM for the host machine. No extra compiler or JVM interactions shall be required. Hence memory types (such as EEPROM), which potentially require special hardware instructions to perform write operations, cannot be used as the backing store for physical memory areas. Similarly, non-volatile memory can be used any objects store therein may contain references to objects in volatile memory. Although these memory types are prohibited from being used as backing stores, they contain objects of primitive Java types and be accessed via the RTSJ Raw Memory facilities (see Section 12.3.1).
2. Any API must delegates detailed knowledge of the memory architecture to the programmer of the specific embedded system to be implemented. There is less requirement for portability here, as embedded systems are usually optimized for their host environment. The model assumes that the programmer is aware of the memory map, either through some native operating system interface¹⁶⁵ or from some property file read at program initialization time.

When accessing physical memory, there are two main considerations:

1. the characteristics of the required physical memory, and
2. how that memory is to be mapped into the virtual memory of the application.

2.0 requires the program to identify (and inform the RTSJ's physical memory manager of) the physical memory characteristics and the range of physical addresses those characteristic apply to. For example, that there is SRAM between physical address range 0x100000000 and 0xA0000000.

The physical memory manager supports a range of options for mapping physical memory into the virtual memory of the application. Examples of such options are

¹⁶⁵For example, the *Advanced Configuration and Power Interface* (ACPI) specification is an open standard for device configuration and power management by the operating system. The ACPI defines platform-independent interfaces for hardware discovery, configuration, power management and monitoring. See <http://www.acpi.info/>

whether the range is to be permanently resident in memory (the default is that it may be subject to paging/swapping), and whether data is written to the cache and the main memory simultaneously (i.e., a write through cache).

Given the required physical and virtual memory characteristics, the programmer requests that the PMM creates a memory filter for accessing this memory. This filter can then be used with new constructors on the physical memory classes. For example,

```
1 public ImmortalPhysicalMemory(PhysicalMemoryFilter filter, long size)
```

Use of this constructor enables the programmer to specify the allocation of the backing store in a particular type of memory with a particular virtual memory characteristic. The filter is used to locate an area in physical memory with the required physical memory characteristics and to direct its mapping into the virtual address space. Other constructors allow multiple filters to be passed.

Hence, once the filters have been created, physical memory areas can be created and objects can be allocated within those memory areas using the usual RTSJ mechanisms for changing the allocation context of the `new` operator.

11.6.2.3 An example

Consider an example of a system that has a SRAM physical memory module configured at a physical base address of `0x10000000` and of length `0x20000000`. Another module (base address of `0xA0000000` and of length `0x10000000`) also supports SRAM, but this module has been configured so that it saves power by sleeping when not in use. The following subsections illustrate how the embedded programmer informs the PMM about the structure during the program's initialization phase, and how the memory may be subsequently used after this. The example assumes that the PMM supports the virtual memory characteristics defined above.

Program Initialization

For simplicity, the example requires that the address of the memory modules are known, rather than being read from a property file. The program needs to have a class that implements the `PhysicalMemoryCharacteristic`. In this simple example, this is empty.

```
1 public class MyMemoryType implements PhysicalMemoryCharacteristic {}
```

The initialization method must now create instances of the `PhysicalMemoryRegion` class to represent the physical memory module memory modules to represent

```

1 PhysicalMemoryRegion staticRam =
2   new PhysicalMemoryRegion(0x10000000L, 0x100000000L);
3 PhysicalMemoryRegion staticSleepableRam =
4   new PhysicalMemoryRegion(0xA0000000L, 0x100000000L);

```

It then creates names for the characteristics that the program wants to associate with each memory module.

```

1 PhysicalMemoryCharacteristic STATIC_RAM = new MyMemoryType();
2 PhysicalMemoryCharacteristic AUTO_SLEEPABLE = new MyMemoryType();

```

It then informs the PMM of the appropriate associations:

```

1 PhysicalMemoryFactory.associate(STATIC_RAM, staticRam);
2 PhysicalMemoryFactory.associate(STATIC_RAM, staticSleepableRam);
3 PhysicalMemoryFactory.associate(AUTO_SLEEPABLE, staticSleepableRam);

```

Once this is done, the program can now create a filter with the required properties. In this case it is for some SRAM that must be auto sleepable.

```

1 PhysicalMemoryCharacteristic [] PMC =
2   new PhysicalMemoryCharacteristic[2];
3 PMC[0] = STATIC_RAM;
4 PMC[1] = AUTO_SLEEPABLE;
5
6 PhysicalMemorySelector selector =
7   new PhysicalMemorySelector(PMC, null, DISABLED, FIXED);

```

If the program had just asked for SRAM then either of the memory modules could satisfy the request.

The initialization is now complete, and the programmer can use the memory for storing objects, as shown below.

Using Physical Memory

Once the programmer has configured the JVM so that it is aware of the physical memory modules, and the programmer names for characteristics of those memory modules, using the physical memory is straight forward. Here is an example.

```

1   ImmortalMemory IM = factory.createImmortalMemory(selector, 0x1000);
2   IM.enter(new Runnable()
3   {
4       public void run()
5       {

```

```
6      // The code executing here is running with its allocation
7      // context set to a physical immortal memory area that is
8      // mapped to RAM which is auto sleepable.
9      // Any objects created will be placed in that
10     // part of physical memory.
11   }
12  });
```

It is the appropriate constructor of the physical memory classes that now interfaces with the PMM. The physical memory manager keeps track of previously allocated memory and is able to determine if memory is available with the appropriate characteristics. Of course, the PMM has no knowledge of what these names mean; it is merely providing a look-up service.

Chapter 12

Devices and Triggering

12.1 Overview

Interacting with the external environment in a timely manner is an important requirement for realtime, embedded systems. From an embedded systems' perspective, all interactions with the physical world are performed by input and output devices. Hence, the problem is one of controlling and monitoring of devices. This is an area insufficiently addressed by other Java standards. A conventional Java Virtual Machine is not designed to support device access and interrupt handling. Programs that need this functionality must resort to code written in another language and called via the Java Native Interface (JNI). This specification addresses the problem by providing APIs for interrupt handling and direct memory access without resorting to JNI.

In contrast to earlier versions of this specification, version 2.0 has extended the goals of the device interfaces to be type safe and user extensible, so that the user can defined new devices without changing the underlying virtual machine.

There are at least four execution (runtime) environments for the RTSJ:

1. on a realtime operating system where the Java application runs in user mode;
2. on a realtime operating system where the Java application runs in a context with a user space device driver;
3. as a “kernel module” incorporated into a realtime kernel where both kernel and application run in supervisor mode; and
4. as part of an embedded device where the Java application runs stand-alone on a hardware machine.

In execution environment 1, interaction with the embedded environment is usually via operating system calls using Java's connection-oriented APIs. The Java program will typically have no direct access to the I/O devices. Although some limited access to physical memory may be provided, it is unlikely that interrupts can be directly

handled. However, asynchronous interaction with the environment is still possible, for example, via POSIX signals.

In execution environments 2, 3, and 4, the Java program may be able to directly access devices and handle interrupts.

A device can be anything from a simple set of registers wired to sensors and actuators to a full processor performing some fixed task. The interface to a device is usually through a set of device registers. Depending on the I/O architecture of the processor, the programmer can either access these registers via predetermined memory location (called *memory mapped I/O*) or via special assembler instructions (called *port-mapped I/O*).

A computer system with processing devices can be considered to be a collection of parallel threads. The device ‘thread’ can communicate and synchronize with the tasks executing inside the main processor either by having the main processor poll registers of the device or via a signal from the device. This signal is usually referred to as an interrupt. All high-level models of device programming must provide [3]

1. facilities for representing, addressing and manipulating device registers; and
2. a suitable representation of interrupts (if interrupts are to be handled).

Version 1.0 of the RTSJ went some way towards supporting this model through the notion of *happenings* and the *raw memory* access facilities. Unfortunately, happenings were under defined and the mechanisms for physical and raw memory were overly complex with no clear delineation of the separations of concerns between application developers and JVM implementers.

Version 2.0 has significantly enhanced the support for happenings, and has provided a clearer separation between physical and raw memory. The interfaces for `Happening`, `Timer`, and `Signal`, as well as the new `RealtimeSignal`, are now unified under `ActiveEvent`. This means that `Happening`, `Signal`, and `RealtimeSignal`, like `Timer` are now subclasses of `AsyncBaseEvent`. As described in Chapter 8, `ActiveEvent` provides a common light-weight means of notifying that its event has occurred. Unlike `fire()`, where dispatching of the associated handlers is done in context of the caller, an `ActiveEvent` separates this notification that the event occurred, its triggering, from the dispatching by providing its own execution context for the dispatching. As with `Timer`, each class has its own `ActiveEventDispatcher`: `HappeningDispatcher`, `TimeDispatcher`, `SignalDispatcher`, and `RealtimeSignalDispatcher`.

12.2 Definitions

Direct Memory Access (DMA) — a data transfer directly to memory without CPU intervention, as in DMA controller.

DMA Controller — a device that can move data in memory without using the CPU.

Happening — an event that takes place outside the Java runtime environment. The triggers for happenings depend on the external environment, but happenings might include signals and interrupts.

Interrupt Service Routine (ISR) — a bit of code that is executed when an interrupt happens. This code runs above the normal priorities and can only be interrupted by another interrupt.

Raw Memory — a means of mapping memory locations, such as device registers, into Java objects for direct access from Java code without using JNI. The memory to map can be in an arbitrary address space.

Raw Memory Region — denotes an address space for Raw Memory.

Stride — the distance between two memory locations. Adjacent memory locations have a stride of one. Stride is measured as units of the memory location size. For example, the stride between two bytes that are adjacent and two integers that are adjacent is both one, but the actual address offsets are one and four bytes respectively.

12.3 Semantics

The classes in this Chapter are part of the Device Module introduced in Section 3.3.2.3 and are only required in implementations that include that module. There are several aspects of the API for supporting devices. Raw Memory provides the means of accessing the I/O register of a device. Direct Memory Access (DMA) support provides a means of transferring data using a DMA controller. Active events and dispatchers support releasing event handlers based on external events. Interrupt service routines and application-defined clocks are for linking external events to the internal active events.

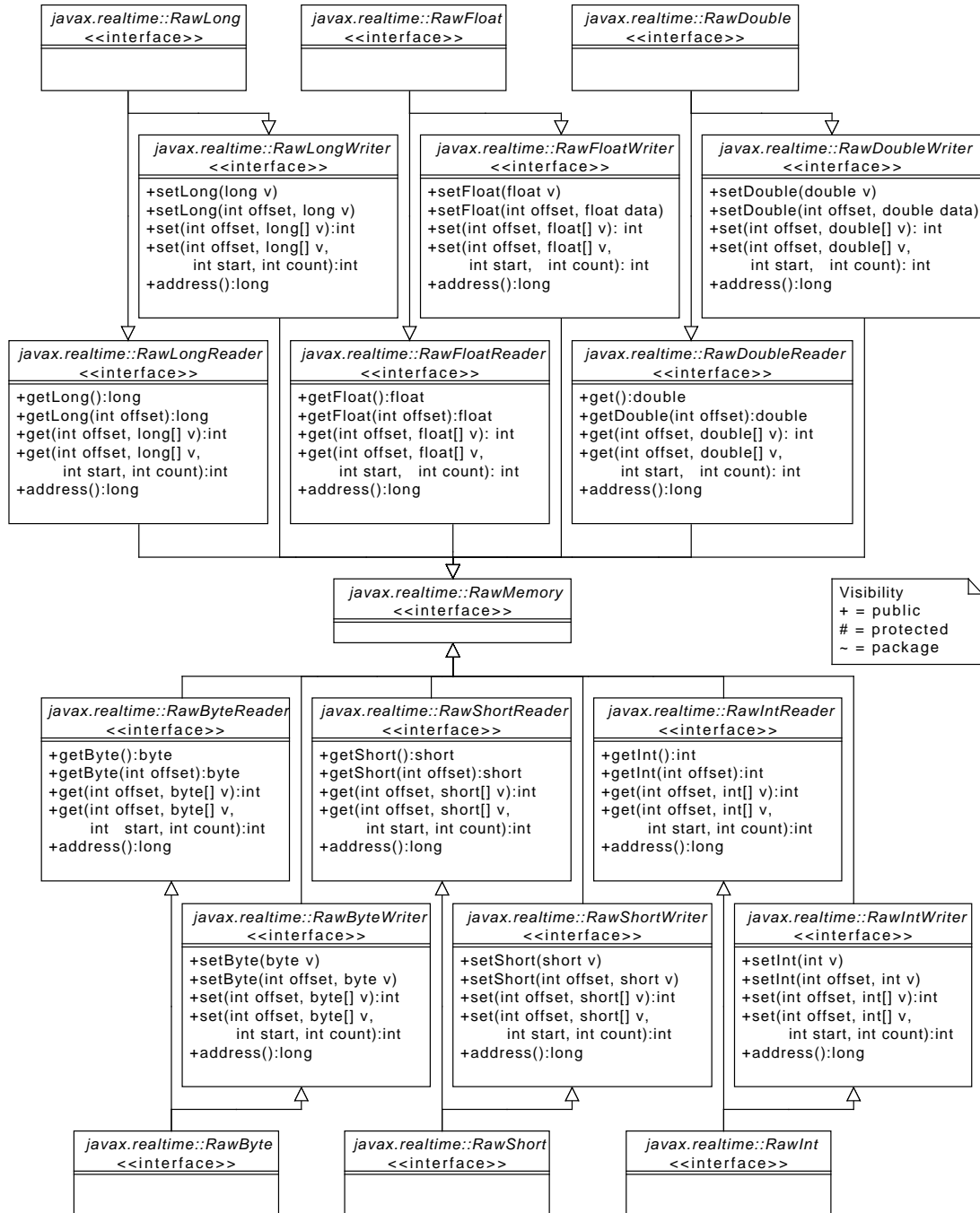
12.3.1 Raw Memory

Raw Memory provides means of accessing particular physical memory addresses as variables of Java's primitive data types, and thereby provides an application with direct access to physical memory, for example, for memory-mapped I/O.

Java objects or references therefore *cannot* be stored in raw memory. The following specifies the RTSJ's facilities for raw memory access.

1. Each area of memory supporting raw memory access is identified by a subclass of `RawMemoryRegion`.
 - (a) The raw memory region `RawMemoryFactory.MEMORY_MAPPED_REGION` facilitates access to memory locations that are outside the main memory

Figure 12.1: Raw Memory Interface



- used by the JVM. It is used to access input and output device registers when such registers are memory mapped.
- (b) The raw memory region `RawMemoryFactory.IO_PORT_MAPPED_REGION` facilitates access to locations that are outside the main memory used by the JVM. It is used to access input and output device registers when such registers are port-based and can only be accessed by special hardware instructions.
 - (c) The application developer can define and register additional regions to support things like emulated access to devices or access to a bus over a bus controller.
2. Access to raw memory is controlled by implementation-defined objects, called *accessor objects*. These implement specification-defined interfaces (e.g., `RawByte`, `RawShort`, `RawInt`, etc.) and are created by implementation-defined factory objects. Each factory implements the `RawMemoryRegionFactory` interface, and is identified by its `RawMemoryRegion`.
 3. The `RawMemoryFactory` class defines the applications programmers interface to the raw memory facilities.
 4. The `RawMemoryRegionFactory` interface defines the interface that all factories must support for creating accessor objects.

12.3.1.1 Raw Memory Region

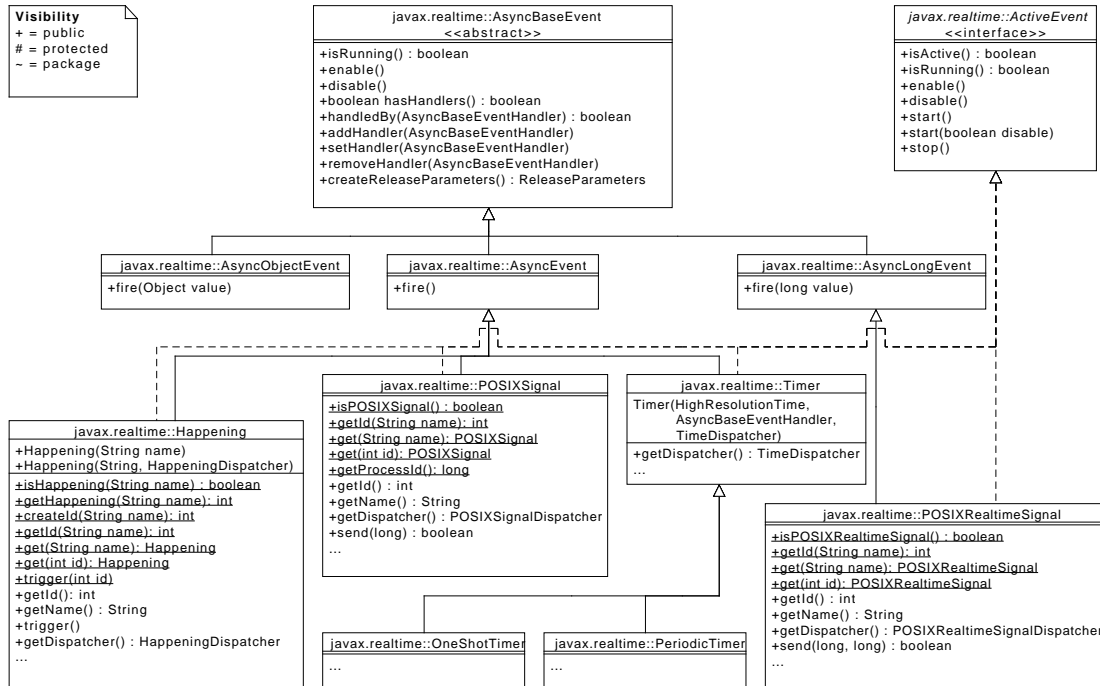
Raw memory is designed to support arbitrary I/O address spaces. The simplest is through the processor address space and is accessible via standard memory access instructions, such as `load` and `store`. This provide access to memory mapped I/O devices, but there are others address spaces as well. Each of these address spaces is referred to as a *Raw Memory Region*.

There are two raw memory regions that can be supported generically. Memory mapped I/O is one. The other is port mapped I/O. The most common instance is the I/O space provided by Intel x86 compatible processors through their `in` and `out` instructions. The memory mapped I/O raw memory region must be supported by all implementations, but the port mapped I/O raw memory region must only be supported on processors that support it.

All other raw memory regions are optional and may be provided by a system integrator or an application developer. The API provides an interface, `RawMemoryRegionFactory`, that can be implemented to provide a means of creating accessor objects for that region. These additional regions can be anything from an I/O space provided by a memory mapped device, using memory mapped I/O to implement it, to a purely synthetic I/O space to emulated hardware that has not yet been built.

Each raw memory region is identified by its raw memory region object. These “types” are defined by instances of `RawMemoryRegion`: `RawMemoryFactory.MEMORY_MAPPED_REGION`

Figure 12.2: Event Classes



for memory mapped devices and `RawMemoryFactory.IO_PORT_MAPPED_REGION` for port mapped devices for processors that have instructions for reading and writing an I/O bus directly. The instances are used to get accessors of a region instead of using a `RawMemoryRegionFactory` directly.

12.3.1.2 Raw Memory Factory

In order to support a variety of device address spaces efficiently, raw memory objects are created using the factory methods provided by `RawMemoryFactory`. This factory provides static methods to get accessors for a region via a region's type. Regions created during runtime can be provided by registering their factory with the main raw memory factory, so the application code only needs to have a reference to the object identifying the required region. For instance, one could create an I^2C raw memory region by implementing a factory for it using a memory mapped I^2C controller.

12.3.1.3 Stride

Since the word size of devices do not always match the word size of the memory or I/O bus, the interface provides for the notion of stride. Stride defines the distance

between elements in a raw memory area. Normally elements of a memory area are mapped sequentially, without any space between the elements. This is a stride of one. A stride of two, means that every other element in physical memory is mapped into the raw memory area.

For example, it is often easier to map a 16 bit device into a 32 bit system by mapping the 16 bit registers at 32 bit intervals. This enables 16 bit accesses to the device to be atomic on 32 bit addressed systems, even when the bus always does 32 bit transfers. One can create a `RawShort` area with a stride of two. Then the area can be accessed as if the registers were contiguous.

Since stride is designed to support mapping devices that have a smaller word size than the host machine, the implementation is allowed to assume that the padding between values is “do not care” data, and can be overwritten arbitrarily.

12.3.2 Direct Memory Access Support

Many embedded systems provide a means of moving data without direct involvement of the main processor. This is typically programmed with a special device called a DMA controller. DMA controllers are treated specially since they are central to bulk transfer in device drivers. The data to be transferred is not in device registers, but in normal RAM. Java already provides an API for managing this kind of memory in `java.nio`. The DMA API defined here provides a seamless means of integrating those features into a device driver for DMA.

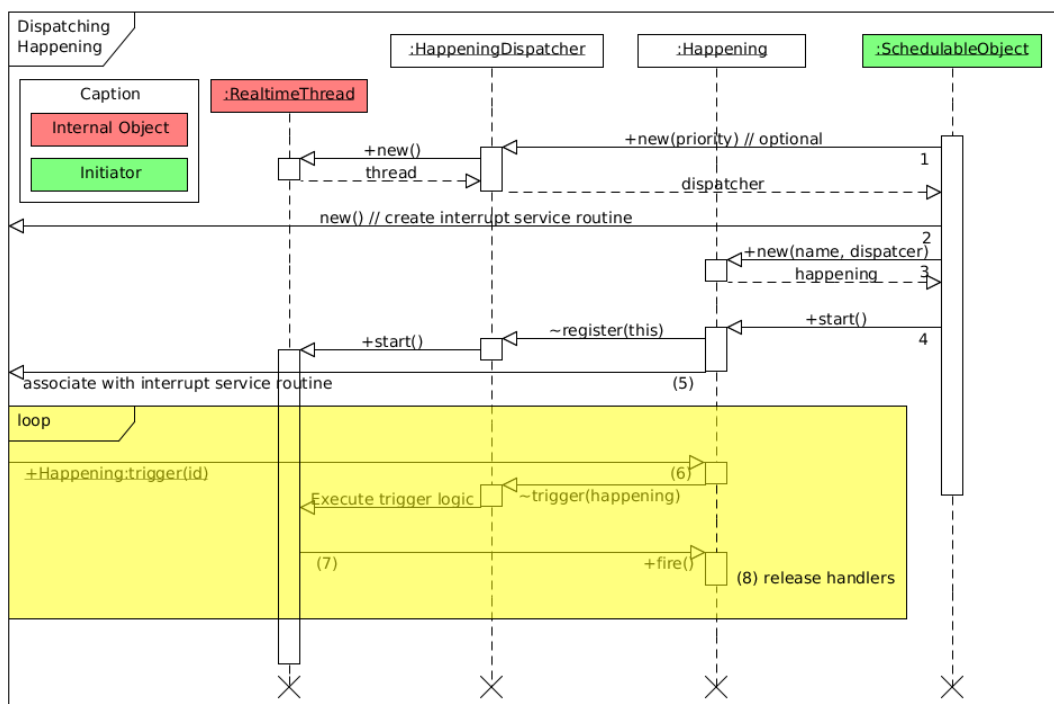
There are various architectures for DMA controllers, each requiring its own programming paradigm, so only common low level support is provided by this specification. Raw memory can be used to program the DMA controller, but there needs to be a means of representing bulk data. The `java.nio.ByteBuffer` provides just such a representation. The only difference is that the restrictions on the memory behind byte buffer objects is a bit different than for other `java.nio` mechanisms.

These differences are covered with a special byte buffer factory: `DMAByteBufferFactory`. An instance of this factory can produce direct byte buffers within a given memory range. This range can be chosen by the programmer to be within the range of a given DMA controller. The factory also provides methods for getting the start address of a buffer’s memory and checking if a buffer’s memory is within a given range. These addresses should be compatible with DMA controllers in the system, though for controllers with a smaller address space than the processor, the DMA address may have fixed offset from the processor physical address. The `DMAByteBufferFactory` class also provides static methods for ensuring that Java-generated changes to DMA-mapped memory buffers are visible to native code, and vice-versa.

12.3.3 External Triggering

It is not enough to be able to read from and write to devices; many applications, need a means of being interrupted when an event happens. This specification provides a two-level interrupt mechanism. For predefined interfaces, such as POSIX signals, the first level handler is provided by the virtual machine and asynchronous events provide the second level event handling. For external events and additional clocks, where the programmer needs to be able to define new instances and provide for their triggering, additional classes are provided to manage both the first level, as well as the second level handling. In all cases, the user can control the priority and affinity of the dispatching between the first level and second level handling.

Figure 12.3: Happening State Transition Diagram



12.3.3.1 Happenings

Whereas, in previous versions of this specification, happenings were represented as a **String**, as of 2.0 they have become an object in their own right. This makes it easier to properly type methods that use them and for the user to define new happening

for an application without the need to change the JVM. Furthermore, indirection is minimized by making the new `Happening` class a subclass of `AsyncEvent`.

Since a `Happening` needs to be triggerrable from an external event, such as an interrupt, the `Happening` class also implements `ActiveEvent`. As with other active events, `Happening` has its own dispatcher class: `HappeningDispatcher`. There is a default happening dispatcher that is used when none is provided at creation time, otherwise, the programmer can provide one to change the priority and affinity of dispatching.

Normally, happenings are triggered either from an `InterruptServiceRoutine` or from JNI code. For the later, the interface provides a means of linking a happening by name. This enables native code to get a handle for triggering a happening without have a direct reference. The given name must follow the Java naming conventions. A happening name defined outside of this specification should not begin with `java` or `javax`.

Figure 12.3 illustrates the sequence of actions necessary for defining and using a `Happening`. When using an application-defined dispatcher, it must be created first (1). When using an `InterruptServiceRoutine` to trigger the happening, it may be created before (2) or after the happening is create. After creating the happening (3), the happening must be started to be registered with it dispatcher to be triggered from native code. Of course, the JVM must have direct access to an interrupt, either by being directly bound in the kernel or by some other means, such as a system call, for setting up user-space device drivers. Only after both an `InterruptServiceRoutine` is registered and a `Happening` with the same name is started, can that happening be triggered (6–8).

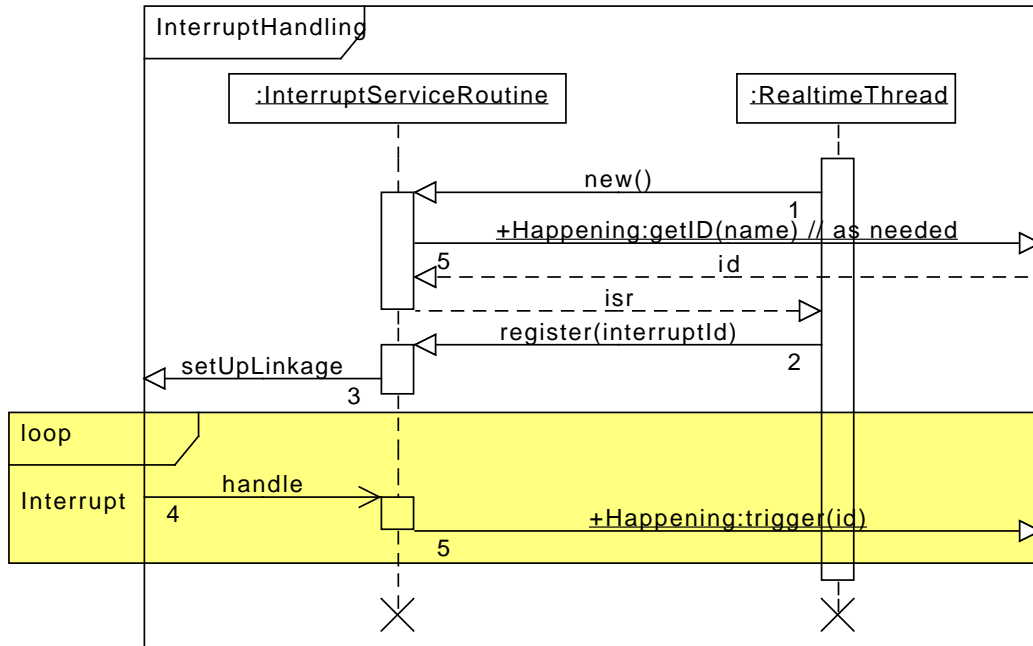
There are three main differences between this mechanism and the string based API.

1. The `Happening` class is now a first-class entity, rather than being buried in the implementation and identified only by a `String` object.
2. They include the `Happening.trigger(int)` method that enables a happening to be explicitly triggered by Java code, and at the implementation's option, a native code function that permits native application code to trigger the happening.
3. Finally, `Happening` is a subclass of `AsyncEvent` just as with `Timer` instead of having a happening attached to an `AsyncEvent`.

12.3.4 Interrupt Service Routines

In Java-based systems, JNI is typically used to transfer control between the assembler/C *interrupt service routine* (ISR) and the program. 2.0 of the RTSJ supports the

Figure 12.4: Interrupt servicing



possibility of the ISR containing Java code. This is clearly an area where it is difficult to maintain the portability goal of Java. Furthermore, not all RTSJ deployments can support `InterruptServiceRoutine`. A JVM that runs in user space does not generally have access to interrupts.

The JVM must either be standalone, running in a kernel module, or running in a special I/O partition on a partitioning OS where interrupts are passed through using some virtualization technique. Hence, JVM support for ISR is not required for RTSJ compliance.

Interrupt handling is necessarily machine dependent. However, the RTSJ provides an abstract model that can be implemented on top of all architectures.

The following semantic model shall be supported by the RTSJ:

1. An *occurrence* of an interrupt consists of its *generation* and *delivery*.
2. Generation of the interrupt is the mechanism in the underlying hardware or system that makes the interrupt available to the Java program.
3. Delivery is the action that invokes an interrupt service routine (ISR) in response to the occurrence of the interrupt. This may be performed by the JVM or application native code linked with the JVM, or directly by the hardware interrupt mechanism.

4. Between generation and delivery, the interrupt is *pending*.
5. Some or all interrupt occurrences may be inhibited. While an interrupt occurrence is inhibited, all occurrences of that interrupt shall be prevented from being delivered. Whether such occurrences remain pending or are lost is implementation defined, but it is expected that the implementation shall make a best effort to avoid losing pending interrupts.
6. Certain implementation-defined interrupts are *reserved*. Reserved interrupts are either interrupts for which application-defined ISRs are not supported, or those that already have ISRs by some other implementation-defined means. For example, a clock interrupt, which is used for internal time keeping by the JVM, is a reserved interrupt.
7. An application-defined ISR can be registered with one or more non-reserved interrupts. Registering an ISR for an interrupt shall implicitly deregister any already registered ISR for that interrupt. Any daisy-chaining of interrupt handlers shall be performed explicitly by the application interrupt handlers.
8. While an ISR is registered to an interrupt, the `handle` method shall be called *once* for each delivery of that interrupt. For locking out further interrupts during interrupt handling, the `handle` method must be synchronized with a priority high enough to lock out the requisite interrupts. This synchronized uses priority ceiling emulation to inhibit the corresponding interrupt (and all lower priority interrupts). The default allocation context of the `handle` method is the memory area passed during construction.
Any exception propagated from the `handle` method shall be caught by the JVM and ignored.
9. Code running in the context of an ISR may only attempt to acquire a lock that has priority ceiling emulation as its monitor control policy. The behavior is undefined, when an ISR attempt to acquire a lock that has a monitor control policy other than priority ceiling emulation.

The model assumes that

1. the processor has a (logical) interrupt controller that monitors a number of *interrupt lines*;
2. the interrupt controller may associate each interrupt line with a particular interrupt priority;
3. associated with the interrupt lines is a (logical) interrupt vector that contains the addresses of the ISRs;
4. the processor has instructions that allow interrupts from a particular line to be disabled/masked irrespective of whether (or the type of) device attached;
5. disabling interrupts from a specific line may disables the interrupts from lines of lower priority;
6. a device can be connected to an arbitrary interrupt line;

7. when an interrupt is signalled on an interrupt line by a device, the processor uses the identity of the interrupt line to index into the interrupt vector and jumps to the address of the ISR; the hardware automatically disables further interrupts (either of the same priority and lower or, possibly, all interrupts);
8. on return from the ISR, interrupts are automatically re-enabled.

For each of the interrupt, the RTSJ has an associated hardware priority that can be used to set the ceiling of an ISR object. The RTSJ virtual machine may use this to disable the interrupts from the associated interrupt line and lower priority interrupts, when it is executing a synchronized method of the interrupt-handling object. On a multicore system, the situation is more complex, since there may be other cores available to handle other interrupts, even at lower priorities, and some other locking mechanism may be necessary as well.

Though synchronization is not required in general, it is required to enforce visibility of changes made to any variables shared between some normal `Schedulable` and a `handle` method. For the `handle` method, this may be done automatically by the hardware interrupt handling mechanism or it may require added support from the realtime Java virtual machine. However, for clarity of the model, RTSJ recommends that the `handle` method should be defined as synchronized.

Support for interrupt handling is encapsulated in the `InterruptServiceRoutine` abstract class that has two main methods. The first is the final `register` method that will register an instance of the class with the system so that the appropriate interrupt vector can be initialized. The second is the abstract `handle` method that provides the code to be executed in response to the interrupt occurring. An individual real-time JVM may place restrictions of the code that can be written in this method. The process is illustrated in Figure 12.4, and is described below.

1. The ISR is created by some application real-time thread.
2. The created ISR is registered with the JVM, the interrupt id is passed as a parameter.
3. As part of the registration process, some internal interface is used to set up the code that will set the underlying interrupt vectors to some C/assembly code that will provide the necessary linkage to allow the callback to the Java handler.
4. When the interrupt occurs, the handler is called.

In order to integrate further the interrupt handling with the Java application, the `handle` method may trigger a happening or fire an event.

Typically an implementation of the RTSJ that supports first-level interrupt handling will document the following items:

1. For each interrupt, its identifying integer value, the priority at which the interrupt occurs and whether it can be inhibited or not, and the effects of registering ISRs to non inhibitable interrupts (if this is permitted).

2. Which run-time stack the **handle** method uses when it executes.
3. Any implementation- or hardware-specific activity that happens before the **handle** method is invoked (e.g., reading device registers, acknowledging devices).
4. The state (inhibited/uninhibited) of the nonreserved interrupts when the program starts; if some interrupts are uninhibited, what the mechanism is that a program can use to protect itself before it can register the corresponding ISR.
5. The treatment of interrupt occurrences that are generated while the interrupt is inhibited; i.e., whether one or more occurrences are held for later delivery, or all are lost.
6. Whether predefined or implementation-defined exceptions are raised as a result of the occurrence of any interrupt (for example, a hardware trap resulting from a segmentation error), and the mapping between the interrupt and the predefined exceptions.
7. On a multiprocessor, the rules governing the delivery of an interrupt occurrence to a particular processor. For example, whether execution of the **handle** method may spin if the lock of the associated object is held by another processor.

12.4 Package javax.realtime.device

12.4.1 Interfaces

12.4.1.1 RawByte

Interfaces

[javax.realtime.device.RawByteReader](#)

[javax.realtime.device.RawByteWriter](#)

Description

A marker for an object that can be used to access to a single byte. Read and write access to that byte is checked by the factory that creates the instance; therefore, no access checking is provided by this interface, only bounds checking.

Available since RTSJ 2.0

12.4.1.2 RawByteReader

Interfaces

[javax.realtime.device.RawMemory](#)

Description

A marker for a byte accessor object encapsulating the protocol for reading bytes from raw memory. A byte accessor can always access at least one byte. Each byte is transfered in a single atomic operation. Groups of bytes may be transfered together; however, this is not required.

Objects of this type are created with the method [RawMemoryFactory.createRawByteReader](#)¹ and [RawMemoryFactory.createRawByte](#)². Each object references a range of elements in the [RawMemoryRegion](#)³ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

¹Section [12.4.2.6.3](#)

²Section [12.4.2.6.3](#)

³Section [12.4.2.7](#)

Available since RTSJ 2.0

12.4.1.2.1 Methods

getBytes

Signature

```
public  
byte getBytes()
```

Description

Get the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address.

Returns

the value at the *base address* provided to the factory method that created this object.

getBytes(int)

Signature

```
public  
byte getBytes(int offset)  
throws OffsetOutOfBoundsException
```

Description

Get the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address* + (**offset** * stride * *element size in bytes*). When an exception is thrown, no data is transferred.

Parameters

offset of byte in the memory region starting from the address specified in the associated factory method.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

Returns

the value at the address specified.

get(int, byte)*Signature*

```
public
int get(int offset,
        byte[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Description

Fill the **values** starting at the address referenced by this instance plus the offset scaled by the element size in bytes and the object's **stride**. Only the bytes in the intersection of the start and end of **values** and the *base address* and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of the first byte in the memory region to transfere
values the array to received the bytes

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.
NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

get(int, byte, int, int)*Signature*

```
public
int get(int offset,
        byte[] values,
        int start,
        int count)
```

throws `OffsetOutOfBoundsException`,
`ArrayIndexOutOfBoundsException`,
`NullPointerException`

Description

Fill `values` with data from the memory region, where `offset` is first byte in the memory region and `start` is the first index in `values`. The number of bytes transfered is the minimum of `count`, the *size* of the memory region minus `offset`, and length of `values` minus `start`. When an exception is thrown, no data is transfered.

Parameters

`offset` of the first byte in the memory region to transfere
`values` the array to received the bytes
`start` the first index in array to fill
`count` the maximum number of bytes to copy

Throws

`OffsetOutOfBoundsException` when `offset` is negative or either `offset` or `offset + count` is greater than or equal to the size of this raw memory area.
`ArrayIndexOutOfBoundsException` when `start` is negative or either `start` or `start + count` is greater than or equal to the size of `values`.
`NullPointerException` when `values` is null or `count` is negative.

Returns

the number of bytes actually transfered.

12.4.1.3 RawByteWriter

Interfaces

`javax.realtime.device.RawMemory`

Description

A marker for a byte accessor object encapsulating the protocol for writing bytes from raw memory. A byte accessor can always access at least one byte. Each byte is transfered in a single atomic operation. Groups of bytes may be transfered together; however, this is not required.

Objects of this type are created with the method `RawMemoryFactory.createRawByteWriter`⁴ and `RawMemoryFactory.createRawByte`⁵. Each object references a range of el-

⁴Section 12.4.2.6.3

⁵Section 12.4.2.6.3

ements in the [RawMemoryRegion](#)⁶ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

Available since RTSJ 2.0

12.4.1.3.1 Methods

setByte(byte)

Signature

```
public  
void setByte(byte value)
```

Description

Set the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

value is the new value for the element.

setByte(int, byte)

Signature

```
public  
void setByte(int offset,  
             byte value)  
throws OffsetOutOfBoundsException
```

Description

⁶Section [12.4.2.7](#)

Set the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address + offset * size of Byte*. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

offset of byte in the memory region.

value is the new value for the element.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

set(int, byte)

Signature

```
public
int set(int offset,
        byte[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Description

Copy **values** to the raw memory starting at the address referenced by this instance plus the **offset** scaled by the element size in bytes and the objects **stride**. Only the bytes in the intersection of **values** and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of byte in the memory region.

values is the source of the data to write.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

set(int, byte, int, int)

Signature

```
public
int set(int offset,
        byte[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
        ArrayIndexOutOfBoundsException,
        NullPointerException
```

Description

Copy **values** to the memory region, where **offset** is first byte in the memory region to write and **start** is the first index in **values** from which to read. The number of bytes transfered is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transfered.

Parameters

offset of the first byte in the memory region to set
values the array from which to retrieve the bytes
start the first index in array to fill
count the maximum number of bytes to copy

Throws

OffsetOutOfBoundsException when **offset** is negative or either **offset** or **offset** + **count** is greater than or equal to the size of this raw memory area.
ArrayIndexOutOfBoundsException when **start** is negative or either **start** or **start** + **count** is greater than or equal to the size of **values**.
NullPointerException when **values** is null.

Returns

the number of bytes actually transfered.

12.4.1.4 RawDouble

Interfaces

[javax.realtime.device.RawDoubleReader](#)
[javax.realtime.device.RawDoubleWriter](#)

Description

A marker for an object that can be used to access to a single double. Read and write access to that double is checked by the factory that creates the instance; therefore, no access checking is provided by this interface, only bounds checking.

Available since RTSJ 2.0

12.4.1.5 RawDoubleReader

Interfaces

[javax.realtime.device.RawMemory](#)

Description

A marker for a double accessor object encapsulating the protocol for reading doubles from raw memory. A double accessor can always access at least one double. Each double is transfered in a single atomic operation. Groups of doubles may be transfered together; however, this is not required.

Objects of this type are created with the method [RawMemoryFactory.createRawDoubleReader](#)⁷ and [RawMemoryFactory.createRawDouble](#)⁸. Each object references a range of elements in the [RawMemoryRegion](#)⁹ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

Available since RTSJ 2.0

12.4.1.5.1 Methods

⁷Section [12.4.2.6.3](#)

⁸Section [12.4.2.6.3](#)

⁹Section [12.4.2.7](#)

getDouble

Signature

```
public  
double getDouble()
```

Description

Get the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address.

Returns

the value at the *base address* provided to the factory method that created this object.

getDouble(int)

Signature

```
public  
double getDouble(int offset)  
throws OffsetOutOfBoundsException
```

Description

Get the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address* + (**offset** * stride * *element size in bytes*). When an exception is thrown, no data is transferred.

Parameters

offset of double in the memory region starting from the address specified in the associated factory method.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

Returns

the value at the address specified.

get(int, double)

Signature

```
public
int get(int offset,
        double[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Description

Fill the **values** starting at the address referenced by this instance plus the offset scaled by the element size in bytes and the object's **stride**. Only the doubles in the intersection of the start and end of **values** and the *base address* and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of the first double in the memory region to transfere

values the array to received the doubles

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

get(int, double, int, int)

Signature

```
public
int get(int offset,
        double[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
        ArrayIndexOutOfBoundsException,
        NullPointerException
```

Description

Fill **values** with data from the memory region, where **offset** is first double in the memory region and **start** is the first index in **values**. The number of bytes transferred is the minimum of **count**, the *size* of the memory region minus **offset**,

and length of `values` minus `start`. When an exception is thrown, no data is transferred.

Parameters

`offset` of the first double in the memory region to transfer
`values` the array to receive the doubles
`start` the first index in array to fill
`count` the maximum number of doubles to copy

Throws

`OffsetOutOfBoundsException` when `offset` is negative or either `offset` or `offset + count` is greater than or equal to the size of this raw memory area.
`ArrayIndexOutOfBoundsException` when `start` is negative or either `start` or `start + count` is greater than or equal to the size of `values`.
`NullPointerException` when `values` is null or `count` is negative.

Returns

the number of doubles actually transferred.

12.4.1.6 RawDoubleWriter

Interfaces

`javax.realtime.device.RawMemory`

Description

A marker for a double accessor object encapsulating the protocol for writing doubles from raw memory. A double accessor can always access at least one double. Each double is transferred in a single atomic operation. Groups of doubles may be transferred together; however, this is not required.

Objects of this type are created with the method `RawMemoryFactory.createRawDoubleWriter`¹⁰ and `RawMemoryFactory.createRawDouble`¹¹. Each object references a range of elements in the `RawMemoryRegion`¹² starting at the *base address* provided to the factory method. The size provided to the factory method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

¹⁰Section 12.4.2.6.3

¹¹Section 12.4.2.6.3

¹²Section 12.4.2.7

Available since RTSJ 2.0

12.4.1.6.1 Methods

setDouble(double)

Signature

```
public  
void setDouble(double value)
```

Description

Set the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

value is the new value for the element.

setDouble(int, double)

Signature

```
public  
void setDouble(int offset,  
               double value)  
throws OffsetOutOfBoundsException
```

Description

Set the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address* + **offset** * *size of Double*. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

offset of double in the memory region.

value is the new value for the element.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

set(int, double)

Signature

```
public
int set(int offset,
        double[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Description

Copy **values** to the raw memory starting at the address referenced by this instance plus the **offset** scaled by the element size in bytes and the objects **stride**. Only the doubles in the intersection of **values** and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of double in the memory region.
values is the source of the data to write.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.
NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

set(int, double, int, int)

Signature

```
public
int set(int offset,
        double[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
        ArrayIndexOutOfBoundsException,
        NullPointerException
```


Description

Copy **values** to the memory region, where **offset** is first double in the memory region to write and **start** is the first index in **values** from which to read. The number of bytes transfered is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transfered.

Parameters

offset of the first double in the memory region to set
values the array from which to retrieve the doubles
start the first index in array to fill
count the maximum number of doubles to copy

Throws

`OffsetOutOfBoundsException` when **offset** is negative or either **offset** or **offset** + **count** is greater than or equal to the size of this raw memory area.
`ArrayIndexOutOfBoundsException` when **start** is negative or either **start** or **start** + **count** is greater than or equal to the size of **values**.
`NullPointerException` when **values** is null.

Returns

the number of doubles actually transfered.

12.4.1.7 RawFloat

Interfaces

`javax.realtime.device.RawFloatReader`
`javax.realtime.device.RawFloatWriter`

Description

A marker for an object that can be used to access to a single float. Read and write access to that float is checked by the factory that creates the instance; therefore, no access checking is provided by this interface, only bounds checking.

Available since RTSJ 2.0

12.4.1.8 RawFloatReader

Interfaces

`javax.realtime.device.RawMemory`

Description

A marker for a float accessor object encapsulating the protocol for reading floats from raw memory. A float accessor can always access at least one float. Each float is transferred in a single atomic operation. Groups of floats may be transferred together; however, this is not required.

Objects of this type are created with the method `RawMemoryFactory.createRawFloatReader`¹³ and `RawMemoryFactory.createRawFloat`¹⁴. Each object references a range of elements in the `RawMemoryRegion`¹⁵ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

Available since RTSJ 2.0

12.4.1.8.1 Methods

getFloat

Signature

```
public
float getFloat()
```

Description

Get the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address.

Returns

the value at the *base address* provided to the factory method that created this object.

¹³Section 12.4.2.6.3

¹⁴Section 12.4.2.6.3

¹⁵Section 12.4.2.7

getFloat(int)

Signature

```
public
float getFloat(int offset)
throws OffsetOutOfBoundsException
```

Description

Get the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address* + (**offset** * stride * *element size in bytes*). When an exception is thrown, no data is transferred.

Parameters

offset of float in the memory region starting from the address specified in the associated factory method.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

Returns

the value at the address specified.

get(int, float)

Signature

```
public
int get(int offset,
        float[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Description

Fill the **values** starting at the address referenced by this instance plus the offset scaled by the element size in bytes and the object's **stride**. Only the floats in the intersection of the start and end of **values** and the *base address* and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of the first float in the memory region to transfere
values the array to received the floats

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

get(int, float, int, int)*Signature*

```
public
int get(int offset,
        float[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
        ArrayIndexOutOfBoundsException,
        NullPointerException
```

Description

Fill **values** with data from the memory region, where **offset** is first float in the memory region and **start** is the first index in **values**. The number of bytes transfered is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transfered.

Parameters

offset of the first float in the memory region to transfere

values the array to received the floats

start the first index in array to fill

count the maximum number of floats to copy

Throws

OffsetOutOfBoundsException when **offset** is negative or either **offset** or **offset** + **count** is greater than or equal to the size of this raw memory area.

ArrayIndexOutOfBoundsException when **start** is negative or either **start** or **start** + **count** is greater than or equal to the size of **values**.

NullPointerException when **values** is null or **count** is negative.

Returns

the number of floats actually transfered.

12.4.1.9 RawFloatWriter

Interfaces

`javax.realtime.device.RawMemory`

Description

A marker for a float accessor object encapsulating the protocol for writing floats from raw memory. A float accessor can always access at least one float. Each float is transferred in a single atomic operation. Groups of floats may be transferred together; however, this is not required.

Objects of this type are created with the method `RawMemoryFactory.createRawFloatWriter`¹⁶ and `RawMemoryFactory.createRawFloat`¹⁷. Each object references a range of elements in the `RawMemoryRegion`¹⁸ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

Available since RTSJ 2.0

12.4.1.9.1 Methods

setFloat(float)

Signature

```
public
void setFloat(float value)
```

Description

Set the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other

¹⁶Section [12.4.2.6.3](#)

¹⁷Section [12.4.2.6.3](#)

¹⁸Section [12.4.2.7](#)

raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

value is the new value for the element.

setFloat(int, float)

Signature

```
public
void setFloat(int offset,
              float value)
throws OffsetOutOfBoundsException
```

Description

Set the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address + offset * size of Float*. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

offset of float in the memory region.
value is the new value for the element.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

set(int, float)

Signature

```
public
int set(int offset,
        float[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Description

Copy **values** to the raw memory starting at the address referenced by this instance plus the **offset** scaled by the element size in bytes and the objects **stride**. Only the floats in the intersection of **values** and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of float in the memory region.

values is the source of the data to write.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

set(int, float, int, int)*Signature*

```
public
int set(int offset,
        float[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
        ArrayIndexOutOfBoundsException,
        NullPointerException
```

Description

Copy **values** to the memory region, where **offset** is first float in the memory region to write and **start** is the first index in **values** from which to read. The number of bytes transfered is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transfered.

Parameters

offset of the first float in the memory region to set

values the array from which to retrieve the floats

start the first index in array to fill

count the maximum number of floats to copy

Throws

OffsetOutOfBoundsException when **offset** is negative or either **offset** or **offset** + **count** is greater than or equal to the size of this raw memory area.

ArrayIndexOutOfBoundsException when **start** is negative or either **start** or **start** + **count** is greater than or equal to the size of **values**.

`NullPointerException` when `values` is null.

Returns

the number of floats actually transfered.

12.4.1.10 RawInt

Interfaces

[javax.realtime.device.RawIntReader](#)
[javax.realtime.device.RawIntWriter](#)

Description

A marker for an object that can be used to access to a single int. Read and write access to that int is checked by the factory that creates the instance; therefore, no access checking is provided by this interface, only bounds checking.

Available since RTSJ 2.0

12.4.1.11 RawIntReader

Interfaces

[javax.realtime.device.RawMemory](#)

Description

A marker for a int accessor object encapsulating the protocol for reading ints from raw memory. A int accessor can always access at least one int. Each int is transfered in a single atomic operation. Groups of ints may be transfered together; however, this is not required.

Objects of this type are created with the method [RawMemoryFactory.createRawIntReader](#)¹⁹ and [RawMemoryFactory.createRawInt](#)²⁰. Each object references a range of elements in the [RawMemoryRegion](#)²¹ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In

¹⁹Section [12.4.2.6.3](#)

²⁰Section [12.4.2.6.3](#)

²¹Section [12.4.2.7](#)

other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

Available since RTSJ 2.0

12.4.1.11.1 Methods

getInt

Signature

```
public  
int getInt()
```

Description

Get the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address.

Returns

the value at the *base address* provided to the factory method that created this object.

getInt(int)

Signature

```
public  
int getInt(int offset)  
throws OffsetOutOfBoundsException
```

Description

Get the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address* + (**offset** * stride * *element size in bytes*). When an exception is thrown, no data is transferred.

Parameters

offset of int in the memory region starting from the address specified in the associated factory method.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

Returns

the value at the address specified.

get(int, int)

Signature

```
public
int get(int offset,
        int[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Description

Fill the **values** starting at the address referenced by this instance plus the offset scaled by the element size in bytes and the object's **stride**. Only the ints in the intersection of the start and end of **values** and the *base address* and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of the first int in the memory region to transfere
values the array to received the ints

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.
NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

get(int, int, int, int)

Signature

```
public
int get(int offset,
        int[] values,
        int start,
        int count)
```

throws `OffsetOutOfBoundsException`,
`ArrayIndexOutOfBoundsException`,
`NullPointerException`

Description

Fill `values` with data from the memory region, where `offset` is first int in the memory region and `start` is the first index in `values`. The number of bytes transfered is the minimum of `count`, the *size* of the memory region minus `offset`, and length of `values` minus `start`. When an exception is thrown, no data is transfered.

Parameters

`offset` of the first int in the memory region to transfere
`values` the array to received the ints
`start` the first index in array to fill
`count` the maximum number of ints to copy

Throws

`OffsetOutOfBoundsException` when `offset` is negative or either `offset` or `offset + count` is greater than or equal to the size of this raw memory area.
`ArrayIndexOutOfBoundsException` when `start` is negative or either `start` or `start + count` is greater than or equal to the size of `values`.
`NullPointerException` when `values` is null or `count` is negative.

Returns

the number of ints actually transfered.

12.4.1.12 RawIntWriter

Interfaces

`javax.realtime.device.RawMemory`

Description

A marker for a int accessor object encapsulating the protocol for writing ints from raw memory. A int accessor can always access at least one int. Each int is transfered in a single atomic operation. Groups of ints may be transfered together; however, this is not required.

Objects of this type are created with the method `RawMemoryFactory.createRawIntWriter`²² and `RawMemoryFactory.createRawInt`²³. Each object references a range of el-

²²Section 12.4.2.6.3

²³Section 12.4.2.6.3

ements in the [RawMemoryRegion](#)²⁴ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

Available since RTSJ 2.0

12.4.1.12.1 Methods

setInt(int)

Signature

```
public
void setInt(int value)
```

Description

Set the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transfered.

Parameters

value is the new value for the element.

setInt(int, int)

Signature

```
public
void setInt(int offset,
            int value)
throws OffsetOutOfBoundsException
```

Description

²⁴Section [12.4.2.7](#)

Set the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address* + **offset** * *size of Int*. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

offset of int in the memory region.

value is the new value for the element.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

set(int, int)

Signature

```
public
int set(int offset,
        int[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Description

Copy **values** to the raw memory starting at the address referenced by this instance plus the **offset** scaled by the element size in bytes and the objects **stride**. Only the ints in the intersection of **values** and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of int in the memory region.

values is the source of the data to write.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

set(int, int, int, int)

Signature

```
public
int set(int offset,
        int[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
        ArrayIndexOutOfBoundsException,
        NullPointerException
```

Description

Copy **values** to the memory region, where **offset** is first int in the memory region to write and **start** is the first index in **values** from which to read. The number of bytes transfered is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transfered.

Parameters

offset of the first int in the memory region to set
values the array from which to retrieve the ints
start the first index in array to fill
count the maximum number of ints to copy

Throws

OffsetOutOfBoundsException when **offset** is negative or either **offset** or **offset** + **count** is greater than or equal to the size of this raw memory area.
ArrayIndexOutOfBoundsException when **start** is negative or either **start** or **start** + **count** is greater than or equal to the size of **values**.
NullPointerException when **values** is null.

Returns

the number of ints actually transfered.

12.4.1.13 RawLong

Interfaces

[javax.realtime.device.RawLongReader](#)
[javax.realtime.device.RawLongWriter](#)

Description

A marker for an object that can be used to access to a single long. Read and write access to that long is checked by the factory that creates the instance; therefore, no access checking is provided by this interface, only bounds checking.

Available since RTSJ 2.0

12.4.1.14 RawLongReader

Interfaces

`javax.realtime.device.RawMemory`

Description

A marker for a long accessor object encapsulating the protocol for reading longs from raw memory. A long accessor can always access at least one long. Each long is transfered in a single atomic operation. Groups of longs may be transfered together; however, this is not required.

Objects of this type are created with the method `RawMemoryFactory.createRawLongReader`²⁵ and `RawMemoryFactory.createRawLong`²⁶. Each object references a range of elements in the `RawMemoryRegion`²⁷ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

Available since RTSJ 2.0

12.4.1.14.1 Methods

²⁵Section [12.4.2.6.3](#)

²⁶Section [12.4.2.6.3](#)

²⁷Section [12.4.2.7](#)

getLong

Signature

```
public  
long getLong()
```

Description

Get the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address.

Returns

the value at the *base address* provided to the factory method that created this object.

getLong(int)

Signature

```
public  
long getLong(int offset)  
throws OffsetOutOfBoundsException
```

Description

Get the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address* + (**offset** * stride * *element size in bytes*). When an exception is thrown, no data is transferred.

Parameters

offset of long in the memory region starting from the address specified in the associated factory method.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

Returns

the value at the address specified.

get(int, long)

Signature


```
public
int get(int offset,
        long[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Description

Fill the **values** starting at the address referenced by this instance plus the offset scaled by the element size in bytes and the object's **stride**. Only the longs in the intersection of the start and end of **values** and the *base address* and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of the first long in the memory region to transfere
values the array to received the longs

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.
NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

get(int, long, int, int)

Signature

```
public
int get(int offset,
        long[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
        ArrayIndexOutOfBoundsException,
        NullPointerException
```

Description

Fill **values** with data from the memory region, where **offset** is first long in the memory region and **start** is the first index in **values**. The number of bytes transferred is the minimum of **count**, the *size* of the memory region minus **offset**,

and length of `values` minus `start`. When an exception is thrown, no data is transferred.

Parameters

`offset` of the first long in the memory region to transfere
`values` the array to received the longs
`start` the first index in array to fill
`count` the maximum number of longs to copy

Throws

`OffsetOutOfBoundsException` when `offset` is negative or either `offset` or `offset + count` is greater than or equal to the size of this raw memory area.
`ArrayIndexOutOfBoundsException` when `start` is negative or either `start` or `start + count` is greater than or equal to the size of `values`.
`NullPointerException` when `values` is null or `count` is negative.

Returns

the number of longs actually transferred.

12.4.1.15 RawLongWriter

Interfaces

`javax.realtime.device.RawMemory`

Description

A marker for a long accessor object encapsulating the protocol for writing longs from raw memory. A long accessor can always access at least one long. Each long is transferred in a single atomic operation. Groups of longs may be transferred together; however, this is not required.

Objects of this type are created with the method `RawMemoryFactory.createRawLongWriter`²⁸ and `RawMemoryFactory.createRawLong`²⁹. Each object references a range of elements in the `RawMemoryRegion`³⁰ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

²⁸Section 12.4.2.6.3

²⁹Section 12.4.2.6.3

³⁰Section 12.4.2.7

Available since RTSJ 2.0

12.4.1.15.1 Methods

setLong(long)

Signature

```
public  
void setLong(long value)
```

Description

Set the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

value is the new value for the element.

setLong(int, long)

Signature

```
public  
void setLong(int offset,  
              long value)  
throws OffsetOutOfBoundsException
```

Description

Set the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address* + **offset** * *size of Long*. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

offset of long in the memory region.

value is the new value for the element.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

set(int, long)

Signature

```
public
int set(int offset,
        long[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Description

Copy **values** to the raw memory starting at the address referenced by this instance plus the **offset** scaled by the element size in bytes and the objects **stride**. Only the longs in the intersection of **values** and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of long in the memory region.
values is the source of the data to write.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.
NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

set(int, long, int, int)

Signature

```
public
int set(int offset,
        long[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
        ArrayIndexOutOfBoundsException,
        NullPointerException
```

Description

Copy **values** to the memory region, where **offset** is first long in the memory region to write and **start** is the first index in **values** from which to read. The number of bytes transfered is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transfered.

Parameters

offset of the first long in the memory region to set
values the array from which to retrieve the longs
start the first index in array to fill
count the maximum number of longs to copy

Throws

OffsetOutOfBoundsException when **offset** is negative or either **offset** or **offset** + **count** is greater than or equal to the size of this raw memory area.
ArrayIndexOutOfBoundsException when **start** is negative or either **start** or **start** + **count** is greater than or equal to the size of **values**.
NullPointerException when **values** is null.

Returns

the number of longs actually transfered.

12.4.1.16 RawMemory

Description

A marker for all raw memory accessor objects.

Available since RTSJ 2.0

12.4.1.16.1 Methods

getAddress

Signature

```
public  
long getAddress()
```

Description

Get the base physical address of this object.

Returns

the first physical address this raw memory object can access.

getSize*Signature*

```
public  
int getSize()
```

Description

Get the number of bytes that this object spans.

Returns

the size of this raw memory

getStride*Signature*

```
public  
int getStride()
```

Description

Get the distance between elements in multiples of element size.

Returns

the span between elements of this raw memory

12.4.1.17 RawMemoryRegionFactory

Description

A class to give an application the ability to provide support for a [RawMemoryRegion](#)³¹ that is not already provided by the standard. An instance of this class can be registered with a [RawMemoryFactory](#)³² and provides the object that that factory should return for a given [RawMemoryRegion](#). It is responsible for checking all requests and throwing the proper exception when a request is invalid or the requester is not authorized to make the request.

Available since RTSJ 2.0

12.4.1.17.1 Methods

getRegion

Signature

```
public  
    javax.realtime.device.RawMemoryRegion getRegion()
```

Description

Determine for what region this factory creates raw memory objects.

Returns

the region of this factory.

getName

Signature

```
public  
    java.lang.String getName()
```

Description

Determine the name of the region for which this factory creates raw memory objects.

Returns

the name of the region of this factory.

³¹Section [12.4.2.7](#)

³²Section [12.4.2.6](#)

createRawByte(long, int, int)*Signature*

```

public
  javax.realtime.device.RawByte createRawByte(long base,
                                              int count,
                                              int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException

```

Description

Create an instance of a class that implements [RawByte](#)³³ and accesses memory of [getRegion](#)³⁴ in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride** * *size of RawByte* * **count**. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements [RawByte](#)³⁵ and supports access to the specified range

³³Section [12.4.1.1](#)

³⁴Section [12.4.1.17.1](#)

³⁵Section [12.4.1.1](#)

in the memory region.

Available since RTSJ 2.0

createRawByteReader(long, int, int)

Signature

```
public
javafx.realtime.device.RawByteReader createRawByteReader(long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Description

Create an instance of a class that implements [RawByteReader](#)³⁶ and accesses memory of [getRegion](#)³⁷ in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawByteReader * count`. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.
count The number of memory elements accessible through the returned instance.
stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

[IllegalArgumentException](#) when `base` is negative, `count` is not greater than zero, or `stride` is not greater than zero.
[SecurityException](#) when the caller does not have permissions to access the given memory region or the specified range of addresses.
[OffsetOutOfBoundsException](#) when `base` is invalid.

³⁶Section [12.4.1.2](#)

³⁷Section [12.4.1.17.1](#)

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawByteReader**³⁸ and supports access to the specified range in the memory region.

Available since RTSJ 2.0

createRawByteWriter(long, int, int)

Signature

```
public
javax.realtime.device.RawByteWriter createRawByteWriter(long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Description

Create an instance of a class that implements **RawByteWriter**³⁹ and accesses memory of **getRegion**⁴⁰ in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawByteWriter * count**. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.
count The number of memory elements accessible through the returned instance.
stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

³⁸Section 12.4.1.2

³⁹Section 12.4.1.3

⁴⁰Section 12.4.1.17.1

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is not greater than zero.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when `base` is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawByteWriter`⁴¹ and supports access to the specified range in the memory region.

Available since RTSJ 2.0

createRawShort(long, int, int)

Signature

```
public
javax.realtime.device.RawShort createRawShort(long base,
                                              int count,
                                              int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Description

Create an instance of a class that implements `RawShort`⁴² and accesses memory of `getRegion`⁴³ in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawShort * count`. The object is allocated in the current memory area of the calling thread.

Parameters

⁴¹Section 12.4.1.3

⁴²Section 12.4.1.18

⁴³Section 12.4.1.17.1

base The starting physical address accessible through the returned instance.
count The number of memory elements accessible through the returned instance.
stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawShort**⁴⁴ and supports access to the specified range in the memory region.

Available since RTSJ 2.0

createRawShortReader(long, int, int)

Signature

```
public
javax.realtime.device.RawShortReader createRawShortReader(long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Description

Create an instance of a class that implements **RawShortReader**⁴⁵ and accesses

⁴⁴Section 12.4.1.18

⁴⁵Section 12.4.1.19

memory of `getRegion`⁴⁶ in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawShortReader * count`. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.
count The number of memory elements accessible through the returned instance.
stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is not greater than zero.
`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.
`OffsetOutOfBoundsException` when `base` is invalid.
`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.
`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawShortReader`⁴⁷ and supports access to the specified range in the memory region.

Available since RTSJ 2.0

createRawShortWriter(long, int, int)

Signature

```
public
javax.realtime.device.RawShortWriter createRawShortWriter(long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
```

⁴⁶Section 12.4.1.17.1

⁴⁷Section 12.4.1.19

UnsupportedRawMemoryRegionException,
MemoryTypeConflictException

Description

Create an instance of a class that implements [RawShortWriter](#)⁴⁸ and accesses memory of [getRegion](#)⁴⁹ in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawShortWriter * count**. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.
count The number of memory elements accessible through the returned instance.
stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.
SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.
OffsetOutOfBoundsException when **base** is invalid.
SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.
MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements [RawShortWriter](#)⁵⁰ and supports access to the specified range in the memory region.

Available since RTSJ 2.0

createRawInt(long, int, int)

Signature

⁴⁸Section [12.4.1.20](#)

⁴⁹Section [12.4.1.17.1](#)

⁵⁰Section [12.4.1.20](#)

```

public
javax.realtime.device.RawInt createRawInt(long base,
                                           int count,
                                           int stride)

throws SecurityException,
        OffsetOutOfBoundsException,
        SizeOutOfBoundsException,
        UnsupportedRawMemoryRegionException,
        MemoryTypeConflictException

```

Description

Create an instance of a class that implements `RawInt`⁵¹ and accesses memory of `getRegion`⁵² in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawInt * count`. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.
count The number of memory elements accessible through the returned instance.
stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is not greater than zero.
`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.
`OffsetOutOfBoundsException` when `base` is invalid.
`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.
`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawInt`⁵³ and supports access to the specified range in the memory region.

⁵¹Section 12.4.1.10

⁵²Section 12.4.1.17.1

⁵³Section 12.4.1.10

Available since RTSJ 2.0

createRawIntReader(long, int, int)

Signature

```
public
javafx.runtime.device.RawIntReader createRawIntReader(long base,
                                                    int count,
                                                    int stride)

throws SecurityException,
        OffsetOutOfBoundsException,
        SizeOutOfBoundsException,
        UnsupportedRawMemoryRegionException,
        MemoryTypeConflictException
```

Description

Create an instance of a class that implements [RawIntReader](#)⁵⁴ and accesses memory of [getRegion](#)⁵⁵ in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawIntReader * count`. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is not greater than zero.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

[OffsetOutOfBoundsException](#) when `base` is invalid.

[SizeOutOfBoundsException](#) when the memory addressed by the object would extend into an invalid range of memory.

⁵⁴Section [12.4.1.11](#)

⁵⁵Section [12.4.1.17.1](#)

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawIntReader**⁵⁶ and supports access to the specified range in the memory region.

Available since RTSJ 2.0

createRawIntWriter(long, int, int)

Signature

```
public
javax.realtime.device.RawIntWriter createRawIntWriter(long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Description

Create an instance of a class that implements **RawIntWriter**⁵⁷ and accesses memory of **getRegion**⁵⁸ in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawIntWriter * count**. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.

⁵⁶Section 12.4.1.11

⁵⁷Section 12.4.1.12

⁵⁸Section 12.4.1.17.1

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawIntWriter**⁵⁹ and supports access to the specified range in the memory region.

Available since RTSJ 2.0

createRawLong(long, int, int)

Signature

```
public
javax.realtime.device.RawLong createRawLong(long base,
                                             int count,
                                             int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Description

Create an instance of a class that implements **RawLong**⁶⁰ and accesses memory of **getRegion**⁶¹ in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawLong * count**. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

⁵⁹Section 12.4.1.12

⁶⁰Section 12.4.1.13

⁶¹Section 12.4.1.17.1

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawLong**⁶² and supports access to the specified range in the memory region.

Available since RTSJ 2.0

createRawLongReader(long, int, int)

Signature

```
public
javax.realtime.device.RawLongReader createRawLongReader(long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedOperationException,
       MemoryTypeConflictException
```

Description

Create an instance of a class that implements **RawLongReader**⁶³ and accesses memory of **getRegion**⁶⁴ in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * count**.

⁶²Section 12.4.1.13

⁶³Section 12.4.1.14

⁶⁴Section 12.4.1.17.1

*size of RawLongReader * count*. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.
count The number of memory elements accessible through the returned instance.
stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.
SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.
OffsetOutOfBoundsException when **base** is invalid.
SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.
MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawLongReader**⁶⁵ and supports access to the specified range in the memory region.

Available since RTSJ 2.0

createRawLongWriter(long, int, int)

Signature

```
public
javax.realtime.device.RawLongWriter createRawLongWriter(long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

⁶⁵Section 12.4.1.14

Description

Create an instance of a class that implements `RawLongWriter`⁶⁶ and accesses memory of `getRegion`⁶⁷ in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawLongWriter * count`. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.
count The number of memory elements accessible through the returned instance.
stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is not greater than zero.
`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.
`OffsetOutOfBoundsException` when `base` is invalid.
`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.
`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawLongWriter`⁶⁸ and supports access to the specified range in the memory region.

Available since RTSJ 2.0

createRawFloat(long, int, int)

Signature

```
public
javax.realtime.device.RawFloat createRawFloat(long base,
                                              int count,
                                              int stride)
```

⁶⁶Section 12.4.1.15

⁶⁷Section 12.4.1.17.1

⁶⁸Section 12.4.1.15

throws `SecurityException`,
`OffsetOutOfBoundsException`,
`SizeOutOfBoundsException`,
`UnsupportedRawMemoryRegionException`,
`MemoryTypeConflictException`

Description

Create an instance of a class that implements `RawFloat`⁶⁹ and accesses memory of `getRegion`⁷⁰ in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawFloat * count`. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.
count The number of memory elements accessible through the returned instance.
stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is not greater than zero.
`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.
`OffsetOutOfBoundsException` when `base` is invalid.
`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.
`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawFloat`⁷¹ and supports access to the specified range in the memory region.

Available since RTSJ 2.0

createRawFloatReader(long, int, int)

⁶⁹Section 12.4.1.7

⁷⁰Section 12.4.1.17.1

⁷¹Section 12.4.1.7

Signature

```
public
javafx.realtime.device.RawFloatReader createRawFloatReader(long base,
                                                            int count,
                                                            int stride)

throws SecurityException,
        OffsetOutOfBoundsException,
        SizeOutOfBoundsException,
        UnsupportedRawMemoryRegionException,
        MemoryTypeConflictException
```

Description

Create an instance of a class that implements [RawFloatReader](#)⁷² and accesses memory of [getRegion](#)⁷³ in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawFloatReader * count`. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.
count The number of memory elements accessible through the returned instance.
stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

[IllegalArgumentException](#) when `base` is negative, `count` is not greater than zero, or `stride` is not greater than zero.
[SecurityException](#) when the caller does not have permissions to access the given memory region or the specified range of addresses.
[OffsetOutOfBoundsException](#) when `base` is invalid.
[SizeOutOfBoundsException](#) when the memory addressed by the object would extend into an invalid range of memory.
[MemoryTypeConflictException](#) when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements [RawFloatReader](#)⁷⁴ and supports access to the specified range in the memory region.

⁷²Section [12.4.1.8](#)

⁷³Section [12.4.1.17.1](#)

⁷⁴Section [12.4.1.8](#)

Available since RTSJ 2.0

createRawFloatWriter(long, int, int)

Signature

```
public
  javax.realtime.device.RawFloatWriter createRawFloatWriter(long base,
                                                             int count,
                                                             int stride)

throws  SecurityException,
        OffsetOutOfBoundsException,
        SizeOutOfBoundsException,
        UnsupportedRawMemoryRegionException,
        MemoryTypeConflictException
```

Description

Create an instance of a class that implements [RawFloatWriter](#)⁷⁵ and accesses memory of [getRegion](#)⁷⁶ in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawFloatWriter * count`. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

[IllegalArgumentException](#) when `base` is negative, `count` is not greater than zero, or `stride` is not greater than zero.

[SecurityException](#) when the caller does not have permissions to access the given memory region or the specified range of addresses.

[OffsetOutOfBoundsException](#) when `base` is invalid.

[SizeOutOfBoundsException](#) when the memory addressed by the object would extend into an invalid range of memory.

⁷⁵Section [12.4.1.9](#)

⁷⁶Section [12.4.1.17.1](#)

`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawFloatWriter`⁷⁷ and supports access to the specified range in the memory region.

Available since RTSJ 2.0

createRawDouble(long, int, int)

Signature

```
public
javafx.realtime.device.RawDouble createRawDouble(long base,
                                                    int count,
                                                    int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Description

Create an instance of a class that implements `RawDouble`⁷⁸ and accesses memory of `getRegion`⁷⁹ in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawDouble * count`. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.
count The number of memory elements accessible through the returned instance.
stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is not greater than zero.

⁷⁷Section 12.4.1.9

⁷⁸Section 12.4.1.4

⁷⁹Section 12.4.1.17.1

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawDouble**⁸⁰ and supports access to the specified range in the memory region.

Available since RTSJ 2.0

createRawDoubleReader(long, int, int)

Signature

```
public
javafx.runtime.device.RawDoubleReader createRawDoubleReader(long base,
                                                             int count,
                                                             int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Description

Create an instance of a class that implements **RawDoubleReader**⁸¹ and accesses memory of **getRegion**⁸² in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawDoubleReader * count**. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.

⁸⁰Section 12.4.1.4

⁸¹Section 12.4.1.5

⁸²Section 12.4.1.17.1

count The number of memory elements accessible through the returned instance.

stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawDoubleReader**⁸³ and supports access to the specified range in the memory region.

Available since RTSJ 2.0

createRawDoubleWriter(long, int, int)

Signature

```
public
  javax.realtime.device.RawDoubleWriter createRawDoubleWriter(long base,
                                                                int count,
                                                                int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       UnsupportedRawMemoryRegionException,
       MemoryTypeConflictException
```

Description

Create an instance of a class that implements **RawDoubleWriter**⁸⁴ and accesses memory of **getRegion**⁸⁵ in the address range described by **base**, **stride**, and

⁸³Section 12.4.1.5

⁸⁴Section 12.4.1.6

⁸⁵Section 12.4.1.17.1

count. The actual extent of the memory addressed by the object is **stride * size of RawDoubleWriter * count**. The object is allocated in the current memory area of the calling thread.

Parameters

base The starting physical address accessible through the returned instance.
count The number of memory elements accessible through the returned instance.
stride The distance to the next element in multiple of element count, where a value of 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is not greater than zero.
SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.
OffsetOutOfBoundsException when **base** is invalid.
SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.
MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawDoubleWriter**⁸⁶ and supports access to the specified range in the memory region.

Available since RTSJ 2.0

12.4.1.18 RawShort

Interfaces

javax.realtime.device.RawShortReader
javax.realtime.device.RawShortWriter

Description

A marker for an object that can be used to access to a single short. Read and write access to that short is checked by the factory that creates the instance; therefore, no access checking is provided by this interface, only bounds checking.

⁸⁶Section 12.4.1.6

Available since RTSJ 2.0

12.4.1.19 RawShortReader

Interfaces

[javax.realtime.device.RawMemory](#)

Description

A marker for a short accessor object encapsulating the protocol for reading shorts from raw memory. A short accessor can always access at least one short. Each short is transferred in a single atomic operation. Groups of shorts may be transferred together; however, this is not required.

Objects of this type are created with the method [RawMemoryFactory.createRawShortReader](#)⁸⁷ and [RawMemoryFactory.createRawShort](#)⁸⁸. Each object references a range of elements in the [RawMemoryRegion](#)⁸⁹ starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessible.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

Available since RTSJ 2.0

12.4.1.19.1 Methods

getShort

Signature

```
public  
short getShort()
```

Description

⁸⁷Section [12.4.2.6.3](#)

⁸⁸Section [12.4.2.6.3](#)

⁸⁹Section [12.4.2.7](#)

Get the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address.

Returns

the value at the *base address* provided to the factory method that created this object.

getShort(int)

Signature

```
public
short getShort(int offset)
throws OffsetOutOfBoundsException
```

Description

Get the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address* + (**offset** * stride * *element size in bytes*). When an exception is thrown, no data is transferred.

Parameters

offset of short in the memory region starting from the address specified in the associated factory method.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

Returns

the value at the address specified.

get(int, short)

Signature

```
public
int get(int offset,
        short[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Description

Fill the **values** starting at the address referenced by this instance plus the offset scaled by the element size in bytes and the object's **stride**. Only the shorts in the intersection of the start and end of **values** and the *base address* and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of the first short in the memory region to transfere
values the array to received the shorts

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.
NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

get(int, short, int, int)

Signature

```
public
int get(int offset,
        short[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
        ArrayIndexOutOfBoundsException,
        NullPointerException
```

Description

Fill **values** with data from the memory region, where **offset** is first short in the memory region and **start** is the first index in **values**. The number of bytes transferred is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transferred.

Parameters

offset of the first short in the memory region to transfere
values the array to received the shorts
start the first index in array to fill
count the maximum number of shorts to copy

Throws

`OffsetOutOfBoundsException` when `offset` is negative or either `offset` or `offset + count` is greater than or equal to the size of this raw memory area.

`ArrayIndexOutOfBoundsException` when `start` is negative or either `start` or `start + count` is greater than or equal to the size of values.

`NullPointerException` when `values` is null or `count` is negative.

Returns

the number of shorts actually transfered.

12.4.1.20 RawShortWriter*Interfaces*

`javax.realtime.device.RawMemory`

Description

A marker for a short accessor object encapsulating the protocol for writing shorts from raw memory. A short accessor can always access at least one short. Each short is transfered in a single atomic operation. Groups of shorts may be transfered together; however, this is not required.

Objects of this type are created with the method `RawMemoryFactory.createRawShortWriter`⁹⁰ and `RawMemoryFactory.createRawShort`⁹¹. Each object references a range of elements in the `RawMemoryRegion`⁹² starting at the *base address* provided to the factory method. The size provided to the factor method determines the number of elements accessable.

Caching of the memory access is controlled by the factory that created this object. If the memory is not cached, this method guarantees serialized access. In other words, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.

Available since RTSJ 2.0

12.4.1.20.1 Methods

⁹⁰Section 12.4.2.6.3

⁹¹Section 12.4.2.6.3

⁹²Section 12.4.2.7

setShort(short)

Signature

```
public  
void setShort(short value)
```

Description

Set the value at the first position referenced by this instance, i.e., the value at its start address. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

value is the new value for the element.

setShort(int, short)

Signature

```
public  
void setShort(int offset,  
              short value)  
throws OffsetOutOfBoundsException
```

Description

Set the value of the n^{th} element referenced by this instance, where **n** is **offset** and the address is *base address + offset * size of Short*. This operation must be atomic with respect to all other raw memory accesses to the address. When an exception is thrown, no data is transferred.

Parameters

offset of short in the memory region.

value is the new value for the element.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.

set(int, short)

Signature

```
public
int set(int offset,
        short[] values)
throws OffsetOutOfBoundsException,
        NullPointerException
```

Description

Copy **values** to the raw memory starting at the address referenced by this instance plus the **offset** scaled by the element size in bytes and the objects **stride**. Only the shorts in the intersection of **values** and the end of the memory region are transferred. When an exception is thrown, no data is transferred.

Parameters

offset of short in the memory region.
values is the source of the data to write.

Throws

OffsetOutOfBoundsException when **offset** is negative or greater than or equal to the number of elements in the raw memory region.
NullPointerException when **values** is null.

Returns

the number of elements copied to **values**

set(int, short, int, int)

Signature

```
public
int set(int offset,
        short[] values,
        int start,
        int count)
throws OffsetOutOfBoundsException,
        ArrayIndexOutOfBoundsException,
        NullPointerException
```

Description

Copy **values** to the memory region, where **offset** is first short in the memory region to write and **start** is the first index in **values** from which to read. The number of bytes transferred is the minimum of **count**, the *size* of the memory region minus **offset**, and length of **values** minus **start**. When an exception is thrown, no data is transferred.

Parameters

`offset` of the first short in the memory region to set
`values` the array from which to retrieve the shorts
`start` the first index in array to fill
`count` the maximum number of shorts to copy

Throws

`OffsetOutOfBoundsException` when `offset` is negative or either `offset` or `offset + count` is greater than or equal to the size of this raw memory area.
`ArrayIndexOutOfBoundsException` when `start` is negative or either `start` or `start + count` is greater than or equal to the size of values.
`NullPointerException` when `values` is null.

Returns

the number of shorts actually transfered.

12.4.2 Classes

12.4.2.1 DMABufferFactory

Inheritance

java.lang.Object
 javax.realtime.device.DMABufferFactory

Description

A factory class for generating raw byte buffers. This enables the infrastructure to limit the address ranges from which a buffer may be taken.

12.4.2.1.1 Constructors

DMABufferFactory(DMARegion, long, long)

Signature

```
public
DMABufferFactory(DMARegion region,
                 long base,
                 long size)
```

throws `MemoryInUseException`

Description

Create a factory for allocating buffers in a particular address range. Whether the address is physical or virtual is system dependent.

Parameters

region is the area of memory a DMA controller can reference, from which this factory takes its memory.

base is the base address of a memory range in **region** for buffer allocation

size is the number of bytes in the memory range

Throws

`MemoryInUseException` when the memory area provide is already in use by or reserved for a `javax.realtime.MemoryArea`⁹³, program code, or other sytem or VM structure.

12.4.2.1.2 Methods

allocateDirectByteBuffer(int)

Signature

```
public
java.nio.ByteBuffer allocateDirectByteBuffer(int capacity)
```

Description

Create a direct byte buffer with the given capacity within the range of this factory.

Parameters

capacity the number of bytes in the buffer.

Throws

`javax.realtime.StaticOutOfMemoryError` when no memory is available

Returns

the new buffer.

⁹³Section 11.4.2.3

defineDirectByteBuffer(long, int)

Signature

```
public
java.nio.ByteBuffer defineDirectByteBuffer(long start,
                                           int capacity)

throws RangeOutOfBoundsException
```

Description

Given a range of memory within the allocation area defined by this factory, create a direct byte buffer to represent that memory range.

Parameters

start is the beginning of the memory range

capacity is number of bytes in the range

Throws

[RangeOutOfBoundsException](#) when **start** or **start + capacity** extends outside of the allocation area of this factory.

[javanx.realtime.StaticOutOfMemoryError](#) when no memory is available

Returns

the new buffer object

inRange(ByteBuffer)

Signature

```
public
boolean inRange(ByteBuffer buffer)
```

Description

Check to see if the buffer's data area is within the range of this factory.

Parameters

buffer to check

Returns

true when and only when buffer's data area is within the range of this factory;
otherwise **false**

addressOf(ByteBuffer)

Signature

```
public  
long addressOf(ByteBuffer buffer)
```

Description

Give the location of this buffers data in memory. The address shall be in the address space of the DMA controller.

Parameters

buffer of which to get the address

Returns

the start address of the data range of this buffer

writeFence(ByteBuffer)

Signature

```
public static  
void writeFence(ByteBuffer buffer)
```

Description

Ensures that all changes to the `DirectByteBuffer` buffer by the current thread have been flushed in a manner that makes them visible to other threads (including native threads), and behaves as a volatile store with respect to the Java Memory Model synchronization order.

This method shall invoke a memory barrier operation that is understood by the VM, runtime, native compiler, and platform to provide visibility to all changes to the associated buffer made before its invocation.

Parameters

buffer the byte buffer which will be flushed

readFence(ByteBuffer)

Signature

```
public static  
void readFence(ByteBuffer buffer)
```

Description

Ensures that any previous changes to the memory represented by the given `DirectByteBuffer` by other threads (including native threads) will be visible when it is next accessed by the current thread, and behaves as a volatile load with respect to the Java Memory Model synchronization order.

This method shall invoke a memory barrier operation that is understood by the VM, runtime, native compiler, and platform to provide visibility for any changes to the associated buffer previously flushed with a call to `writeFence(ByteBuffer)`⁹⁴ or its native equivalent on the buffer's memory.

Parameters

`buffer` the byte buffer which will be updated

12.4.2.2 DMARegion

Inheritance

java.lang.Object
 javafx.realtime.device.DMARegion

Description

Define the reachable memory for a given DMA controller in terms of the physical address space of the system.

12.4.2.2.1 Constructors

DMARegion(long, long)

Signature

```
public  
DMARegion(long start,  
           long size)  
throws IllegalArgumentException
```

Description

Create a DMA memory definition.

⁹⁴Section 12.4.2.1.2

Parameters

start address of the DMA address space in the physical address address space of the main processor.

size is the number of bytes in the DMA address space

Throws

IllegalArgumentException when **start** is less than zero or **start + size** is larger than the physical memory of the system.

12.4.2.2.2 Methods

regionAddressOf(long)

Signature

```
public  
long regionAddressOf(long address)  
throws IllegalArgumentException
```

Description

Translate a physical address into a DMA region address.

Parameters

address to translate

Throws

IllegalArgumentException when the results is outside the DMA space.

Returns

the equivalent address in DMA space.

physicalAddressOf(long)

Signature

```
public  
long physicalAddressOf(long address)  
throws IllegalArgumentException
```

Description

Translate a DMA space address into a physical address.

Parameters

`address` to translate

Throws

`IllegalArgumentException` when the input is outside the DMA space.

Returns

the corresponding physical address

12.4.2.3 Happening

Inheritance

`java.lang.Object`
`javax.realtime.AsyncBaseEvent`
`javax.realtime.AsyncEvent`
`javax.realtime.device.Happening`

Interfaces

`javax.realtime.ActiveEvent`

Description

This class provides second level handling for external events such as interrupts. A happening can be triggered by an `InterruptServiceRoutine`⁹⁵ or from native code. Application-defined `Happenings` can be identified by an application-provided name or a system-provided `id`, both of which must be unique. A system `Happening` has a name provide by the system which is a string beginning with `@`.

Available since RTSJ 2.0

12.4.2.3.1 Constructors

Happening(String, HappeningDispatcher)

Signature

```
public  
Happening(String name,  
           HappeningDispatcher dispatcher)
```

⁹⁵Section 12.4.2.5

throws `IllegalArgumentException`

Description

Create a `Happening` with the given name.

Parameters

`name` of the happening.

`dispatcher` to use when being triggered.

Throws

`IllegalArgumentException` when `name` is `null` or does not match the pattern full identifier naming convention, i.e., package plus `name`. An implementation may throw this exception for all names starting with `java.` and `javax.`

Happening(String)

Signature

```
public  
Happening(String name)  
throws IllegalArgumentException
```

Description

Create a `Happening` with the given `name` and the default dispatcher.

Parameters

`name` of the happening.

Throws

`IllegalArgumentException` when `name` is `null` or does not match the pattern full type naming convention, i.e., package plus `name`. An implementation may throw this exception for all names starting with `java.` and `javax.`

12.4.2.3.2 Methods

getHappening(String)

Signature

```
public static  
    javax.realtime.device.Happening getHappening(String name)
```

Description

Find an active happening by its name.

Parameters

name of the happening to get.

Throws

IllegalArgumentException when **name** is null.

Returns

a reference to the happening with name **name**, or null if no happening is found.

isHappening(String)

Signature

```
public static  
    boolean isHappening(String name)
```

Description

Is there an active happening with name **name**?

Parameters

name A string that might name an active happening.

Throws

IllegalArgumentException when **name** is null.

Returns

True only when there is a registered happening with the name **name**.

createId(String)

Signature

```
public static  
    int createId(String name)  
    throws IllegalStateException
```

Description

Sets up a mapping between a **name** and a system dependent ID. This can be called either in the constructor of an instance of `InterruptServiceRoutine`⁹⁶ or in native code that sets up an interrupt service routine to link it with a `Happening`. Once created, it cannot be removed.

This must take no more than linear time in the number of ID (**n**) registered, but should be $O(\log_2(n))$.

Parameters

name is a happening name string.

Throws

`IllegalStateException` when **name** is already registered.

`IllegalArgumentException` when **name** is null.

Returns

an ID assigned by the system

getId(String)

Signature

```
public static  
int getId(String name)
```

Description

Return the ID of **name**, when one exists or -1, when **name** is not registered.

This must take no more than linear time in the number of ID (**n**) registered, but should be $O(\log_2(n))$.

Parameters

name is a happening name string.

Throws

`IllegalArgumentException` when **name** is null.

Returns

The id, or -1 when no happening is found with that name.

get(int)

Signature

⁹⁶Section 12.4.2.5

```
public static  
    javax.realtime.device.Happening get(int id)
```

Description

Get the external event corresponding to a given `id`.

Parameters

`id` of a registered signal

Returns

the signal corresponding to `id`.

get(String)

Signature

```
public static  
    javax.realtime.device.Happening get(String name)
```

Description

Get the external event corresponding to a given `name`.

Parameters

`name` of a registered signal

Throws

`IllegalArgumentException` when `name` is null.

Returns

the signal corresponding to `name`.

trigger(int)

Signature

```
public static  
    boolean trigger(int id)
```

Description

Causes the event dispatcher corresponding to `happeningId` to be scheduled for execution. The implementation should be simple enough so that it can be done in the context of an `InterruptServiceRoutine.handle`⁹⁷ method.

⁹⁷Section 12.4.2.5.2

`trigger()` and any native code analog to it interact with other `javax.realtime.ActiveEvent`⁹⁸ code effectively as if `trigger()` signals a POSIX counting semaphore that the happening is waiting on.

The implementation is encouraged to create (and document) a native code analog to this method that can be used without a Java context.

This method must execute in constant time.

Parameters

`id` identifies which happening to trigger.

Returns

true if a happening with id `happeningId` was found, false otherwise.

getId

Signature

```
public final  
int getId()
```

Description

Get the number of this happening.

Returns

the happening number or -1, when not registered.

getName

Signature

```
public  
java.lang.String getName()
```

Description

Get the name of this happening.

Returns

the name of this happening.

⁹⁸Section 8.4.1.1

start

Signature

```
public  
void start()  
throws IllegalStateException
```

Description

Start this **Happening**, i.e., change to the active and enabled state. Once a happening is started for the first time, when it is in a scoped memory it increments the scope count of that scope; otherwise, it becomes a member of the root set. An active and enabled happening dispatches its handlers when fired.

Throws

IllegalStateException when this **Happening** has already been started or its **name** is already in use by another happening that has been started.

See [Section stop\(\)](#)

start(boolean)

Signature

```
public  
void start(boolean disabled)  
throws IllegalStateException
```

Description

Start this **Happening**, but leave it in the disabled state. When fired before being enabled, it does not dispatch its handlers.

Parameters

disabled true for starting in a disabled state.

Throws

IllegalStateException when this **Happening** has already been started.

See [Section stop\(\)](#)

stop

Signature

```
public  
boolean stop()  
throws IllegalStateException
```

Description

Stop this **happening** from responding to the **fire** and **trigger** methods.

Throws

IllegalStateException when this **Happening** is not active.

Returns

true when this is in the *enabled* state **false** otherwise.

isActive

Signature

```
public  
boolean isActive()
```

Description

Determine the activation state of this happening, i.e., it has been started.

Returns

true when active, **false** otherwise.

isRunning

Signature

```
public  
boolean isRunning()
```

Description

Determine whether or not this **Happening** is both active and enabled.

Returns

true when this **Happening** is both active and enabled, **false** otherwise.

trigger

Signature

```
public  
void trigger()
```

Description

Causes the event dispatcher associated with **this** to be scheduled for execution. The implementation should be simple enough so that it can be done in the context of an [InterruptServiceRoutine.handle](#)⁹⁹ method.

This method must execute in constant time.

getDispatcher

Signature

```
public  
javax.realtime.device.HappeningDispatcher getDispatcher()
```

Description

Obtain the dispatcher for **this**.

Returns

that dispatcher.

12.4.2.4 HappeningDispatcher

Inheritance

```
java.lang.Object  
  javax.realtime.ActiveEventDispatcher  
    javax.realtime.device.HappeningDispatcher
```

Description

This class provides a means of dispatching a set of [Happening](#)¹⁰⁰.

12.4.2.4.1 Constructors

⁹⁹Section [12.4.2.5.2](#)

¹⁰⁰Section [12.4.2.3](#)

HappeningDispatcher(SchedulingParameters, SchedulingGroup)

Signature

```
public  
HappeningDispatcher(SchedulingParameters schedule,  
                    SchedulingGroup group)
```

Description

Create a new dispatcher, whose dispatching thread runs with the given scheduling parameters.

Parameters

`schedule` give the parameters for scheduling this dispatcher

HappeningDispatcher(SchedulingParameters)

Signature

```
public  
HappeningDispatcher(SchedulingParameters schedule)
```

Description

Create a new dispatcher, whose dispatching thread runs with the given scheduling parameters.

Parameters

`schedule` give the parameters for scheduling this dispatcher

12.4.2.4.2 Methods

register(Happening)

Signature

```
public synchronized  
void register(Happening happening)
```

```
throws RegistrationException,  
        IllegalStateException,  
        IllegalArgumentException
```

Description

Register a **Happening**¹⁰¹ with this dispatcher.

Parameters

happening to register

Throws

RegistrationException when **happening** is already registered.
IllegalStateException when this object has been destroyed.
IllegalArgumentException when **happening** is not stopped.

unregister(Happening)

Signature

```
public synchronized  
void unregister(Happening happening)  
throws DeregistrationException,  
        IllegalStateException,  
        IllegalArgumentException
```

Description

Unregister a **Happening**¹⁰² from this dispatcher.

Parameters

happening to unregister

Throws

DeregistrationException when **happening** is not already registered.
IllegalStateException when this object has been destroyed.
IllegalArgumentException when **happening** is not stopped.

destroy

Signature

¹⁰¹Section 12.4.2.3

¹⁰²Section 12.4.2.3

```

public
void destroy()
throws IllegalStateException

```

Description

Release all reasources thereby making the dispatcher unusable.

Throws

`IllegalStateException` when called on a dispatcher that has one or more registered `Happening`¹⁰³ objects.

12.4.2.5 InterruptServiceRoutine

Inheritance

```

java.lang.Object
  javax.realtime.device.InterruptServiceRoutine

```

Interfaces

```

  javax.realtime.RealtimeExecutionContext

```

Description

A class for defining a first level interrupt handler. The implementation must override the `handle`¹⁰⁴ method to provide the code to be run when an interrupt occurs. This class must always be present in the Device module, but may do nothing in a context that does not provide direct access to interrupts, e.g., in user space on an operating system that does not support user space device drivers.

12.4.2.5.1 Constructors

InterruptServiceRoutine(MemoryArea)

Signature

```

public
InterruptServiceRoutine(MemoryArea area)

```

¹⁰³Section 12.4.2.3

¹⁰⁴Section 12.4.2.5.2

throws `NullPointerException`,
`IllegalArgumentException`

Description

Create an interrupt service routine with a particular memory area.

Parameters

`area` the allocation context in which the `handle`¹⁰⁵ method runs.

Throws

`NullPointerException` when `initial_area` is null.

`IllegalArgumentException` when `id` is not a valid interrupt id.

12.4.2.5.2 Methods

validInterruptIds

Signature

```
public static  
int[] validInterruptIds()
```

Description

Determine which interrupt identifiers are valid.

Returns

an ordered array of integers representing the valid interrupts in the system.
On a machine that does not support any interrupts, a zero length array is returned.

getHandler(int)

Signature

```
public static  
javax.realtime.device.InterruptServiceRoutine getHandler(int interrupt)
```

Description

Find the `InterruptServiceRoutine` that is handling a given interrupt.

¹⁰⁵Section 12.4.2.5.2

Parameters

`interrupt` for which to find the `InterruptServiceRoutine`

Returns

the `InterruptServiceRoutine` registered to the given `interrupt`. Null is returned when nothing is registered for that `interrupt`.

getMaximumInterruptPriority

Signature

```
public static  
int getMaximumInterruptPriority()
```

Description

Retrieve the maximum interrupt priority. It must be greater than or equal to the result of `getMinimumInterruptPriority`¹⁰⁶.

Returns

the maximum interrupt priority.

getMinimumInterruptPriority

Signature

```
public static  
int getMinimumInterruptPriority()
```

Description

Retrieve the minimum interrupt priority. It must be higher than all other priorities provided by the system.

Returns

the minimum interrupt priority.

getInterruptPriority(int)

Signature

```
public static  
int getInterruptPriority(int interruptId)
```

¹⁰⁶Section 12.4.2.5.2

throws `IllegalArgumentException`

Description

Get the interrupt priority of a given interrupt.

Throws

`IllegalArgumentException` when there is no interrupt corresponding to `interruptId`

Returns

the priority at which the `handle`¹⁰⁷ method is invoked. The returned value is always greater than `javax.realtime.PriorityScheduler.getMaxPriority()`¹⁰⁸.

isRegistered

Signature

```
public final
boolean isRegistered()
```

Description

A predicate for the registration state.

Returns

true when registered, otherwise false.

register(int)

Signature

```
public
void register(int interrupt)
throws RegistrationException
```

Description

Register this interrupt service routine with the system so that it can be triggered.

Parameters

`interrupt` a system dependent identifier for the interrupt.

Throws

¹⁰⁷Section 12.4.2.5.2

¹⁰⁸Section 6.4.3.8.3

`RegistrationException` when this is already registered or some other `InterruptServiceRoutine`¹⁰⁹ is registered for `interrupt`.

unregister

Signature

```
public
void unregister()
throws DeregistrationException
```

Description

Deregister this interrupt service routine with the system so that it can no longer be triggered.

Throws

`DeregistrationException` when this interrupt service routine is not registered.

handle

Signature

```
protected abstract
void handle()
```

Description

The code to execute for first level interrupt handling. A subclass defines this to give the required behavior. `RawMemory`¹¹⁰ classes may be used to access the associated device registers and a `Happening`¹¹¹ may be triggered for second level interrupt handling.

The code used to implement this method should not block itself for an unbound amount of time or induce a context switch, e.g., sleeping. The effects of unbound blocking and inducing a context switch here are undefined and could result in deadlocking the machine. `Object.notify()` and `Object.notifyAll()` may be called, but `Object.wait()` should not be called.

Unless the overridden method is synchronized, the infrastructure shall provide no synchronization for the execution of this method. When the `javax.realtime.MemoryArea`¹¹²

¹⁰⁹Section 12.4.2.5

¹¹⁰Section 12.4.1.16

¹¹¹Section 12.4.2.3

¹¹²Section 11.4.2.3

provided at creation is a `javax.realtime.memory.ScopedMemory`¹¹³, its count is incremented on entry to this method and decremented on exit.

12.4.2.6 RawMemoryFactory

Inheritance

```
java.lang.Object
  javax.realtime.device.RawMemoryFactory
```

Description

This class is the hub of a system that constructs special purpose objects to access particular types and ranges of raw memory. This facility is supported by the `register(RawMemoryRegionFactory)`¹¹⁴ methods. An application developer can use this method to add support for additional memory regions.

Each create method returns an object of the corresponding type, e.g., the `createRawByte(RawMemoryRegion, long, int, int)`¹¹⁵ method returns a reference to an object that implements the `RawByte`¹¹⁶ interface and supports access to the requested type of memory and address range. Each create method is permitted to optimize error checking and access based on the requested memory type and address range.

The usage pattern for raw memory, assuming the necessary factory has been registered, is illustrated by this example.

```
// Get an accessor object that can access memory starting at
// baseAddress, for size bytes.
RawInt memory =
    RawMemoryFactory.createRawInt(RawMemoryFactory.MEMORY_MAPPED_REGION,
                                address, count, stride, false);
// Use the accessor to load from and store to raw memory.
int loadedData = memory.getInt(someOffset);
memory.setInt(otherOffset, intVal);
```

When an application needs to access a class of memory that is not already supported by a registered factory, the developer must define a memory region by implementing a factory which can create objects to access memory in that

¹¹³Section 11.5.3.6

¹¹⁴Section 12.4.2.6.3

¹¹⁵Section 12.4.2.6.3

¹¹⁶Section 12.4.1.1

region. Thus, the application must implement a factory that implements the `RawMemoryRegionFactory`¹¹⁷ interface.

A raw memory region factory is identified by a `RawMemoryRegion`¹¹⁸ that is used by each create method, e.g., `createRawByte(RawMemoryRegion, long, int, int)`¹¹⁹, to locate the appropriate factory. The name is not passed to `register(RawMemoryRegionFactory)`¹²⁰ as a separate argument, rather the name is provided to `register(RawMemoryRegionFactory)`¹²¹ through the factory's `RawMemoryRegionFactory.getName`¹²² method.

The `register(RawMemoryRegionFactory)`¹²³ method is only used when by application code when it needs to add support for a new type of raw memory.

Whether a given `offset` addresses a high-order or low-order byte of an aligned `short` in memory is determined by the value of the `javax.realtime.RealtimeSystem.BYTE_ORDER`¹²⁴ static byte variable in class `javax.realtime.RealtimeSystem`¹²⁵, the start address of the object, the `offset` given the `stride` of the object. Regardless of the byte ordering, accessor methods for `byte` continue to select bytes starting at `offset` from the base address and continuing toward greater addresses.

The `RawMemory` class enables a realtime program to implement device drivers, memory-mapped I/O, flash memory, battery-backed RAM, and similar low-level software.

A raw memory region cannot contain references to Java objects. Such a capability would be unsafe (since it could be used to defeat Java's type checking) and error prone (since it is sensitive to the specific representational choices made by the Java compiler).

Atomic loads and stores on raw memory are defined in terms of physical memory. This memory may be accessible to threads outside the JVM and to non-programmed access (e.g., DMA). Consequently, atomic access must be supported by hardware. This specification is written with the assumption that all suitable hardware platforms support atomic loads from raw memory for aligned bytes, shorts, and ints. Atomic access beyond the specified minimum may be supported by the implementation.

Storing values into raw memory is more hardware-dependent than loading values. Many processor architectures do not support atomic stores of variables

¹¹⁷Section 12.4.1.17

¹¹⁸Section 12.4.2.7

¹¹⁹Section 12.4.2.6.3

¹²⁰Section 12.4.2.6.3

¹²¹Section 12.4.2.6.3

¹²²Section 12.4.1.17.1

¹²³Section 12.4.2.6.3

¹²⁴Section 14.3.2.3.1

¹²⁵Section 14.3.2.3

except for aligned stores of the processor's word size. For instance, storing a byte into memory might require reading a 32-bit quantity into a processor register, updating the register to reflect the new byte value, then restoring the whole 32-bit quantity. Changes to other bytes in the 32-bit quantity that take place between the load and the store are lost.

Some processors have mechanisms that can be used to implement an atomic store of a byte, but those mechanisms are often slow and not universally supported.

This class need not support unaligned access to data; but if it does, it is not require the implementation to make such access atomic. Accesses to data aligned on its natural boundary will be atomic if the processor implements atomic loads and stores of that data size.

Except where noted, accesses to raw memory are not atomic with respect to the memory or with respect to schedulable objects. A raw memory region could be updated by another schedulable object, or even unmapped in the middle of an access method, or even *removed* mid method.

The characteristics of raw-memory access are necessarily platform dependent. This specification provides a minimum requirement for the RTSJ platform, but it also supports optional system properties that identify a platform's level of support for atomic raw put and get. The properties represent a four-dimensional sparse array of access type, data type, alignment, and atomicity with boolean values indicating whether that combination of access attributes is atomic. The default value for array entries is false. The dimension are

The true values in the table are represented by properties of the following form. `javax.realtime.atomicaccess_<access>_<type>_<alignment>_atomicity=true` for example,

`javax.realtime.atomicaccess_read_byte_0_memory=true`

Table entries with a value of false may be explicitly represented, but since false is the default value, such properties are redundant.

All raw memory access is treated as volatile, and *serialized*. The runtime must be forced to read memory or write to memory on each call to a raw memory objects's getter or setter method, and to complete the reads and writes in the order they appear in the program order.

Available since RTSJ 2.0

12.4.2.6.1 Fields

Table 12.1: Properties Array

Attribute	Values	Comment
Access type	read, write	
Data type	byte, short, int, long, float, double	
Alignment	0	aligned
	1 to one less than data type size	the first byte of the data is <i>alignment</i> bytes away from natural alignment.
Atomicity	processor	means access is atomic with respect to other tasks on processor.
	smp	means access is <i>processor</i> atomic, and atomic with respect to all processors in an SMP.
	memory	means that access is <i>smp</i> atomic, and atomic with respect to all access to the memory including DMA.

MEMORY_MAPPED_REGION

```
public static final MEMORY_MAPPED_REGION
```

Description

This raw memory name is predefined for use to request access to memory mapped I/O devices.

IO_PORT_MAPPED_REGION

```
public static final IO_PORT_MAPPED_REGION
```

Description

This raw memory name is predefined for use to request access to I/O device space implemented by processor instructions, such as the x86 `in` and `out` instructions.

12.4.2.6.2 Constructors

RawMemoryFactory

Signature

```
public  
RawMemoryFactory()
```

Description

Create an empty factory. For a factory with support for the platform defined [RawMemoryRegion](#)¹²⁶s, use [getDefaultFactory](#)¹²⁷ instead.

12.4.2.6.3 Methods

getDefaultFactory

Signature

```
public static  
javax.realtime.device.RawMemoryFactory getDefaultFactory()
```

Description

Get the factory with support for the platform defined regions.

Returns

the platform defined factory

register(RawMemoryRegionFactory)

Signature

```
public  
void register(RawMemoryRegionFactory factory)  
throws RegistrationException
```

Description

Add support for a new memory region

¹²⁶Section [12.4.2.7](#)

¹²⁷Section [12.4.2.6.3](#)

Parameters

factory is the [RawMemoryRegionFactory](#)¹²⁸ to use for creating [RawMemory](#)¹²⁹ objects for the the [RawMemoryRegion](#)¹³⁰ it makes available.

Throws

[RegistrationException](#) when the [RawMemoryRegion](#) of **factory** already has a factory registered.

deregister(RawMemoryRegionFactory)*Signature*

```
public
void deregister(RawMemoryRegionFactory factory)
throws DeregistrationException
```

Description

Remove support for a new memory region

Parameters

factory is the [RawMemoryRegionFactory](#)¹³¹ to make unavailable.

Throws

[RegistrationException](#) when the factory is not registered.

createRawByte(RawMemoryRegion, long, int, int)*Signature*

```
public
javax.realtime.device.RawByte createRawByte(RawMemoryRegion region,
                                              long base,
                                              int count,
                                              int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

¹²⁸Section [12.4.1.17](#)

¹²⁹Section [12.4.1.16](#)

¹³⁰Section [12.4.2.7](#)

¹³¹Section [12.4.1.17](#)

Description

Create an instance of a class that implements `RawByte`¹³² and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride** * *size of RawByte* * **count**. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when **base** is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawByte`¹³³ and supports access to the specified range in the memory region.

`createRawByteReader(RawMemoryRegion, long, int, int)`

Signature

`public`

```
javax.realtime.device.RawByteReader createRawByteReader(RawMemoryRegion region,  
                                                         long base,  
                                                         int count,  
                                                         int stride)
```

¹³²Section 12.4.1.1

¹³³Section 12.4.1.1

throws `SecurityException`,
`OffsetOutOfBoundsException`,
`SizeOutOfBoundsException`,
`MemoryTypeConflictException`,
`UnsupportedRawMemoryRegionException`

Description

Create an instance of a class that implements `RawByteReader`¹³⁴ and accesses memory of `region` in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawByteReader * count`. The object is allocated in the current memory area of the calling thread.

Parameters

`region` indicated the address space from which the new instance should be taken.

`base` The starting physical address accessible through the returned instance.

`count` The number of memory elements accessible through the returned instance.

`stride` The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is less than one.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when `base` is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawByteReader`¹³⁵ and supports access to the specified range in the memory region.

createRawByteWriter(RawMemoryRegion, long, int, int)

¹³⁴Section 12.4.1.2

¹³⁵Section 12.4.1.2

Signature

```
public
javafx.realtime.device.RawByteWriter createRawByteWriter(RawMemoryRegion region,
                                                         long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Description

Create an instance of a class that implements `RawByteWriter`¹³⁶ and accesses memory of `region` in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawByteWriter * count`. The object is allocated in the current memory area of the calling thread.

Parameters

`region` indicated the address space from which the new instance should be taken.

`base` The starting physical address accessible through the returned instance.

`count` The number of memory elements accessible through the returned instance.

`stride` The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is less than one.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when `base` is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

¹³⁶Section 12.4.1.3

an object that implements `RawByteWriter`¹³⁷ and supports access to the specified range in the memory region.

`createRawShort(RawMemoryRegion, long, int, int)`

Signature

```
public
javax.realtime.device.RawShort createRawShort(RawMemoryRegion region,
                                              long base,
                                              int count,
                                              int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Description

Create an instance of a class that implements `RawShort`¹³⁸ and accesses memory of `region` in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawShort * count`. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is less than one.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when `base` is invalid.

¹³⁷Section 12.4.1.3

¹³⁸Section 12.4.1.18

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawShort`¹³⁹ and supports access to the specified range in the memory region.

`createRawShortReader(RawMemoryRegion, long, int, int)`

Signature

```
public
javax.realtime.device.RawShortReader createRawShortReader(RawMemoryRegion region,
                                                           long base,
                                                           int count,
                                                           int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Description

Create an instance of a class that implements `RawShortReader`¹⁴⁰ and accesses memory of `region` in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawShortReader * count`. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

¹³⁹Section 12.4.1.18

¹⁴⁰Section 12.4.1.19

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawShortReader**¹⁴¹ and supports access to the specified range in the memory region.

createRawShortWriter(RawMemoryRegion, long, int, int)*Signature*

```
public
javax.realtime.device.RawShortWriter createRawShortWriter(RawMemoryRegion region,
                                                         long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Description

Create an instance of a class that implements **RawShortWriter**¹⁴² and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawShortWriter * count**. The object is allocated in the current memory area of the calling thread.

Parameters

¹⁴¹Section 12.4.1.19

¹⁴²Section 12.4.1.20

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawShortWriter**¹⁴³ and supports access to the specified range in the memory region.

createRawInt(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawInt createRawInt(RawMemoryRegion region,
                                           long base,
                                           int count,
                                           int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Description

¹⁴³Section 12.4.1.20

Create an instance of a class that implements `RawInt`¹⁴⁴ and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride** * *size of RawInt* * **count**. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when **base** is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawInt`¹⁴⁵ and supports access to the specified range in the memory region.

`createRawIntReader(RawMemoryRegion, long, int, int)`

Signature

```
public
javax.realtime.device.RawIntReader createRawIntReader(RawMemoryRegion region,
                                                       long base,
                                                       int count,
                                                       int stride)
```

¹⁴⁴Section 12.4.1.10

¹⁴⁵Section 12.4.1.10

throws `SecurityException`,
`OffsetOutOfBoundsException`,
`SizeOutOfBoundsException`,
`MemoryTypeConflictException`,
`UnsupportedRawMemoryRegionException`

Description

Create an instance of a class that implements `RawIntReader`¹⁴⁶ and accesses memory of `region` in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawIntReader * count`. The object is allocated in the current memory area of the calling thread.

Parameters

`region` indicated the address space from which the new instance should be taken.

`base` The starting physical address accessible through the returned instance.

`count` The number of memory elements accessible through the returned instance.

`stride` The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is less than one.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when `base` is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawIntReader`¹⁴⁷ and supports access to the specified range in the memory region.

createRawIntWriter(RawMemoryRegion, long, int, int)

¹⁴⁶Section 12.4.1.11

¹⁴⁷Section 12.4.1.11

Signature

```

public
    javax.realtime.device.RawIntWriter createRawIntWriter(RawMemoryRegion region,
                                                         long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
        OffsetOutOfBoundsException,
        SizeOutOfBoundsException,
        MemoryTypeConflictException,
        UnsupportedRawMemoryRegionException

```

Description

Create an instance of a class that implements `RawIntWriter`¹⁴⁸ and accesses memory of `region` in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawIntWriter * count`. The object is allocated in the current memory area of the calling thread.

Parameters

`region` indicated the address space from which the new instance should be taken.

`base` The starting physical address accessible through the returned instance.

`count` The number of memory elements accessible through the returned instance.

`stride` The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is less than one.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when `base` is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

¹⁴⁸Section 12.4.1.12

an object that implements `RawIntWriter`¹⁴⁹ and supports access to the specified range in the memory region.

`createRawLong(RawMemoryRegion, long, int, int)`

Signature

```
public
javax.realtime.device.RawLong createRawLong(RawMemoryRegion region,
                                             long base,
                                             int count,
                                             int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Description

Create an instance of a class that implements `RawLong`¹⁵⁰ and accesses memory of `region` in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawLong * count`. The object is allocated in the current memory area of the calling thread.

Parameters

`region` indicated the address space from which the new instance should be taken.

`base` The starting physical address accessible through the returned instance.

`count` The number of memory elements accessible through the returned instance.

`stride` The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is less than one.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when `base` is invalid.

¹⁴⁹Section 12.4.1.12

¹⁵⁰Section 12.4.1.13

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawLong**¹⁵¹ and supports access to the specified range in the memory region.

createRawLongReader(RawMemoryRegion, long, int, int)

Signature

```
public
javafx.realtime.device.RawLongReader createRawLongReader(RawMemoryRegion region,
                                                         long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Description

Create an instance of a class that implements **RawLongReader**¹⁵² and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawLongReader * count**. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

¹⁵¹Section 12.4.1.13

¹⁵²Section 12.4.1.14

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is less than one.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when `base` is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawLongReader`¹⁵³ and supports access to the specified range in the memory region.

`createRawLongWriter(RawMemoryRegion, long, int, int)`

Signature

```
public
javax.realtime.device.RawLongWriter createRawLongWriter(RawMemoryRegion region,
                                                         long base,
                                                         int count,
                                                         int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Description

Create an instance of a class that implements `RawLongWriter`¹⁵⁴ and accesses memory of `region` in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawLongWriter * count`. The object is allocated in the current memory area of the calling thread.

Parameters

¹⁵³Section 12.4.1.14

¹⁵⁴Section 12.4.1.15

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawLongWriter**¹⁵⁵ and supports access to the specified range in the memory region.

createRawFloat(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawFloat createRawFloat(RawMemoryRegion region,
                                              long base,
                                              int count,
                                              int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Description

¹⁵⁵Section 12.4.1.15

Create an instance of a class that implements `RawFloat`¹⁵⁶ and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride** * *size of RawFloat* * **count**. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when **base** is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawFloat`¹⁵⁷ and supports access to the specified range in the memory region.

`createRawFloatReader(RawMemoryRegion, long, int, int)`

Signature

`public`

```
javax.realtime.device.RawFloatReader createRawFloatReader(RawMemoryRegion region,
                                                            long base,
                                                            int count,
                                                            int stride)
```

¹⁵⁶Section 12.4.1.7

¹⁵⁷Section 12.4.1.7

throws `SecurityException`,
`OffsetOutOfBoundsException`,
`SizeOutOfBoundsException`,
`MemoryTypeConflictException`,
`UnsupportedRawMemoryRegionException`

Description

Create an instance of a class that implements `RawFloatReader`¹⁵⁸ and accesses memory of `region` in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawFloatReader * count`. The object is allocated in the current memory area of the calling thread.

Parameters

`region` indicated the address space from which the new instance should be taken.
`base` The starting physical address accessible through the returned instance.
`count` The number of memory elements accessible through the returned instance.
`stride` The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is less than one.
`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.
`OffsetOutOfBoundsException` when `base` is invalid.
`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.
`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawFloatReader`¹⁵⁹ and supports access to the specified range in the memory region.

createRawFloatWriter(RawMemoryRegion, long, int, int)

¹⁵⁸Section 12.4.1.8

¹⁵⁹Section 12.4.1.8

Signature

```
public
javafx.realtime.device.RawFloatWriter createRawFloatWriter(RawMemoryRegion region,
                                                            long base,
                                                            int count,
                                                            int stride)

throws SecurityException,
        OffsetOutOfBoundsException,
        SizeOutOfBoundsException,
        MemoryTypeConflictException,
        UnsupportedRawMemoryRegionException
```

Description

Create an instance of a class that implements `RawFloatWriter`¹⁶⁰ and accesses memory of `region` in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawFloatWriter * count`. The object is allocated in the current memory area of the calling thread.

Parameters

`region` indicated the address space from which the new instance should be taken.

`base` The starting physical address accessible through the returned instance.

`count` The number of memory elements accessible through the returned instance.

`stride` The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is less than one.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when `base` is invalid.

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

¹⁶⁰Section 12.4.1.9

an object that implements `RawFloatWriter`¹⁶¹ and supports access to the specified range in the memory region.

createRawDouble(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawDouble createRawDouble(RawMemoryRegion region,
                                                long base,
                                                int count,
                                                int stride)

throws SecurityException,
        OffsetOutOfBoundsException,
        SizeOutOfBoundsException,
        MemoryTypeConflictException,
        UnsupportedRawMemoryRegionException
```

Description

Create an instance of a class that implements `RawDouble`¹⁶² and accesses memory of `region` in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawDouble * count`. The object is allocated in the current memory area of the calling thread.

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

`IllegalArgumentException` when `base` is negative, `count` is not greater than zero, or `stride` is less than one.

`SecurityException` when the caller does not have permissions to access the given memory region or the specified range of addresses.

`OffsetOutOfBoundsException` when `base` is invalid.

¹⁶¹Section 12.4.1.9

¹⁶²Section 12.4.1.4

`SizeOutOfBoundsException` when the memory addressed by the object would extend into an invalid range of memory.

`MemoryTypeConflictException` when `base` does not point to memory that matches the type served by this factory.

Returns

an object that implements `RawDouble`¹⁶³ and supports access to the specified range in the memory region.

createRawDoubleReader(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawDoubleReader createRawDoubleReader(RawMemoryRegion region,
                                                             long base,
                                                             int count,
                                                             int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Description

Create an instance of a class that implements `RawDoubleReader`¹⁶⁴ and accesses memory of `region` in the address range described by `base`, `stride`, and `count`. The actual extent of the memory addressed by the object is `stride * size of RawDoubleReader * count`. The object is allocated in the current memory area of the calling thread.

Parameters

`region` indicated the address space from which the new instance should be taken.

`base` The starting physical address accessible through the returned instance.

`count` The number of memory elements accessible through the returned instance.

¹⁶³Section 12.4.1.4

¹⁶⁴Section 12.4.1.5

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawDoubleReader**¹⁶⁵ and supports access to the specified range in the memory region.

createRawDoubleWriter(RawMemoryRegion, long, int, int)

Signature

```
public
javax.realtime.device.RawDoubleWriter createRawDoubleWriter(RawMemoryRegion region,
                                                             long base,
                                                             int count,
                                                             int stride)

throws SecurityException,
       OffsetOutOfBoundsException,
       SizeOutOfBoundsException,
       MemoryTypeConflictException,
       UnsupportedRawMemoryRegionException
```

Description

Create an instance of a class that implements **RawDoubleWriter**¹⁶⁶ and accesses memory of **region** in the address range described by **base**, **stride**, and **count**. The actual extent of the memory addressed by the object is **stride * size of RawDoubleWriter * count**. The object is allocated in the current memory area of the calling thread.

¹⁶⁵Section 12.4.1.5

¹⁶⁶Section 12.4.1.6

Parameters

region indicated the address space from which the new instance should be taken.

base The starting physical address accessible through the returned instance.

count The number of memory elements accessible through the returned instance.

stride The distance to the next element as a multiple of element size, where 1 means the elements are adjacent in memory.

Throws

IllegalArgumentException when **base** is negative, **count** is not greater than zero, or **stride** is less than one.

SecurityException when the caller does not have permissions to access the given memory region or the specified range of addresses.

OffsetOutOfBoundsException when **base** is invalid.

SizeOutOfBoundsException when the memory addressed by the object would extend into an invalid range of memory.

MemoryTypeConflictException when **base** does not point to memory that matches the type served by this factory.

Returns

an object that implements **RawDoubleWriter**¹⁶⁷ and supports access to the specified range in the memory region.

12.4.2.7 RawMemoryRegion

Inheritance

java.lang.Object

javax.realtime.device.RawMemoryRegion

Description

RawMemoryRegion is a class for typing raw memory regions. It is returned by the **RawMemoryRegionFactory.getRegion**¹⁶⁸ methods of the raw memory region factory classes, and it is used with methods such as **RawMemoryFactory.createRawByte(RawMemoryRegion, long, int, int)**¹⁶⁹ and **RawMemoryFactory.createRawDouble(RawMemoryRegion,**

¹⁶⁷Section 12.4.1.6

¹⁶⁸Section 12.4.1.17.1

¹⁶⁹Section 12.4.2.6.3

`long, int, int)`¹⁷⁰ methods to identify the region from which the application wants to get an accessor instance.

Available since RTSJ 2.0

12.4.2.7.1 Methods

getRegion(String)

Signature

```
public static
    javax.realtime.device.RawMemoryRegion getRegion(String name)
```

Description

Get a region type when it already exists or creates a new one.

Parameters

name of the region

Returns

the region type object.

isRawMemoryRegion(String)

Signature

```
public static
    boolean isRawMemoryRegion(String name)
```

Description

Ask whether or not there is a memory region type of a given name.

Parameters

name for which to search

Returns

true when there is one and **false** otherwise.

¹⁷⁰Section 12.4.2.6.3

getName

Signature

```
public final  
java.lang.String getName()
```

Description

Obtains the name of this region type.

Returns

the region types name

toString

Signature

```
public final  
java.lang.String toString()
```

Description

Gets a printable representation for a Region.

Returns

the name of this memory region type.

12.5 Rationale

12.5.1 Raw Memory

Raw memory in the RTSJ refers to any memory in which only objects of primitive types can be stored; *Java objects or their references cannot be stored in raw memory.* RTSJ Version 2.0 provides two categories:

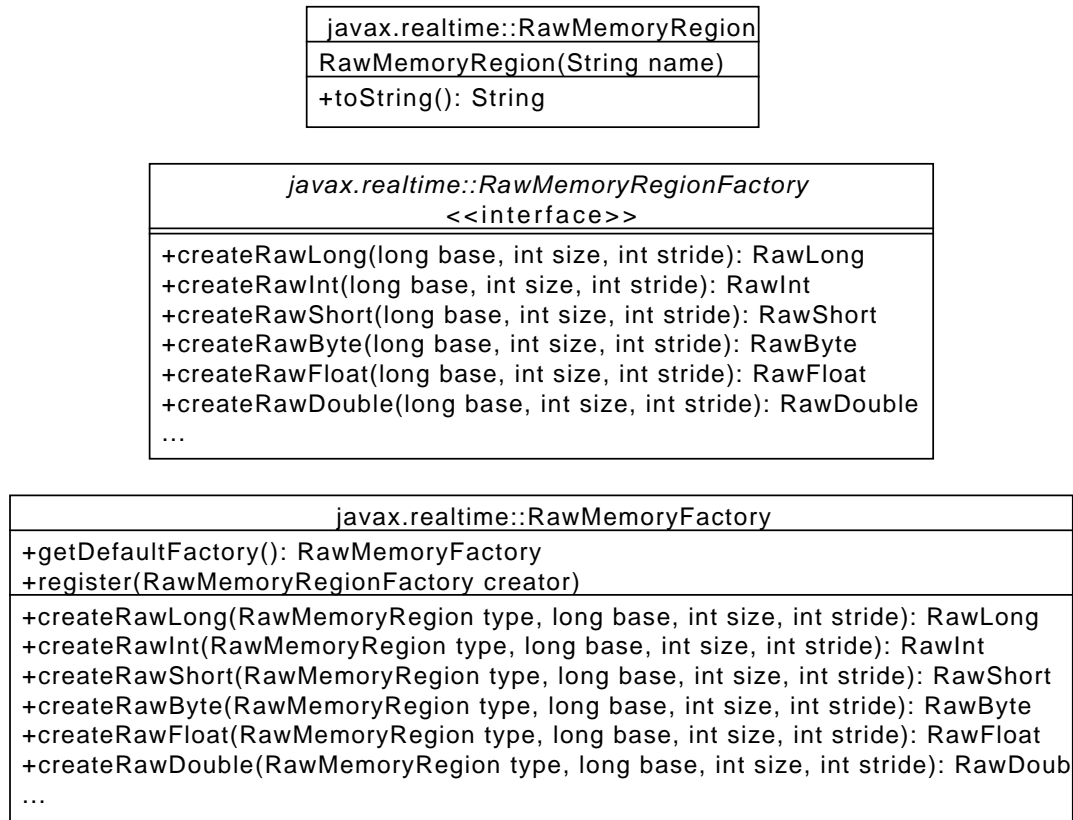
1. memory that is used to access memory-mapped device registers, and
2. logical memory that can be used to access port-based device registers.

Each of these categories of memory is represented by an instance of **RawMemoryRegion**. In addition, the application can define other regions outside these two, either for accessing devices registers in some other address space or for other purposes, such as emulating device access.

Java's primitive types are partitioned into two groups: integral (short, int, long, byte) and real (float, double) types, including arrays of each type. For integral types, individual interfaces are also defined to facilitate greater type security during

access. Objects that support these interfaces are created by factory methods, which again have predefined interfaces. Such objects are called *accessor* objects as they encapsulates the access protocol to the raw memory.

Figure 12.5: Creating Raw Memory Accessors



Control over all these objects is managed by the `RawMemoryFactory` class that provides a set of static methods, as shown in Figure 12.5. There are two groups of methods, those that

1. enable a factory to be registered, and
2. request the creation of *accessor* object for a particular memory type at a particular address.

The latter consists of methods to create Java-primitive-type accessor objects, which will throw exceptions if the appropriate addresses are not on correct boundaries to

enable the underlying machine instructions to be used without causing hardware exceptions (e.g., `createRawByteReader`).

As with interrupt handling, some realtime JVMs may not be able to support all of the memory categories. However, the expectation is that for all supported categories, they will also provide and register the associated factories for object creation.

For the case of `IO_PORT_MAPPED` raw memory, the accessor objects will need to arrange to execute the appropriate machine instructions to access the device registers.

Consider, the simple case where a device has a two device registers: a control/status register that is a 32 bits integer, and a data register that is a 64 bits long. The registers have been memory mapped to locations: 0x20 and 0x24 respectively. Assuming the realtime JVM has registered a factory for the `IO_MEMORY_MAPPED_REGION` raw memory name, then the following code will create the objects that facilitate the memory access

```

1 RawMemoryFactory factor = RawMemoryFactory.getDefaultFactory();
2 RawInt controlReg =
3   factor.createRawInt(RawMemoryFactory.IO_MEMORY_MAPPED_REGION, 0x20);
4 RawLong dataReg =
5   factor.createRawLong(RawMemoryFactory.IO_MEMORY_MAPPED_REGION, 0x24);

```

The above definitions reflect the structure of the actual registers. The JVM will check that the memory locations are on the correct boundaries and that they can be accessed without any hardware exceptions being generated. If they cannot, the create methods will throw an appropriate exceptions. If successfully created, all future access to the `controlReg` and `dataReg` will be exception free. The registers can be manipulated by calling the appropriate methods, as in the following example.

```

1 dataReg.setLong(1);
2   // where 1 is of type long and is data to be sent to the device
3 controlReg.setInt(i);
4   // where i is of type int and is the command to the device

```

In the general case, programmers themselves may create their own memory categories and provide associated factories (that may use the implementation-defined factories). These factories are written in Java and are, therefore, constrained by what the language allows them to do. Typically, they will use the JVM-supplied raw memory types to facilitate access to a device's external memory.

The facilities provided by the RTSJ allow an application to supports the notion of removable memory. When this memory is inserted or removed, an asynchronous event can be set up to fire, thereby alerting the application that the device has become active. Of course, any removable memory has to be treated with extreme caution. Hence, the RTSJ facilities allows it only to be accessed as a raw memory

device. An example of this will be given in Section 12.5.3.

12.5.1.1 Direct memory access

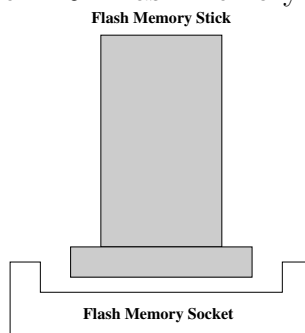
DMA requires access to memory out side of the heap. It is often crucial for performance in embedded systems; however, it does cause problems both from a realtime analysis perspective and from a JVM-implementation perspective. The latter is the primary concern here.

There are a few crucial points to note about DMA and the RTSJ.

1. The RTSJ does not address issues of persistent objects; so the input and output of Java objects to devices (other than by using the Java serialization mechanism) is not supported.
2. The RTSJ requires that RTSJ programs can be compiled by regular Java compilers. Different bytecode compilers (and their supporting JVM) use different representation for objects. Java arrays (even of primitive types) are objects, and the data they contain might not be stored in contiguous memory.
3. The package `java.nio.channels` provides a mechanism for I/O that was not specifically designed for DMA, but provides an applicable pattern for it.

For these reasons, without explicit knowledge of the compiler and JVM, allowing any DMA into any RTSJ memory area is a very dangerous action; therefore, the RTSJ provides some special support for DMA. Unfortunately, it would be difficult to find a general pattern to fit all DMA controllers. With raw memory and raw byte buffers, one could construct a higher level API that would cover most DMA controllers, but there will always odd cases that would still not fit the general pattern, especially for embedded systems. For this reason, only this low level API is provided.

Figure 12.6: Flash memory device



12.5.2 Interrupt Handling

Handling interrupts is a necessary part of many embedded systems. Interrupt handlers have traditionally been implemented in assembler code or C. With the growing popularity of high-level concurrent languages, there has been interest in better integration between the interrupt handling code and the application. Ada, for example, allows a “protected” procedure to be called directly from an interrupt [3].

Regehr [7] defines the terms used for the core components of interrupts and their handlers as follows.

1. *Interrupt*—a hardware supported asynchronous transfer of control mechanism initiated by an event external to the processor. Control of the processor is transferred through an interrupt vector.
2. *Interrupt vector*—a dedicated (or configurable) location that specifies the location of an interrupt handler.
3. *Interrupt handler*—code that is reachable from the interrupt vector.
4. *An interrupt controller*—a peripheral device that manages interrupts for the processor.

He further identifies the following problems with programming interrupt-driven software on single processors:

1. *Stack overflow*—the difficulty determining how much call-chain stack is required to handle an interrupt. The problem is compounded if the stack is borrowed from the currently executing thread or process.
2. *Interrupt overload*—the problem of ensuring that non-interrupt driven processing is not swamped by unexpected or misbehaving interrupts.
3. *Real-time analysis*—the need to have appropriate schedulability analysis models to bound the impact of interrupt handlers.

The problems above are accentuated in multiprocessor systems where interrupts can be handled globally. Fortunately, many multiprocessor systems allow interrupts to be bound to particular processors. For example, the ARM Cortex A9-MPCore supports the Arm Generic Interrupt Controller¹⁷¹. This enables a target list of CPUs to be specified for each hardware interrupt. Software generated interrupts can also be sent to the list or set up to be delivered to all but the requesting CPU or only the requesting CPU.

Regehr’s problems are all generic and can be solved irrespective of the language used to implement the handlers. In general they can be addressed by a combination of techniques.

1. *Stack overflow*—static analysis techniques can usually be used to determine the worst-case stack usage of all interrupt handlers. If stack is borrowed from the executing thread then this amount must be added to the worst-case stack

¹⁷¹ See <http://infocenter.arm.com/help/index.jsp?topic=/com.arm.doc.ddi0375a/Cegbfjhf.html>

usage of all threads.

2. Interrupt overload—this is typically managed by aperiodic server technology in combination with interrupt masking (see Section 13.6 of [3]).
3. Real-time analysis—again this can be catered for in modern schedulability analysis techniques, such as response-time analysis (see Section 14.6 of [3]).

From a RTSJ perspective, the following distinctions are useful

1. The *first-level interrupt handlers* are the code that the platform executes in response to the hardware interrupts (or traps). A first-level interrupt is assumed to be executed at an execution eligibility (priority) and by a processor dictated by the underlying platform (which may be controllable at the platform level). On some RTSJ implementations it will not be possible to write Java code for these handlers. Implementations that do enable Java-level handlers may restrict the code that can be written. For example, the handler code should not suspend itself or throw unhandled exceptions. The RTSJ 2.0 optional `InterruptServiceRoutine` class supports first level interrupt handling.
2. The *external event handler* is the code that the JVM executes as a result of being notified that an external event (be it an operating system signal, an ISR or some other program) is targeted at the RTSJ application. The programmer should be able to specify the processor affinity and execution eligibility of this code. In RTSJ 2.0, all external events are represented by instances of the `Happening` interface. Every happening has an associated dispatcher which is responsible for the initial response to an occurrence of the event.
3. A happening dispatcher is able to find one or more associated RTSJ asynchronous events and fire them. This then releases the associated asynchronous event handlers.

12.5.3 An Illustrative Example

Consider an embedded system that has a simple flash memory device that supports a single type of removable flash memory stick, as illustrated in Figure 12.6.

When the memory stick is inserted or removed, an interrupt is generated. This interrupt is known to the realtime JVM. The interrupt is also generated when operations requested on the device are completed. For simplicity, it is assumed that the application has associated this interrupt to an happening called `FlashHappening` with a default happening dispatcher.

The example illustrates how

1. a programmer can use the RTSJ facilities to write a device handler,
2. a factory class can be constructed and how the accessor objects police the access,
3. removable memory can be handled.

Table 12.2: Device registers

Register	Location	Bit Positions	Values
Command	0x20	0	0 = Disable device, 1 = Enable device
		4	0 = Disable interrupts, 1 = Enable interrupts
		5-8	1 = Read byte, 2 = Write byte 3 = Read short, 4 = Write short 5 = Read int, 6 = Write int 7 = Read long, 8 = Write long
		9	0 = DMA Read, 1 = DMA
		31-63	Offset into flash memory
Data	0x28	0-63	Simple data or memory address if DMA
Length	0x30	0-31	Length of data transfer
Status	0x38	0	1 = Device enabled
		3	1 = Interrupts enabled
		4	1 = Device in error
		5	1 = Transfer complete
		6	1 = Memory stick present 0 = Memory stick absent
		7	1 = Memory stick inserted
		8	0 = Memory stick removed

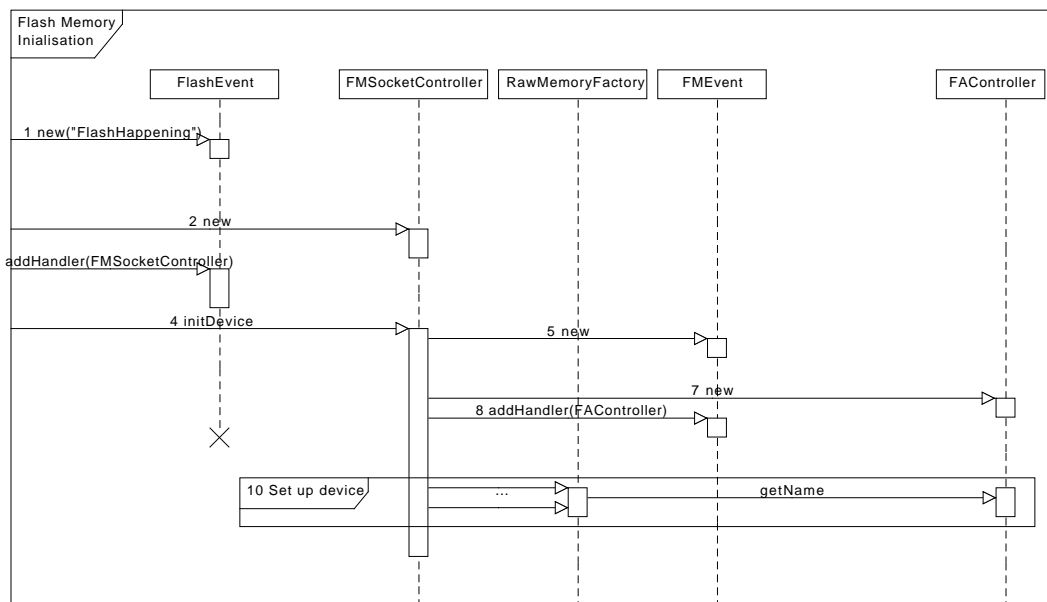
The flash memory device is accessed via several associated registers, which are shown in Table 12.2. These have all been memory mapped to the indicated locations.

12.5.3.1 Software architecture

There are many ways in which the software architecture for the example could be constructed. Here, for simplicity of representation, an architecture is chosen with a minimal number of classes. It is illustrated in Figure 12.7. There are three key components.

1. **FlashHappening**—This is the happening that has been associated with the flash device’s interrupt. The RTSJ will provide a default dispatcher, which will release any associated handler when the interrupt occurs and the happening is triggered.
2. **FMSocketController**—This is the object that encapsulates the access to the flash memory device. In essence, it is the device driver; it is also the handler for the **FlashHappening** and is responsibly for firing the **FMInserted** and **FMRemoved** asynchronous events.
3. **FAController**—This is the object that controls access to the flash memory, it

Figure 12.8: Sequence diagram showing initialization operations



12.5.3.3 Responding to external happenings

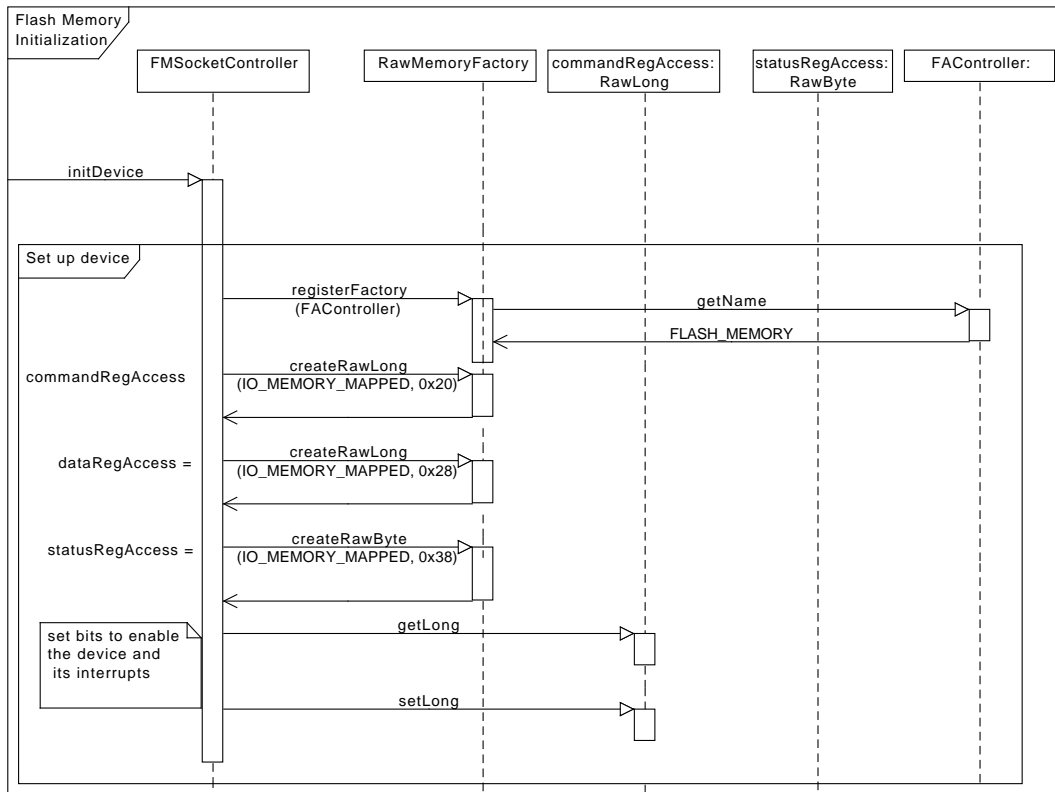
In the example, interrupts are handled by the JVM, which turns them into an external happening. The application code that indirectly responds to the happening is provided in the `handleAsyncEvent` method in the `FMSocketController` object. Figure 12.10 illustrates the approach. In this example, the actions in response to the *memory stick inserted* and *memory stick removed* flash events is simply shown as the execution of the `FMInserted` and `FMRemoved` handlers. These will inform the application. The memory accessor classes themselves will ensure that the stick is present when performing the required application accesses.

12.5.3.4 Access to the flash controller's device registers

Figure 12.11 shows the sequence of events that the application follows. First it must register a handler with the `FMInserted` asynchronous event. Here, the application itself is an asynchronous event handler. When this is released, the memory has been inserted.

In this simple example, the application simply reads a byte from an offset within the memory stick. It, therefore, creates an accessor to access the data. When this has been returned (it is the `FAController` itself), the application can now call the `getByte` method (called *FA getByte*, in the following, for clarity). This method must implement the sequence of raw memory access on the device's registers to perform the operation. In Figure 12.11, they are as follows.

Figure 12.9: Sequence diagrams showing operations to initialize the hardware device



1. *FA* `getByte` calls the `getByte` method of the status register's accessor object. This can check to make sure that the flash memory is present (bit 6, as shown in Table 12.2). If it is not, an exception can be thrown.
2. Assuming the memory is present, it then sets the control register with the offset required (bits 31–63, as shown in Table 12.2) and sets the read byte request bit (bits 5–8, as shown in Table 12.2).
3. The *FA* `getByte` method must then wait for indication that the requested operation has been completed by the device. This is detected by the `handleAsyncEvent` method of the *FMController*, which performs the necessary notify.
4. Once notified of completion, the *FA* `getByte` method, again reads the status register to make sure there were no errors on the device (bit 4 in Table 12.2) and that the memory is still present
5. The *FA* `getLong` then reads the data register to get the requested data, which it returns.

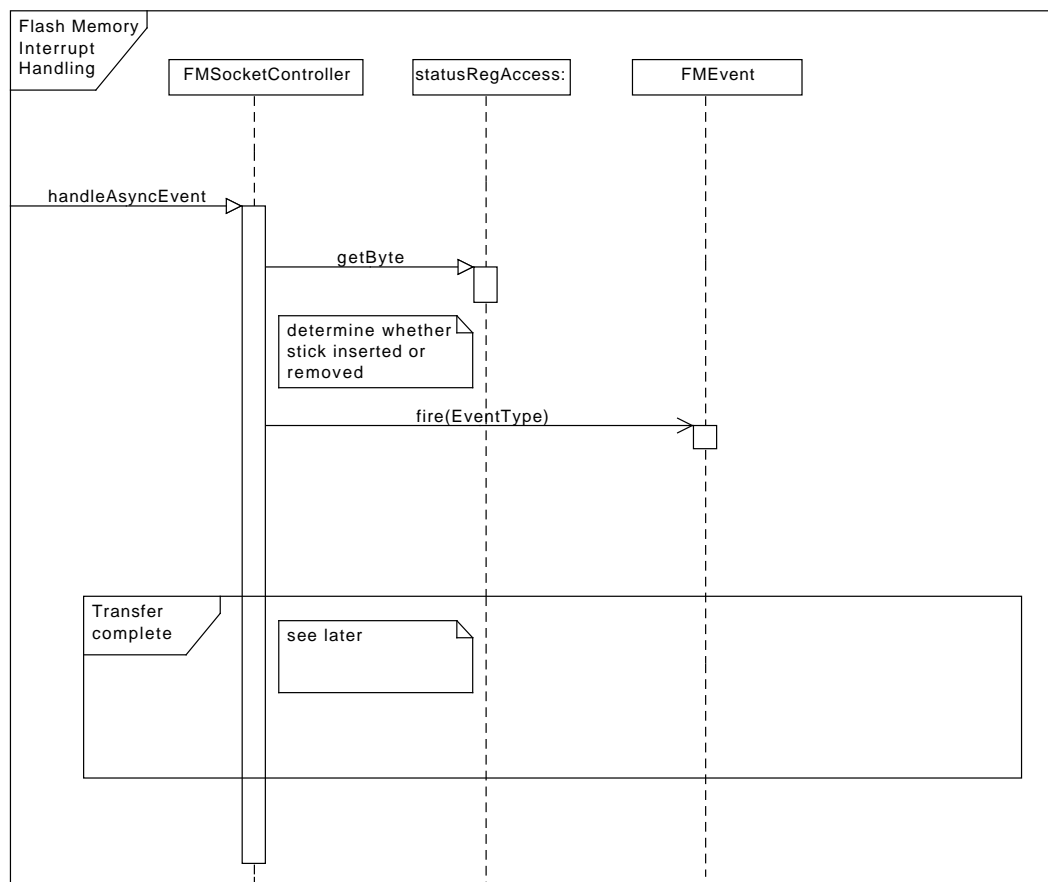
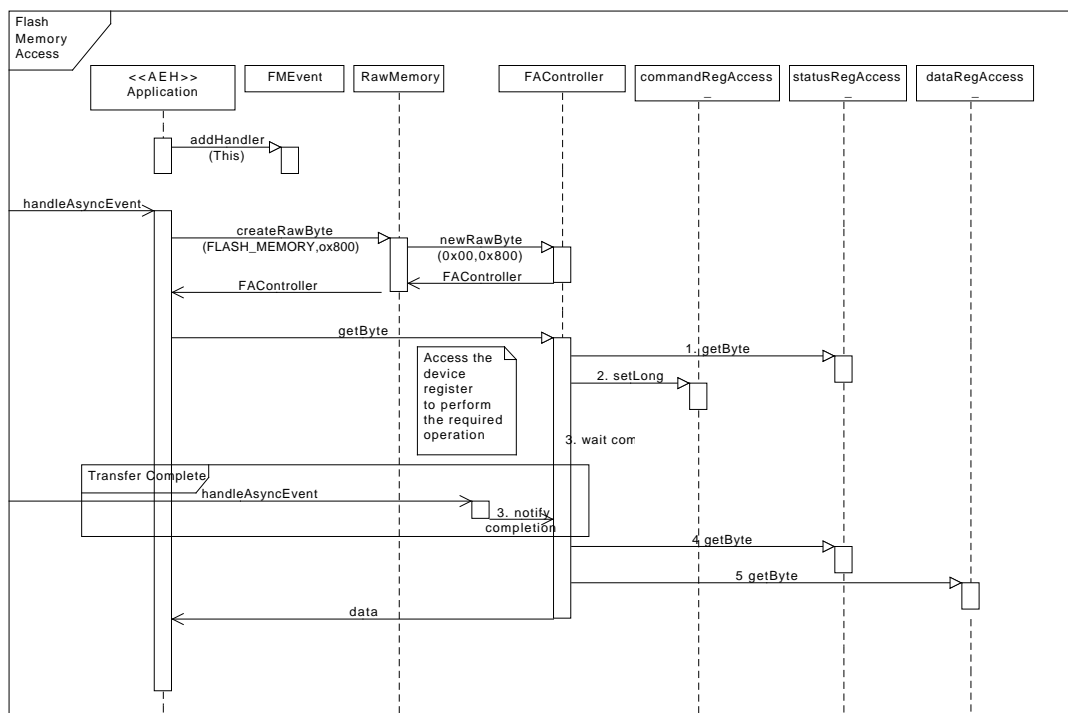
Figure 12.10: The `FMSocketController.handleAsync` method

Figure 12.11: Application usage



Chapter 13

Interprocess Signalling

13.1 Overview

On many operating systems, it is possible for one process to signal another. POSIX provides a well defined means of signalling other processes and receiving signals from them, therefore one would like to be able to use this facility when it or a similar mechanism is available. The POSIX module provides the means to do this. It provides a common idiom for binding signals to instances of `AsyncEventHandler`.

13.2 Definitions

Signal — a notification between two system process, which may or may not contain a data packet.

13.3 Semantics

The POSIX interface provides two main facilities: sending signals and receiving signals. These are supported by a means of determining which signals are supported on an implementation. In addition, not only stateless signals, but also signals with data are also supported. All classes are in the `javax.realtime.posix` package.

13.3.1 POSIX Signals

The `Signal` class represents POSIX signals and is required on platforms that provide POSIX signals. As with a `Happening`, it is a subclass of `AsyncEvent` and implements `ActiveEvent`. Unlike `Happening`, it cannot be instantiated by the user. Instead, an instance exists for each POSIX signal defined on the system. They can be retrieved

either by name or number using the `Signal.get(int)` and `Signal.get(String)` methods.

13.3.2 POSIX Realtime Signals

The `RealtimeSignal` class represents POSIX realtime events. It is also implements `ActiveEvent`, but is a subclass of `AsyncLongEvent`, so that it can pass the data sent with its signal. As with `Signal`, it cannot be instantiated by the user, rather an instance exists for each POSIX signal defined on the system, which can be retrieved either by name or number using the `RealtimeSignal.get(int)` and `RealtimeSignal.get(String)` methods.

13.4 Package javax.realtime.posix

13.4.1 Classes

13.4.1.1 RealtimeSignal

Inheritance

```
java.lang.Object
  javax.realtime.AsyncBaseEvent
    javax.realtime.AsyncLongEvent
      javax.realtime.posix.RealtimeSignal
```

Interfaces

```
javax.realtime.ActiveEvent
```

Description

A `javax.realtime.ActiveEvent`¹ subclass for defining a POSIX realtime signal.

Available since RTSJ 2.0

13.4.1.1.1 Methods

isPOSIXRealtimeSignal(String)

Signature

```
public static
boolean isPOSIXRealtimeSignal(String name)
```

Description

Determine if a signal with a given name is registered.

Parameters

name of the signal

Returns

true when a signal with the given name is registered

¹Section 8.4.1.1

getId(String)

Signature

```
public static  
int getId(String name)
```

Description

Get the ID of a registered signal.

Parameters

name of the signal for which to search

Returns

the ID of the signal named by **name**

get(String)

Signature

```
public static  
javax.realtime.posix.RealtimeSignal get(String name)
```

Description

Get the registered realtime signal with the given name.

Parameters

name of the signal to get.

Returns

the registered signal with name or **null**.

get(int)

Signature

```
public static  
javax.realtime.posix.RealtimeSignal get(int id)
```

Description

Get the realtime signal corresponding to a given id.

Parameters

id of a registered signal

Returns

the signal corresponding to **id**.

getId

Signature

```
public  
int getId()
```

Description

Get the name of this realtime signal.

Returns

the ID of this signal.

getName

Signature

```
public final  
java.lang.String getName()
```

Description

Get the name of this signal.

Returns

the name of this signal.

getDispatcher

Signature

```
public  
javax.realtime.posix.RealtimeSignalDispatcher getDispatcher()
```

Description

Obtain the dispatcher for **this**.

Returns

that dispatcher.

isActive

Signature

```
public  
boolean isActive()
```

Description

Determine the activation state of this signal, i.e., it has been started.

Returns

true when active, **false** otherwise.

isRunning

Signature

```
public  
boolean isRunning()
```

Description

Determine the firing state (releasing or skipping) of this signal, i.e., it is active and enabled.

Returns

true when releasing, **false** when skipping.

start

Signature

```
public final synchronized  
void start()  
throws IllegalStateException
```

Description

Start this **RealtimeSignal**, i.e., change to a running state. A running realtime signal is a source of activation when in a scoped memory and is a member of the root set when in the heap. A running realtime signal can be triggered.

Throws

IllegalStateException when this **RealtimeSignal** has already been started.

See Section [stop\(\)](#)

start(boolean)

Signature

```
public final synchronized  
void start(boolean disabled)  
throws IllegalStateException
```

Description

Start this `RealtimeSignal`, i.e., change to a running state. A running realtime signal is a source of activation when in a scoped memory and is a member of the root set when in the heap. A running realtime signal can be triggered.

Parameters

`disabled` true for starting in a disabled state.

Throws

`IllegalStateException` when this `RealtimeSignal` has already been started.

See [Section stop\(\)](#)

stop

Signature

```
public final  
boolean stop()  
throws IllegalStateException
```

Description

Stop this `RealtimeSignal`. A stopped realtime signal ceases to be a source of activation and no longer cause any AE attached to it to be a source of activation.

Throws

`IllegalStateException` when this `RealtimeSignal` is not running.

Returns

`true` when this was *enabled* and `false` otherwise.

send(long, long)

Signature

```
public native
boolean send(long pid,
             long payload)
```

Description

Send this signal to another process

Parameters

pid of the process to which to send the signal

Returns

true when signal can be sent, otherwise false.

13.4.1.2 RealtimeSignalDispatcher**Inheritance**

```
java.lang.Object
  javax.realtime.ActiveEventDispatcher
    javax.realtime.posix.RealtimeSignalDispatcher
```

Description

Provides a means of dispatching a set of **RealtimeSignal**²s. An application can provide its own dispatcher, providing the priority for the internal dispatching thread. This dispatching thread calls process() each time the signal is triggered.

Available since RTSJ 2.0

13.4.1.2.1 Constructors**RealtimeSignalDispatcher(SchedulingParameters, Scheduling-Group)***Signature*

²Section 13.4.1.1


```
public
RealtimeSignalDispatcher(SchedulingParameters schedule,
                        SchedulingGroup group)
```

Description

Create a new dispatcher, whose dispatching thread runs with the given scheduling parameters.

Parameters

`schedule` give the parameters for scheduling this dispatcher

RealtimeSignalDispatcher(SchedulingParameters)

Signature

```
public
RealtimeSignalDispatcher(SchedulingParameters schedule)
```

Description

Create a new dispatcher, whose dispatching thread runs with the given scheduling parameters.

Parameters

`schedule` give the parameters for scheduling this dispatcher

13.4.1.2.2 Methods

register(RealtimeSignal)

Signature

```
public
void register(RealtimeSignal signal)
throws RegistrationException,
        IllegalStateException,
        IllegalArgumentException
```

Description

Register `signal` with this dispatcher.

Parameters

`signal` to register

Throws

`RegistrationException` when `signal` is already registered.

`IllegalStateException` when this object has been destroyed.

`IllegalArgumentException` when `signal` is not stopped.

unregister(RealtimeSignal)

Signature

```
public
void unregister(RealtimeSignal signal)
throws DeregistrationException,
       IllegalStateException,
       IllegalArgumentException
```

Description

Deregister the `signal` from this dispatcher.

Parameters

`signal` to unregister

Throws

`DeregistrationException` when `signal` is not already registered.

`IllegalStateException` when this object has been destroyed.

`IllegalArgumentException` when `signal` is not stopped.

destroy

Signature

```
public
void destroy()
throws IllegalStateException
```

Description

Release all resources thereby making the dispatcher unusable.

Throws

`IllegalStateException` when called on a dispatcher that has one or more registered `RealtimeSignal`³ objects.

13.4.1.3 Signal

Inheritance

`java.lang.Object`
 `javax.realtime.AsyncBaseEvent`
 `javax.realtime.AsyncEvent`
 `javax.realtime.posix.Signal`

Interfaces

`javax.realtime.ActiveEvent`

Description

A `javax.realtime.ActiveEvent`⁴ subclass for defining a POSIX signal.

Available since RTSJ 2.0

13.4.1.3.1 Fields

MAX_NUM_SIGNALS

```
public static final MAX_NUM_SIGNALS
```

Description

this number of signals can be processed.

13.4.1.3.2 Methods

³Section 13.4.1.1

⁴Section 8.4.1.1

isPOSIXSignal(String)

Signature

```
public static  
boolean isPOSIXSignal(String name)
```

Description

Determine if a signal with a given name is registered.

Parameters

name of the signal

Returns

true when a signal with the given name is registered

getId(String)

Signature

```
public static  
int getId(String name)
```

Description

Get the ID of a registered signal.

Parameters

name of the signal for which to search

Returns

the ID of the signal named by **name**

get(String)

Signature

```
public static  
javax.realtime.posix.Signal get(String name)
```

Description

Get the registered signal with the given name.

Parameters

name of the signal to get.

Returns

the registered signal with name or **null**.

get(int)

Signature

```
public static  
    javax.realtime.posix.Signal get(int id)
```

Description

Get the signal corresponding to a given id.

Parameters

id of a registered signal

Returns

the signal corresponding to id or null.

getProcessId

Signature

```
public static  
    long getProcessId()
```

Description

Obtain the OS Id of the JVM process. When running in kernel space, the result is VM dependent and must be documented. This number returned is only usable with `Signal.send(long)`⁵.

Returns

the OS process id.

getId

Signature

```
public  
    int getId()
```

Description

Get the number of this signal.

Returns

the signal number

⁵Section 13.4.1.3.2

getName

Signature

```
public  
java.lang.String getName()
```

Description

Get the name of this signal.

Returns

the name of this signal.

getDispatcher

Signature

```
public  
javax.realtime.posix.SignalDispatcher getDispatcher()
```

Description

Obtain the dispatcher for **this**.

Returns

that dispatcher.

isActive

Signature

```
public  
boolean isActive()
```

Description

Determine the activation state of this signal, i.e., it has been started.

Returns

true when active, **false** otherwise.

isRunning

Signature

```
public  
boolean isRunning()
```

Description

Determine the firing state (releasing or skipping) of this signal, i.e., it is active and enabled.

Returns

`true` when releasing, `false` when skipping.

start

Signature

```
public  
void start()  
throws IllegalStateException
```

Description

Start this `Signal`, i.e., change to a running state. A running signal is a source of activation when in a scoped memory and is a member of the root set when in the heap. A running signal can be triggered.

Throws

`IllegalStateException` when this `Signal` has already been started.

See [Section stop\(\)](#)

start(boolean)

Signature

```
public  
void start(boolean disabled)  
throws IllegalStateException
```

Description

Start this **Signal**, i.e., change to a running state. A running signal is a source of activation when in a scoped memory and is a member of the root set when in the heap. A running signal can be triggered.

Parameters

disabled true for starting in a disabled state.

Throws

IllegalStateException when this **Signal** has already been started.

See [Section stop\(\)](#)

stop

Signature

```
public
boolean stop()
throws IllegalStateException
```

Description

Stop this **Signal**. A stopped signal ceases to be a source of activation and no longer cause any AE attached to it to be a source of activation.

Throws

IllegalStateException when this **Signal** is not running.

Returns

true when this was *enabled* and false otherwise.

send(long)

Signature

```
public
void send(long pid)
throws POSIXInvalidSignalException,
       POSIXSignalPermissionException,
       POSIXInvalidTargetException
```

Description

Send this signal to another process or process group.

On POSIX systems running in user space, the following holds:

- when pid is positive, the signal is sent to pid;

- when pid equals 0, the signal is sent to every process in the process group of the current process;
- when pid equals -1, the signal is sent to every process for which the calling process has permission to send signals, except for possibly OS-defined system processes; otherwise
- when pid is less than -1, the signal is sent to every process in the process group -pid.

POSIX.1-2001 requires the underlying mechanism of `signal.send(-1)` to send `signal` to all processes for which the current process may signal, except possibly for some OS-defined system processes.

For an RTVM running in kernel space, the meaning of the `pid` is implementation dependent, though it should be as closed to the standard definition as possible.

Parameters

`pid` Id of the process to which to send the signal

Throws

`POSIXInvalidSignalException` when the signal number is not valid.

`POSIXSignalPermissionException` when the process does not have permission to send the target.

`POSIXInvalidTargetException` when the target does not exist.

13.4.1.4 SignalDispatcher

Inheritance

`java.lang.Object`
`javax.realtime.ActiveEventDispatcher`
`javax.realtime.posix.SignalDispatcher`

Description

Provides a means of dispatching a set of `Signal`⁶s. An application can provide its own dispatcher, providing the priority for the internal dispatching thread. This dispatching thread calls `process()` each time the signal is triggered.

13.4.1.4.1 Constructors

⁶Section 13.4.1.3

SignalDispatcher(SchedulingParameters, SchedulingGroup)

Signature

```
public  
SignalDispatcher(SchedulingParameters scheduling,  
                 SchedulingGroup group)
```

Description

Create a new dispatcher, whose dispatching thread runs with the given scheduling parameters.

Parameters

`scheduling` give the parameters for scheduling this dispatcher

SignalDispatcher(SchedulingParameters)

Signature

```
public  
SignalDispatcher(SchedulingParameters scheduling)
```

Description

Create a new dispatcher, whose dispatching thread runs with the given scheduling parameters.

Parameters

`scheduling` give the parameters for scheduling this dispatcher

13.4.1.4.2 Methods

register(Signal)

Signature

```
public synchronized  
void register(Signal signal)
```

```
throws RegistrationException,  
        IllegalStateException,  
        IllegalArgumentException
```

Description

Register a POSIX signal with this dispatcher.

Parameters

signal to register

Throws

`RegistrationException` when signal is already registered.
`IllegalStateException` when this object has been destroyed.
`IllegalArgumentException` when signal is not stopped.

unregister(Signal)

Signature

```
public synchronized  
void unregister(Signal signal)  
throws DeregistrationException,  
        IllegalStateException,  
        IllegalArgumentException
```

Description

Deregister a POSIX Signal form this dispatcher. (This is a really naive implementation.)

Parameters

signal to deregister

Throws

`DeregistrationException` when signal not is already registered.
`IllegalStateException` when this object has been destroyed.
`IllegalArgumentException` when signal is not stopped.

destroy

Signature

```
public  
void destroy()
```

throws `IllegalStateException`

Description

Release all resources thereby making the dispatcher unusable.

Throws

`IllegalStateException` when called on a dispatcher that has one or more registered `Signal`⁷ objects.

13.5 Rationale

POSIX is the most widely supported standard for operating systems, both conventional and realtime. Providing support for sending and receiving signals as encapsulated in the `Signal` and `RealtimeSignal` enables realtime java programs to interact, not just with the environment, but also other processes in a system. Even for systems that are not strictly POSIX compatible, one can implement this interface for encapsulating similar functionality in a common API.

⁷Section 13.4.1.3

Chapter 14

System and Options

14.1 Overview

Implementations of this specification run on many operating systems and this specification itself supports several variants, therefore a means of querying and handling this variation is required. For instance, though many realtime operating systems support the POSIX standard, many do not. Even the ones that do vary in their degree of compliance. Also, the type of garbage collection provided may also vary from one implementation to another. The specification defines classes to help manage these differences providing the following:

- a class that contains operations and semantics that affect the entire system;
- the security semantics required by the additional features in the entirety of this specification, which are additional to those required by implementations of the Java Language Specification; and
- a class that provides some basic information about the garbage collector.

14.2 Semantics

There are three classes with semantics that do not fall into other categories: **RealtimeSystem**, **RealtimeSecurity**, and **GarbageCollection**. Their overall semantics is detailed below. Thereafter, semantics applying to methods, constructors, and fields of these classes are provided.

14.2.1 RealtimeSystem

RealtimeSystem is a required class, which provides basic information about the RTSJ extensions supported by the system. Via this class, a program can query the default monitor policy, the realtime security manager, and other realtime properties

of the system. Starting from version 2.0, a program can also ask what modules are supported. The enumeration `RTSJModule` supports this capability.

14.2.2 RealtimeSecurity

The `RealtimeSecurity` class controls access to key realtime features. Particularly critical is access to memory outside the heap. Core RTSJ features also have security checks. This should enable an application to restrict the use of the RTSJ, particularly for dynamically loaded code. Detailed information is provided in the class documentation below.

14.2.3 GarbageCollection

It is extremely difficult to characterize garbage collectors in a uniform manner. The only information that can be provided by all collectors is the preemption latency. Each implementation may provide its own subclass of `GarbageCollector` to provide additional information, which may be queried via reflection.

14.2.4 Compliance Version

Determining the current version is supported by a system property. When an application calls the method, `System.getProperty("javax.realtime.version")`, the return value will be a string of the form, "x.y.z". Where 'x' is the major version number and 'y' and 'z' are minor version numbers. These version numbers state to which version of the RTSJ the underlying implementation claims conformance. The first release of the RTSJ, dated 11/2001, was numbered 1.0.0. A release conforming to the version defined by this specification should return the string "2.0.0".

14.3 Package javax.realtime

14.3.1 Enumerations

14.3.1.1 RTSJModule

Inheritance

java.lang.Object
 java.lang.Enum
 javax.realtime.RTSJModule

Description

Modules an RTSJ implementation may provide.

14.3.1.1.1 Enumeration Constants

CORE

```
public static final CORE
```

Description

Indicates the presence of the core module.

DEVICE

```
public static final DEVICE
```

Description

Indicates the presence of the device access module.

MEMORY

```
public static final MEMORY
```

Description

Indicates the presence of the alternate memory module.

POSIX

```
public static final POSIX
```

Description

Indicates the presence of the POSIX module.

SCJ

```
public static final SCJ
```

Description

Indicates the presence of the Safety-Critical Java module.

14.3.1.1.2 Methods

values

Signature

```
public static  
javax.realtime.RTSJModule[] values()
```

Description

valueOf(String)

Signature

```
public static  
javax.realtime.RTSJModule valueOf(String name)
```

Description

value

Signature

```
public  
int value()
```

Description

Determine the numeric value of an element of this enumeration. This value can be used in bit sets to determine the presence of the given element.

Returns

a number with a single bit set representing this element.

in(int)

Signature

```
public  
boolean in(int value)
```

Description

Given an int representing a set of enumeration elements via bit value, see whether or not this element is contained within that set.

Parameters

value the set to test against

Returns

true when and only when **value** has the bit set that represents **this**.

14.3.2 Classes

14.3.2.1 GarbageCollector

Inheritance

```
java.lang.Object  
  javax.realtime.GarbageCollector
```

Description

The system shall provide dynamic and static information characterizing the temporal behavior and imposed overhead of any garbage collection algorithm provided by the system. This information shall be made available to applications

via methods on subclasses of `GarbageCollector`. Implementations are allowed to provide any set of methods in subclasses as long as the temporal behavior and overhead are sufficiently categorized. The implementations are also required to fully document the subclasses.

A reference to the garbage collector responsible for heap memory is available from `RealtimeSystem.currentGC()`¹.

14.3.2.1.1 Methods

`getPreemptionLatency`

Signature

```
public abstract  
    javax.realtime.RelativeTime getPreemptionLatency()
```

Description

Preemption latency is a measure of the maximum time a schedulable object may have to wait for the collector to reach a preemption-safe point.

Schedulables which may not use the heap preempt garbage collection immediately, but other schedulables must wait until the collector reaches a preemption-safe point. For many garbage collectors the only preemption safe point is at the end of garbage collection, but an implementation of the garbage collector could permit a schedulable to preempt garbage collection before it completes. The `getPreemptionLatency` method gives such a garbage collector a way to report the worst-case interval between release of a schedulable during garbage collection, and the time the schedulable starts execution or gains full access to heap memory, whichever comes later.

Returns

The worst-case preemption latency of the garbage collection algorithm represented by `this`. The returned object is allocated in the current allocation context. When there is no constant that bounds garbage collector preemption latency, this method shall return a relative time with `Long.MAX_VALUE` milliseconds. The number of nanoseconds in this special value is unspecified.

¹Section 14.3.2.3.2

14.3.2.2 RealtimeSecurity

Inheritance

java.lang.Object
javax.realtime.RealtimeSecurity

Description

Security policy object for realtime specific issues. Primarily used to control access to physical memory.

Security requirements are generally application-specific. Every implementation shall have a default `RealtimeSecurity` instance, and a way to install a replacement at run-time, `RealtimeSystem.setSecurityManager`². The default security is minimal. All security managers should prevent access to JVM internal data and the Java heap; additional protection is implementation-specific and must be documented.

Open issue 14.3.1

Look at security closely. Try to make this a Java Security Manager if possible.

End of issue 14.3.1

14.3.2.2.1 Constructors

RealtimeSecurity

Signature

```
public  
RealtimeSecurity()
```

Description

Create an `RealtimeSecurity` object.

14.3.2.2.2 Methods

²Section 14.3.2.3.2

checkAccessPhysical

Signature

```
public  
void checkAccessPhysical()  
throws SecurityException
```

Description

Check whether the application is allowed to access physical memory.

Throws

SecurityException The application doesn't have permission to access physical memory.

checkAccessPhysicalRange(long, long)

Signature

```
public  
void checkAccessPhysicalRange(long base,  
                               long size)  
throws SecurityException
```

Description

Checks whether the application is allowed to access physical memory within the specified range.

Parameters

base The beginning of the address range.

size The size of the address range.

Throws

SecurityException The application doesn't have permission to access the memory in the given range.

checkSetFilter

Signature

```
public  
void checkSetFilter()  
throws SecurityException
```

Description

Checks whether the application is allowed to register `PhysicalMemoryType-Filter`³ objects with the `PhysicalMemoryManager`⁴.

Throws

`SecurityException` The application doesn't have permission to register filter objects.

checkSetMonitorControl(MonitorControl)

Signature

```
public  
void checkSetMonitorControl(MonitorControl policy)  
throws SecurityException
```

Description

Checks whether the application is allowed to set the default monitor control policy.

Parameters

`policy` The new policy

Throws

`SecurityException` when the application doesn't have permission to change the default monitor control policy to `policy`.

Available since RTSJ 1.0.1

checkAEHSetDaemon

Signature

```
public  
void checkAEHSetDaemon()  
throws SecurityException
```

Description

Checks whether the application is allowed to set the daemon status of an AEH.

Throws

³Section [A.3.1.1](#)

⁴Section [A.3.3.6](#)

`SecurityException` when the application is not permitted to alter the daemon status.

Available since RTSJ 1.0.1

checkSetScheduler

Signature

```
public  
void checkSetScheduler()  
throws SecurityException
```

Description

Checks whether the application is allowed to set the scheduler.

Throws

`SecurityException` The application doesn't have permission to set the scheduler.

checkCreateRealtimeThread

Signature

```
public  
void checkCreateRealtimeThread()  
throws SecurityException
```

Description

Check if an application may create a realtime thread.

Throws

`SecurityException` when not allowed

Available since RTSJ 2.0

checkCreateTimer

Signature

```
public  
void checkCreateTimer()
```

throws `SecurityException`

Description

Check if an application may create a `Timer`.

Throws

`SecurityException` when not allowed.

Available since RTSJ 2.0

checkPOSIXSendSignal(Signal, long)

Signature

```
public  
void checkPOSIXSendSignal(Signal signal,  
                           long pid)  
throws SecurityException
```

Description

Check if the given signal can be sent to the given process id.

Parameters

`signal` is the signal being sent

`pid` is the id to which the signal is being set.

Throws

`SecurityException` when the operation is not allowed.

Available since RTSJ 2.0

14.3.2.3 RealtimeSystem

Inheritance

```
java.lang.Object  
  javax.realtime.RealtimeSystem
```

Description

`RealtimeSystem` provides a means for tuning the behavior of the implementation by specifying parameters such as the maximum number of locks that can be in use concurrently, and the monitor control policy. In addition, `RealtimeSystem`

provides a mechanism for obtaining access to the security manager, garbage collector, and scheduler, to query or set parameters.

14.3.2.3.1 Fields

BIG_ENDIAN

```
public static final BIG_ENDIAN
```

Description

Value indicating that the highest order byte of a bit word is stored at the lowest byte address: the int 0x0A0B0C0D is stored in the byte sequence 0x0A, 0x0B, 0x0C, 0x0D. and the long 0x0102030405060708 is stored in the sequence 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08.

LITTLE_ENDIAN

```
public static final LITTLE_ENDIAN
```

Description

Value indicating that the lowest order byte of a word is stored at the lowest byte address: the int 0x0A0B0C0D is stored in the byte sequence 0x0D, 0x0C, 0x0B, 0x0A and the long 0x0102030405060708 is stored in the sequence 0x08, 0x07, 0x06, 0x05, 0x04, 0x03, 0x02, 0x01.

PDP_ENDIAN

```
public static final PDP_ENDIAN
```

Description

Value indicating a mixed endian mode used by among others the PDP-11: the int 0x0A0B0C0D is stored in the byte sequence 0x0B, 0x0A, 0x0D, 0x0C, and the long 0x0102030405060708 is stored in the sequence 0x03, 0x04, 0x01, 0x02, 0x07, 0x08, 0x05, 0x06.

BYTE_ORDER

```
public static final BYTE_ORDER
```

Description

The byte ordering of the underlying hardware.

14.3.2.3.2 Methods

currentGC

Signature

```
public static  
javax.realtime.GarbageCollector currentGC()
```

Description

Return a reference to the currently active garbage collector for the heap.

Returns

A [GarbageCollector](#)⁵ object which is the current collector collecting objects on the conventional Java heap.

getConcurrentLocksUsed

Signature

```
public static  
int getConcurrentLocksUsed()
```

Description

Gets the maximum number of locks that have been used concurrently. This value can be used for tuning the concurrent locks parameter, which is used as a hint by systems that use a monitor cache.

Returns

An integer whose value is the maximum number of locks that have been used concurrently. When the number of concurrent locks is not tracked by the implementation, return -1. Note that when the number of concurrent locks is not tracked, the number of available concurrent locks is effectively unlimited.

⁵Section [14.3.2.1](#)

getMaximumConcurrentLocks

Signature

```
public static  
int getMaximumConcurrentLocks()
```

Description

Gets the maximum number of locks that can be used concurrently without incurring an execution time increase as set by the `setMaximumConcurrentLocks()` methods.

Note: Any relationship between this method and `setMaximumConcurrentLocks` is implementation-specific. This method returns the actual maximum number of concurrent locks the platform can currently support, or `Integer.MAX_VALUE` when there is no maximum. The `setMaximumConcurrentLocks` method give the implementation a hint as to the maximum number of concurrent locks it should expect.

Returns

An integer whose value is the maximum number of locks that can be in simultaneous use.

getSecurityManager

Signature

```
public static  
javafx.realtime.RealtimeSecurity getSecurityManager()
```

Description

Gets a reference to the security manager used to control access to realtime system features such as access to physical memory.

Returns

A `RealtimeSecurity`⁶ object representing the default realtime security manager.

setMaximumConcurrentLocks(int)

Signature

⁶Section 14.3.2.2

```
public static
void setMaximumConcurrentLocks(int numLocks)
```

Description

Sets the anticipated maximum number of locks that may be held or waited on concurrently. Provide a hint to systems that use a monitor cache as to how much space to dedicate to the cache.

Parameters

numLocks An integer whose value becomes the number of locks that can be in simultaneous use without incurring an execution time increase. When **number** is less than or equal to zero nothing happens. When the system does not use this hint this method has no effect other than on the value returned by `getMaximumConcurrentLocks()`⁷.

setMaximumConcurrentLocks(int, boolean)

Signature

```
public static
void setMaximumConcurrentLocks(int number,
                                boolean hard)
```

Description

Sets the anticipated maximum number of locks that may be held or waited on concurrently. Provide a limit for the size of the monitor cache on systems that provide one when **hard** is true.

Parameters

number The maximum number of locks that can be in simultaneous use without incurring an execution time increase. When **number** is less than or equal to zero nothing happens. When the system does not use this hint this method has no effect other than on the value returned by `getMaximumConcurrentLocks()`⁸.
hard When true, **number** sets a limit. When a lock is attempted which would cause the number of locks to exceed **number** then a `ResourceLimitError`⁹ is thrown. When the system does not limit use of concurrent locks, this parameter is silently ignored.

⁷Section 14.3.2.3.2

⁸Section 14.3.2.3.2

⁹Section 15.3.3.4

setSecurityManager(RealtimeSecurity)

Signature

```
public static  
void setSecurityManager(RealtimeSecurity manager)
```

Description

Sets a new realtime security manager.

Parameters

manager A **RealtimeSecurity**¹⁰ object which will become the new security manager.

Throws

SecurityException when security manager has already been set.

getInitialMonitorControl

Signature

```
public static  
javax.realtime.MonitorControl getInitialMonitorControl()
```

Description

Returns the monitor control object that represents the initial monitor control policy.

Returns

The initial monitor control policy.

Available since RTSJ 1.0.1

supports(RTSJModule)

Signature

```
public static  
boolean supports(RTSJModule module)
```

Description

Determine if a particular module is supported.

¹⁰Section [14.3.2.2](#)

Parameters

`module` of interest.

Returns

`true` when `module` is supported; otherwise `false`.

Available since RTSJ 2.0

modules

Signature

```
public static  
int modules()
```

Description

The set of modules supported.

Returns

an integer representing all the modules supported.

Available since RTSJ 2.0

canEnforceCost

Signature

```
public static  
boolean canEnforceCost()
```

Description

Determine whether or not hard cost enforcement is supported.

Returns

`true` when cost enforcement is supported, otherwise `false`.

Available since RTSJ 2.0

canEnforceAllocationRate

Signature

```
public static  
boolean canEnforceAllocationRate()
```

Description

Determine whether or not allocation rate enforcement is supported.

Returns

`true` when allocation rate enforcement is supported, otherwise `false`.

Available since RTSJ 2.0

14.4 Rationale

This specification accommodates the variation in underlying systems in a number of ways. The `RealtimeSystem` class functions in similar capacity to `java.lang.System`. Similarly, the `RealtimeSecurity` class functions similarly to `java.lang.SecurityManager`. The concept of optionally required classes provides additional flexibility. Such classes provide a commonality that can be relied upon by program logic that intends to execute on implementations that supports a given function, such as `Signal` and `RealtimeSignal` encapsulate common functionality for POSIX compliant systems.

Open issue 14.4.1 (elb)

Discuss briefly why the characterization of garbage collectors for RTSJ is so weak.

End of issue 14.4.1

Chapter 15

Exceptions

15.1 Overview

As with other Java specifications, the RTSJ uses exceptions and errors to signal conditions that are abnormal, incorrect, or disallowed. In cases where these exceptional and error conditions are substantially the same as those defined in conventional Java, those exceptions and errors are used. They are taken primarily from the `java.lang` package, but also a few from the `java.lang.reflect` and `java.io` packages as well. In other cases, new exceptions are defined in the `javax.realtime` package. These exception classes provide

Please review for jjh: Overview of static throwables

- additional exception classes required for other sections of this specification,
- the ability to throw exceptions without allocating memory, and
- the ability to asynchronously transfer the control of program logic (see `Asyn-chronouslyInterruptedException`).

The ability to throw exceptions without memory allocation is important for using scoped and immortal memory; otherwise, throwing an exception would use too much memory to be useful.

End review request

15.2 Semantics

Except for how information associated with a `Throwable` is stored and managed, the semantics of the subclasses of `Error`, `Exception`, and `RuntimeException` are the same as for all other Java throwables. All classes in this section are required. Semantics that apply to particular classes, constructors, methods, and fields will be found in the class description and the constructor, method, and field detail sections.

Please review for jjh: Semantics of static throwables

All exceptions defined in this section, as opposed to those that are standard exceptions used without change by the specification, are statically allocated. There is at most one instance of each of these exceptions and errors. All information they would normally carry is held in a thread local data structure. This means this information, such as message and stack data, is only valid within the thread that threw the `StaticThrowable` and only until a new `StaticThrowable` is thrown.

End review request

Though the `AsynchronouslyInterruptedException` class defines an exception, it provides additional functionality for supporting ATC. This functionality is more closely related to asynchronous operation than to exception handling. For this reason, it is not included in this chapter, but rather in Chapter 8 on asynchrony.

15.3 Package javax.realtime

15.3.1 Interfaces

15.3.1.1 StaticThrowable

Description

A marker interface to indicate that a `Throwable` is intended to be created once and reused. `Throwables` that implement this interface kept their state in a `RealtimeThread` local data structure instead of the object itself. This means that data is only valid until the next `StaticThrowable` is thrown in the context of the current thread. Instances `AsyncBaseEventHandler`¹ always have some instance of `RealtimeThread` when executing. Having a marker interface makes it easier to provide checking tools to ensure the proper throw sequence for all `Throwables` thrown from application code.

`Throwables` which implement this interface should define a `get()` method that returns the singleton throwable of that class. It should also initialize the stack backtrace. The message and cause should be cleared.

An application which throws a static exception should use the following paradigm:

```
throw LateStartException.get().initMessage("....").initCause(...);
```

The message must be initialized before the cause, because `initMessage` is defined on `StaticThrowable` but not `Throwable`. Setting the message and the cause are both optional.

Applications which define static throwables should extend one of `StaticError`², `StaticCheckedException`³, or `StaticRuntimeException`⁴

See Section [ConfigurationParameters](#)

Available since RTSJ 2.0

15.3.1.1.1 Methods

¹Section [8.4.3.3](#)

²Section [15.3.3.5](#)

³Section [15.3.2.20](#)

⁴Section [15.3.2.21](#)

initMessage(String)

Signature

```
public  
java.lang.Throwable initMessage(String message)
```

Description

Set the message in SO local storage. This is the only method not defined in `java.lang.Throwable`.

Parameters

`message` is the text to save.

getMessage

Signature

```
public  
java.lang.String getMessage()
```

Description

get the message describing the problem from SO local memory.

Returns

the message given to the constructor or `null` when no message was set.

getLocalizedMessage

Signature

```
public  
java.lang.String getLocalizedMessage()
```

Description

Subclasses may override this message to get an error message that is localized to the default locale.

By default it returns `getMessage()`.

Returns

the value of `getMessage()`.

initCause(Throwable)

Signature

```
public  
java.lang.Throwable initCause(Throwable causingThrowable)
```

Description

Initializes the cause to the given Throwable in SO local memory.

Parameters

causingThrowable the reason why this Throwable gets Thrown.

Throws

IllegalArgumentException when the cause is this Throwable itself.

Returns

the reference to this Throwable.

getCause

Signature

```
public  
java.lang.Throwable getCause()
```

Description

getCause returns the cause of this exception or **null** when no cause was set. The cause is another exception that was caught before this exception was created.

Returns

The cause or **null**.

fillInStackTrace

Signature

```
public  
java.lang.Throwable fillInStackTrace()
```

Description

Calls into the virtual machine to capture the current stack trace in SO local memory.

Returns

a reference to this Throwable.

setStackTrace(StackTraceElement)

Signature

```
public  
void setStackTrace(java.lang.StackTraceElement[] new_stackTrace)  
throws NullPointerException
```

Description

This method allows overriding the stack trace that was filled during construction of this object. It is intended to be used in a serialization context when the stack trace of a remote exception should be treated like a local.

Parameters

`new_stackTrace` the stack trace to replace be used.

Throws

`NullPointerException` when `new_stackTrace` or any element of `new_stackTrace` is `null`.

getStackTrace

Signature

```
public  
java.lang.StackTraceElement[] getStackTrace()
```

Description

Get the stack trace created by `fillInStackTrace` for this `Throwable` as an array of `StackTraceElements`.

The stack trace does not need to contain entries for all methods that are actually on the call stack, the virtual machine may decide to skip some stack trace entries. Even an empty array is a valid result of this function.

Repeated calls of this function without intervening calls to `fillInStackTrace` will return the same result.

When memory areas of the RTSJ are used (see [MemoryArea](#)⁵), and this `Throwable` was allocated in a different memory area than the current allocation context, the resulting stack trace will be allocated in either the same memory area this was allocated in or the current memory area, depending on which is the least deeply nested, thereby creating objects that are assignment compatible with both areas.

⁵Section [11.4.2.3](#)

Returns

array representing the stack trace, never `null`.

printStackTrace*Signature*

```
public  
void printStackTrace()
```

Description

Print stack trace of this Throwable to `System.err`.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

printStackTrace(PrintStream)*Signature*

```
public  
void printStackTrace(PrintStream stream)
```

Description

Print the stack trace of this Throwable to the given stream.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

Parameters

stream the stream to print to.

printStackTrace(PrintWriter)*Signature*

```
public  
void printStackTrace(PrintWriter s)
```

Description

Print the stack trace of this Throwable to the given PrintWriter.

The printed stack trace contains the result of toString() as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

Parameters

s the PrintWriter to write to.

15.3.2 Exceptions

15.3.2.1 ArrivalTimeQueueOverflowException

Inheritance

```

java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      java.lang.RuntimeException
        javax.realtime.StaticRuntimeException
          javax.realtime.ArrivalTimeQueueOverflowException

```

Description

When an arrival time occurs and should be queued, but the queue already holds a number of times equal to the initial queue length, an instance of this class is thrown.

Available since RTSJ 1.0.1 this is unchecked

Available since RTSJ 2.0 extends StaticRuntimeException

15.3.2.1.1 Constructors

ArrivalTimeQueueOverflowException

Signature

```

public
ArrivalTimeQueueOverflowException()

```

Description

The default constructor for `ArrivalTimeQueueOverflowException`.

ArrivalTimeQueueOverflowException(String)*Signature*

```
public  
ArrivalTimeQueueOverflowException(String description)
```

Description

A descriptive constructor for `ArrivalTimeQueueOverflowException`.

Parameters

description A description of the exception.

15.3.2.1.2 Methods

get*Signature*

```
public  
javax.realtime.ArrivalTimeQueueOverflowException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

Available since RTSJ 2.0

15.3.2.2 CeilingViolationException

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      java.lang.RuntimeException
        java.lang.IllegalArgumentException
          java.lang.IllegalThreadStateException
            javax.realtime.CeilingViolationException
```

Interfaces

```
    javax.realtime.StaticThrowable
```

Description

This exception is thrown when a schedulable or `java.lang.Thread` attempts to lock an object governed by an instance of `PriorityCeilingEmulation`⁶ and the thread or SO's base priority exceeds the policy's ceiling.

Available since RTSJ 2.0 implements StaticThrowable

15.3.2.2.1 Methods

get

Signature

```
public
    javax.realtime.CeilingViolationException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

Available since RTSJ 2.0

getCeiling

Signature

⁶Section 7.4.1.2


```
public  
int getCeiling()
```

Description

Gets the ceiling of the `PriorityCeilingEmulation` policy which was exceeded by the base priority of an SO or thread that attempted to synchronize on an object governed by the policy, which resulted in throwing of `this`.

Returns

The ceiling of the `PriorityCeilingEmulation` policy which caused this exception to be thrown.

getCallerPriority

Signature

```
public  
int getCallerPriority()
```

Description

Gets the base priority of the SO or thread whose attempt to synchronize resulted in the throwing of this.

Returns

The synchronizing thread's base priority.

initMessage(String)

Signature

```
public  
java.lang.Throwable initMessage(String message)
```

Description

Set the message in SO local storage. This is the only method not defined in `java.lang.Throwable`.

Parameters

`message` is the text to save.

getMessage

Signature

```
public  
java.lang.String getMessage()
```

Description

get the message describing the problem from SO local memory.

Returns

the message given to the constructor or `null` when no message was set.

getLocalizedMessage

Signature

```
public  
java.lang.String getLocalizedMessage()
```

Description

Subclasses may override this message to get an error message that is localized to the default locale.

By default it returns `getMessage()`.

Returns

the value of `getMessage()`.

initCause(Throwable)

Signature

```
public  
java.lang.Throwable initCause(Throwable causingThrowable)
```

Description

Initializes the cause to the given Throwable in SO local memory.

Parameters

`causingThrowable` the reason why this Throwable gets Thrown.

Throws

`IllegalArgumentException` when the cause is this Throwable itself.

Returns

the reference to this Throwable.

getCause

Signature

```
public  
java.lang.Throwable getCause()
```

Description

getCause returns the cause of this exception or `null` when no cause was set. The cause is another exception that was caught before this exception was created.

Returns

The cause or `null`.

fillInStackTrace

Signature

```
public  
java.lang.Throwable fillInStackTrace()
```

Description

Calls into the virtual machine to capture the current stack trace in SO local memory.

Returns

a reference to this `Throwable`.

setStackTrace(StackTraceElement)

Signature

```
public  
void setStackTrace(java.lang.StackTraceElement[] new_stackTrace)  
throws NullPointerException
```

Description

This method allows overriding the stack trace that was filled during construction of this object. It is intended to be used in a serialization context when the stack trace of a remote exception should be treated like a local.

Parameters

`new_stackTrace` the stack trace to replace be used.

Throws

`NullPointerException` when `new_stackTrace` or any element of `new_stackTrace` is `null`.

getStackTrace

Signature

```
public  
java.lang.StackTraceElement[] getStackTrace()
```

Description

Get the stack trace created by `fillInStackTrace` for this `Throwable` as an array of `StackTraceElements`.

The stack trace does not need to contain entries for all methods that are actually on the call stack, the virtual machine may decide to skip some stack trace entries. Even an empty array is a valid result of this function.

Repeated calls of this function without intervening calls to `fillInStackTrace` will return the same result.

When memory areas of the RTSJ are used (see [MemoryArea⁷](#)), and this `Throwable` was allocated in a different memory area than the current allocation context, the resulting stack trace will be allocated in either the same memory area this was allocated in or the current memory area, depending on which is the least deeply nested, thereby creating objects that are assignment compatible with both areas.

Returns

array representing the stack trace, never `null`.

printStackTrace

Signature

```
public  
void printStackTrace()
```

Description

Print stack trace of this `Throwable` to `System.err`.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the

⁷Section [11.4.2.3](#)

method or constructor, optionally followed by the source file name and source file line number when available.

printStackTrace(PrintStream)

Signature

```
public  
void printStackTrace(PrintStream stream)
```

Description

Print the stack trace of this Throwable to the given stream.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

Parameters

stream the stream to print to.

printStackTrace(PrintWriter)

Signature

```
public  
void printStackTrace(PrintWriter writer)
```

Description

Print the stack trace of this Throwable to the given PrintWriter.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

Parameters

s the PrintWriter to write to.

15.3.2.3 DeregistrationException

Inheritance

java.lang.Object

```
java.lang.Throwable
  java.lang.Exception
    java.lang.RuntimeException
      javax.realtime.StaticRuntimeException
        javax.realtime.DeregistrationException
```

Description

An exception to throw when trying to deregister an [ActiveEvent](#)⁸ from an [ActiveEventDispatcher](#)⁹ to which it is not registered.

Available since RTSJ 2.0

15.3.2.3.1 Constructors

DeregistrationException

Signature

```
public
DeregistrationException()
```

Description

Create an exception with neither message nor cause

15.3.2.3.2 Methods

get

Signature

```
public
javax.realtime.DeregistrationException get()
```

Description

⁸Section [8.4.1.1](#)

⁹Section [8.4.3.1](#)

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

15.3.2.4 InaccessibleAreaException

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      java.lang.RuntimeException
        javax.realtime.StaticRuntimeException
          javax.realtime.InaccessibleAreaException
```

Description

The specified memory area is not on the current thread's scope stack.

Available since RTSJ 1.0.1 **Becomes unchecked**

Available since RTSJ 2.0 **extends StaticRuntimeException**

15.3.2.4.1 Constructors

InaccessibleAreaException

Signature

```
public
  InaccessibleAreaException()
```

Description

A constructor for InaccessibleAreaException.

InaccessibleAreaException(String)

Signature

```
public  
InaccessibleAreaException(String description)
```

Description

A descriptive constructor for `InaccessibleAreaException`.

Parameters

`description` Description of the error.

15.3.2.4.2 Methods

get

Signature

```
public  
javax.realtime.InaccessibleAreaException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

Available since RTSJ 2.0

15.3.2.5 LateStartException

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Exception  
      javax.realtime.StaticCheckedException
```


`javafx.runtime.LateStartException`

Description

Exception thrown when a periodic realtime thread or timer is started after its assigned, absolute, start time.

Available since RTSJ 2.0

Available since RTSJ 2.0 extends `StaticRuntimeException`

15.3.2.5.1 Methods

get

Signature

```
public  
    javafx.runtime.LateStartException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

15.3.2.6 MITViolationException

Inheritance

```
java.lang.Object  
    java.lang.Throwable  
        java.lang.Exception  
            java.lang.RuntimeException  
                javafx.runtime.StaticRuntimeException  
                    javafx.runtime.MITViolationException
```

Description

Thrown by the `AsyncEvent.fire()`¹⁰ on a minimum interarrival time violation. More specifically, it is thrown under the semantics of the base priority scheduler's sporadic parameters' `mitViolationExcept` policy when an attempt is made to introduce a release that would violate the MIT constraint.

Available since RTSJ 1.0.1 **Becomes unchecked**

Available since RTSJ 2.0 **extends** `StaticRuntimeException`

15.3.2.6.1 Constructors

MITViolationException

Signature

```
public  
MITViolationException()
```

Description

A constructor for `MITViolationException`.

MITViolationException(String)

Signature

```
public  
MITViolationException(String description)
```

Description

A descriptive constructor for `MITViolationException`.

Parameters

description Description of the error.

¹⁰Section [8.4.3.4.2](#)

15.3.2.6.2 Methods

get

Signature

```
public  
javafx.runtime.MITViolationException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

Available since RTSJ 2.0

15.3.2.7 MemoryInUseException

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Exception  
      java.lang.RuntimeException  
        javafx.runtime.StaticRuntimeException  
          javafx.runtime.MemoryInUseException
```

Description

There has been attempt to allocate a range of physical or virtual memory that is already in use.

Available since RTSJ 2.0 extends StaticRuntimeException

15.3.2.7.1 Constructors

MemoryInUseException

Signature

```
public  
MemoryInUseException()
```

Description

A constructor for MemoryInUseException.

MemoryInUseException(String)

Signature

```
public  
MemoryInUseException(String description)
```

Description

A descriptive constructor for MemoryInUseException.

Parameters

description Description of the error.

15.3.2.7.2 Methods

get

Signature

```
public  
javax.realtime.MemoryInUseException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

Available since RTSJ 2.0

15.3.2.8 MemoryScopeException

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      java.lang.RuntimeException
        javax.realtime.StaticRuntimeException
          javax.realtime.MemoryScopeException
```

Description

When construction of any of the wait-free queues is attempted with the ends of the queue in incompatible memory areas. Also thrown by wait-free queue methods when such an incompatibility is detected after the queue is constructed.

Available since RTSJ 2.0 extends `StaticRuntimeException`

15.3.2.8.1 Constructors

MemoryScopeException

Signature

```
public
MemoryScopeException()
```

Description

A constructor for `MemoryScopeException`.

MemoryScopeException(String)

Signature

```
public
MemoryScopeException(String description)
```

Description

A descriptive constructor for `MemoryScopeException`.

Parameters

`description` A description of the exception.

15.3.2.8.2 Methods

get

Signature

```
public  
javax.realtime.MemoryScopeException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

Available since RTSJ 2.0

15.3.2.9 MemoryTypeConflictException

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Exception  
      java.lang.RuntimeException  
        javax.realtime.StaticRuntimeException  
          javax.realtime.MemoryTypeConflictException
```

Description

This exception is thrown when the `PhysicalMemoryManager`¹¹ is given conflicting specifications for memory. The conflict can be between types in an array of memory type specifiers, or between the specifiers and a specified base address.

¹¹Section [A.3.3.6](#)

Available since RTSJ 1.0.1 Changed to an unchecked exception.

Available since RTSJ 2.0 extends StaticRuntimeException

15.3.2.9.1 Constructors

MemoryTypeConflictException

Signature

```
public  
MemoryTypeConflictException()
```

Description

A constructor for MemoryTypeConflictException.

MemoryTypeConflictException(String)

Signature

```
public  
MemoryTypeConflictException(String description)
```

Description

A descriptive constructor for MemoryTypeConflictException.

Parameters

description A description of the exception.

15.3.2.9.2 Methods

get

Signature

```
public
  javax.realtime.MemoryTypeConflictException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

Available since RTSJ 2.0

15.3.2.10 OffsetOutOfBoundsException

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      java.lang.RuntimeException
        javax.realtime.StaticRuntimeException
          javax.realtime.OffsetOutOfBoundsException
```

Description

when the constructor of an [ImmortalPhysicalMemory](#)¹², [LTPhysicalMemory](#)¹³, [VTPhysicalMemory](#)¹⁴, [RawMemoryAccess](#)¹⁵, or [RawMemoryFloatAccess](#)¹⁶ is given an invalid address.

Available since RTSJ 1.0.1 Becomes unchecked

Available since RTSJ 2.0 extends StaticRuntimeException

15.3.2.10.1 Constructors

¹²Section [A.3.3.1](#)

¹³Section [A.3.3.3](#)

¹⁴Section [A.3.3.13](#)

¹⁵Section [A.3.3.9](#)

¹⁶Section [A.3.3.10](#)

OffsetOutOfBoundsException

Signature

```
public  
OffsetOutOfBoundsException()
```

Description

A constructor for `OffsetOutOfBoundsException`.

OffsetOutOfBoundsException(String)

Signature

```
public  
OffsetOutOfBoundsException(String description)
```

Description

A descriptive constructor for `OffsetOutOfBoundsException`.

Parameters

`description` A description of the exception.

15.3.2.10.2 Methods

get

Signature

```
public  
javax.realtime.OffsetOutOfBoundsException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

Available since RTSJ 2.0

15.3.2.11 POSIXException

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      javax.realtime.StaticCheckedException
        javax.realtime.POSIXException
```

Description

A base class for all POSIX exceptions.

Available since RTSJ 2.0

15.3.2.11.1 Constructors

POSIXException

Signature

```
public
  POSIXException()
```

Description

POSIXException(String)

Signature

```
public
  POSIXException(String s)
```

Description

15.3.2.12 POSIXInvalidSignalException

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      javax.realtime.StaticCheckedException
        javax.realtime.POSIXException
          javax.realtime.POSIXInvalidSignalException
```

Description

An invalid POSIX signal number has been specified.

Available since RTSJ 2.0

15.3.2.12.1 Methods

get

Signature

```
public
  javax.realtime.POSIXInvalidSignalException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

15.3.2.13 POSIXInvalidTargetException

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      javax.realtime.StaticCheckedException
```

[javax.realtime.POSIXException](#)
[javax.realtime.POSIXInvalidTargetException](#)

Description

The target of the signal does not exist.

Available since RTSJ 2.0

15.3.2.13.1 Methods

get*Signature*

```
public
  javax.realtime.POSIXInvalidTargetException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

15.3.2.14 POSIXSignalPermissionException

Inheritance

```

java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      javax.realtime.StaticCheckedException
        javax.realtime.POSIXException
          javax.realtime.POSIXSignalPermissionException

```

Description

The process does not have permission to send the given signal to the given target.

Available since RTSJ 2.0

15.3.2.14.1 Methods

get*Signature*

```
public  
javafx.runtime.POSIXSignalPermissionException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

15.3.2.15 ProcessorAffinityException

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Exception  
      javafx.runtime.StaticCheckedException  
        javafx.runtime.ProcessorAffinityException
```

Description

Exception used to report processor affinity-related errors.

Available since RTSJ 2.0

15.3.2.15.1 Methods

get*Signature*

```
public  
javax.realtime.ProcessorAffinityException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

15.3.2.16 RangeOutOfBoundsException

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Exception  
      javax.realtime.StaticCheckedException  
        javax.realtime.RangeOutOfBoundsException
```

Description

Available since RTSJ 2.0

15.3.2.16.1 Methods

get*Signature*

```
public  
javax.realtime.RangeOutOfBoundsException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

15.3.2.17 RegistrationException

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      java.lang.RuntimeException
        javax.realtime.StaticRuntimeException
          javax.realtime.RegistrationException
```

Description

An exception to throw when trying to register an [ActiveEvent](#)¹⁷ with an [ActiveEventDispatcher](#)¹⁸ to which it is already registered.

Available since RTSJ 2.0

15.3.2.17.1 Methods

get

Signature

```
public
  javax.realtime.RegistrationException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

15.3.2.18 ScopedCycleException

Inheritance

¹⁷Section 8.4.1.1

¹⁸Section 8.4.3.1

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      java.lang.RuntimeException
        javax.realtime.StaticRuntimeException
          javax.realtime.ScopedCycleException
```

Description

Thrown when a schedulable attempts to enter an instance of **ScopedMemory**¹⁹ where that operation would cause a violation of the single parent rule.

Available since RTSJ 2.0 extends **StaticRuntimeException**

15.3.2.18.1 Constructors

ScopedCycleException

Signature

```
public
  ScopedCycleException()
```

Description

A constructor for **ScopedCycleException**.

ScopedCycleException(String)

Signature

```
public
  ScopedCycleException(String description)
```

Description

A descriptive constructor for **ScopedCycleException**.

Parameters

description Description of the error.

¹⁹Section [A.3.3.11](#)

15.3.2.18.2 Methods

get

Signature

```
public  
javafx.runtime.ScopedCycleException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

Available since RTSJ 2.0

15.3.2.19 SizeOutOfBoundsException

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Exception  
      java.lang.RuntimeException  
        javafx.runtime.StaticRuntimeException  
          javafx.runtime.SizeOutOfBoundsException
```

Description

To throw when the constructor of an **ImmutablePhysicalMemory**²⁰, **LTPhysicalMemory**²¹, or **VTPhysicalMemory**²² is given an invalid size or when a memory access generated by a raw memory accessor instance (See **javafx.runtime.device.RawMemory**²³.) would cause access to an invalid address.

Available since RTSJ 1.0.1 became unchecked

²⁰Section [A.3.3.1](#)

²¹Section [A.3.3.3](#)

²²Section [A.3.3.13](#)

²³Section [12.4.1.16](#)

Available since RTSJ 2.0 extends `StaticRuntimeException`

15.3.2.19.1 Constructors

SizeOutOfBoundsException

Signature

```
public  
SizeOutOfBoundsException()
```

Description

A constructor for `SizeOutOfBoundsException`.

SizeOutOfBoundsException(String)

Signature

```
public  
SizeOutOfBoundsException(String description)
```

Description

A descriptive constructor for `SizeOutOfBoundsException`.

Parameters

description The description of the exception.

15.3.2.19.2 Methods

get

Signature

```
public  
javax.realtime.SizeOutOfBoundsException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

Available since RTSJ 2.0

15.3.2.20 StaticCheckedException

Inheritance

java.lang.Object
 java.lang.Throwable
 java.lang.Exception
 javax.realtime.StaticCheckedException

Interfaces

 javax.realtime.StaticThrowable

Description

Available since RTSJ 2.0

15.3.2.20.1 Constructors

StaticCheckedException

Signature

protected
StaticCheckedException()

Description

StaticCheckedException(String)

Signature

```
protected  
StaticCheckedException(String s)
```

Description

15.3.2.20.2 Methods

initMessage(String)

Signature

```
public  
java.lang.Throwable initMessage(String message)
```

Description

Set the message in SO local storage. This is the only method not defined in `java.lang.Throwable`.

Parameters

`message` is the text to save.

getMessage

Signature

```
public  
java.lang.String getMessage()
```

Description

get the message describing the problem from SO local memory.

Returns

the message given to the constructor or `null` when no message was set.

getLocalizedMessage

Signature

```
public  
java.lang.String getLocalizedMessage()
```

Description

Subclasses may override this message to get an error message that is localized to the default locale.

By default it returns `getMessage()`.

Returns

the value of `getMessage()`.

initCause(Throwable)

Signature

```
public  
java.lang.Throwable initCause(Throwable causingThrowable)
```

Description

Initializes the cause to the given Throwable is SO local memory.

Parameters

`causingThrowable` the reason why this Throwable gets Thrown.

Throws

`IllegalArgumentException` when the cause is this Throwable itself.

Returns

the reference to this Throwable.

getCause

Signature

```
public  
java.lang.Throwable getCause()
```

Description

`getCause` returns the cause of this exception or `null` when no cause was set. The cause is another exception that was caught before this exception was created.

Returns

The cause or `null`.

fillInStackTrace*Signature*

```
public  
java.lang.Throwable fillInStackTrace()
```

Description

Calls into the virtual machine to capture the current stack trace in SO local memory.

Returns

a reference to this `Throwable`.

setStackTrace(StackTraceElement)*Signature*

```
public  
void setStackTrace(java.lang.StackTraceElement[] new_stackTrace)  
throws NullPointerException
```

Description

This method allows overriding the stack trace that was filled during construction of this object. It is intended to be used in a serialization context when the stack trace of a remote exception should be treated like a local.

Parameters

`new_stackTrace` the stack trace to replace be used.

Throws

`NullPointerException` when `new_stackTrace` or any element of `new_stackTrace` is `null`.

getStackTrace*Signature*

```
public  
java.lang.StackTraceElement[] getStackTrace()
```

Description

Get the stack trace created by `fillInStackTrace` for this `Throwable` as an array of `StackTraceElements`.

The stack trace does not need to contain entries for all methods that are actually on the call stack, the virtual machine may decide to skip some stack trace entries. Even an empty array is a valid result of this function.

Repeated calls of this function without intervening calls to `fillInStackTrace` will return the same result.

When memory areas of the RTSJ are used (see [MemoryArea²⁴](#)), and this `Throwable` was allocated in a different memory area than the current allocation context, the resulting stack trace will be allocated in either the same memory area this was allocated in or the current memory area, depending on which is the least deeply nested, thereby creating objects that are assignment compatible with both areas.

Returns

array representing the stack trace, never `null`.

printStackTrace

Signature

```
public  
void printStackTrace()
```

Description

Print stack trace of this `Throwable` to `System.err`.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

printStackTrace(PrintStream)

Signature

```
public  
void printStackTrace(PrintStream stream)
```

Description

²⁴Section [11.4.2.3](#)

Print the stack trace of this Throwable to the given stream.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

Parameters

stream the stream to print to.

printStackTrace(PrintWriter)

Signature

```
public  
void printStackTrace(PrintWriter writer)
```

Description

Print the stack trace of this Throwable to the given PrintWriter.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

Parameters

s the PrintWriter to write to.

15.3.2.21 StaticRuntimeException

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Exception  
      java.lang.RuntimeException  
        javax.realtime.StaticRuntimeException
```

Interfaces

```
javax.realtime.StaticThrowable
```

Description

Available since RTSJ 2.0

15.3.2.21.1 Constructors

StaticRuntimeException

Signature

```
protected  
StaticRuntimeException()
```

Description

StaticRuntimeException(String)

Signature

```
protected  
StaticRuntimeException(String s)
```

Description

15.3.2.21.2 Methods

initMessage(String)

Signature

```
public  
java.lang.Throwable initMessage(String message)
```

Description

Set the message in SO local storage. This is the only method not defined in `java.lang.Throwable`.

Parameters

`message` is the text to save.

getMessage

Signature

```
public  
java.lang.String getMessage()
```

Description

get the message describing the problem from SO local memory.

Returns

the message given to the constructor or `null` when no message was set.

getLocalizedMessage

Signature

```
public  
java.lang.String getLocalizedMessage()
```

Description

Subclasses may override this message to get an error message that is localized to the default locale.

By default it returns `getMessage()`.

Returns

the value of `getMessage()`.

initCause(Throwable)

Signature

```
public  
java.lang.Throwable initCause(Throwable causingThrowable)
```

Description

Initializes the cause to the given Throwable in SO local memory.

Parameters

`causingThrowable` the reason why this Throwable gets Thrown.

Throws

`IllegalArgumentException` when the cause is this Throwable itself.

Returns

the reference to this Throwable.

getCause

Signature

```
public  
java.lang.Throwable getCause()
```

Description

getCause returns the cause of this exception or `null` when no cause was set. The cause is another exception that was caught before this exception was created.

Returns

The cause or `null`.

fillInStackTrace

Signature

```
public  
java.lang.Throwable fillInStackTrace()
```

Description

Calls into the virtual machine to capture the current stack trace in SO local memory.

Returns

a reference to this `Throwable`.

setStackTrace(StackTraceElement)

Signature

```
public  
void setStackTrace(java.lang.StackTraceElement[] new_stackTrace)  
throws NullPointerException
```

Description

This method allows overriding the stack trace that was filled during construction of this object. It is intended to be used in a serialization context when the stack trace of a remote exception should be treated like a local.

Parameters

`new_stackTrace` the stack trace to replace be used.

Throws

`NullPointerException` when `new_stackTrace` or any element of `new_stackTrace` is `null`.

getStackTrace

Signature

```
public  
java.lang.StackTraceElement[] getStackTrace()
```

Description

Get the stack trace created by `fillInStackTrace` for this `Throwable` as an array of `StackTraceElements`.

The stack trace does not need to contain entries for all methods that are actually on the call stack, the virtual machine may decide to skip some stack trace entries. Even an empty array is a valid result of this function.

Repeated calls of this function without intervening calls to `fillInStackTrace` will return the same result.

When memory areas of the RTSJ are used (see [MemoryArea²⁵](#)), and this `Throwable` was allocated in a different memory area than the current allocation context, the resulting stack trace will be allocated in either the same memory area this was allocated in or the current memory area, depending on which is the least deeply nested, thereby creating objects that are assignment compatible with both areas.

Returns

array representing the stack trace, never `null`.

printStackTrace

Signature

```
public  
void printStackTrace()
```

Description

Print stack trace of this `Throwable` to `System.err`.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the

²⁵Section [11.4.2.3](#)

method or constructor, optionally followed by the source file name and source file line number when available.

printStackTrace(PrintStream)

Signature

```
public  
void printStackTrace(PrintStream stream)
```

Description

Print the stack trace of this Throwable to the given stream.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

Parameters

stream the stream to print to.

printStackTrace(PrintWriter)

Signature

```
public  
void printStackTrace(PrintWriter writer)
```

Description

Print the stack trace of this Throwable to the given PrintWriter.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

Parameters

s the PrintWriter to write to.

15.3.2.22 UnsupportedPhysicalMemoryException

Inheritance

java.lang.Object

```
java.lang.Throwable
  java.lang.Exception
    java.lang.RuntimeException
      javax.realtime.StaticRuntimeException
        javax.realtime.UnsupportedPhysicalMemoryException
```

Description

Thrown when the underlying hardware does not support the type of physical memory requested.

See Section [PhysicalMemoryFactory](#)

Available since RTSJ 1.0.1 Becomes unchecked

Available since RTSJ 2.0 extends StaticRuntimeException

15.3.2.22.1 Constructors

UnsupportedPhysicalMemoryException

Signature

```
public
  UnsupportedPhysicalMemoryException()
```

Description

A constructor for UnsupportedPhysicalMemoryException.

UnsupportedPhysicalMemoryException(String)

Signature

```
public
  UnsupportedPhysicalMemoryException(String description)
```

Description

A descriptive constructor for UnsupportedPhysicalMemoryException.

Parameters

description The description of the exception.

15.3.2.22.2 Methods

get

Signature

```
public  
javafx.runtime.UnsupportedPhysicalMemoryException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

Available since RTSJ 2.0

15.3.2.23 UnsupportedRawMemoryRegionException

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Exception  
      java.lang.RuntimeException  
        javafx.runtime.StaticRuntimeException  
          javafx.runtime.UnsupportedRawMemoryRegionException
```

Description

Available since RTSJ 2.0

15.3.2.23.1 Methods

get

Signature

```
public  
javax.realtime.UnsupportedRawMemoryRegionException get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

15.3.3 Classes

15.3.3.1 AlignmentError

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Error  
      javax.realtime.StaticError  
        javax.realtime.AlignmentError
```

Description

The exception thrown on an on a request for a raw memory factory to return memory for a base address that is aligned such that the factory cannot guarantee that loads and stores based on that address will meet the factory's specifications. For instance, on many processors, odd addresses are unsuitable for anything but byte access.

Available since RTSJ 2.0 extends StaticError

15.3.3.1.1 Constructors

AlignmentError

Signature

```
public  
AlignmentError()
```

Description

15.3.3.1.2 Methods

get

Signature

```
public  
javax.realtime.AlignmentError get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

Available since RTSJ 2.0

15.3.3.2 IllegalAssignmentError

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Error  
      javax.realtime.StaticError  
        javax.realtime.IllegalAssignmentError
```

Description

The exception thrown on an attempt to make an illegal assignment. For example, this will be thrown on any attempt to assign a reference to an object in scoped memory (an area of memory identified by an instance of [ScopedMemory](#)²⁶) to a field of an object in immortal memory.

Available since RTSJ 2.0 extends `StaticError`

15.3.3.2.1 Constructors

IllegalAssignmentError

Signature

```
public  
IllegalAssignmentError()
```

Description

A constructor for `IllegalAssignmentError`.

IllegalAssignmentError(String)

Signature

```
public  
IllegalAssignmentError(String description)
```

Description

A descriptive constructor for `IllegalAssignmentError`.

Parameters

description Description of the error.

15.3.3.2.2 Methods

²⁶Section [A.3.3.11](#)

get*Signature*

```
public  
javax.realtime.IllegalAssignmentError get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

Available since RTSJ 2.0

15.3.3.3 MemoryAccessError

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Error  
      javax.realtime.StaticError  
        javax.realtime.MemoryAccessError
```

Description

This error is thrown on an attempt to refer to an object in an inaccessible [MemoryArea](#)²⁷. For example this will be when logic in a [NoHeapRealtimeThread](#)²⁸ attempts to refer to an object in the traditional Java heap.

Available since RTSJ 2.0 extends StaticError

15.3.3.3.1 Constructors

²⁷Section [11.4.2.3](#)

²⁸Section [A.3.3.4](#)

MemoryAccessError

Signature

```
public  
MemoryAccessError()
```

Description

A constructor for `MemoryAccessError`.

MemoryAccessError(String)

Signature

```
public  
MemoryAccessError(String description)
```

Description

A descriptive constructor for `MemoryAccessError`.

Parameters

`description` Description of the error.

15.3.3.3.2 Methods

get

Signature

```
public  
javax.realtime.IllegalAssignmentError get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

Available since RTSJ 2.0

15.3.3.4 ResourceLimitError

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Error
      javax.realtime.StaticError
        javax.realtime.ResourceLimitError
```

Description

when an attempt is made to exceed a system resource limit, such as the maximum number of locks.

Available since RTSJ 2.0 extends StaticError

15.3.3.4.1 Constructors

ResourceLimitError

Signature

```
public
ResourceLimitError()
```

Description

A constructor for ResourceLimitError.

ResourceLimitError(String)

Signature

```
public
ResourceLimitError(String description)
```

Description

A descriptive constructor for ResourceLimitError.

Parameters

description The description of the exception.

15.3.3.4.2 Methods

get*Signature*

```
public  
    javax.realtime.ResourceLimitError get()
```

Description

Obtain the singleton of this static throwable. It is prepared for immediate throwing.

Returns

the single instance of this throwable.

Available since RTSJ 2.0

15.3.3.5 StaticError

Inheritance

```
java.lang.Object  
    java.lang.Throwable  
        java.lang.Error  
            javax.realtime.StaticError
```

Interfaces

```
    javax.realtime.StaticThrowable
```

Description

Available since RTSJ 2.0

15.3.3.5.1 Constructors

StaticError

Signature

```
protected  
StaticError()
```

Description

StaticError(String)

Signature

```
protected  
StaticError(String s)
```

Description

15.3.3.5.2 Methods

initMessage(String)

Signature

```
public  
java.lang.Throwable initMessage(String message)
```

Description

Set the message in SO local storage. This is the only method not defined in `java.lang.Throwable`.

Parameters

`message` is the text to save.

getMessage

Signature

```
public  
java.lang.String getMessage()
```

Description

get the message describing the problem from SO local memory.

Returns

the message given to the constructor or `null` when no message was set.

getLocalizedMessage

Signature

```
public  
java.lang.String getLocalizedMessage()
```

Description

Subclasses may override this message to get an error message that is localized to the default locale.

By default it returns `getMessage()`.

Returns

the value of `getMessage()`.

initCause(Throwable)

Signature

```
public  
java.lang.Throwable initCause(Throwable causingThrowable)
```

Description

Initializes the cause to the given Throwable in SO local memory.

Parameters

`causingThrowable` the reason why this Throwable gets Thrown.

Throws

`IllegalArgumentException` when the cause is this Throwable itself.

Returns

the reference to this Throwable.

getCause

Signature

```
public  
java.lang.Throwable getCause()
```

Description

getCause returns the cause of this exception or `null` when no cause was set. The cause is another exception that was caught before this exception was created.

Returns

The cause or `null`.

fillInStackTrace

Signature

```
public  
java.lang.Throwable fillInStackTrace()
```

Description

Calls into the virtual machine to capture the current stack trace in SO local memory.

Returns

a reference to this `Throwable`.

setStackTrace(StackTraceElement)

Signature

```
public  
void setStackTrace(java.lang.StackTraceElement[] new_stackTrace)  
throws NullPointerException
```

Description

This method allows overriding the stack trace that was filled during construction of this object. It is intended to be used in a serialization context when the stack trace of a remote exception should be treated like a local.

Parameters

`new_stackTrace` the stack trace to replace be used.

Throws

`NullPointerException` when `new_stackTrace` or any element of `new_stackTrace` is `null`.

getStackTrace

Signature

```
public  
java.lang.StackTraceElement[] getStackTrace()
```

Description

Get the stack trace created by `fillInStackTrace` for this `Throwable` as an array of `StackTraceElements`.

The stack trace does not need to contain entries for all methods that are actually on the call stack, the virtual machine may decide to skip some stack trace entries. Even an empty array is a valid result of this function.

Repeated calls of this function without intervening calls to `fillInStackTrace` will return the same result.

When memory areas of the RTSJ are used (see [MemoryArea](#)²⁹), and this `Throwable` was allocated in a different memory area than the current allocation context, the resulting stack trace will be allocated in either the same memory area this was allocated in or the current memory area, depending on which is the least deeply nested, thereby creating objects that are assignment compatible with both areas.

Returns

array representing the stack trace, never `null`.

printStackTrace

Signature

```
public  
void printStackTrace()
```

Description

Print stack trace of this `Throwable` to `System.err`.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the

²⁹Section [11.4.2.3](#)

method or constructor, optionally followed by the source file name and source file line number when available.

printStackTrace(PrintStream)

Signature

```
public  
void printStackTrace(PrintStream stream)
```

Description

Print the stack trace of this Throwable to the given stream.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

Parameters

stream the stream to print to.

printStackTrace(PrintWriter)

Signature

```
public  
void printStackTrace(PrintWriter writer)
```

Description

Print the stack trace of this Throwable to the given PrintWriter.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

Parameters

s the PrintWriter to write to.

15.3.3.6 StaticOutOfMemoryError

Inheritance

java.lang.Object

```
java.lang.Throwable
  java.lang.Error
    java.lang.VirtualMachineError
      java.lang.OutOfMemoryError
        javax.realtime.StaticOutOfMemoryError
```

Interfaces

```
javax.realtime.StaticThrowable
```

Description

A version of `OutOfMemoryError` that does not require allocation. It should be thrown from all RTSJ memory subclasses except `HeapMemory`³⁰. It is up to the implementation as to whether `HeapMemory` throws this exception or its parent.

Available since RTSJ 2.0

15.3.3.6.1 Constructors

StaticOutOfMemoryError

Signature

```
public
StaticOutOfMemoryError()
```

Description

15.3.3.6.2 Methods

get

Signature

```
public static
javax.realtime.StaticOutOfMemoryError get()
```

³⁰Section 11.4.2.1

Description

Get the preallocated version of this Throwable. Allocation is done in memory that acts like [ImmutableMemory](#)³¹. The message and cause are cleared and the stack trace is filled out.

Returns

the preallocated exception

get(String)*Signature*

```
public static  
    javax.realtime.StaticOutOfMemoryError get(String message)
```

Description

Same as [get](#)³² except the message is set to `message`

Parameters

`message` text describing the issue.

Returns

the preallocated exception

get(Throwable)*Signature*

```
public static  
    javax.realtime.StaticOutOfMemoryError get(Throwable cause)
```

Description

Same as [get](#)³³ except the cause is set to `cause`

Parameters

`cause` a throwable that lead to this issue.

Returns

the preallocated exception

³¹Section [11.4.2.2](#)

³²Section [15.3.3.6.2](#)

³³Section [15.3.3.6.2](#)

get(String, Throwable)

Signature

```
public static
    javax.realtime.StaticOutOfMemoryError get(String Message,
                                              Throwable cause)
```

Description

Same as `get`³⁴ except the message is set to `message` and cause is set to `cause`

Parameters

`Message` text describing the issue.
`cause` a throwable that lead to this issue.

Returns

the preallocated exception

initMessage(String)

Signature

```
public
    java.lang.Throwable initMessage(String message)
```

Description

Set the message in SO local storage. This is the only method not defined in `java.lang.Throwable`.

Parameters

`message` is the text to save.

getMessage

Signature

```
public
    java.lang.String getMessage()
```

Description

get the message describing the problem from SO local memory.

Returns

the message given to the constructor or `null` when no message was set.

³⁴Section 15.3.3.6.2

getLocalizedMessage

Signature

```
public  
java.lang.String getLocalizedMessage()
```

Description

Subclasses may override this message to get an error message that is localized to the default locale.

By default it returns `getMessage()`.

Returns

the value of `getMessage()`.

initCause(Throwable)

Signature

```
public  
java.lang.Throwable initCause(Throwable causingThrowable)
```

Description

Initializes the cause to the given Throwable is SO local memory.

Parameters

`causingThrowable` the reason why this Throwable gets Thrown.

Throws

`IllegalArgumentException` when the cause is this Throwable itself.

Returns

the reference to this Throwable.

getCause

Signature

```
public  
java.lang.Throwable getCause()
```

Description

`getCause` returns the cause of this exception or `null` when no cause was set. The cause is another exception that was caught before this exception was created.

Returns

The cause or `null`.

fillInStackTrace*Signature*

```
public  
java.lang.Throwable fillInStackTrace()
```

Description

Calls into the virtual machine to capture the current stack trace in SO local memory.

Returns

a reference to this `Throwable`.

setStackTrace(StackTraceElement)*Signature*

```
public  
void setStackTrace(java.lang.StackTraceElement[] new_stackTrace)  
throws NullPointerException
```

Description

This method allows overriding the stack trace that was filled during construction of this object. It is intended to be used in a serialization context when the stack trace of a remote exception should be treated like a local.

Parameters

`new_stackTrace` the stack trace to replace be used.

Throws

`NullPointerException` when `new_stackTrace` or any element of `new_stackTrace` is `null`.

getStackTrace*Signature*

```
public  
java.lang.StackTraceElement[] getStackTrace()
```


Description

Get the stack trace created by `fillInStackTrace` for this `Throwable` as an array of `StackTraceElements`.

The stack trace does not need to contain entries for all methods that are actually on the call stack, the virtual machine may decide to skip some stack trace entries. Even an empty array is a valid result of this function.

Repeated calls of this function without intervening calls to `fillInStackTrace` will return the same result.

When memory areas of the RTSJ are used (see [MemoryArea³⁵](#)), and this `Throwable` was allocated in a different memory area than the current allocation context, the resulting stack trace will be allocated in either the same memory area this was allocated in or the current memory area, depending on which is the least deeply nested, thereby creating objects that are assignment compatible with both areas.

Returns

array representing the stack trace, never `null`.

printStackTrace

Signature

```
public  
void printStackTrace()
```

Description

Print stack trace of this `Throwable` to `System.err`.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

printStackTrace(PrintStream)

Signature

```
public  
void printStackTrace(PrintStream stream)
```

Description

³⁵Section [11.4.2.3](#)

Print the stack trace of this Throwable to the given stream.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

Parameters

stream the stream to print to.

printStackTrace(PrintWriter)

Signature

```
public  
void printStackTrace(PrintWriter s)
```

Description

Print the stack trace of this Throwable to the given PrintWriter.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

Parameters

s the PrintWriter to write to.

15.3.3.7 StaticThrowableStorage

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    javax.realtime.StaticThrowableStorage
```

Interfaces

```
    javax.realtime.StaticThrowable
```

Description

Provide the methods for managing the thread local memory used for storing the data needed by preallocated throwables, i.e., exceptions and errors which implement **StaticThrowable**³⁶. This call is visible so that an application can

³⁶Section 15.3.1.1

extend an existing conventional Java throwable and still implement `StaticThrowable`; its methods can be implemented using the methods defined in this class. An application defined throwable that does not need to extend an existing conventional Java throwable should extend on of `StaticCheckedException`³⁷, `StaticRuntimeException`³⁸, or `StaticError`³⁹ instead.

Available since RTSJ 2.0

15.3.3.7.1 Methods

getCurrent

Signature

```
public static  
javax.realtime.StaticThrowableStorage getCurrent()
```

Description

A means of obtaining the storage object for the current task.

Returns

the storage object for the current task.

fillInStackTrace

Signature

```
public  
java.lang.Throwable fillInStackTrace()
```

Description

Capture the current thread's stack trace and save it in thread local storage. Only the part of the stack trace that fits in the preallocated buffer is stored. This method should be called by a preallocated exception to implement its method of the same name.

Returns

³⁷Section 15.3.2.20

³⁸Section 15.3.2.21

³⁹Section 15.3.3.5

getMessage

Signature

```
public  
java.lang.String getMessage()
```

Description

Get the message from thread local storage that was saved by the last preallocated exception thrown. This method should be called by a preallocated exception to implement its method of the same name.

Returns

the message

initMessage(String)

Signature

```
public  
java.lang.Throwable initMessage(String message)
```

Description

Save the message in thread local storage for later retrieval. Only the part of the message that fits in the preallocated buffer is stored. This method should be called by a preallocated exception to implement its method of the same name.

Parameters

message the message to save.

getCause

Signature

```
public  
java.lang.Throwable getCause()
```

Description

Get the cause from thread local storage that was saved by the last preallocated exception thrown. The actual exception that of the cause is not saved, but just a reference to its type. This returns a newly allocated exception without any valid

content, i.e., no valid stack trace. This method should be called by a preallocated exception to implement its method of the same name.

Returns

the message

initCause(Throwable)*Signature*

```
public  
java.lang.Throwable initCause(Throwable causingThrowable)
```

Description

Save the message in thread local storage for later retrieval. Only a reference to the exception class is stored. The rest of its information is lost. This method should be called by a preallocated exception to implement its method of the same name.

Parameters

causingThrowable

*Returns***getStackTrace***Signature*

```
public  
java.lang.StackTraceElement[] getStackTrace()
```

Description

Get the stack trace from thread local storage that was saved by the last preallocated exception thrown. This method should be called by a preallocated exception to implement its method of the same name.

Returns

an array of the elements of the stack trace.

getLocalizedMessage

Signature

```
public  
java.lang.String getLocalizedMessage()
```

Description

Subclasses may override this message to get an error message that is localized to the default locale.

By default it returns `getMessage()`.

Returns

the value of `getMessage()`.

setStackTrace(StackTraceElement)

Signature

```
public  
void setStackTrace(java.lang.StackTraceElement[] new_stackTrace)
```

Description

This method allows overriding the stack trace that was filled during construction of this object. It is intended to be used in a serialization context when the stack trace of a remote exception should be treated like a local.

Parameters

`new_stackTrace` the stack trace to replace be used.

Throws

`NullPointerException` when `new_stackTrace` or any element of `new_stackTrace` is `null`.

printStackTrace

Signature

```
public  
void printStackTrace()
```

Description

Print stack trace of this Throwable to System.err.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

printStackTrace(PrintStream)

Signature

```
public  
void printStackTrace(PrintStream stream)
```

Description

Print the stack trace of this Throwable to the given stream.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

Parameters

stream the stream to print to.

printStackTrace(PrintWriter)

Signature

```
public  
void printStackTrace(PrintWriter writer)
```

Description

Print the stack trace of this Throwable to the given PrintWriter.

The printed stack trace contains the result of `toString()` as the first line followed by one line for each stack trace element that contains the name of the method or constructor, optionally followed by the source file name and source file line number when available.

Parameters

s the PrintWriter to write to.

15.3.3.8 ThrowBoundaryError

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Error
      javax.realtime.StaticError
        javax.realtime.ThrowBoundaryError
```

Description

The error thrown by `MemoryArea.enter(Runnable logic)`⁴⁰ when a `Throwable` allocated from memory that is not usable in the surrounding scope tries to propagate out of the scope of the `enter`.

Available since RTSJ 2.0 extends `StaticError`

15.3.3.8.1 Constructors

ThrowBoundaryError

Signature

```
public
  ThrowBoundaryError()
```

Description

A constructor for `ThrowBoundaryError`.

ThrowBoundaryError(String)

Signature

```
public
  ThrowBoundaryError(String description)
```

⁴⁰Section 11.4.2.3.2

Description

A descriptive constructor for `ThrowBoundaryError`.

Parameters

`description` Description of the error.

15.3.3.8.2 Methods

getPreallocatedThrowable*Signature*

```
public  
javax.realtime.ThrowBoundaryError getPreallocatedThrowable()
```

Description

Get the preallocated instance of this exception.

Returns

the preallocated instance of this exception.

initMessage(String)*Signature*

```
public  
java.lang.Throwable initMessage(String message)
```

Description

Set the message in SO local storage. This is the only method not defined in `java.lang.Throwable`.

Parameters

`message` is the text to save.

15.4 Rationale

The need for additional exceptions given the new semantics added by the other sections of this specification is obvious. That the specification attaches new, non-conventional, exception semantics to `AsynchronouslyInterruptedException` is,

perhaps, not so obvious. However, after careful thought, and given our self-imposed directive that only well-defined code blocks would be subject to having their control asynchronously transferred, the chosen mechanism is logical.

Open Issues

Editorial:

- The `\classref` tag should suppress multiple footnotes on the same {page,section,whatever}.
- We should consider numbered paragraphs.
- Move the complete constructors for all classes to the front of their javadoc, and make sure all other constructors are defined in terms of the complete constructor.
- Ensure that all statically allocated exceptions have a `.get()` method, and ideally enforce this somehow. (We might want to ensure this with a TCK test. –jjh)

List of Open Issues

Issue 5.4.1	66
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Priority inversion avoidance across schedulers (elb)	225
Overview of static throwables (jjh)	733
Semantics of static throwables (jjh)	733

Appendix A

Deprecated Classes

A.1 Overview

Since modules are new in 2.0 and this version introduces new ways of handling happening, POSIX signals, and raw memory access, there is no need to include the old API in the RTSJ subsets. Therefore the deprecated classes have moved here. Only full implementation of the RTSJ should implement them.

A.2 Semantics

Implementations of these classes are optional. They are only needed for backward compatibility. They should not be included in implementations that do not include all modules.

A.3 Package *javax.realtime*

A.3.1 Interfaces

A.3.1.1 PhysicalMemoryTypeFilter

Description

Implementation or device providers may include classes that implement `PhysicalMemoryTypeFilter` which allow additional characteristics of memory in devices to be specified. Implementations of `PhysicalMemoryTypeFilter` are intended to be used by the `PhysicalMemoryManager`¹, not directly from application code.

Deprecated since RTSJ version as of RTSJ 2.0

A.3.1.1.1 Methods

`contains(long, long)`

Signature

```
public  
boolean contains(long base,  
                 long size)
```

Description

Queries the system about whether the specified range of memory contains any of this type.

Parameters

base The physical address of the beginning of the memory region.
size The size of the memory region.

Throws

`IllegalArgumentException` when **base** or **size** is negative.
`OffsetOutOfBoundsException` when **base** is less than zero.

¹Section [A.3.3.6](#)

`SizeOutOfBoundsException` when `base` plus `size` would be greater than the physical addressing range of the processor.

Returns

true when the specified range contains ANY of this type of memory.

See Section `PhysicalMemoryManager.isRemovable`

find(long, long)

Signature

```
public
long find(long base,
          long size)
```

Description

Search for physical memory of the right type.

Parameters

base The physical address at which to start searching.

size The amount of memory to be found.

Throws

`OffsetOutOfBoundsException` when `base` is less than zero.

`SizeOutOfBoundsException` when `base` plus `size` would be greater than the physical addressing range of the processor.

`IllegalArgumentException` when `base` or `size` is negative.

Returns

The address where memory was found or -1 when it was not found.

getVMAttributes

Signature

```
public
int getVMAttributes()
```

Description

Gets the virtual memory attributes of `this`. The value of this field is as defined for the POSIX `mmap` function's `prot` parameter for the platform. The meaning of the bits is platform-dependent. POSIX defines constants for `PROT_READ`, `PROT_WRITE`, `PROT_EXEC`, and `PROT_NONE`.

Returns

The virtual memory attributes as an integer.

getVMFlags*Signature*

```
public
int getVMFlags()
```

Description

Gets the virtual memory flags of **this**. The value of this field is as defined for the POSIX `mmap` function's `flags` parameter for the platform. The meaning of the bits is platform-dependent. POSIX defines constants for `MAP_SHARED`, `MAP_PRIVATE`, and `MAP_FIXED`.

Returns

The virtual memory flags as an integer.

initialize(long, long, long)*Signature*

```
public
void initialize(long base,
               long vBase,
               long size)
```

Description

When configuration is required for memory to fit the attribute of this object, do the configuration here.

Parameters

base The address of the beginning of the physical memory region.

vBase The address of the beginning of the virtual memory region.

size The size of the memory region.

Throws

IllegalArgumentException when **base** or **size** is negative.

OffsetOutOfBoundsException when **base** is less than zero.

SizeOutOfBoundsException when **base** plus **size** would be greater than the physical addressing range of the processor, or **vBase** plus **size** would exceed the virtual addressing range of the processor.

isPresent(long, long)

Signature

```
public
boolean isPresent(long base,
                  long size)
```

Description

Queries the system about the existence of the specified range of physical memory.

Parameters

base The address of the beginning of the memory region.
size The size of the memory region.

Throws

IllegalArgumentException when the base and size do not fall into this type of memory.
OffsetOutOfBoundsException when **base** is less than zero.
SizeOutOfBoundsException when **base** plus **size** would be greater than the physical addressing range of the processor.

Returns

True when all of the memory is present. False when any of the memory has been removed.

See [Section PhysicalMemoryManager.isRemoved](#)

isRemovable

Signature

```
public
boolean isRemovable()
```

Description

Queries the system about the removability of this memory.

Returns

true when this type of memory is removable.

onInsertion(long, long, AsyncEvent)

Signature

```
public
void onInsertion(long base,
                 long size,
                 AsyncEvent ae)
```

Description

Register the specified [AsyncEvent](#)² to fire when any memory of this type in the range is added to the system.

Parameters

base The starting address in physical memory.

size The size of the memory area.

ae The async event to fire.

Throws

[IllegalArgumentException](#) when **ae** is null, or when the specified range contains no removable memory of this type. [IllegalArgumentException](#) may also be thrown when **size** is less than zero.

[OffsetOutOfBoundsException](#) when **base** is less than zero.

[SizeOutOfBoundsException](#) when **base** plus **size** would be greater than the physical addressing range of the processor.

Available since RTSJ 1.0.1

onRemoval(long, long, AsyncEvent)

Signature

```
public
void onRemoval(long base,
               long size,
               AsyncEvent ae)
```

Description

Register the specified AE to fire when any memory in the range is removed from the system.

²Section [8.4.3.4](#)

Parameters

base The starting address in physical memory.

size The size of the memory area.

ae The async event to register.

Throws

IllegalArgumentException when the specified range contains no removable memory of this type, when **ae** is null, or when **size** is less than zero.

OffsetOutOfBoundsException when **base** is less than zero.

SizeOutOfBoundsException when **base** plus **size** would be greater than the physical addressing range of the processor.

Available since RTSJ 1.0.1

unregisterInsertionEvent(long, long, AsyncEvent)

Signature

```
public
boolean unregisterInsertionEvent(long base,
                                long size,
                                AsyncEvent ae)
```

Description

Unregister the specified insertion event. The event is only unregistered when all three arguments match the arguments used to register the event, except that **ae** of null matches all values of **ae** and will unregister every **ae** that matches the address range.

Note: This method has no effect on handlers registered directly as async event handlers.

Parameters

base The starting address in physical memory associated with **ae**.

size The size of the memory area associated with **ae**.

ae The event to unregister.

Throws

IllegalArgumentException when **size** is less than 0.

OffsetOutOfBoundsException when **base** is less than zero.

SizeOutOfBoundsException when **base** plus **size** would be greater than the physical addressing range of the processor.

Returns

True when at least one event matched the pattern, false when no such event was found.

Available since RTSJ 1.0.1

unregisterRemovalEvent(long, long, AsyncEvent)

Signature

```
public
boolean unregisterRemovalEvent(long base,
                                long size,
                                AsyncEvent ae)
```

Description

Unregister the specified removal event. The async event is only unregistered when all three arguments match the arguments used to register the event, except that **ae** of **null** matches all values of **ae** and will unregister every **ae** that matches the address range. Note: This method has no effect on handlers registered directly as async event handlers.

Parameters

base The starting address in physical memory associated with **ae**.
size The size of the memory area associated with **ae**.
ae The async event to unregister.

Throws

IllegalArgumentException when **size** is less than 0.
OffsetOutOfBoundsException when **base** is less than zero.
SizeOutOfBoundsException when **base** plus **size** would be greater than the physical addressing range of the processor.

Returns

True when at least one event matched the pattern, false when no such event was found.

Available since RTSJ 1.0.1

vFind(long, long)

Signature

```
public
long vFind(long base,
           long size)
```

Description

Search for virtual memory of the right type. This is important for systems where attributes are associated with particular ranges of virtual memory.

Parameters

base The address at which to start searching.
size The amount of memory to be found.

Throws

[OffsetOutOfBoundsException](#) when **base** is less than zero.
[SizeOutOfBoundsException](#) when **base** plus **size** would be greater than the physical addressing range of the processor.
[IllegalArgumentException](#) when **base** or **size** is negative. [IllegalArgumentException](#) may also be when **base** is an invalid virtual address.

Returns

The address where memory was found or -1 when it was not found.

A.3.2 Exceptions

A.3.2.1 DuplicateFilterException

Inheritance

```
java.lang.Object
  java.lang.Throwable
    java.lang.Exception
      javax.realtime.DuplicateFilterException
```

Description

[PhysicalMemoryManager](#)³ can only accommodate one filter object for each type of memory. It throws this exception when an attempt is made to register more than one filter for a type of memory.

Deprecated since RTSJ version since RTSJ 2.0

³Section [A.3.3.6](#)

A.3.2.1.1 Constructors

DuplicateFilterException

Signature

```
public  
DuplicateFilterException()
```

Description

A constructor for DuplicateFilterException.

DuplicateFilterException(String)

Signature

```
public  
DuplicateFilterException(String description)
```

Description

A descriptive constructor for DuplicateFilterException.

Parameters

`description` Description of the error.

A.3.2.2 UnknownHappeningException

Inheritance

```
java.lang.Object  
  java.lang.Throwable  
    java.lang.Exception  
      java.lang.RuntimeException  
        javax.realtime.UnknownHappeningException
```

Description

This exception is used to indicate a situation where an instance of [AsyncEvent](#)⁴ attempts to bind to a happening that does not exist.

⁴Section [8.4.3.4](#)

Deprecated since RTSJ version since RTSJ 2.0

A.3.2.2.1 Constructors

UnknownHappeningException

Signature

```
public  
UnknownHappeningException()
```

Description

A constructor for UnknownHappeningException.

UnknownHappeningException(String)

Signature

```
public  
UnknownHappeningException(String description)
```

Description

A descriptive constructor for UnknownHappeningException.

Parameters

`description` Description of the error.

A.3.3 Classes

A.3.3.1 ImmortalPhysicalMemory

Inheritance

```
java.lang.Object  
  javax.realtime.MemoryArea  
    javax.realtime.ImmortalPhysicalMemory
```

Description

An instance of `ImmortalPhysicalMemory` allows objects to be allocated from a range of physical memory with particular attributes, determined by their memory type. This memory area has the same restrictive set of assignment rules as `ImmortalMemory`⁵ memory areas, and may be used in any execution context where `ImmortalMemory` is appropriate.

No provision is made for sharing object in `ImmortalPhysicalMemory` with entities outside the JVM that creates them, and, while the memory backing an instance of `ImmortalPhysicalMemory` could be shared by multiple JVMs, the class does not support such sharing.

Methods from `ImmortalPhysicalMemory` should be overridden only by methods that use `super`.

Deprecated since RTSJ version since RTSJ 2.0

A.3.3.1.1 Constructors

`ImmortalPhysicalMemory(Object, long)`

Signature

```
public  
    ImmortalPhysicalMemory(Object type,  
                           long size)
```

Description

Create an instance with the given parameters.

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

size The size of the area in bytes.

Throws

⁵Section 11.4.2.2

SecurityException when the application doesn't have permissions to access physical memory or the given type of memory.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryTypeFilter**⁶ has been registered with the **PhysicalMemoryManager**⁷.

MemoryTypeConflictException when **type** specifies incompatible memory attributes.

IllegalArgumentException when **size** is less than zero.

OutOfMemoryError when there is insufficient memory for the **ImmortalPhysicalMemory** object or for the backing memory.

SizeOutOfBoundsException when the **size** extends into an invalid range of memory.

ImmortalPhysicalMemory(Object, long, long)

Signature

```
public
ImmortalPhysicalMemory(Object type,
                        long base,
                        long size)
```

Description

Create an instance with the given parameters.

Parameters

type An instance of **Object** or an array of objects representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute **type** may be an array of objects. When **type** is **null** or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (**==**), not by value (**equals**).

base The physical memory address of the area.

size The size of the area in bytes.

Throws

SecurityException when the application doesn't have permissions to access physical memory or the given range of memory.

⁶Section [A.3.1.1](#)

⁷Section [A.3.3.6](#)

OffsetOutOfBoundsException when the **base** address is invalid.

SizeOutOfBoundsException when the **size** extends into an invalid range of memory.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryTypeFilter**⁸ has been registered with the **PhysicalMemoryManager**⁹.

MemoryTypeConflictException when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

IllegalArgumentException when **size** is less than zero. **IllegalArgumentException** may also be when **base** plus **size** would be greater than the maximum physical address supported by the processor.

MemoryInUseException when the specified memory is already in use.

OutOfMemoryError when there is insufficient memory for the **ImmortalPhysicalMemory** object or for the backing memory.

ImmortalPhysicalMemory(Object, SizeEstimator)

Signature

```
public
ImmortalPhysicalMemory(Object type,
                        SizeEstimator size)
```

Description

Create an instance with the given parameters.

Parameters

type An instance of **Object** or an array of objects representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute **type** may be an array of objects. When **type** is **null** or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (**==**), not by value (**equals**).

size A size estimator for this area.

Throws

⁸Section A.3.1.1

⁹Section A.3.3.6

SecurityException when the application doesn't have permissions to access physical memory or the given type of memory.

SizeOutOfBoundsException when the size estimate from **size** extends into an invalid range of memory.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryTypeFilter**¹⁰ has been registered with the **PhysicalMemoryManager**¹¹.

MemoryTypeConflictException when **type** specifies incompatible memory attributes.

IllegalArgumentException when **size** is null, or **size.getEstimate()** is negative.

OutOfMemoryError when there is insufficient memory for the **ImmortalPhysicalMemory** object or for the backing memory.

ImmortalPhysicalMemory(Object, long, SizeEstimator)

Signature

```
public
ImmortalPhysicalMemory(Object type,
                        long base,
                        SizeEstimator size)
```

Description

Create an instance with the given parameters.

Parameters

type An instance of **Object** or an array of objects representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute **type** may be an array of objects. When **type** is null or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (**==**), not by value (**equals**).

base The physical memory address of the area.

size A size estimator for this memory area.

Throws

¹⁰Section [A.3.1.1](#)

¹¹Section [A.3.3.6](#)

SecurityException when the application doesn't have permissions to access physical memory or the given type of memory.

OffsetOutOfBoundsException when the **base** address is invalid.

SizeOutOfBoundsException when the size estimate from **size** extends into an invalid range of memory.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryTypeFilter**¹² has been registered with the **PhysicalMemoryManager**¹³.

MemoryTypeConflictException when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

IllegalArgumentException when **size** is null, or **size.getEstimate()** is negative. **IllegalArgumentException** may also be when **base** plus the size indicated by **size** would be greater than the maximum physical address supported by the processor.

MemoryInUseException when the specified memory is already in use.

OutOfMemoryError when there is insufficient memory for the **ImmortalPhysicalMemory** object or for the backing memory.

ImmortalPhysicalMemory(Object, long, Runnable)

Signature

```
public
ImmortalPhysicalMemory(Object type,
                        long size,
                        Runnable logic)
```

Description

Create an instance with the given parameters.

Parameters

type An instance of **Object** or an array of objects representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute **type** may be an array of objects. When **type** is null or a reference to an array

¹²Section A.3.1.1

¹³Section A.3.3.6

with no entries, any type of memory is acceptable. Note that `type` values are compared by reference (`==`), not by value (`equals`).

size The size of the area in bytes.

logic The `run()` method of this object will be called whenever `MemoryArea.enter()`¹⁴ is called. When `logic` is `null`, `logic` must be supplied when the memory area is entered.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given type of memory.

`SizeOutOfBoundsException` when `size` extends into an invalid range of memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`¹⁵ has been registered with the `PhysicalMemoryManager`¹⁶.

`IllegalArgumentException` when `size` is negative.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when `type` specifies incompatible memory attributes.

`OutOfMemoryError` when there is insufficient memory for the `ImmortalPhysicalMemory` object or for the backing memory.

`IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

ImmortalPhysicalMemory(Object, long, long, Runnable)

Signature

```
public
    ImmortalPhysicalMemory(Object type,
                           long base,
                           long size,
                           Runnable logic)
```

Description

Create an instance with the given parameters.

¹⁴Section 11.4.2.3.2

¹⁵Section A.3.1.1

¹⁶Section A.3.3.6

Parameters

type An instance of `Object` or an array of objects representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the area.

size The size of the area in bytes.

logic The `run()` method of this object will be called whenever `MemoryArea.enter()`¹⁷ is called. When **logic** is `null`, **logic** must be supplied when the memory area is entered.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given type of memory.

`OffsetOutOfBoundsException` when the **base** address is invalid.

`SizeOutOfBoundsException` when **size** extends into an invalid range of memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`¹⁸ has been registered with the `PhysicalMemoryManager`¹⁹.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

`IllegalArgumentException` when **size** is negative. `IllegalArgumentException` may also be when **base** plus **size** would be greater than the maximum physical address supported by the processor.

`MemoryInUseException` when the specified memory is already in use.

`OutOfMemoryError` when there is insufficient memory for the `ImmortalPhysicalMemory` object or for the backing memory.

`IllegalAssignmentError` when storing **logic** in **this** would violate the assignment rules.

ImmortalPhysicalMemory(Object, SizeEstimator, Runnable)

¹⁷Section 11.4.2.3.2

¹⁸Section A.3.1.1

¹⁹Section A.3.3.6

Signature

```
public
ImmortalPhysicalMemory(Object type,
                        SizeEstimator size,
                        Runnable logic)
```

Description

Create an instance with the given parameters.

Parameters

type An instance of `Object` or an array of objects representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

size A size estimator for this area.

logic The `run()` method of this object will be called whenever `MemoryArea.enter()`²⁰ is called. When **logic** is `null`, **logic** must be supplied when the memory area is entered.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given type of memory.

`SizeOutOfBoundsException` when the **size** extends into an invalid range of memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`²¹ has been registered with the `PhysicalMemoryManager`²².

`IllegalArgumentException` when **size** is `null`, or `size.getEstimate()` is negative.

`MemoryTypeConflictException` when **type** specifies incompatible memory attributes.

`OutOfMemoryError` when there is insufficient memory for the `ImmortalPhysicalMemory` object or for the backing memory.

²⁰Section 11.4.2.3.2

²¹Section A.3.1.1

²²Section A.3.3.6

`IllegalAssignmentError` when storing logic in this would violate the assignment rules.

ImmutablePhysicalMemory(Object, long, SizeEstimator, Runnable)

Signature

```
public
ImmutablePhysicalMemory(Object type,
                        long base,
                        SizeEstimator size,
                        Runnable logic)
```

Description

Create an instance with the given parameters.

Parameters

type An instance of `Object` or an array of objects representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the area.

size A size estimator for this memory area.

logic The `run()` method of this object will be called whenever `MemoryArea.enter()`²³ is called. When **logic** is `null`, **logic** must be supplied when the memory area is entered.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given type of memory.

`OffsetOutOfBoundsException` when the **base** address is invalid.

`SizeOutOfBoundsException` when the size estimate from **size** extends into an invalid range of memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`²⁴

²³Section 11.4.2.3.2

²⁴Section A.3.1.1

has been registered with the `PhysicalMemoryManager`²⁵.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when `type` specifies incompatible memory attributes.

`IllegalArgumentException` when `size` is `null`, or `size.getEstimate()` is negative. `IllegalArgumentException` may also be when `base` plus the size indicated by `size` would be greater than the maximum physical address supported by the processor.

`MemoryInUseException` when the specified memory is already in use.

`OutOfMemoryError` when there is insufficient memory for the `ImmortalPhysicalMemory` object or for the backing memory.

`IllegalAssignmentError` when storing logic in `this` would violate the assignment rules.

A.3.3.2 LTMemory

Inheritance

```
java.lang.Object
  javax.realtime.MemoryArea
    javax.realtime.ScopedMemory
      javax.realtime.LTMemory
```

Description

`LTMemory` represents a memory area guaranteed by the system to have linear time allocation when memory consumption from the memory area is less than the memory area's *initial* size. Execution time for allocation is allowed to vary when memory consumption is between the initial size and the maximum size for the area. Furthermore, the underlying system is not required to guarantee that memory between initial and maximum will always be available.

The memory area described by a `LTMemory` instance does not exist in the Java heap, and is not subject to garbage collection. Thus, it is safe to use a `LTMemory` object as the initial memory area associated with a `NoHeapRealtimeThread`²⁶, or to enter the memory area using the `ScopedMemory.enter`²⁷ method within a `NoHeapRealtimeThread`²⁸.

²⁵Section A.3.3.6

²⁶Section A.3.3.4

²⁷Section A.3.3.11.2

²⁸Section A.3.3.4

Enough memory must be committed by the completion of the constructor to satisfy the initial memory requirement. (Committed means that this memory must always be available for allocation). The initial memory allocation must behave, with respect to successful allocation, as if it were contiguous; i.e., a correct implementation must guarantee that any sequence of object allocations that could ever succeed without exceeding a specified initial memory size will always succeed without exceeding that initial memory size and succeed for any instance of `LTMemory` with that initial memory size. (Note: to ensure that all requested memory is available set initial and maximum to the same value) Methods from `LTMemory` should be overridden only by methods that use `super`.

[See Section MemoryArea](#)

[See Section ScopedMemory](#)

[See Section RealtimeThread](#)

[See Section NoHeapRealtimeThread](#)

Deprecated since RTSJ version since RTSJ 2.0

A.3.3.2.1 Constructors

LTMemory(long, long)

Signature

```
public
LTMemory(long initial,
         long maximum)
```

Description

Create an `LTMemory` of the given size.

Parameters

initial The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

maximum The size in bytes of the memory to allocate for this area.

Throws

`IllegalArgumentException` when `initial` is greater than `maximum`, or when `initial` or `maximum` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

`LTMemory(long, long, Runnable)`

Signature

```
public
LTMemory(long initial,
         long maximum,
         Runnable logic)
```

Description

Create an `LTMemory` of the given size.

Parameters

`initial` The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

`maximum` The size in bytes of the memory to allocate for this area.

`logic` The `run()` of the given `Runnable` will be executed using `this` as its initial memory area. When `logic` is `null`, this constructor is equivalent to `LTMemory(long initial, long maximum)`²⁹.

Throws

`IllegalArgumentException` when `initial` is greater than `maximum`, or when `initial` or `maximum` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

`IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

`LTMemory(SizeEstimator, SizeEstimator)`

Signature

²⁹Section [A.3.3.2.1](#)

```
public
LTMemory(SizeEstimator initial,
         SizeEstimator maximum)
```

Description

Create an LTMemory of the given size.

Parameters

initial An instance of [SizeEstimator](#)³⁰ used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

maximum An instance of [SizeEstimator](#)³¹ used to give an estimate for the maximum bytes to allocate for this area.

Throws

IllegalArgumentException when **initial** is null, **maximum** is null, **initial.getEstimate()** is greater than **maximum.getEstimate()**, or when **initial.getEstimate()** is less than zero.

OutOfMemoryError when there is insufficient memory for the LTMemory object or for the backing memory.

LTMemory(SizeEstimator, SizeEstimator, Runnable)

Signature

```
public
LTMemory(SizeEstimator initial,
         SizeEstimator maximum,
         Runnable logic)
```

Description

Create an LTMemory of the given size.

Parameters

initial An instance of [SizeEstimator](#)³² used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

maximum An instance of [SizeEstimator](#)³³ used to give an estimate for the maximum bytes to allocate for this area.

³⁰Section [11.4.2.5](#)

³¹Section [11.4.2.5](#)

³²Section [11.4.2.5](#)

³³Section [11.4.2.5](#)

`logic` The `run()` of the given `Runnable` will be executed using `this` as its initial memory area. When `logic` is `null`, this constructor is equivalent to `LTMemory(SizeEstimator initial, SizeEstimator maximum)`³⁴.

Throws

`IllegalArgumentException` when `initial` is `null`, `maximum` is `null`, `initial.getEstimate()` is greater than `maximum.getEstimate()`, or when `initial.getEstimate()` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

`IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

LTMemory(long)

Signature

```
public
LTMemory(long size)
```

Description

Create an `LTMemory` of the given size. This constructor is equivalent to `LTMemory(size, size)`

Available since RTSJ 1.0.1

Parameters

`size` The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

Throws

`IllegalArgumentException` when `size` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

LTMemory(long, Runnable)

Signature

³⁴Section [A.3.3.2.1](#)

```
public
LTMemory(long size,
          Runnable logic)
```

Description

Create an LTMemory of the given size. This constructor is equivalent to `LTMemory(size, size, logic)`.

Available since RTSJ 1.0.1

Parameters

size The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

logic The `run()` of the given `Runnable` will be executed using `this` as its initial memory area. When `logic` is `null`, this constructor is equivalent to `LTMemory(long size)`³⁵.

Throws

`IllegalArgumentException` when `size` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the LTMemory object or for the backing memory.

`IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

LTMemory(SizeEstimator)

Signature

```
public
LTMemory(SizeEstimator size)
```

Description

Create an LTMemory of the given size. This constructor is equivalent to `LTMemory(size, size)`.

Available since RTSJ 1.0.1

Parameters

³⁵Section [A.3.3.2.1](#)

size An instance of `SizeEstimator`³⁶ used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

Throws

`IllegalArgumentException` when `size` is null, or `size.getEstimate()` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

LTMemory(SizeEstimator, Runnable)

Signature

```
public
LTMemory(SizeEstimator size,
         Runnable logic)
```

Description

Create an `LTMemory` of the given size.

Available since RTSJ 1.0.1

Parameters

size An instance of `SizeEstimator`³⁷ used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

logic The `run()` of the given `Runnable` will be executed using `this` as its initial memory area. When `logic` is null, this constructor is equivalent to `LTMemory(SizeEstimator initial)`³⁸.

Throws

`IllegalArgumentException` when `size` is null, or `size.getEstimate()` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `LTMemory` object or for the backing memory.

`IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

³⁶Section 11.4.2.5

³⁷Section 11.4.2.5

³⁸Section A.3.3.2.1

A.3.3.2.2 Methods

toString

Signature

```
public  
java.lang.String toString()
```

Description

Create a string representation of this object. The string is of the form
(LMemory) Scoped memory # num
where num uniquely identifies the LMemory area.

Returns

A string representing the value of `this`.

A.3.3.3 LTPhysicalMemory

Inheritance

```
java.lang.Object  
  javax.realtime.MemoryArea  
    javax.realtime.memory.ScopedMemory  
      javax.realtime.LTPhysicalMemory
```

Description

An instance of `LTPhysicalMemory` allows objects to be allocated from a range of physical memory with particular attributes, determined by their memory type. This memory area has the same semantics as `ScopedMemory`³⁹ memory areas, and the same performance restrictions as `LMemory`⁴⁰.

No provision is made for sharing object in `LTPhysicalMemory` with entities outside the JVM that creates them, and, while the memory backing an instance of `LTPhysicalMemory` could be shared by multiple JVMs, the class does not support such sharing.

Methods from `LTPhysicalMemory` should be overridden only by methods that use `super`.

³⁹Section [A.3.3.11](#)

⁴⁰Section [A.3.3.2](#)

Deprecated since RTSJ version since RTSJ 2.0

A.3.3.3.1 Constructors

LTPhysicalMemory(Object, long)

Signature

```
public
LTPhysicalMemory(Object type,
                  long size)
```

Description

Create an instance of `LTPhysicalMemory` with the given parameters.

See [Section PhysicalMemoryManager](#)

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

size The size of the area in bytes.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given type of memory.

`IllegalArgumentException` when **size** is less than zero.

`SizeOutOfBoundsException` when the implementation detects **size** extends beyond physically addressable memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`⁴¹ has been registered with the `PhysicalMemoryManager`⁴².

⁴¹Section [A.3.1.1](#)

⁴²Section [A.3.3.6](#)

MemoryTypeConflictException when **type** specifies incompatible memory attributes.

LTPhysicalMemory(Object, long, long)

Signature

```
public
LTPhysicalMemory(Object type,
                  long base,
                  long size)
```

Description

Create an instance of **LTPhysicalMemory** with the given parameters.

See Section [PhysicalMemoryManager](#)

Parameters

type An instance of **Object** representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is **null** or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (**==**), not by value (**equals**).

base The physical memory address of the area.

size The size of the area in bytes.

Throws

SecurityException when the application doesn't have permissions to access physical memory or the given type of memory.

SizeOutOfBoundsException when the size is less than zero, or the implementation detects that **base** plus **size** extends beyond physically addressable memory.

OffsetOutOfBoundsException when the address is invalid.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryTypeFilter**⁴³ has been registered with the **PhysicalMemoryManager**⁴⁴.

⁴³Section [A.3.1.1](#)

⁴⁴Section [A.3.3.6](#)

MemoryTypeConflictException when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

IllegalArgumentException when **size** is less than zero.

MemoryInUseException when the specified memory is already in use.

LTPhysicalMemory(Object, SizeEstimator)

Signature

```
public
LTPhysicalMemory(Object type,
                  SizeEstimator size)
```

Description

Create an instance of **LTPhysicalMemory** with the given parameters.

See Section [PhysicalMemoryManager](#)

Parameters

type An instance of **Object** representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is **null** or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (**==**), not by value (**equals**).

size A size estimator for this area.

Throws

SecurityException when the application doesn't have permissions to access physical memory or the given type of memory.

SizeOutOfBoundsException when the implementation detects that **size** extends beyond physically addressable memory.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryTypeFilter**⁴⁵ has been registered with the **PhysicalMemoryManager**⁴⁶.

MemoryTypeConflictException when **type** specifies incompatible memory attributes.

⁴⁵Section [A.3.1.1](#)

⁴⁶Section [A.3.3.6](#)

`IllegalArgumentException` when `size` is null, or `size.getEstimate()` is negative.

LTPhysicalMemory(Object, long, SizeEstimator)

Signature

```
public
LTPhysicalMemory(Object type,
                  long base,
                  SizeEstimator size)
```

Description

Create an instance of `LTPhysicalMemory` with the given parameters.

See [Section PhysicalMemoryManager](#)

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the area.

size A size estimator for this memory area.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given type of memory.

`SizeOutOfBoundsException` when the implementation detects that **base** plus the size estimate extends beyond physically addressable memory.

`OffsetOutOfBoundsException` when the address is invalid.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`⁴⁷ has been registered with the `PhysicalMemoryManager`⁴⁸.

⁴⁷Section [A.3.1.1](#)

⁴⁸Section [A.3.3.6](#)

MemoryTypeConflictException when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

MemoryInUseException when the specified memory is already in use.

IllegalArgumentException when **size** is null, or **size.getEstimate()** is negative.

LTPhysicalMemory(Object, long, Runnable)

Signature

```
public
LTPhysicalMemory(Object type,
                  long size,
                  Runnable logic)
```

Description

Create an instance of **LTPhysicalMemory** with the given parameters.

See Section [PhysicalMemoryManager](#)

Parameters

type An instance of **Object** representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is null or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (**==**), not by value (**equals**).

size The size of the area in bytes.

logic The **run()** method of this object will be called whenever **MemoryArea.enter()**⁴⁹ is called. When **logic** is null, **logic** must be supplied when the memory area is entered.

Throws

SecurityException when the application doesn't have permissions to access physical memory or the given type of memory.

IllegalArgumentException when **size** is less than zero.

SizeOutOfBoundsException when the implementation detects that **size** extends beyond physically addressable memory.

⁴⁹Section [11.4.2.3.2](#)

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryTypeFilter**⁵⁰ has been registered with the **PhysicalMemoryManager**⁵¹.

MemoryTypeConflictException when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

IllegalAssignmentError when storing logic in this would violate the assignment rules.

LTPhysicalMemory(Object, long, long, Runnable)

Signature

```
public
LTPhysicalMemory(Object type,
                  long base,
                  long size,
                  Runnable logic)
```

Description

Create an instance of **LTPhysicalMemory** with the given parameters.

See Section **PhysicalMemoryManager**

Parameters

type An instance of **Object** representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is **null** or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (**==**), not by value (**equals**).

base The physical memory address of the area.

size The size of the area in bytes.

logic The **run()** method of this object will be called whenever **MemoryArea.enter()**⁵² is called. When **logic** is **null**, **logic** must be supplied when the memory area is entered.

⁵⁰Section **A.3.1.1**

⁵¹Section **A.3.3.6**

⁵²Section **11.4.2.3.2**

Throws

SizeOutOfBoundsException when the implementation detects that **base** plus **size** extends beyond physically addressable memory.

SecurityException when the application doesn't have permissions to access physical memory or the given type of memory.

IllegalArgumentException when **size** is less than zero.

OffsetOutOfBoundsException when the address is invalid.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryTypeFilter**⁵³ has been registered with the **PhysicalMemoryManager**⁵⁴.

MemoryTypeConflictException when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

MemoryInUseException when the specified memory is already in use.

IllegalAssignmentError when storing logic in **this** would violate the assignment rules.

LTPhysicalMemory(Object, SizeEstimator, Runnable)

Signature

```
public
LTPhysicalMemory(Object type,
                  SizeEstimator size,
                  Runnable logic)
```

Description

Create an instance of **LTPhysicalMemory** with the given parameters.

See Section [PhysicalMemoryManager](#)

Parameters

type An instance of **Object** representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is **null** or a reference to an array with no entries, any type

⁵³Section [A.3.1.1](#)

⁵⁴Section [A.3.3.6](#)

of memory is acceptable. Note that `type` values are compared by reference (`==`), not by value (`equals`).

size A size estimator for this area.

logic The `run()` method of this object will be called whenever `MemoryArea.enter()`⁵⁵ is called. When `logic` is `null`, `logic` must be supplied when the memory area is entered.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given type of memory.

`SizeOutOfBoundsException` when the implementation detects that `base` plus the size estimate extends beyond physically addressable memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`⁵⁶ has been registered with the `PhysicalMemoryManager`⁵⁷.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the request type, or when `type` specifies attributes with a conflict.

`IllegalArgumentException` when `size` is `null`, or `size.getEstimate()` is negative.

`IllegalAssignmentError` when storing `logic` in this would violate the assignment rules.

LTPhysicalMemory(Object, long, SizeEstimator, Runnable)

Signature

```
public
LTPhysicalMemory(Object type,
                  long base,
                  SizeEstimator size,
                  Runnable logic)
```

Description

Create an instance of `LTPhysicalMemory` with the given parameters.

⁵⁵Section 11.4.2.3.2

⁵⁶Section A.3.1.1

⁵⁷Section A.3.3.6

See Section [PhysicalMemoryManager](#)

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the area.

size A size estimator for this memory area.

logic The `run()` method of this object will be called whenever [MemoryArea.enter\(\)](#)⁵⁸ is called. When **logic** is `null`, **logic** must be supplied when the memory area is entered.

Throws

[SecurityException](#) when the application doesn't have permissions to access physical memory or the given type of memory.

[SizeOutOfBoundsException](#) when the implementation detects that **base** plus the size estimate extends beyond physically addressable memory.

[OffsetOutOfBoundsException](#) when the address is invalid.

[UnsupportedPhysicalMemoryException](#) when the underlying hardware does not support the given type, or when no matching [PhysicalMemoryTypeFilter](#)⁵⁹ has been registered with the [PhysicalMemoryManager](#)⁶⁰.

[MemoryTypeConflictException](#) when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

[MemoryInUseException](#) when the specified memory is already in use.

[IllegalArgumentException](#) when **size** is `null`, or `size.getEstimate()` is negative.

[IllegalAssignmentError](#) when storing **logic** in **this** would violate the assignment rules.

A.3.3.3.2 Methods

⁵⁸Section [11.4.2.3.2](#)

⁵⁹Section [A.3.1.1](#)

⁶⁰Section [A.3.3.6](#)

toString

Signature

```
public  
java.lang.String toString()
```

Description

Creates a string describing this object. The string is of the form (LTPhysicalMemory) Scoped memory # num where num is a number that uniquely identifies this LTPhysicalMemory memory area, representing the value of `this`.

Returns

A string representing the value of `this`.

A.3.3.4 NoHeapRealtimeThread

Inheritance

```
java.lang.Object  
  java.lang.Thread  
    javax.realtime.RealtimeThread  
      javax.realtime.NoHeapRealtimeThread
```

Description

A `NoHeapRealtimeThread` is a specialized form of `RealtimeThread`⁶¹. Because an instance of `NoHeapRealtimeThread` may immediately preempt any implemented garbage collector, logic contained in its `run()` is never allowed to allocate or reference any object allocated in the heap. At the byte-code level, it is illegal for a reference to an object allocated in heap to appear on a `this` realtime thread's operand stack.

Thus, it is always safe for a `NoHeapRealtimeThread` to interrupt the garbage collector at any time, without waiting for the end of the garbage collection cycle or a defined preemption point. Due to these restrictions, a `NoHeapRealtimeThread` object must be placed in a memory area such that thread logic may unexceptionally access instance variables and such that Java methods on `Thread` (e.g., `enumerate` and `join`) complete normally except where execution would cause access violations. The constructors of `NoHeapRealtimeThread` require a reference to `ScopedMemory`⁶² or `ImmortalMemory`⁶³.

⁶¹Section 5.4.2.2

⁶²Section A.3.3.11

⁶³Section 11.4.2.2

When the thread is started, all execution occurs in the scope of the given memory area. Thus, all memory allocation performed with the *new* operator is taken from this given area.

Deprecated since RTSJ version since RTSJ 2.0

A.3.3.4.1 Constructors

NoHeapRealtimeThread(SchedulingParameters, ReleaseParameters, MemoryParameters, MemoryArea, ProcessingGroupParameters, Runnable)

Signature

```
public
NoHeapRealtimeThread(SchedulingParameters scheduling,
                      ReleaseParameters release,
                      MemoryParameters memory,
                      MemoryArea area,
                      ProcessingGroupParameters group,
                      Runnable logic)
```

Description

Create a realtime thread with the given characteristics and a Runnable. The thread group of the new thread is (effectively) null. The newly-created realtime thread which may not use the heap is associated with the scheduler in effect during execution of the constructor.

Parameters

scheduling the SchedulingParameters associated with this (and possibly other instances of Schedulable). When scheduling is null, the default is a copy of the creator's scheduling parameters created in the same memory area as the new NoHeapRealtimeThread.

release the ReleaseParameters associated with this (and possibly other instances of Schedulable). When release is null the it defaults to the a copy of the creator's release parameters created in the same memory area as the new NoHeapRealtimeThread.

memory the MemoryParameters associated with this (and possibly other instances of Schedulable). When memory is null, the new NoHeapRealtimeThread will have a null value for its memory parameters, and the amount or rate of memory allocation is unrestricted.

area the MemoryArea associated with this. When area is null, an IllegalArgumentException is thrown.

group the ProcessingGroupParameters associated with this (and possibly other instances of Schedulable). When null, the new NoHeapRealtimeThread will not be associated with any processing group.

logic the Runnable object whose run() method will serve as the logic for the new NoHeapRealtimeThread. When logic is null, the run() method in the new object will serve as its logic.

Throws

IllegalArgumentException when the parameters are not compatible with the associated scheduler, when area is null, when area is heap memory, when area, scheduling release, memory or group is allocated in heap memory. when this is in heap memory, or when logic is in heap memory.

IllegalAssignmentError when the new NoHeapRealtimeThread instance cannot hold references to non-null values of the scheduling release, memory and group, or when those parameters cannot hold a reference to the new NoHeapRealtimeThread.

NoHeapRealtimeThread(SchedulingParameters, ReleaseParameters, MemoryArea)

Signature

```
public
NoHeapRealtimeThread(SchedulingParameters scheduling,
                      ReleaseParameters release,
                      MemoryArea area)
```

Description

Create a realtime thread which may not use the heap with the given **SchedulingParameters**⁶⁴, **ReleaseParameters**⁶⁵ and **MemoryArea**⁶⁶, and default values

⁶⁴Section 6.4.3.14

⁶⁵Section 6.4.3.10

⁶⁶Section 11.4.2.3

for all other parameters. This constructor is equivalent to `NoHeapRealtimeThread(scheduling, release, null, area, null, null, null)`.

NoHeapRealtimeThread(SchedulingParameters, MemoryArea)

Signature

```
public  
NoHeapRealtimeThread(SchedulingParameters scheduling,  
                      MemoryArea area)
```

Description

Create a realtime thread with the given [SchedulingParameters](#)⁶⁷ and [MemoryArea](#)⁶⁸ and default values for all other parameters.

This constructor is equivalent to `NoHeapRealtimeThread(scheduling, null, null, area, null, null, null)`.

A.3.3.4.2 Methods

start

Signature

```
public  
void start()
```

Description

Set up the realtime thread's environment and start it. The set up might include delaying it until the assigned start time and initializing the thread's scope stack. (See [ScopedMemory](#)⁶⁹.)

See [Section RealtimeThread.start\(\)](#)

⁶⁷Section 6.4.3.14

⁶⁸Section 11.4.2.3

⁶⁹Section A.3.3.11

startPeriodic(PhasingPolicy)

Signature

```
public  
void startPeriodic(PhasingPolicy phasingPolicy)  
throws LateStartException
```

Description

Start the thread with the specified phasing policy.

See Section [RealtimeThread.startPeriodic\(PhasingPolicy\)](#)

Available since RTSJ 2.0

A.3.3.5 POSIXSignalHandler

Inheritance

```
java.lang.Object  
  javax.realtime.POSIXSignalHandler
```

Description

This class enables the use of an AsyncEventHandler to react on the occurrence of POSIX signals.

On systems that support POSIX signals fully, the 13 signals required by POSIX will be supported. Any further signals defined in this class may be supported by the system. On systems that do not support POSIX signals, even the 13 standard signals may never be fired.

Deprecated since RTSJ version since RTSJ 2.0

A.3.3.5.1 Fields

SIGHUP

```
public static final SIGHUP
```

Description

Hangup (POSIX).

SIGINT

```
public static final SIGINT
```

Description

interrupt (ANSI)

SIGQUIT

```
public static final SIGQUIT
```

Description

quit (POSIX)

SIGILL

```
public static final SIGILL
```

Description

illegal instruction (ANSI)

SIGTRAP

```
public static final SIGTRAP
```

Description

trace trap (POSIX), optional signal.

SIGABRT

```
public static final SIGABRT
```

Description

Abort (ANSI).

SIGBUS

```
public static final SIGBUS
```

Description

BUS error (4.2 BSD), optional signal.

SIGFPE

```
public static final SIGFPE
```

Description

floating point exception

SIGKILL

```
public static final SIGKILL
```

Description

Kill, unblockable (POSIX).

SIGUSR1

```
public static final SIGUSR1
```

Description

User-defined signal 1 (POSIX).

SIGSEGV

```
public static final SIGSEGV
```

Description

Segmentation violation (ANSI).

SIGUSR2

```
public static final SIGUSR2
```

Description

User-defined signal 2 (POSIX).

SIGPIPE

```
public static final SIGPIPE
```

Description

Broken pipe (POSIX).

SIGALRM

```
public static final SIGALRM
```

Description

Alarm clock (POSIX).

SIGTERM

```
public static final SIGTERM
```

Description

Termination (ANSI).

SIGCHLD

```
public static final SIGCHLD
```

Description

Child status has changed (POSIX).

SIGCONT

```
public static final SIGCONT
```

Description

Continue (POSIX), optional signal.

SIGSTOP

```
public static final SIGSTOP
```

Description

Stop, unblockable (POSIX), optional signal.

SIGTSTP

```
public static final Sigtstp
```

Description

Keyboard stop (POSIX), optional signal.

SIGTTIN

```
public static final Sigtstin
```

Description

Background read from tty (POSIX), optional signal.

SIGTTOU

```
public static final Sigtttou
```

Description

Background write to tty (POSIX), optional signal.

SIGURG

```
public static final Sigurg
```

Description

Urgent condition on socket (4.2 BSD).

Deprecated since RTSJ version as of RTSJ 1.0.1 not part of POSIX 9945-1-1996 standard

SIGXCPU

```
public static final Sigxcpu
```

Description

CPU limit exceeded (4.2 BSD).

Deprecated since RTSJ version as of RTSJ 1.0.1 not part of POSIX 9945-1-1996 standard

SIGXFSZ

```
public static final SIGXFSZ
```

Description

File size limit exceeded (4.2 BSD).

Deprecated since RTSJ version as of RTSJ 1.0.1 not part of POSIX 9945-1-1996 standard

SIGVTALRM

```
public static final SIGVTALRM
```

Description

Virtual alarm clock (4.2 BSD).

Deprecated since RTSJ version as of RTSJ 1.0.1 not part of POSIX 9945-1-1996 standard

SIGPROF

```
public static final SIGPROF
```

Description

Profiling alarm clock (4.2 BSD).

Deprecated since RTSJ version as of RTSJ 1.0.1 not part of POSIX 9945-1-1996 standard

SIGWINCH

```
public static final SIGWINCH
```

Description

Window size change (4.3 BSD, Sun).

Deprecated since RTSJ version as of RTSJ 1.0.1 not part of POSIX 9945-1-1996 standard

SIGIO

```
public static final SIGIO
```

Description

I/O now possible (4.2 BSD).

Deprecated since RTSJ version as of RTSJ 1.0.1 not part of POSIX 9945-1-1996 standard

SIGPWR

```
public static final SIGPWR
```

Description

Power failure restart (System V).

Deprecated since RTSJ version as of RTSJ 1.0.1 not part of POSIX 9945-1-1996 standard

SIGSYS

```
public static final SIGSYS
```

Description

Bad system call, optional signal.

SIGIOT

```
public static final SIGIOT
```

Description

IOT instruction (4.2 BSD), optional signal.

SIGPOLL

```
public static final SIGPOLL
```

Description

Pollable event occurred (System V).

Deprecated since RTSJ version as of RTSJ 1.0.1 not part of POSIX 9945-1-1996 standard

SIGCLD

```
public static final SIGCLD
```

Description

Same as SIGCHLD (System V), optional signal.

SIGEMT

```
public static final SIGEMT
```

Description

EMT instruction, optional signal.

SIGLOST

```
public static final SIGLOST
```

Description

Deprecated since RTSJ version as of RTSJ 1.0.1 not part of POSIX 9945-1-1996 standard

SIGCANCEL

```
public static final SIGCANCEL
```

Description

Deprecated since RTSJ version as of RTSJ 1.0.1 not part of POSIX 9945-1-1996 standard

SIGFREEZE

```
public static final SIGFREEZE
```

Description

Deprecated since RTSJ version as of RTSJ 1.0.1 not part of POSIX 9945-1-1996 standard

SIGLWP

```
public static final SIGLWP
```

Description

Deprecated since RTSJ version as of RTSJ 1.0.1 not part of POSIX 9945-1-1996 standard

SIGTHAW

```
public static final SIGTHAW
```

Description

Deprecated since RTSJ version as of RTSJ 1.0.1 not part of POSIX 9945-1-1996 standard

SIGWAITING

```
public static final SIGWAITING
```

Description

Deprecated since RTSJ version as of RTSJ 1.0.1 not part of POSIX 9945-1-1996 standard

A.3.3.5.2 Constructors

POSIXSignalHandler

Signature

```
public
    POSIXSignalHandler()
```

Description

A.3.3.5.3 Methods

addHandler(int, AsyncEventHandler)

Signature

```
public static
    void addHandler(int signal,
                    AsyncEventHandler handler)
```

Description

addHandler adds the handler provided to the set of handlers that will be released on the provided signal.

Parameters

signal The POSIX signal as defined in the constants SIG*.

handler the handler to be released on the given signal.

Throws

IllegalArgumentException iff signal is not defined by any of the constants in this class or handler is null.

removeHandler(int, AsyncEventHandler)

Signature

```
public static  
void removeHandler(int signal,  
                    AsyncEventHandler handler)
```

Description

removeHandler removes a handler that was added for a given signal.

Parameters

signal The POSIX signal as defined in the constants SIG*.
handler the handler to be removed from the given signal. When this handler is null or has not been added to the signal, nothing will happen.

Throws

IllegalArgumentException iff signal is not defined by any of the constants in this class.

setHandler(int, AsyncEventHandler)

Signature

```
public static  
void setHandler(int signal,  
                AsyncEventHandler handler)
```

Description

setHandler sets the set of handlers that will be released on the provided signal to the set with the provided handler being the single element.

Parameters

signal The POSIX signal as defined in the constants SIG*.
handler the handler to be released on the given signal, null to remove all handlers for the given signal.

Throws

IllegalArgumentException iff signal is not defined by any of the constants in this class.

A.3.3.6 PhysicalMemoryManager

Inheritance

java.lang.Object
 javax.realtime.PhysicalMemoryManager

Description

The `PhysicalMemoryManager` is not ordinarily used by applications, except that the implementation may require the application to use the `registerFilter`⁷⁰ method to make the physical memory manager aware of the memory types on their platform. The `PhysicalMemoryManager` class is primarily intended for use by the various physical memory accessor objects (`VTPhysicalMemory`⁷¹, `LTPhysicalMemory`⁷², and `ImmortalPhysicalMemory`⁷³) to create objects of the types requested by the application. The physical memory manager is responsible for finding areas of physical memory with the appropriate characteristics and access rights, and moderating any required combination of physical and virtual memory characteristics.

The Physical Memory Manager assumes that the physical address space is linear but not necessarily contiguous. That is, addresses range from 0 .. `MAX_LONG` but there may be holes in the memory space. Some of these holes may be filled with removable memory.

The physical memory is partitioned into chunks (pages, segments, etc.). Each chunk of memory has a base address and a length.

Each chunk of memory has certain properties. Some of these properties may require actions to be performed by the Physical Memory Manager when the memory is accessed. For example, access to `IO_PAGE` may require the use of special instructions to even reach the devices, or it may require special code sequences to ensure proper handling of processor write queues and caches.

Filters tell the Physical Memory Manager about the properties of the memory that are available on the machine by registering with the Physical Memory Manager.

When the program requests a physical memory area with particular properties, the constructor communicates with the Physical Memory Manager through a private interface. The Physical Memory Manager asks the filter if the address specified has the required properties and whether it is free, or asks for a chunk of memory with the requested size.

⁷⁰Section [A.3.3.6.2](#)

⁷¹Section [A.3.3.13](#)

⁷²Section [A.3.3.3](#)

⁷³Section [A.3.3.1](#)

The Physical Memory Manager then maps the physical memory chunk into virtual memory (on systems that support virtual memory). and locks the virtual memory to the memory chunk.

Examples of characteristics that might be specified are: DMA memory, hardware byte swapping, non-cached access to memory, etc. Standard "names" for some memory characteristics are included in this class — DMA, SHARED, ALIGNED, BYTESWAP, and IO_PAGE — support for these characteristics is optional, but when they are supported they must use these names. Additional characteristics may be supported, but only names defined in this specification may be visible in the `PhysicalMemoryManager` API.

The base implementation will provide a `PhysicalMemoryManager`.

Original Equipment Manufacturers or other interested parties may provide `PhysicalMemoryTypeFilter`⁷⁴ classes that allow additional characteristics of memory devices to be specified.

Deprecated since RTSJ version as of RTSJ 2.0

A.3.3.6.1 Fields

ALIGNED

```
public static final ALIGNED
```

Description

When aligned memory is supported by the implementation specify `ALIGNED` to identify aligned memory. This type of memory ignores low-order bits in load and store accesses to force accesses to fall on natural boundaries for the access type even when the processor uses a poorly aligned address.

Deprecated since RTSJ version as of RTSJ 2.0 This is only applicable to raw memory. Use `javax.realtime.device.RawMemory`⁷⁵.

BYTESWAP

```
public static final BYTESWAP
```

⁷⁴Section A.3.1.1

⁷⁵Section 12.4.1.16

Description

When automatic byte swapping is supported by the implementation specify `BYTESWAP` when byte swapping should be used. Byte-swapping memory re-orders the bytes in accesses for 16 bits or more such that little-endian data in memory is accessed as big-endian, and vice-versa. Such memory would typically be available in swapped mode in one physical address range and in un-swapped mode in another address range.

Deprecated since RTSJ version as of RTSJ 2.0 This is only applicable to raw memory. Use `javax.realtime.device.RawMemory`⁷⁶.

DMA

```
public static final DMA
```

Description

When DMA (Direct Memory Access) memory is supported by the implementation, specify `DMA` to identify DMA memory. This memory is visible to devices that use DMA. In some systems, only a portion of the physical address space is available to DMA devices. On such systems, memory that will be used for DMA must be allocated from the range of addresses that DMA can reach.

Deprecated since RTSJ version as of RTSJ 2.0 This is only applicable to raw memory. Use `javax.realtime.device.RawMemory`⁷⁷.

IO_PAGE

```
public static final IO_PAGE
```

Description

When access to the system I/O space is supported by the implementation specify `IO_PAGE` when I/O space should be used. Addresses tagged with the name `IO_PAGE` are used for memory mapped I/O devices. Such addresses are almost certainly not suitable for physical memory, but only for raw memory access.

Available since RTSJ 1.0.1

⁷⁶Section [12.4.1.16](#)

⁷⁷Section [12.4.1.16](#)

SHARED

```
public static final SHARED
```

Description

When shared memory is supported by the implementation specify **SHARED** to identify shared memory. In a NUMA (Non-Uniform Memory Access) architecture, processors may make some part of their local memory available to other processors. This memory would be tagged with **SHARED**, as would memory that is shared and non-local.

A fully built-out NUMA system might well need sub-classifications of **SHARED** to reflect different paths to memory. Note that, as with other physical memory names, a single byte of memory may be visible at several physical addresses with different access properties at each address. For instance, a byte of shared memory accesses at address *x* might be shared with high-performance access, but without the support of coherent caches. The same byte accessed at address *y* might be shared with coherent cache support, but substantially longer access times.

A.3.3.6.2 Methods

isRemovable(long, long)

Signature

```
public static  
boolean isRemovable(long base,  
                    long size)
```

Description

Queries the system about the removability of the specified range of memory.

Parameters

base The starting address in physical memory.
size The size of the memory area.

Throws

IllegalArgumentException when **size** is less than zero.
SizeOutOfBoundsException when **base** plus **size** would be greater than the physical addressing range of the processor.
OffsetOutOfBoundsException when **base** is less than zero.

Returns

true when any part of the specified range can be removed.

isRemoved(long, long)*Signature*

```
public static
boolean isRemoved(long base,
                  long size)
```

Description

Queries the system about the removed state of the specified range of memory. This method is used for devices that lie in the memory address space and can be removed while the system is running. (Such as PC cards).

Parameters

base The starting address in physical memory.

size The size of the memory area.

Throws

`IllegalArgumentException` when **size** is less than zero.

`OffsetOutOfBoundsException` when **base** is less than zero.

`SizeOutOfBoundsException` when **base** plus **size** would be greater than the physical addressing range of the processor.

Returns

true when any part of the specified range is currently not usable.

onInsertion(long, long, AsyncEvent)*Signature*

```
public static
void onInsertion(long base,
                 long size,
                 AsyncEvent ae)
```

Description

Register the specified `AsyncEvent`⁷⁸ to fire when any memory in the range is added to the system. When the specified range of physical memory contains

⁷⁸Section 8.4.3.4

multiple different types of removable memory, the AE will be registered with each of them.

Parameters

base The starting address in physical memory.

size The size of the memory area.

ae The async event to fire.

Throws

IllegalArgumentException when **ae** is null, or when the specified range contains no removable memory, or when **size** is less than zero.

OffsetOutOfBoundsException when **base** is less than zero.

SizeOutOfBoundsException when **base** plus **size** would be greater than the physical addressing range of the processor.

Available since RTSJ 1.0.1

onInsertion(long, long, AsyncEventHandler)

Signature

```
public static
void onInsertion(long base,
                 long size,
                 AsyncEventHandler aeh)
```

Description

Register the specified **AsyncEventHandler**⁷⁹ to run when any memory in the range is added to the system. When the specified range of physical memory contains multiple different types of removable memory, the AEH will be registered with each of them. When the size or the base is less than 0, unregister all "onInsertion" references to the handler.

Note: This method only removes handlers that were registered with the same method. It has no effect on handlers that were registered using an associated async event.

Parameters

base The starting address in physical memory.

size The size of the memory area.

aeh The handler to register.

⁷⁹Section 8.4.3.5

Throws

`IllegalArgumentException` when `aeh` is `null`, or when the specified range contains no removable memory, or when `aeh` is `null` and `size` and `base` are both greater than or equal to zero.

`SizeOutOfBoundsException` when `base` plus `size` would be greater than the physical addressing range of the processor.

onRemoval(long, long, AsyncEvent)*Signature*

```
public static
void onRemoval(long base,
               long size,
               AsyncEvent ae)
```

Description

Register the specified AE to fire when any memory in the range is removed from the system. When the specified range of physical memory contains multiple different types of removable memory, the AE will be registered with each of them.

Parameters

base The starting address in physical memory.

size The size of the memory area.

ae The async event to register.

Throws

`IllegalArgumentException` when the specified range contains no removable memory, when `ae` is `null`, or when `size` is less than zero.

`OffsetOutOfBoundsException` when `base` is less than zero.

`SizeOutOfBoundsException` when `base` plus `size` would be greater than the physical addressing range of the processor.

onRemoval(long, long, AsyncEventHandler)*Signature*

```
public static
void onRemoval(long base,
               long size,
               AsyncEventHandler aeh)
```

Description

Register the specified AEH to run when any memory in the range is removed from the system. When the specified range of physical memory contains multiple different types of removable memory, the AEH will be registered with each of them. When **size** or **base** is less than 0, unregister all "onRemoval" references to the handler parameter.

Note: This method only removes handlers that were registered with the same method. It has no effect on handlers that were registered using an associated async event.

Parameters

base The starting address in physical memory.

size The size of the memory area.

aeH The handler to register.

Throws

IllegalArgumentException when the specified range contains no removable memory, or when **aeH** is null and **size** and **base** are both greater than or equal to zero.

SizeOutOfBoundsException when **base** plus **size** would be greater than the physical addressing range of the processor.

registerFilter(Object, PhysicalMemoryTypeFilter)*Signature*

```
public static final
void registerFilter(Object name,
                    PhysicalMemoryTypeFilter filter)
throws DuplicateFilterException
```

Description

Register a memory type filter with the physical memory manager.

Values of **name** are compared using reference equality (==) not value equality (equals()).

Parameters

name The type of memory handled by this filter.

filter The filter object.

Throws

DuplicateFilterException when a filter for this type of memory already exists.

ResourceLimitError when the system is configured for a bounded number of filters. This filter exceeds the bound.

IllegalArgumentException when the name parameter is an array of objects, when the name and filter are not both in immortal memory, or when either name or filter is null.

SecurityException when this operation is not permitted.

removeFilter(Object)

Signature

```
public static final
void removeFilter(Object name)
```

Description

Remove the identified filter from the set of registered filters. When the filter is not registered, silently do nothing.

Values of **name** are compared using reference equality (==) not value equality (equals()).

Parameters

name The identifying object for this memory attribute.

Throws

IllegalArgumentException when name is null.

SecurityException when this operation is not permitted.

unregisterInsertionEvent(long, long, AsyncEvent)

Signature

```
public static
boolean unregisterInsertionEvent(long base,
                                long size,
                                AsyncEvent ae)
```

Description

Unregister the specified insertion event. The event is only unregistered when all three arguments match the arguments used to register the event, except that **ae** of **null** matches all values of **ae** and will unregister every **ae** that matches the address range.

Note: This method has no effect on handlers registered directly as async event handlers.

Parameters

base The starting address in physical memory associated with **ae**.

size The size of the memory area associated with **ae**.

ae The event to unregister.

Throws

`IllegalArgumentException` when **size** is less than 0.

`OffsetOutOfBoundsException` when **base** is less than zero.

`SizeOutOfBoundsException` when **base** plus **size** would be greater than the physical addressing range of the processor.

Returns

True when at least one event matched the pattern, false when no such event was found.

Available since RTSJ 1.0.1

unregisterRemovalEvent(long, long, AsyncEvent)

Signature

```
public static
boolean unregisterRemovalEvent(long base,
                               long size,
                               AsyncEvent ae)
```

Description

Unregister the specified removal event. The async event is only unregistered when all three arguments match the arguments used to register the event, except that **ae** of **null** matches all values of **ae** and will unregister every **ae** that matches the address range.

Note: This method has no effect on handlers registered directly as async event handlers.

Parameters

base The starting address in physical memory associated with **ae**.

size The size of the memory area associated with **ae**.

ae The async event to unregister.

Throws

`IllegalArgumentException` when **size** is less than 0.

`OffsetOutOfBoundsException` when **base** is less than zero.

`SizeOutOfBoundsException` when `base` plus `size` would be greater than the physical addressing range of the processor.

Returns

True when at least one event matched the pattern, false when no such event was found.

Available since RTSJ 1.0.1

A.3.3.7 ProcessingGroupParameters

Inheritance

java.lang.Object
 javax.realtime.ProcessingGroupParameters

Interfaces

Cloneable
Serializable

Description

This is associated with one or more schedulables for which the system guarantees that the associated objects will not be given more time per period than indicated by `cost`. The motivation for this class is to allow the execution demands of one or more aperiodic schedulables to be bound. However, periodic or sporadic schedulables can also be associated with a processing group.

Processing groups have an associated affinity set that must contain only a single processor. The default affinity set is given by `Affinity.getGroupDefaultAffinity()`.

For all schedulables with a reference to an instance of `ProcessingGroupParameters` `p` no more than `p.cost` will be allocated to the execution of these schedulables on the processor associated with its processing group in each interval of time given by `p.period` after the time indicated by `p.start`. No execution of the schedulables will be allowed on any processor other than this processor. When there is no intersection between the a schedulable objects affinity set and its processing group's affinity set, then the schedulable execution is constrained by the default processing group's affinity set.

Logically a virtual server is associated with each instance of `ProcessingGroupParameters`. This server has a start time, a period, a cost (budget) and a deadline. The server can only logically execute when (a) it has not consumed more execution time in its current release than the cost (budget) parameter, (b) one of its associated schedulables is executable and is the most eligible of the executable schedulables. When the server is logically executable, the associated

schedulable is executed. When the cost has been consumed, any `overrunHandler` is released, and the server is not eligible for logical execution until its next period is due. At this point, its allocated cost (budget) is replenished. When the server is logically executing when its deadline expires, any associated `missHandler` is released. The deadline and cost parameters of all the associated schedulable objects have the same impact as they would if the objects were not bound to a processing group.

Processing group parameters use `HighResolutionTime`⁸⁰ values for cost, deadline, period and start time. Since those times are expressed as a `HighResolutionTime`⁸¹, the values use accurate timers with nanosecond granularity. The actual resolution available and even the quantity it measures depends on the clock associated with each time value.

When a reference to a `ProcessingGroupParameters` object is given as a parameter to a schedulable's constructor or passed as an argument to one of the schedulable's setter methods, the `ProcessingGroupParameters` object becomes the processing group parameters object bound to that schedulable object. Changes to the values in the `ProcessingGroupParameters` object affect that schedulable object. When bound to more than one schedulable then changes to the values in the `ProcessingGroupParameters` object affect *all* of the associated objects. Note that this is a one-to-many relationship and *not* a many-to-many.

The implementation must use modified copy semantics for each `HighResolutionTime`⁸² parameter value. The value of each time object should be treated as if it were copied at the time it is passed to the parameter object, but the object reference must also be retained. Only changes to a `ProcessingGroupParameters` object caused by methods on that object are immediately visible to the scheduler. For instance, invoking `setPeriod()` on a `ProcessingGroupParameters` object will make the change, then notify that the scheduler that the parameter object has changed. At that point the scheduler's view of the processing group parameters object is updated. Invoking a method on the `RelativeTime` object that is the period for this object may change the period but it does not pass the change to the scheduler at that time. That new value for period must not change the behavior of the SOs that use the parameter object until a setter method on the `ProcessingGroupParameters` object is invoked, or the parameter object is used in `setProcessingGroupParameters()` or a constructor for an SO.

The implementation may use copy semantics for each `HighResolutionTime` parameter value. For instance the value returned by `getCost()` must be equal to the value passed in by `setCost`, but it need not be the same object.

⁸⁰Section 9.4.1.2

⁸¹Section 9.4.1.2

⁸²Section 9.4.1.2

Table A.1: ProcessingGroupParameter Default Values

Attribute	Default Value
start	new RelativeTime(0,0)
period	No default. A value must be supplied
cost	No default. A value must be supplied
deadline	new RelativeTime(period)
overrunHandler	None
missHandler	None

The following table gives the default parameter values for the constructors.

Caution: This class is explicitly unsafe in multithreaded situations when it is being changed. No synchronization is done. It is assumed that users of this class who are mutating instances will be doing their own synchronization at a higher level.

Caution: The `cost` parameter time should be considered to be measured against the target platform.

Deprecated since RTSJ version as of RTSJ 2.0

A.3.3.7.1 Constructors

ProcessingGroupParameters(HighResolutionTime, RelativeTime, RelativeTime, RelativeTime, AsyncEventHandler, AsyncEventHandler)

Signature

```
public
ProcessingGroupParameters(javax.realtime.HighResolutionTime<?> start,
                           RelativeTime period,
                           RelativeTime cost,
                           RelativeTime deadline,
                           AsyncEventHandler overrunHandler,
```

2.0 (Draft 34)

AsyncEventHandler missHandler)

throws IllegalArgumentException,
IllegalAssignmentError

Description

Create a `ProcessingGroupParameters` object.

Parameters

start Time at which the first period begins. When a `RelativeTime`, this time is relative to the creation of this. When an `AbsoluteTime`, then the first release of the logical server is at the start time (or immediately when the absolute time is in the past). When `null`, the default value is a new instance of `RelativeTime(0,0)`.

period The period is the interval between successive replenishment of the logical server's associated cost budget. There is no default value. When `period` is `null` an exception is thrown.

cost Processing time per period. The budget CPU time that the logical server can consume each period. When `null`, an exception is thrown.

deadline The latest permissible completion time measured from the start of the current period. Changing the deadline might not take effect after the expiration of the current deadline. Specifying a deadline less than the period constrains execution of all the members of the group to the beginning of each period. When `null`, the default value is new instance of `RelativeTime(period)`.

overrunHandler This handler is invoked when any schedulable object member of this processing group attempts to use processor time beyond the group's budget. When `null`, no application async event handler is fired on the overrun condition.

missHandler This handler is invoked when the logical server is still executing after the deadline has passed. When `null`, no application async event handler is fired on the deadline miss condition.

Throws

`IllegalArgumentException` when the `period` is `null` or its time value is not greater than zero, when `cost` is `null`, or when the time value of `cost` is less than zero, when `start` is an instance of `RelativeTime` and its value is negative, or when the time value of `deadline` is not greater than zero and less than or equal to the `period`. When the implementation does not support processing group deadline less than period, `deadline` less than `period` will cause `IllegalArgumentException` to be thrown.

`IllegalAssignmentError` when `start`, `period`, `cost`, `deadline`, `overrunHandler` or `missHandler` cannot be stored in this.

A.3.3.7.2 Methods

clone

Signature

```
public  
java.lang.Object clone()  
throws CloneNotSupportedException
```

Description

Create a clone of **this**. This method should behave effectively as when it constructed a new object with clones of the high-resolution time values of **this**.

- The new object is in the current allocation context.
- **clone** does not copy any associations from **this** and it does not implicitly bind the new object to a SO.
- The new object has clones of all high-resolution time values (deep copy).
- References to event handlers are copied (shallow copy.)

Throws

CloneNotSupportedException never

Returns

the clone of **this**

Available since RTSJ 1.0.1

getCost

Signature

```
public  
javax.realtime.RelativeTime getCost()
```

Description

Gets the value of **cost**.

Returns

a reference to the value of **cost**.

getCostOverrunHandler

Signature

```
public  
    javax.realtime.AsyncEventHandler getCostOverrunHandler()
```

Description

Gets the cost overrun handler.

Returns

A reference to an instance of [AsyncEventHandler](#)⁸³ that is cost overrun handler of **this**.

getDeadline

Signature

```
public  
    javax.realtime.RelativeTime getDeadline()
```

Description

Gets the value of deadline.

Returns

A reference to an instance of [RelativeTime](#)⁸⁴ that is the deadline of **this**.

getDeadlineMissHandler

Signature

```
public  
    javax.realtime.AsyncEventHandler getDeadlineMissHandler()
```

Description

Gets the deadline miss handler.

Returns

A reference to an instance of [AsyncEventHandler](#)⁸⁵ that is deadline miss handler of **this**.

⁸³Section [8.4.3.5](#)

⁸⁴Section [9.4.1.3](#)

⁸⁵Section [8.4.3.5](#)

getPeriod

Signature

```
public  
javax.realtime.RelativeTime getPeriod()
```

Description

Gets the value of `period`.

Returns

A reference to an instance of [RelativeTime](#)⁸⁶ that represents the value of `period`.

getStart

Signature

```
public  
javax.realtime.HighResolutionTime<?> getStart()
```

Description

Gets the value of `start`. This is the value that was specified in the constructor or by `setStart()`, not the actual absolute time the corresponding to the start of the processing group.

Returns

A reference to an instance of [HighResolutionTime](#)⁸⁷ that represents the value of `start`.

setCost(RelativeTime)

Signature

```
public  
void setCost(RelativeTime cost)  
throws IllegalArgumentException,  
    IllegalAssignmentError
```

Description

⁸⁶Section [9.4.1.3](#)

⁸⁷Section [9.4.1.2](#)

Sets the value of `cost`.

Parameters

`cost` The new value for `cost`. When `null`, an exception is thrown.

Throws

`IllegalArgumentException` when `cost` is `null` or its time value is less than zero.

`IllegalAssignmentError` when `cost` cannot be stored in `this`.

setCostOverrunHandler(AsyncEventHandler)

Signature

```
public
void setCostOverrunHandler(AsyncEventHandler handler)
throws IllegalAssignmentError
```

Description

Sets the cost overrun handler.

Parameters

`handler` This handler is invoked when the `run()` method of and of the the schedulables attempt to execute for more than `cost` time units in any period. When `null`, no handler is attached, and any previous handler is removed.

Throws

`IllegalAssignmentError` when `handler` cannot be stored in `this`.

setDeadline(RelativeTime)

Signature

```
public
void setDeadline(RelativeTime deadline)
throws IllegalArgumentException,
    IllegalAssignmentError
```

Description

Sets the value of `deadline`.

Parameters

`deadline` The new value for `deadline`. When `null`, the default value is new instance of `RelativeTime(period)`.

Throws

`IllegalArgumentException` when `deadline` has a value less than zero or greater than the period. Unless the implementation supports deadline less than period in processing groups, `IllegalArgumentException` is also when `deadline` is less than the period.

`IllegalAssignmentError` when `deadline` cannot be stored in `this`.

setDeadlineMissHandler(AsyncEventHandler)

Signature

```
public
void setDeadlineMissHandler(AsyncEventHandler handler)
throws IllegalAssignmentError
```

Description

Sets the deadline miss handler.

Parameters

handler This handler is invoked when the `run()` method of any of the schedulables still expect to execute after the deadline has passed. When `null`, no handler is attached, and any previous handler is removed.

Throws

`IllegalAssignmentError` when `handler` cannot be stored in `this`.

setPeriod(RelativeTime)

Signature

```
public
void setPeriod(RelativeTime period)
throws IllegalArgumentException,
    IllegalAssignmentError
```

Description

Sets the value of `period`.

Parameters

period The new value for `period`. There is no default value. When `period` is `null` an exception is thrown.

Throws

`IllegalArgumentException` when `period` is `null`, or its time value is not greater than zero. When the implementation does not support processing group deadline less than `period`, and `period` is not equal to the current value of the processing group's deadline, the deadline is set to a clone of `period` created in the same memory area as `period`.

`IllegalAssignmentError` when `period` cannot be stored in `this`.

setStart(HighResolutionTime)

Signature

```
public
void setStart(javax.realtime.HighResolutionTime<?> start)
throws IllegalArgumentException,
    IllegalAssignmentError
```

Description

Sets the value of `start`. When the processing group is already started this method alters the value of this object's start time property, but has no other effect.

Parameters

`start` The new value for `start`. When `null`, the default value is a new instance of `RelativeTime(0,0)`.

Throws

`IllegalAssignmentError` when `start` cannot be stored in `this`.

`IllegalArgumentException` when `start` is a relative time value and less than zero.

A.3.3.8 RationalTime

Inheritance

```
java.lang.Object
  javax.realtime.HighResolutionTime
    javax.realtime.RelativeTime
      javax.realtime.RationalTime
```

Description

An object that represents a time interval $\text{milliseconds}/10^3 + \text{nanoseconds}/10^9$ seconds long that is divided into subintervals by some frequency. This is generally

used in periodic events, threads, and feasibility analysis to specify periods where there is a basic period that must be adhered to strictly (the interval), but within that interval the periodic events are supposed to happen frequency times, as uniformly spaced as possible, but clock and scheduling jitter is moderately acceptable.

Caution: This class is explicitly unsafe for multithreading when being changed. Code that mutates instances of this class should synchronize at a higher level. **Deprecated since RTSJ version as of RTSJ 1.0.1**

A.3.3.9 RawMemoryAccess

Inheritance

java.lang.Object
 javax.realtime.RawMemoryAccess

Description

An instance of **RawMemoryAccess** models a range of physical memory as a fixed sequence of bytes. A complement of accessor methods enable the contents of the physical area to be accessed through offsets from the base, interpreted as byte, short, int, or long data values or as arrays of these types.

Whether an offset addresses the high-order or low-order byte is normally based on the value of the **RealtimeSystem.BYTE_ORDER**⁸⁸ static byte variable in class **RealtimeSystem**⁸⁹. When the type of memory used for this **RawMemoryAccess** region implements non-standard byte ordering, accessor methods in this class continue to select bytes starting at **offset** from the base address and continuing toward greater addresses. The memory type may control the mapping of these bytes into the primitive data type. The memory type could even select bytes that are not contiguous. In each case the documentation for the **PhysicalMemoryTypeFilter**⁹⁰ must document any mapping other than the "normal" one specified above.

The **RawMemoryAccess** class allows a realtime program to implement device drivers, memory-mapped I/O, flash memory, battery-backed RAM, and similar low-level software.

A raw memory area cannot contain references to Java objects. Such a capability would be unsafe (since it could be used to defeat Java's type checking)

⁸⁸Section 14.3.2.3.1

⁸⁹Section 14.3.2.3

⁹⁰Section A.3.1.1

and error-prone (since it is sensitive to the specific representational choices made by the Java compiler).

Many of the constructors and methods in this class throw `OffsetOutOfBoundsException`⁹¹. This exception means that the value given in the offset parameter is either negative or outside the memory area.

Many of the constructors and methods in this class throw `SizeOutOfBoundsException`⁹². This exception means that the value given in the size parameter is either negative, larger than an allowable range, or would cause an accessor method to access an address outside of the memory area.

Unlike other integral parameters in this chapter, negative values are valid for `byte`, `short`, `int`, and `long` values that are copied in and out of memory by the `set` and `get` methods of this class.

All offset values used in this class are measured in bytes.

Atomic loads and stores on raw memory are defined in terms of physical memory. This memory may be accessible to threads outside the JVM and to non-programmed access (e.g., DMA), consequently atomic access must be supported by hardware. This specification is written with the assumption that all suitable hardware platforms support atomic loads for aligned bytes, shorts, and ints. Atomic access beyond the specified minimum may be supported by the implementation.

Storing values into raw memory is more hardware-dependent than loading values. Many processor architectures do not support atomic stores of variables except for aligned stores of the processor's word size. For instance, storing a byte into memory might require reading a 32-bit quantity into a processor register, updating the register to reflect the new byte value, then re-storing the whole 32-bit quantity. Changes to other bytes in the 32-bit quantity that take place between the load and the store will be lost.

Some processors have mechanisms that can be used to implement an atomic store of a byte, but those mechanisms are often slow and not universally supported.

This class supports unaligned access to data, but it does not require the implementation to make such access atomic. Accesses to data aligned on its natural boundary will be atomic when the processor implements atomic loads and stores of that data size.

Except where noted, accesses to raw memory are not atomic with respect to the memory or with respect to schedulables. A raw memory area could be updated by another schedulable, or even unmapped in the middle of a method.

The characteristics of raw-memory access are necessarily platform dependent. This specification provides a minimum requirement for the RTSJ platform, but

⁹¹Section 15.3.2.10

⁹²Section 15.3.2.19

Table A.2: Properties Array

Attribute	Values	Comment
Access type	read, write	
Data type	byte, short, int, long, float, double	
Alignment	0	aligned
	1 to one less than data type size	the first byte of the data is <i>alignment</i> bytes away from natural alignment.
Atomicity	processor	means access is atomic with respect to other tasks on processor.
	smp	means access is <i>processor</i> atomic, and atomic with respect to all processors in an SMP.
	memory	means that access is <i>smp</i> atomic, and atomic with respect to all access to the memory including DMA.

it also supports optional system properties that identify a platform's level of support for atomic raw put and get. The properties represent a four-dimensional sparse array with boolean values indicating whether that combination of access attributes is atomic. The default value for array entries is false. The dimensions are

The true values in the table are represented by properties of the following form. `javax.realtime.atomicaccess_<access>_<type>_<alignment>_atomicity=true` for example:

```
javax.realtime.atomicaccess_read_byte_0_memory=true
```

Table entries with a value of false may be explicitly represented, but since false is the default value, such properties are redundant.

All raw memory access is treated as volatile, and *serialized*. The run-time must be forced to re-read memory or write to memory on each call to a raw memory `getxxx` or `putxxx` method, and to complete the reads and writes in the order they appear in the program order.

Deprecated since RTSJ version as of RTSJ 2.0. Use `javax.realtime.device.RawMemoryFactory` to create the appropriate `javax.realtime.device.RawMemory`⁹⁴ object.

⁹³Section 12.4.2.6

⁹⁴Section 12.4.1.16

A.3.3.9.1 Constructors

RawMemoryAccess(Object, long)

Signature

```
public
RawMemoryAccess(Object type,
                 long size)
```

Description

Construct an instance of `RawMemoryAccess` with the given parameters, and set the object to the mapped state. When the platform supports virtual memory, map the raw memory into virtual memory.

The run time environment is allowed to choose the virtual address where the raw memory area corresponding to this object will be mapped. The attributes of the mapping operation are controlled by the `VMFlags` and `VMAttributes` of the `PhysicalMemoryTypeFilter` objects that matched this object's `type` parameter. (See `PhysicalMemoryTypeFilter.getVMAttributes`⁹⁵ and `PhysicalMemoryTypeFilter.getVMFlags`⁹⁶).

Deprecated since RTSJ version as of RTSJ 2.0. Use `javax.realtime.device.RawMemoryFactory`⁹⁷ to create the appropriate `javax.realtime.device.RawMemory`⁹⁸ object.

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

size The size of the area in bytes.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory, the specified range of addresses, or the given type of memory.

⁹⁵Section [A.3.1.1.1](#)

⁹⁶Section [A.3.1.1.1](#)

⁹⁷Section [12.4.2.6](#)

⁹⁸Section [12.4.1.16](#)

SizeOutOfBoundsException when the size is negative or extends into an invalid range of memory.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryTypeFilter**⁹⁹ has been registered with the **PhysicalMemoryManager**¹⁰⁰.

MemoryTypeConflictException when the specified base does not point to memory that matches the request type, or when **type** specifies incompatible memory attributes.

OutOfMemoryError when the requested type of memory exists, but there is not enough of it free to satisfy the request.

SecurityException when the application doesn't have permissions to access physical memory or the given range of memory.

RawMemoryAccess(Object, long, long)

Signature

```
public
RawMemoryAccess(Object type,
                  long base,
                  long size)
```

Description

Construct an instance of **RawMemoryAccess** with the given parameters, and set the object to the mapped state. When the platform supports virtual memory, map the raw memory into virtual memory.

The run time environment is allowed to choose the virtual address where the raw memory area corresponding to this object will be mapped. The attributes of the mapping operation are controlled by the **VMFlags** and **VMAttributes** of the **PhysicalMemoryTypeFilter** objects that matched this object's **type** parameter. (See **PhysicalMemoryTypeFilter.getVMAttributes**¹⁰¹ and **PhysicalMemoryTypeFilter.getVMFlags**¹⁰²).

Deprecated since RTSJ version as of RTSJ 2.0. Use `javax.realtime.device.RawMemoryFact`

⁹⁹Section A.3.1.1

¹⁰⁰Section A.3.3.6

¹⁰¹Section A.3.1.1.1

¹⁰²Section A.3.1.1.1

¹⁰³Section 12.4.2.6

to create the appropriate `javax.realtime.device.RawMemory`¹⁰⁴ object.

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the region.

size The size of the area in bytes.

Throws

`SecurityException` when application doesn't have permissions to access physical memory, the specified range of addresses, or the given type of memory.

`OffsetOutOfBoundsException` when the address is invalid.

`SizeOutOfBoundsException` when the size is negative or extends into an invalid range of memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`¹⁰⁵ has been registered with the `PhysicalMemoryManager`¹⁰⁶.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the request type, or when **type** specifies incompatible memory attributes.

`OutOfMemoryError` when the requested type of memory exists, but there is not enough of it free to satisfy the request.

A.3.3.9.2 Methods

`getBytes(long)`

Signature

```
public
byte getBytes(long offset)
```

¹⁰⁴Section 12.4.1.16

¹⁰⁵Section A.3.1.1

¹⁰⁶Section A.3.3.6

Description

Gets the **byte** at the given offset in the memory area associated with this object. The byte is always loaded from memory in a single atomic operation.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory from which to load the byte.

Throws

SizeOutOfBoundsException when the object is not mapped, or when the byte falls in an invalid address range.

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException**¹⁰⁷ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SecurityException when this access is not permitted by the security manager.

Returns

The byte from raw memory.

See Section [RawMemoryAccess.map\(long,long\)](#)

getBytes(long, byte, int, int)

Signature

```
public
void getBytes(long offset,
              byte[] bytes,
              int low,
              int number)
```

Description

Gets **number** bytes starting at the given offset in the memory area associated with this object and assigns them to the byte array passed starting at position

¹⁰⁷Section [15.3.2.19](#)

low. Each byte is loaded from memory in a single atomic operation. Groups of bytes may be loaded together, but this is unspecified.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory from which to start loading.

bytes The array into which the loaded items are placed.

low The offset which is the starting point in the given array for the loaded items to be placed.

number The number of items to load.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException**¹⁰⁸ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when the byte falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The **bytes** array could, therefore, be partially updated when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when **low** is less than 0 or greater than **bytes.length - 1**, or when **low + number** is greater than or equal to **bytes.length**.

SecurityException when this access is not permitted by the security manager.

See Section [RawMemoryAccess.map\(long,long\)](#)

getInt(long)

Signature

```
public
int getInt(long offset)
```

Description

¹⁰⁸Section [15.3.2.19](#)

Gets the `int` at the given offset in the memory area associated with this object. When the integer is aligned on a "natural" boundary it is always loaded from memory in a single atomic operation. When it is not on a natural boundary it may not be loaded atomically, and the number and order of the load operations is unspecified.

Caching of the memory access is controlled by the memory `type` requested when the `RawMemoryAccess` instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area from which to load the integer.

Throws

`OffsetOutOfBoundsException` when the offset is negative or greater than the size of the raw memory area. The role of the `SizeOutOfBoundsException`¹⁰⁹ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

`SizeOutOfBoundsException` when the object is not mapped, or when the integer falls in an invalid address range.

`SecurityException` when this access is not permitted by the security manager.

Returns

The integer from raw memory.

See Section `RawMemoryAccess.map(long,long)`

getInts(long, int, int, int)

Signature

```
public
void getInts(long offset,
             int[] ints,
             int low,
             int number)
```

Description

¹⁰⁹Section [15.3.2.19](#)

Gets **number** integers starting at the given offset in the memory area associated with this object and assign them to the int array passed starting at position **low**.

When the integers are aligned on natural boundaries each integer is loaded from memory in a single atomic operation. Groups of integers may be loaded together, but this is unspecified. When the integers are not aligned on natural boundaries they may not be loaded atomically and the number and order of load operations is unspecified.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to start loading.

ints The array into which the integers read from the raw memory are placed.

low The offset which is the starting point in the given array for the loaded items to be placed.

number The number of integers to loaded.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException**¹¹⁰ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when the integers fall in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The **ints** array could, therefore, be partially updated when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when **low** is less than 0 or greater than **bytes.length - 1**, or when **low + number** is greater than or equal to **bytes.length**.

SecurityException when this access is not permitted by the security manager.

See Section [RawMemoryAccess.map\(long,long\)](#)

getLong(long)

¹¹⁰Section [15.3.2.19](#)

Signature

```
public  
long getLong(long offset)
```

Description

Gets the **long** at the given offset in the memory area associated with this object.

The load is not required to be atomic even it is located on a natural boundary.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area from which to load the long.

Throws

OffsetOutOfBoundsException when the offset is invalid.

SizeOutOfBoundsException when the object is not mapped, or when the double falls in an invalid address range.

SecurityException when this access is not permitted by the security manager.

Returns

The long from raw memory.

getLongs(long, long, int, int)*Signature*

```
public  
void getLongs(long offset,  
              long[] longs,  
              int low,  
              int number)
```

Description

Gets **number** longs starting at the given offset in the memory area associated with this object and assign them to the long array passed starting at position **low**.

The loads are not required to be atomic even when they are located on natural boundaries.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not

cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to start loading.

longs The array into which the loaded items are placed.

low The offset which is the starting point in the given array for the loaded items to be placed.

number The number of longs to load.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException**¹¹¹ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when a long falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The **longs** array could, therefore, be partially updated when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when **low** is less than 0 or greater than **bytes.length - 1**, or when **low + number** is greater than or equal to **bytes.length**.

SecurityException when this access is not permitted by the security manager.

See Section [RawMemoryAccess.map\(long,long\)](#)

getMappedAddress

Signature

```
public  
long getMappedAddress()
```

Description

Gets the virtual memory location at which the memory region is mapped.

Throws

¹¹¹Section [15.3.2.19](#)

`IllegalStateException` when the raw memory object is not in the mapped state.

Returns

The virtual address to which this is mapped (for reference purposes). Same as the base address when virtual memory is not supported.

Deprecated since RTSJ version as of RTSJ 2.0 The program should never need this information.

getShort(long)

Signature

```
public  
short getShort(long offset)
```

Description

Gets the **short** at the given offset in the memory area associated with this object. When the short is aligned on a natural boundary it is always loaded from memory in a single atomic operation. When it is not on a natural boundary it may not be loaded atomically, and the number and order of the load operations is unspecified.

Caching of the memory access is controlled by the memory **type** requested when the `RawMemoryAccess` instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area from which to load the short.

Throws

`OffsetOutOfBoundsException` when the offset is negative or greater than the size of the raw memory area. The role of the `SizeOutOfBoundsException`¹¹² somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

`SizeOutOfBoundsException` when the object is not mapped, or when the short falls in an invalid address range.

`SecurityException` when this access is not permitted by the security manager.

Returns

¹¹²Section 15.3.2.19

The short loaded from raw memory.

See Section [RawMemoryAccess.map\(long,long\)](#)

getShorts(long, short, int, int)

Signature

```
public
void getShorts(long offset,
               short[] shorts,
               int low,
               int number)
```

Description

Gets **number** shorts starting at the given offset in the memory area associated with this object and assign them to the short array passed starting at position **low**.

When the shorts are located on natural boundaries each short is loaded from memory in a single atomic operation. Groups of shorts may be loaded together, but this is unspecified.

When the shorts are not located on natural boundaries the load may not be atomic, and the number and order of load operations is unspecified. Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area from which to start loading.

shorts The array into which the loaded items are placed.

low The offset which is the starting point in the given array for the loaded shorts to be placed.

number The number of shorts to load.

Throws

[OffsetOutOfBoundsException](#) when the offset is negative or greater than the size of the raw memory area. The role of the [SizeOutOfBoundsException](#)¹¹³

¹¹³Section [15.3.2.19](#)

somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when a short falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The **shorts** array could, therefore, be partially updated when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when **low** is less than 0 or greater than **bytes.length - 1**, or when **low + number** is greater than or equal to **bytes.length**.

SecurityException when this access is not permitted by the security manager.

See Section [RawMemoryAccess.map\(long,long\)](#)

map

Signature

```
public  
long map()
```

Description

Maps the physical memory range into virtual memory. No-op when the system doesn't support virtual memory.

The run time environment is allowed to choose the virtual address where the raw memory area corresponding to this object will be mapped. The attributes of the mapping operation are controlled by the **vmFlags** and **vmAttributes** of the **PhysicalMemoryTypeFilter** objects that matched this object's **type** parameter. (See [PhysicalMemoryTypeFilter.getVMAttributes](#)¹¹⁴ and [PhysicalMemoryTypeFilter.getVMFlags](#)¹¹⁵).

When the object is already mapped into virtual memory, this method does not change anything.

Throws

OutOfMemoryError when there is insufficient free virtual address space to map the object.

Returns

The starting point of the virtual memory range.

¹¹⁴Section [A.3.1.1.1](#)

¹¹⁵Section [A.3.1.1.1](#)

map(long)

Signature

```
public  
long map(long base)
```

Description

Maps the physical memory range into virtual memory at the specified location. No-op when the system doesn't support virtual memory.

The attributes of the mapping operation are controlled by the `VMFlags` and `VMAttributes` of the `PhysicalMemoryTypeFilter` objects that matched this object's `type` parameter. (See `PhysicalMemoryTypeFilter.getVMAttributes`¹¹⁶ and `PhysicalMemoryTypeFilter.getVMFlags`¹¹⁷).

When the object is already mapped into virtual memory at a different address, this method remaps it to `base`.

When a remap is requested while another schedulable is accessing the raw memory, the map will block until one load or store completes. It can interrupt an array operation between entries.

Parameters

base The location to map at the virtual memory space.

Throws

`OutOfMemoryError` when there is insufficient free virtual memory at the specified address.

`IllegalArgumentException` when `base` is not a legal value for a virtual address, or the memory-mapping hardware cannot place the physical memory at the designated address.

Returns

The starting point of the virtual memory.

Deprecated since RTSJ version as of RTSJ 2.0 No replacement

map(long, long)

Signature

```
public  
long map(long base,
```

¹¹⁶Section [A.3.1.1.1](#)

¹¹⁷Section [A.3.1.1.1](#)

long size)

Description

Maps the physical memory range into virtual memory. No-op when the system doesn't support virtual memory.

The attributes of the mapping operation are controlled by the `VMFlags` and `VMAttributes` of the `PhysicalMemoryTypeFilter` objects that matched this object's `type` parameter. (See [PhysicalMemoryTypeFilter.getVMAttributes](#)¹¹⁸ and [PhysicalMemoryTypeFilter.getVMFlags](#)¹¹⁹).

When the object is already mapped into virtual memory at a different address, this method remaps it to `base`.

When a remap is requested while another schedulable is accessing the raw memory, the map will block until one load or store completes. It can interrupt an array operation between entries.

Parameters

base The location to map at the virtual memory space.

size The size of the block to map in. When the size of the raw memory area is greater than `size`, the object is unchanged but accesses beyond the mapped region will throw [SizeOutOfBoundsException](#)¹²⁰. When the size of the raw memory area is smaller than the mapped region access to the raw memory will behave as if the mapped region matched the raw memory area, but additional virtual address space will be consumed after the end of the raw memory area.

Throws

`IllegalArgumentException` when `size` is not greater than zero, `base` is not a legal value for a virtual address, or the memory-mapping hardware cannot place the physical memory at the designated address.

Returns

The starting point of the virtual memory.

Deprecated since RTSJ version as of RTSJ 2.0 No replacement

setByte(long, byte)

Signature

¹¹⁸Section [A.3.1.1.1](#)

¹¹⁹Section [A.3.1.1.1](#)

¹²⁰Section [15.3.2.19](#)

```
public
void setByte(long offset,
             byte value)
```

Description

Sets the **byte** at the given offset in the memory area associated with this object.

This memory access may involve a load and a store, and it may have unspecified effects on surrounding bytes in the presence of concurrent access.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area to which to write the byte.

value The byte to write.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException**¹²¹ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when the byte falls in an invalid address range.

SecurityException when this access is not permitted by the security manager.

See Section [RawMemoryAccess.map\(long,long\)](#)

setBytes(long, byte, int, int)

Signature

```
public
void setBytes(long offset,
              byte[] bytes,
              int low,
              int number)
```

¹²¹Section [15.3.2.19](#)

Description

Sets **number** bytes starting at the given offset in the memory area associated with this object from the byte array passed starting at position **low**.

This memory access may involve multiple load and a store operations, and it may have unspecified effects on surrounding bytes (even bytes in the range being stored) in the presence of concurrent access.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area to which to start writing.

bytes The array from which the items are obtained.

low The offset which is the starting point in the given array for the items to be obtained.

number The number of items to write.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException**¹²² somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when the a short falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The store of the array into memory could, therefore, be only partially complete when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when **low** is less than 0 or greater than **bytes.length - 1**, or when **low + number** is greater than or equal to **bytes.length**.

SecurityException when this access is not permitted by the security manager.

See Section [RawMemoryAccess.map\(long,long\)](#)

setInt(long, int)*Signature*

¹²²Section [15.3.2.19](#)

```
public
void setInt(long offset,
            int value)
```

Description

Sets the `int` at the given offset in the memory area associated with this object. On most processor architectures an aligned integer can be stored in an atomic operation, but this is not required.

This memory access may involve multiple load and a store operations, and it may have unspecified effects on surrounding bytes (even bytes in the range being stored) in the presence of concurrent access.

Caching of the memory access is controlled by the memory **type** requested when the `RawMemoryAccess` instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to write the integer.

value The integer to write.

Throws

`OffsetOutOfBoundsException` when the offset is negative or greater than the size of the raw memory area. The role of the `SizeOutOfBoundsException`¹²³ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

`SizeOutOfBoundsException` when the object is not mapped, or when the integer falls in an invalid address range.

`SecurityException` when this access is not permitted by the security manager.

See Section `RawMemoryAccess.map(long,long)`

setInts(long, int, int, int)

Signature

```
public
void setInts(long offset,
             int[] ints,
```

¹²³Section 15.3.2.19


```
int low,  
int number)
```

Description

Sets `number` ints starting at the given offset in the memory area associated with this object from the int array passed starting at position `low`. On most processor architectures each aligned integer can be stored in an atomic operation, but this is not required.

This memory access may involve multiple load and a store operations, and it may have unspecified effects on surrounding bytes (even bytes in the range being stored) in the presence of concurrent access.

Caching of the memory access is controlled by the memory `type` requested when the `RawMemoryAccess` instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to start writing.

ints The array from which the items are obtained.

low The offset which is the starting point in the given array for the items to be obtained.

number The number of items to write.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException**¹²⁴ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when an int falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The store of the array into memory could, therefore, be only partially complete when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when `low` is less than 0 or greater than `bytes.length - 1`, or when `low + number` is greater than or equal to `bytes.length`.

SecurityException when this access is not permitted by the security manager.

¹²⁴Section 15.3.2.19

See Section [RawMemoryAccess.map\(long,long\)](#)

setLong(long, long)

Signature

```
public
void setLong(long offset,
             long value)
```

Description

Sets the **long** at the given offset in the memory area associated with this object. Even when it is aligned, the long value may not be updated atomically. It is unspecified how many load and store operations will be used or in what order.

This memory access may involve multiple load and a store operations, and it may have unspecified effects on surrounding bytes (even bytes in the range being stored) in the presence of concurrent access.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to write the long.

value The long to write.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException**¹²⁵ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when the long falls in an invalid address range.

SecurityException when this access is not permitted by the security manager.

See Section [RawMemoryAccess.map\(long,long\)](#)

¹²⁵Section [15.3.2.19](#)

setLongs(long, long, int, int)

Signature

```
public
void setLongs(long offset,
               long[] longs,
               int low,
               int number)
```

Description

Sets **number** longs starting at the given offset in the memory area associated with this object from the long array passed starting at position **low**. Even when they are aligned, the long values may not be updated atomically. It is unspecified how many load and store operations will be used or in what order.

This memory access may involve multiple load and a store operations, and it may have unspecified effects on surrounding bytes (even bytes in the range being stored) in the presence of concurrent access.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to start writing.

longs The array from which the items are obtained.

low The offset which is the starting point in the given array for the items to be obtained.

number The number of items to write.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException**¹²⁶ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when the a short falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or

¹²⁶Section 15.3.2.19

remapped. The store of the array into memory could, therefore, be only partially complete when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when `low` is less than 0 or greater than `bytes.length - 1`, or when `low + number` is greater than or equal to `bytes.length`.

SecurityException when this access is not permitted by the security manager.

See Section [RawMemoryAccess.map\(long,long\)](#)

setShort(long, short)

Signature

```
public
void setShort(long offset,
              short value)
```

Description

Sets the **short** at the given offset in the memory area associated with this object.

This memory access may involve a load and a store, and it may have unspecified effects on surrounding shorts in the presence of concurrent access.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to write the short.

value The short to write.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException**¹²⁷ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

SizeOutOfBoundsException when the object is not mapped, or when the short falls in an invalid address range.

SecurityException when this access is not permitted by the security manager.

¹²⁷Section [15.3.2.19](#)

See Section [RawMemoryAccess.map\(long,long\)](#)

setShorts(long, short, int, int)

Signature

```
public
void setShorts(long offset,
               short[] shorts,
               int low,
               int number)
```

Description

Sets **number** shorts starting at the given offset in the memory area associated with this object from the short array passed starting at position **low**.

Each write of a short value may involve a load and a store, and it may have unspecified effects on surrounding shorts in the presence of concurrent access - even on other shorts in the array.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to start writing.

shorts The array from which the items are obtained.

low The offset which is the starting point in the given array for the items to be obtained.

number The number of items to write.

Throws

[OffsetOutOfBoundsException](#) when the offset is negative or greater than the size of the raw memory area. The role of the [SizeOutOfBoundsException](#)¹²⁸ somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area.

[SizeOutOfBoundsException](#) when the object is not mapped, or when the a short falls in an invalid address range. This is checked at every entry in the

¹²⁸Section [15.3.2.19](#)

array to allow for the possibility that the memory area could be unmapped or remapped. The store of the array into memory could, therefore, be only partially complete when the raw memory is unmapped or remapped mid-method.

`ArrayIndexOutOfBoundsException` when `low` is less than 0 or greater than `bytes.length - 1`, or when `low + number` is greater than or equal to `bytes.length`.

`SecurityException` when this access is not permitted by the security manager.

See Section [RawMemoryAccess.map\(long,long\)](#)

unmap

Signature

```
public
void unmap()
```

Description

Unmap the physical memory range from virtual memory. This changes the raw memory from the mapped state to the unmapped state. When the platform supports virtual memory, this operation frees the virtual addresses used for the raw memory region.

When the object is already in the unmapped state, this method has no effect.

While a raw memory object is unmapped all attempts to set or get values in the raw memory will throw [SizeOutOfBoundsException](#)¹²⁹.

An unmapped raw memory object can be returned to mapped state with any of the object's `map` methods.

When an `unmap` is requested while another schedulable is accessing the raw memory, the `unmap` will throw an `IllegalStateException`. The `unmap` method can interrupt an array operation between entries.

A.3.3.10 RawMemoryFloatAccess

Inheritance

```
java.lang.Object
  javax.realtime.RawMemoryAccess
    javax.realtime.RawMemoryFloatAccess
```

Description

¹²⁹Section [15.3.2.19](#)

This class holds the accessor methods for accessing a raw memory area by float and double types. Implementations are required to implement this class when and only when the underlying Java Virtual Machine supports floating point data types.

See [RawMemoryAccess](#)¹³⁰ for commentary on changes in the preferred use of this class following RTSJ 2.0.

By default, the byte addressed by `offset` is the byte at the lowest address of the floating point processor's floating point representation. When the type of memory used for this `RawMemoryFloatAccess` region implements a non-standard floating point format, accessor methods in this class continue to select bytes starting at `offset` from the base address and continuing toward greater addresses. The memory type may control the mapping of these bytes into the primitive data type. The memory type could even select bytes that are not contiguous. In each case the documentation for the [PhysicalMemoryTypeFilter](#)¹³¹ must document any mapping other than the "normal" one specified above.

All offset values used in this class are measured in bytes.

Atomic loads and stores on raw memory are defined in terms of physical memory. This memory may be accessible to threads outside the JVM and to non-programmed access (e.g., DMA), consequently atomic access must be supported by hardware. This specification is written with the assumption that all suitable hardware platforms support atomic loads for aligned floats. Atomic access beyond the specified minimum may be supported by the implementation.

Storing values into raw memory is more hardware-dependent than loading values. Many processor architectures do not support atomic stores of variables except for aligned stores of the processor's word size.

This class supports unaligned access to data, but it does not require the implementation to make such access atomic. Accesses to data aligned on its natural boundary will be atomic when the processor implements atomic loads and stores of that data size.

Except where noted, accesses to raw memory are not atomic with respect to the memory or with respect to threads. A raw memory area could be updated by another thread, or even unmapped in the middle of a method.

The characteristics of raw-memory access are necessarily platform dependent. This specification provides a minimum requirement for the RTSJ platform, but it also supports a optional system properties that identify a platform's level of support for atomic raw put and get. (See [RawMemoryAccess](#)¹³².) The properties represent a four-dimensional sparse array with boolean values whether that

¹³⁰Section [A.3.3.9](#)

¹³¹Section [A.3.1.1](#)

¹³²Section [A.3.3.9](#)

combination of access attributes is atomic. The default value for array entries is false.

Many of the constructors and methods in this class throw `OffsetOutOfBoundsException`¹³³. This exception means that the value given in the offset parameter is either negative or outside the memory area.

Many of the constructors and methods in this class throw `SizeOutOfBoundsException`¹³⁴. This exception means that the value given in the size parameter is either negative, larger than an allowable range, or would cause an accessor method to access an address outside of the memory area.

Deprecated since RTSJ version as of RTSJ 2.0. Use `javax.realtime.device.RawMemory`¹³⁵.

A.3.3.10.1 Constructors

RawMemoryFloatAccess(Object, long)

Signature

```
public
RawMemoryFloatAccess(Object type,
                      long size)
```

Description

Construct an instance of `RawMemoryFloatAccess` with the given parameters, and set the object to the mapped state. When the platform supports virtual memory, map the raw memory into virtual memory.

The run time environment is allowed to choose the virtual address where the raw memory area corresponding to this object will be mapped. The attributes of the mapping operation are controlled by the `VMFlags` and `VMAttributes` of the `PhysicalMemoryTypeFilter` objects that matched this object's `type` parameter. (See `PhysicalMemoryTypeFilter.getVMAttributes`¹³⁶ and `PhysicalMemoryTypeFilter.getVMFlags`¹³⁷).

¹³³Section 15.3.2.10

¹³⁴Section 15.3.2.19

¹³⁵Section 12.4.1.16

¹³⁶Section A.3.1.1.1

¹³⁷Section A.3.1.1.1

Deprecated since RTSJ version as of RTSJ 2.0. Use `javax.realtime.device.RawMemoryFactory.createRawDouble(long, int, int)`¹³⁸ or `javax.realtime.device.RawMemoryFactory.createRawDouble(RawMemoryFactory, long, int, int)`¹³⁹.

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

size The size of the area in bytes.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory, the specified range of addresses, or the given type of memory.
`SizeOutOfBoundsException` when the size is negative or extends into an invalid range of memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`¹⁴⁰ has been registered with the `PhysicalMemoryManager`¹⁴¹.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the request type, or when **type** specifies incompatible memory attributes.

`OutOfMemoryError` when the requested type of memory exists, but there is not enough of it free to satisfy the request.

RawMemoryFloatAccess(Object, long, long)

Signature

```
public
RawMemoryFloatAccess(Object type,
                      long base,
                      long size)
```

¹³⁸Section 12.4.2.6.3

¹³⁹Section 12.4.2.6.3

¹⁴⁰Section A.3.1.1

¹⁴¹Section A.3.3.6

Description

Construct an instance of `RawMemoryFloatAccess` with the given parameters, and set the object to the mapped state. When the platform supports virtual memory, map the raw memory into virtual memory.

The run time environment is allowed to choose the virtual address where the raw memory area corresponding to this object will be mapped. The attributes of the mapping operation are controlled by the `VMFlags` and `VMAttributes` of the `PhysicalMemoryTypeFilter` objects that matched this object's `type` parameter. (See `PhysicalMemoryTypeFilter.getVMAttributes`¹⁴² and `PhysicalMemoryTypeFilter.getVMFlags`¹⁴³).

Deprecated since RTSJ version as of RTSJ 2.0. Use `javafx.realtime.device.RawMemoryFactory.createRawFloat(long, int, int)`¹⁴⁴ or `javafx.realtime.device.RawMemoryFactory.createRawDouble(RawMemoryRegistry, long, int, int)`¹⁴⁵.

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the region.

size The size of the area in bytes.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory, the specified range of addresses, or the given type of memory.

`OffsetOutOfBoundsException` when the address is invalid.

`SizeOutOfBoundsException` when the size is negative or extends into an invalid range of memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`¹⁴⁶ has been registered with the `PhysicalMemoryManager`¹⁴⁷.

¹⁴²Section A.3.1.1.1

¹⁴³Section A.3.1.1.1

¹⁴⁴Section 12.4.2.6.3

¹⁴⁵Section 12.4.2.6.3

¹⁴⁶Section A.3.1.1

¹⁴⁷Section A.3.3.6

MemoryTypeConflictException when the specified base does not point to memory that matches the request type, or when **type** specifies incompatible memory attributes.

OutOfMemoryError when the requested type of memory exists, but there is not

A.3.3.10.2 Methods

getDouble(long)

Signature

```
public  
double getDouble(long offset)
```

Description

Gets the **double** at the given offset in the memory area associated with this object.

The load is not required to be atomic even it is located on a natural boundary.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area from which to load the long.

Throws

OffsetOutOfBoundsException when the offset is invalid.

SizeOutOfBoundsException when the object is not mapped, or when the double falls in an invalid address range.

SecurityException when this access is not permitted by the security manager.

Returns

The double from raw memory.

getDoubles(long, double, int, int)

Signature

```

public
void getDoubles(long offset,
                double[] doubles,
                int low,
                int number)

```

Description

Gets **number** doubles starting at the given offset in the memory area associated with this object and assign them to the double array passed starting at position **low**.

The loads are not required to be atomic even when they are located on natural boundaries.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to start loading.

doubles The array into which the loaded items are placed.

low The offset which is the starting point in the given array for the loaded items to be placed.

number The number of doubles to load.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException** somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area. (See **RawMemoryAccess.map(long,long)**¹⁴⁸).

SizeOutOfBoundsException when the object is not mapped, or when a double falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The **doubles** array could, therefore, be partially updated when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when **low** is less than 0 or greater than **bytes.length - 1**, or when **low + number** is greater than or equal to **bytes.length**.

SecurityException when this access is not permitted by the security manager.

¹⁴⁸Section [A.3.3.9.2](#)

getFloat(long)

Signature

```
public  
float getFloat(long offset)
```

Description

Gets the `float` at the given offset in the memory area associated with this object. When the float is aligned on a "natural" boundary it is always loaded from memory in a single atomic operation. When it is not on a natural boundary it may not be loaded atomically, and the number and order of the load operations is unspecified.

Caching of the memory access is controlled by the memory `type` requested when the `RawMemoryAccess` instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area from which to load the float.

Throws

[OffsetOutOfBoundsException](#) when the offset is negative or greater than the size of the raw memory area. The role of the `SizeOutOfBoundsException` somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area. (See [RawMemoryAccess.map\(long, long\)](#)¹⁴⁹).

[SizeOutOfBoundsException](#) when the object is not mapped, or when the float falls in an invalid address range.

[SecurityException](#) when this access is not permitted by the security manager.

Returns

The float from raw memory.

getFloats(long, float, int, int)

Signature

```
public  
void getFloats(long offset,  
                float[] floats,
```

¹⁴⁹Section [A.3.3.9.2](#)

```
int low,  
int number)
```

Description

Gets **number** floats starting at the given offset in the memory area associated with this object and assign them to the int array passed starting at position **low**.

When the floats are aligned on natural boundaries each float is loaded from memory in a single atomic operation. Groups of floats may be loaded together, but this is unspecified.

When the floats are not aligned on natural boundaries they may not be loaded atomically and the number and order of load operations is unspecified.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to start loading.

floats The array into which the floats loaded from the raw memory are placed.

low The offset which is the starting point in the given array for the loaded items to be placed.

number The number of floats to loaded.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException** somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area. (See **RawMemoryAccess.map(long, long)**¹⁵⁰).

SizeOutOfBoundsException when the object is not mapped, or when a float falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The **floats** array could, therefore, be partially updated when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when **low** is less than 0 or greater than **bytes.length - 1**, or when **low + number** is greater than or equal to **bytes.length**.

SecurityException when this access is not permitted by the security manager.

¹⁵⁰Section [A.3.3.9.2](#)

setDouble(long, double)

Signature

```
public
void setDouble(long offset,
               double value)
```

Description

Sets the **double** at the given offset in the memory area associated with this object. Even when it is aligned, the double value may not be updated atomically. It is unspecified how many load and store operations will be used or in what order.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to write the double.

value The double to write.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException** somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area. (See **RawMemoryAccess.map(long,long)**¹⁵¹).

SizeOutOfBoundsException when the object is not mapped, or when the double falls in an invalid address range.

SecurityException when this access is not permitted by the security manager.

setDoubles(long, double, int, int)

Signature

```
public
void setDoubles(long offset,
               double[] doubles,
               int low,
               int number)
```

¹⁵¹Section [A.3.3.9.2](#)

Description

Sets **number** doubles starting at the given offset in the memory area associated with this object from the double array passed starting at position **low**. Even when they are aligned, the double values may not be updated atomically. It is unspecified how many load and store operations will be used or in what order.

Caching of the memory access is controlled by the memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to start writing.

doubles The array from which the items are obtained.

low The offset which is the starting point in the given array for the items to be obtained.

number The number of items to write.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException** somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area. (See **RawMemoryAccess.map(long,long)**¹⁵²).

SizeOutOfBoundsException when the object is not mapped, or when the a short falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The **doubles** array could, therefore, be partially updated when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when **low** is less than 0 or greater than **bytes.length - 1**, or when **low + number** is greater than or equal to **bytes.length**.

SecurityException when this access is not permitted by the security manager.

setFloat(long, float)*Signature*

```
public
void setFloat(long offset,
              float value)
```

¹⁵²Section [A.3.3.9.2](#)

Description

Sets the `float` at the given offset in the memory area associated with this object. On most processor architectures an aligned float can be stored in an atomic operation, but this is not required.

Caching of the memory access is controlled by the memory `type` requested when the `RawMemoryAccess` instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to write the integer.

value The float to write.

Throws

[OffsetOutOfBoundsException](#) when the offset is negative or greater than the size of the raw memory area. The role of the [SizeOutOfBoundsException](#) somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area. (See [RawMemoryAccess.map\(long, long\)](#)¹⁵³).

[SizeOutOfBoundsException](#) when the object is not mapped, or when the float falls in an invalid address range.

[SecurityException](#) when this access is not permitted by the security manager.

setFloats(long, float, int, int)

Signature

```
public
void setFloats(long offset,
               float[] floats,
               int low,
               int number)
```

Description

Sets `number` floats starting at the given offset in the memory area associated with this object from the float array passed starting at position `low`. On most processor architectures each aligned float can be stored in an atomic operation, but this is not required. Caching of the memory access is controlled by the

¹⁵³Section [A.3.3.9.2](#)

memory **type** requested when the **RawMemoryAccess** instance was created. When the memory is not cached, this method guarantees serialized access (that is, the memory access at the memory occurs in the same order as in the program. Multiple writes to the same location may not be coalesced.)

Parameters

offset The offset in bytes from the beginning of the raw memory area at which to start writing.

floats The array from which the items are obtained.

low The offset which is the starting point in the given array for the items to be obtained.

number The number of floats to write.

Throws

OffsetOutOfBoundsException when the offset is negative or greater than the size of the raw memory area. The role of the **SizeOutOfBoundsException** somewhat overlaps this exception since it is when the offset is within the object but outside the mapped area. (See **RawMemoryAccess.map(long, long)**¹⁵⁴).

SizeOutOfBoundsException when the object is not mapped, or when the float falls in an invalid address range. This is checked at every entry in the array to allow for the possibility that the memory area could be unmapped or remapped. The store of the array into memory could, therefore, be only partially complete when the raw memory is unmapped or remapped mid-method.

ArrayIndexOutOfBoundsException when **low** is less than 0 or greater than **bytes.length - 1**, or when **low + number** is greater than or equal to **bytes.length**.

SecurityException when this access is not permitted by the security manager.

A.3.3.11 ScopedMemory

Inheritance

```
java.lang.Object
    javax.realtime.MemoryArea
        javax.realtime.ScopedMemory
```

Description

ScopedMemory is the abstract base class of all classes dealing with representations of memory spaces which have a limited lifetime. In general, objects allocated in scoped memory are freed when (and only when) no schedulable object has access to the objects in the scoped memory.

¹⁵⁴Section [A.3.3.9.2](#)

A `ScopedMemory` area is a connection to a particular region of memory and reflects the current status of that memory. The object does not necessarily contain direct references to the region of memory. That is implementation dependent.

When a `ScopedMemory` area is instantiated, the object itself is allocated from the current memory allocation context, but the memory space that object represents (its backing store) is allocated from memory that is not otherwise directly visible to Java code; e.g., it might be allocated with the C `malloc` function. This backing store behaves effectively as if it were allocated when the associated scoped memory object is constructed and freed at that scoped memory object's finalization.

The `ScopedMemory.enter`¹⁵⁵ method of `ScopedMemory` is one mechanism used to make a memory area the current allocation context. The other mechanism for activating a memory area is making it the initial memory area for a realtime thread or async event handler. Entry into the scope is accomplished, for example, by calling the method:

```
public void enter(Runnable logic)
```

where `logic` is a instance of `Runnable` whose `run()` method represents the entry point of the code that will run in the new scope. Exit from the scope occurs between the time the `runnable.run()` method completes and the time control returns from the `enter` method. By default, allocations of objects within `runnable.run()` are taken from the backing store of the `ScopedMemory`.

`ScopedMemory` is an abstract class, but all specified methods include implementations. The responsibilities of `MemoryArea`, `ScopedMemory` and the classes that extend `ScopedMemory` are not specified. Application code should not extend `ScopedMemory` without detailed knowledge of its implementation.

Deprecated since RTSJ version since RTSJ 2.0

A.3.3.11.1 Constructors

ScopedMemory(long)

Signature

```
public  
    ScopedMemory(long size)
```

¹⁵⁵Section [A.3.3.11.2](#)

Description

Create a new `ScopedMemory` area with the given parameters.

Parameters

`size` of the new `ScopedMemory` area in bytes.

Throws

`IllegalArgumentException` when `size` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `ScopedMemory` object or for the backing memory.

`ScopedMemory(long, Runnable)`

Signature

```
public  
    ScopedMemory(long size,  
                  Runnable logic)
```

Description

Create a new `ScopedMemory` area with the given parameters.

Parameters

`size` The size of the new `ScopedMemory` area in bytes.

`logic` The `Runnable` to execute when this `ScopedMemory` is entered. When `logic` is `null`, this constructor is equivalent to constructing the memory area without a logic value.

Throws

`IllegalArgumentException` when `size` is less than zero.

`IllegalAssignmentError` when storing `logic` in this would violate the assignment rules.

`OutOfMemoryError` when there is insufficient memory for the `ScopedMemory` object or for the backing memory.

`ScopedMemory(SizeEstimator)`

Signature

```
public  
ScopedMemory(SizeEstimator size)
```

Description

Create a new `ScopedMemory` area with the given parameters.

Parameters

size The size of the new `ScopedMemory` area estimated by an instance of `SizeEstimator`¹⁵⁶.

Throws

`IllegalArgumentException` when `size` is null, or `size.getEstimate()` is negative.

`OutOfMemoryError` when there is insufficient memory for the `ScopedMemory` object or for the backing memory.

ScopedMemory(SizeEstimator, Runnable)

Signature

```
public  
ScopedMemory(SizeEstimator size,  
              Runnable logic)
```

Description

Create a new `ScopedMemory` area with the given parameters.

Parameters

size The size of the new `ScopedMemory` area estimated by an instance of `SizeEstimator`¹⁵⁷.

logic The logic which will use the memory represented by `this` as its initial memory area. When `logic` is null, this constructor is equivalent to constructing the memory area without a logic value.

Throws

`IllegalArgumentException` when `size` is null, or `size.getEstimate()` is negative.

`OutOfMemoryError` when there is insufficient memory for the `ScopedMemory` object or for the backing memory.

¹⁵⁶Section 11.4.2.5

¹⁵⁷Section 11.4.2.5

`IllegalAssignmentError` when storing logic in `this` would violate the assignment rules.

A.3.3.11.2 Methods

enter

Signature

```
public  
void enter()
```

Description

Associate this memory area with the current schedulable for the duration of the execution of the `run()` method of the instance of `Runnable` given in the constructor. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected (using `enter`, or `executeInArea`¹⁵⁸) or the `enter` method exits.

Throws

`ScopedCycleException` when this invocation would break the single parent rule.

`ThrowBoundaryError` Thrown when the JVM needs to propagate an exception allocated in `this` scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `IllegalAssignmentError`¹⁵⁹, so the JVM cannot be permitted to deliver the exception. The `ThrowBoundaryError`¹⁶⁰ is allocated in the current allocation context and contains information about the exception it replaces.

`IllegalThreadStateException` when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

`IllegalArgumentException` `IllegalArgumentException` when the caller is a schedulable and a `null` value for `logic` was supplied when the memory area was constructed.

¹⁵⁸Section A.3.3.11.2

¹⁵⁹Section 15.3.3.2

¹⁶⁰Section 15.3.3.8

MemoryAccessError MemoryAccessError when caller is a schedulable that may not use the heap and this memory area's logic value is allocated in heap memory.

enter(Runnable)

Signature

```
public
void enter(Runnable logic)
```

Description

Associate this memory area with the current schedulable for the duration of the execution of the `run()` method of the given **Runnable**. During this period of execution, this memory area becomes the default allocation context until another default allocation context is selected (using `enter`, or `executeInArea`¹⁶¹) or the `enter` method exits.

Parameters

logic logic The Runnable object whose `run()` method should be invoked.

Throws

ScopedCycleException when this invocation would break the single parent rule.

ThrowBoundaryError Thrown when the JVM needs to propagate an exception allocated in **this** scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an **IllegalAssignmentError**¹⁶², so the JVM cannot be permitted to deliver the exception. The **ThrowBoundaryError**¹⁶³ is allocated in the current allocation context and contains information about the exception it replaces.

IllegalThreadStateException when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

IllegalArgumentException IllegalArgumentException when the caller is a schedulable and **logic** is `null`.

¹⁶¹Section [A.3.3.11.2](#)

¹⁶²Section [15.3.3.2](#)

¹⁶³Section [15.3.3.8](#)

executeInArea(Runnable)

Signature

```
public  
void executeInArea(Runnable logic)
```

Description

Execute the run method from the `logic` parameter using this memory area as the current allocation context. This method behaves as if it moves the allocation context down the scope stack to the occurrence of `this`.

Parameters

`logic` The runnable object whose `run()` method should be executed.

Throws

`IllegalThreadStateException` when the caller is a Java thread.

`InaccessibleAreaException` when the memory area is not in the schedulable's scope stack.

`IllegalArgumentException` when the caller is a schedulable and `logic` is null.

getPortal

Signature

```
public  
java.lang.Object getPortal()
```

Description

Return a reference to the portal object in this instance of `ScopedMemory`.

Assignment rules are enforced on the value returned by `getPortal` as if the return value were first stored in an object allocated in the current allocation context, then moved to its final destination.

Throws

`IllegalAssignmentError` when a reference to the portal object cannot be stored in the caller's allocation context; that is, when `this` is "inner" relative to the current allocation context or not on the caller's scope stack.

`IllegalThreadStateException` when the caller is a Java thread.

Returns

A reference to the portal object or `null` when there is no portal object. The portal value is always set to `null` when the contents of the memory are deleted.

getReferenceCount

Signature

```
public  
int getReferenceCount()
```

Description

Returns the reference count of this `ScopedMemory`.

Note: A reference count of 0 reliably means that the scope is not referenced, but other reference counts are subject to artifacts of lazy/eager maintenance by the implementation.

Returns

The reference count of this `ScopedMemory`.

join

Signature

```
public  
void join()  
throws InterruptedException
```

Description

Wait until the reference count of this `ScopedMemory` goes down to zero. Return immediately when the memory is unreferenced.

Throws

`InterruptedException` When this schedulable is interrupted by `RealtimeThread.interrupt()`¹⁶⁴ or `AsynchronouslyInterruptedException.fire()`¹⁶⁵ while waiting for the reference count to go to zero.

`IllegalThreadStateException` when the caller is a Java thread.

join(HighResolutionTime)

Signature

```
public  
void join(javax.realtime.HighResolutionTime<?> time)
```

¹⁶⁴Section 5.4.1

¹⁶⁵Section 8.4.2.1.2

throws `InterruptedException`

Description

Wait at most until the time designated by the `time` parameter for the reference count of this `ScopedMemory` to drop to zero. Return immediately when the memory area is unreferenced.

Since the time is expressed as a `HighResolutionTime`¹⁶⁶, this method is an accurate timer with nanosecond granularity. The actual resolution of the timer and even the quantity it measures depends on the clock associated with `time`. The delay time may be relative or absolute. When relative, then the delay is the amount of time given by `time`, and measured by its associated clock. When absolute, then the delay is until the indicated value is reached by the clock. When the given absolute time is less than or equal to the current value of the clock, the call to `join` returns immediately.

Parameters

`time` When this time is an absolute time, the wait is bounded by that point in time. When the time is a relative time (or a member of the `RationalTime` subclass of `RelativeTime`) the wait is bounded by a the specified interval from some time between the time `join` is called and the time it starts waiting for the reference count to reach zero.

Throws

`InterruptedException` When this schedulable is interrupted by `RealtimeThread.interrupt()`¹⁶⁷ or `AsynchronouslyInterruptedException.fire()`¹⁶⁸ while waiting for the reference count to go to zero.

`IllegalThreadStateException` when the caller is a Java thread.

`IllegalArgumentException` when the caller is a schedulable and `time` is `null`.

`UnsupportedOperationException` when the wait operation is not supported using the clock associated with `time`.

joinAndEnter

Signature

```
public
void joinAndEnter()
throws InterruptedException
```

¹⁶⁶Section 9.4.1.2

¹⁶⁷Section 5.4.1

¹⁶⁸Section 8.4.2.1.2

Description

In the error-free case, `joinAndEnter` combines `join();enter();` such that no `enter()` from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this `ScopedMemory` to reach zero, then enter the `ScopedMemory` and execute the `run` method from `logic` passed in the constructor. When no instance of `Runnable` was passed to the memory area's constructor, the method throws `IllegalArgumentException` immediately.

When multiple threads are waiting in `joinAndEnter` family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Note that although `joinAndEnter` guarantees that the reference count is zero when the schedulable is released for entry, it does not guarantee that the reference count will remain one for any length of time. A subsequent `enter` could raise the reference count to two.

Throws

InterruptedException When this schedulable is interrupted by `RealtimeThread.interrupt()`¹⁶⁹ or `AsynchronouslyInterruptedException.fire()`¹⁷⁰ while waiting for the reference count to go to zero.

IllegalThreadStateException when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

ThrowBoundaryError Thrown when the JVM needs to propagate an exception allocated in *this* scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `IllegalAssignmentError`¹⁷¹, so the JVM cannot be permitted to deliver the exception. The `ThrowBoundaryError`¹⁷² is allocated in the current allocation context and contains information about the exception it replaces.

ScopedCycleException when this invocation would break the single parent rule.

IllegalArgumentException when the caller is a schedulable and no non-null `logic` value was supplied to the memory area's constructor.

¹⁶⁹Section 5.4.1

¹⁷⁰Section 8.4.2.1.2

¹⁷¹Section 15.3.3.2

¹⁷²Section 15.3.3.8

MemoryAccessError when caller is a non-heap schedulable and this memory area's logic value is allocated in heap memory.

joinAndEnter(HighResolutionTime)

Signature

```
public  
void joinAndEnter(javax.realtime.HighResolutionTime<?> time)  
throws InterruptedException
```

Description

In the error-free case, `joinAndEnter` combines `join();enter();` such that no `enter()` from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this **ScopedMemory** to reach zero, or for the current time to reach the designated time, then enter the **ScopedMemory** and execute the `run` method from **Runnable** object passed to the constructor. When no instance of **Runnable** was passed to the memory area's constructor, the method throws **IllegalArgumentException** immediately. *

When multiple threads are waiting in `joinAndEnter` family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Since the time is expressed as a **HighResolutionTime**¹⁷³, this method has an accurate timer with nanosecond granularity. The actual resolution of the timer and even the quantity it measures depends on the clock associated with `time`. The delay time may be relative or absolute. When relative, then the calling thread is blocked for at most the amount of time given by `time`, and measured by its associated clock. When absolute, then the time delay is until the indicated value is reached by the clock. When the given absolute time is less than or equal to the current value of the clock, the call to `joinAndEnter` behaves effectively like `enter`¹⁷⁴.

Note that expiration of `time` may cause control to enter the memory area before its reference count has gone to zero.

Parameters

`time` The time that bounds the wait.

Throws

ThrowBoundaryError Thrown when the JVM needs to propagate an exception allocated in `this` scope to (or through) the memory area of the caller. Storing

¹⁷³Section 9.4.1.2

¹⁷⁴Section A.3.3.11.2

a reference to that exception would cause an `IllegalAssignmentError`¹⁷⁵, so the JVM cannot be permitted to deliver the exception. The `ThrowBoundaryError`¹⁷⁶ is allocated in the current allocation context and contains information about the exception it replaces.

InterruptedException When this schedulable is interrupted by `RealtimeThread.interrupt()`¹⁷⁷ or `AsynchronouslyInterruptedException.fire()`¹⁷⁸ while waiting for the reference count to go to zero.

IllegalThreadStateException when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

ScopedCycleException when the caller is a schedulable and this invocation would break the single parent rule.

IllegalArgumentException when the caller is a schedulable, and `time` is `null` or `null` was supplied as `logic` value to the memory area's constructor.

UnsupportedOperationException when the wait operation is not supported using the clock associated with `time`.

MemoryAccessError when the calling schedulable may not use the heap and this memory area's `logic` value is allocated in heap memory.

joinAndEnter(Runnable)

Signature

```
public
void joinAndEnter(Runnable logic)
throws InterruptedException
```

Description

In the error-free case, `joinAndEnter` combines `join();enter();` such that no `enter()` from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this `ScopedMemory` to reach zero, then enter the `ScopedMemory` and execute the `run` method from `logic`

When `logic` is `null`, throw `IllegalArgumentException` immediately.

¹⁷⁵Section 15.3.3.2

¹⁷⁶Section 15.3.3.8

¹⁷⁷Section 5.4.1

¹⁷⁸Section 8.4.2.1.2

When multiple threads are waiting in `joinAndEnter` family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Note that although `joinAndEnter` guarantees that the reference count is zero when the schedulable is released for entry, it does not guarantee that the reference count will remain one for any length of time. A subsequent `enter` could raise the reference count to two.

Parameters

`logic` The `Runnable` object which contains the code to execute.

Throws

`InterruptedException` When this schedulable is interrupted by `RealtimeThread.interrupt()`¹⁷⁹ or `AsynchronouslyInterruptedException.fire()`¹⁸⁰ while waiting for the reference count to go to zero.

`IllegalThreadStateException` when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

`ThrowBoundaryError` Thrown when the JVM needs to propagate an exception allocated in *this* scope to (or through) the memory area of the caller. Storing a reference to that exception would cause an `IllegalAssignmentError`¹⁸¹, so the JVM cannot be permitted to deliver the exception. The `ThrowBoundaryError`¹⁸² is allocated in the current allocation context and contains information about the exception it replaces.

`ScopedCycleException` when this invocation would break the single parent rule.

`IllegalArgumentException` when the caller is a schedulable and `logic` is `null`.

`joinAndEnter(Runnable, HighResolutionTime)`

Signature

```
public
void joinAndEnter(Runnable logic,
                  javax.realtime.HighResolutionTime<?> time)
```

¹⁷⁹Section 5.4.1

¹⁸⁰Section 8.4.2.1.2

¹⁸¹Section 15.3.3.2

¹⁸²Section 15.3.3.8

throws `InterruptedException`

Description

In the error-free case, `joinAndEnter` combines `join();enter();` such that no `enter()` from another schedulable can intervene between the two method invocations. The resulting method will wait for the reference count on this `ScopedMemory` to reach zero, or for the current time to reach the designated time, then enter the `ScopedMemory` and execute the `run` method from `logic`.

Since the time is expressed as a `HighResolutionTime`¹⁸³, this method is an accurate timer with nanosecond granularity. The actual resolution of the timer and even the quantity it measures depends on the clock associated with `time`. The delay time may be relative or absolute. When relative, then the delay is the amount of time given by `time`, and measured by its associated clock. When absolute, then the delay is until the indicated value is reached by the clock. When the given absolute time is less than or equal to the current value of the clock, the call to `joinAndEnter` behaves effectively like `enter(Runnable)`¹⁸⁴.

Throws `IllegalArgumentException` immediately when `logic` is `null`.

When multiple threads are waiting in `joinAndEnter` family methods for a memory area, at most *one* of them will be released each time the reference count goes to zero.

Note that expiration of `time` may cause control to enter the memory area before its reference count has gone to zero.

Parameters

`logic` The `Runnable` object which contains the code to execute.

`time` The time that bounds the wait.

Throws

`InterruptedException` When this schedulable is interrupted by `RealtimeThread.interrupt()`¹⁸⁵ or `AsynchronouslyInterruptedException.fire()`¹⁸⁶ while waiting for the reference count to go to zero.

`IllegalThreadStateException` when the caller is a Java thread, or when this method is invoked during finalization of objects in scoped memory and entering this scoped memory area would force deletion of the SO that triggered finalization. This would include the scope containing the SO, and the scope (if any) containing the scope containing the SO.

`ThrowBoundaryError` Thrown when the JVM needs to propagate an exception allocated in `this` scope to (or through) the memory area of the caller. Storing

¹⁸³Section 9.4.1.2

¹⁸⁴Section A.3.3.11.2

¹⁸⁵Section 5.4.1

¹⁸⁶Section 8.4.2.1.2

a reference to that exception would cause an `IllegalAssignmentError`¹⁸⁷, so the JVM cannot be permitted to deliver the exception. The `ThrowBoundaryError`¹⁸⁸ is allocated in the current allocation context and contains information about the exception it replaces.

`ScopedCycleException` when the caller is a schedulable and this invocation would break the single parent rule.

`IllegalArgumentException` when the caller is a schedulable and `time` or `logic` is `null`.

`UnsupportedOperationException` when the wait operation is not supported using the clock associated with `time`.

newArray(Class, int)

Signature

```
public
java.lang.Object newArray(java.lang.Class<?> type,
                           int number)
```

Description

Allocate an array of the given type in this memory area. This method may be concurrently used by multiple threads.

Parameters

type `type` The class of the elements of the new array. To create an array of a primitive type use a `type` such as `Integer.TYPE` (which would call for an array of the primitive `int` type.)

number `number` The number of elements in the new array.

Throws

`IllegalArgumentException` `IllegalArgumentException` when `number` is less than zero, `type` is `null`, or `type` is `java.lang.Void.TYPE`.

`OutOfMemoryError` `OutOfMemoryError` when space in the memory area is exhausted.

`IllegalThreadStateException` when the caller is a Java thread.

`InaccessibleAreaException` when the memory area is not in the schedulable's scope stack.

Returns

¹⁸⁷Section 15.3.3.2

¹⁸⁸Section 15.3.3.8

A new array of class type, of number elements.

newInstance(Class)

Signature

```
public  
T newInstance(java.lang.Class<T> type)  
throws IllegalAccessException,  
    InstantiationException
```

Description

Allocate an object in this memory area. This method may be concurrently used by multiple threads.

Parameters

type type The class of which to create a new instance.

Throws

IllegalAccessException IllegalAccessException The class or initializer is inaccessible.

IllegalArgumentException IllegalArgumentException when **type** is **null**.

ExceptionInInitializerError ExceptionInInitializerError when an unexpected exception has occurred in a static initializer

OutOfMemoryError OutOfMemoryError when space in the memory area is exhausted.

InstantiationException InstantiationException when the specified class object could not be instantiated. Possible causes are: it is an interface, it is abstract, it is an array, or an exception was thrown by the constructor.

IllegalThreadStateException when the caller is a Java thread.

InaccessibleAreaException when the memory area is not in the schedulable's scope stack.

Returns

A new instance of class **type**.

newInstance(Constructor, Object)

Signature

```
public  
T newInstance(java.lang.reflect.Constructor<T> c,
```

```
        java.lang.Object[] args)
throws IllegalAccessException,
       InstantiationException,
       InvocationTargetException
```

Description

Allocate an object in this memory area. This method may be concurrently used by multiple threads.

Parameters

c Tc The constructor for the new instance.

args args An array of arguments to pass to the constructor.

Throws

IllegalAccessException IllegalAccessException when the class or initializer is inaccessible under Java access control.

InstantiationException InstantiationException when the specified class object could not be instantiated. Possible causes are: it is an interface, it is abstract, it is an array.

OutOfMemoryError OutOfMemoryError when space in the memory area is exhausted.

IllegalArgumentException IllegalArgumentException when **c** is **null**, or the **args** array does not contain the number of arguments required by **c**. A **null** value of **args** is treated like an array of length 0.

IllegalThreadStateException when the caller is a Java thread.

InvocationTargetException InvocationTargetException when the underlying constructor throws an exception.

InaccessibleAreaException when the memory area is not in the schedulable's scope stack.

Returns

A new instance of the object constructed by **c**.

setPortal(Object)

Signature

```
public
void setPortal(Object object)
```

Description

Sets the *portal* object of the memory area represented by this instance of **ScopedMemory** to the given object. The object must have been allocated in this **ScopedMemory** instance.

Parameters

object The object which will become the portal for this. When **null** the previous portal object remains the portal object for this or when there was no previous portal object then there is still no portal object for **this**.

Throws

IllegalThreadStateException when the caller is a Java Thread.

IllegalAssignmentError when the caller is a schedulable, and **object** is not allocated in this scoped memory instance and not **null**.

InaccessibleAreaException when the caller is a schedulable, **this** memory area is not in the caller's scope stack and **object** is not **null**.

toString

Signature

```
public  
java.lang.String toString()
```

Description

Returns a user-friendly representation of this **ScopedMemory** of the form **ScopedMemory#<num>** where **<num>** is a number that uniquely identifies this scoped memory area.

Returns

The string representation

A.3.3.12 VTMemory

Inheritance

```
java.lang.Object  
  javax.realtime.MemoryArea  
    javax.realtime.ScopedMemory  
      javax.realtime.VTMemory
```

Description

VTMemory is similar to [LTMemory](#)¹⁸⁹ except that the execution time of an allocation from a VTMemory area need not complete in linear time.

Methods from VTMemory should be overridden only by methods that use `super`.

Deprecated since RTSJ version as of RTSJ 2.0

A.3.3.12.1 Constructors

VTMemory(long, long)

Signature

```
public
    VTMemory(long initial,
              long maximum)
```

Description

Creates a VTMemory with the given parameters.

Parameters

initial The size in bytes of the memory to initially allocate for this area.
maximum The maximum size in bytes this memory area to which the size may grow.

Throws

`IllegalArgumentException` when **initial** is greater than **maximum** or when **initial** or **maximum** is less than zero.
`OutOfMemoryError` when there is insufficient memory for the VTMemory object or for the backing memory.

VTMemory(long, long, Runnable)

Signature

¹⁸⁹Section [A.3.3.2](#)

```
public
VTMemory(long initial,
         long maximum,
         Runnable logic)
```

Description

Creates a `VTMemory` with the given parameters.

Parameters

initial The size in bytes of the memory to initially allocate for this area.

maximum The maximum size in bytes this memory area to which the size may grow.

logic An instance of `Runnable` whose `run()` method will use `this` as its initial memory area. When `logic` is `null`, this constructor is equivalent to `VTMemory(long initial, long maximum)`¹⁹⁰.

Throws

`IllegalArgumentException` when `initial` is greater than `maximum`, or when `initial` or `maximum` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `VTMemory` object or for the backing memory.

`IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

VTMemory(SizeEstimator, SizeEstimator)

Signature

```
public
VTMemory(SizeEstimator initial,
         SizeEstimator maximum)
```

Description

Creates a `VTMemory` with the given parameters.

Parameters

initial The size in bytes of the memory to initially allocate for this area.

maximum The maximum size in bytes this memory area to which the size may grow estimated by an instance of `SizeEstimator`¹⁹¹.

¹⁹⁰Section [A.3.3.12.1](#)

¹⁹¹Section [11.4.2.5](#)

Throws

`IllegalArgumentException` when `initial` is null, `maximum` is null, `initial.getEstimate()` is greater than `maximum.getEstimate()`, or when `initial.getEstimate()` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `VTMemory` object or for the backing memory.

VTMemory(SizeEstimator, SizeEstimator, Runnable)*Signature*

```
public
VTMemory(SizeEstimator initial,
          SizeEstimator maximum,
          Runnable logic)
```

Description

Creates a `VTMemory` with the given parameters.

Parameters

initial The size in bytes of the memory to initially allocate for this area.

maximum The maximum size in bytes this memory area to which the size may grow estimated by an instance of `SizeEstimator`¹⁹².

logic An instance of `Runnable` whose `run()` method will use `this` as its initial memory area. When `logic` is null, this constructor is equivalent to `VTMemory(SizeEstimator initial, SizeEstimator maximum)`¹⁹³.

Throws

`IllegalArgumentException` when `initial` is null, `maximum` is null, `initial.getEstimate()` is greater than `maximum.getEstimate()`, or when `initial.getEstimate()` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `VTMemory` object or for the backing memory.

`IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

¹⁹²Section 11.4.2.5

¹⁹³Section A.3.3.12.1

VTMemory(long)

Signature

```
public  
VTMemory(long size)
```

Description

Create an `VTMemory` of the given size. This constructor is equivalent to `VTMemory(size, size)`

Available since RTSJ 1.0.1

Parameters

size The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

Throws

`IllegalArgumentException` when **size** is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `VTMemory` object or for the backing memory.

VTMemory(long, Runnable)

Signature

```
public  
VTMemory(long size,  
          Runnable logic)
```

Description

Create an `VTMemory` of the given size. This constructor is equivalent to `VTMemory(size, size, logic)`.

Available since RTSJ 1.0.1

Parameters

size The size in bytes of the memory to allocate for this area. This memory must be committed before the completion of the constructor.

`logic` The `run()` of the given `Runnable` will be executed using `this` as its initial memory area. When `logic` is `null`, this constructor is equivalent to `VTMemory(long size)`¹⁹⁴.

Throws

`IllegalArgumentException` when `size` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `VTMemory` object or for the backing memory.

`IllegalAssignmentError` when storing `logic` in `this` would violate the assignment rules.

VTMemory(SizeEstimator)

Signature

```
public
VTMemory(SizeEstimator size)
```

Description

Create an `VTMemory` of the given size. This constructor is equivalent to `VTMemory(size, size)`.

Available since RTSJ 1.0.1

Parameters

`size` An instance of `SizeEstimator`¹⁹⁵ used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

Throws

`IllegalArgumentException` when `size` is `null`, or `size.getEstimate()` is less than zero.

`OutOfMemoryError` when there is insufficient memory for the `VTMemory` object or for the backing memory.

VTMemory(SizeEstimator, Runnable)

Signature

¹⁹⁴Section [A.3.3.12.1](#)

¹⁹⁵Section [11.4.2.5](#)


```
public
VTMemory(SizeEstimator size,
         Runnable logic)
```

Description

Create an VTMemory of the given size.

Available since RTSJ 1.0.1

Parameters

size An instance of [SizeEstimator](#)¹⁹⁶ used to give an estimate of the initial size. This memory must be committed before the completion of the constructor.

logic The run() of the given Runnable will be executed using **this** as its initial memory area. When **logic** is **null**, this constructor is equivalent to [VTMemory\(SizeEstimator initial\)](#)¹⁹⁷.

Throws

IllegalArgumentException when **size** is **null**, or **size.getEstimate()** is less than zero.

OutOfMemoryError when there is insufficient memory for the VTMemory object or for the backing memory.

IllegalAssignmentError when storing **logic** in **this** would violate the assignment rules.

A.3.3.12.2 Methods

toString

Signature

```
public
java.lang.String toString()
```

Description

Create a string representing this object. The string is of the form (VTMemory) Scoped memory # num where **num** uniquely identifies the VTMemory area.

¹⁹⁶Section [11.4.2.5](#)

¹⁹⁷Section [A.3.3.12.1](#)

Returns

A string representing the value of `this`.

A.3.3.13 VTPhysicalMemory

Inheritance

```
java.lang.Object
  javax.realtime.MemoryArea
    javax.realtime.ScopedMemory
      javax.realtime.VTPhysicalMemory
```

Description

An instance of `VTPhysicalMemory` allows objects to be allocated from a range of physical memory with particular attributes, determined by their memory type. This memory area has the same semantics as `ScopedMemory`¹⁹⁸ memory areas, and the same performance restrictions as `VTMemory`.

No provision is made for sharing object in `VTPhysicalMemory` with entities outside the JVM that creates them, and, while the memory backing an instance of `VTPhysicalMemory` could be shared by multiple JVMs, the class does not support such sharing.

Methods from `VTPhysicalMemory` should be overridden only by methods that use `super`.

See Section [MemoryArea](#)

See Section [ScopedMemory](#)

See Section [VTMemory](#)

See Section [LTMemory](#)

See Section [LTPhysicalMemory](#)

See Section [ImmortalPhysicalMemory](#)

See Section [RealtimeThread](#)

See Section [NoHeapRealtimeThread](#)

¹⁹⁸Section [A.3.3.11](#)

Deprecated since RTSJ version since RTSJ 2.0

A.3.3.13.1 Constructors

VTPhysicalMemory(Object, long)

Signature

```
public
VTPhysicalMemory(Object type,
                  long size)
```

Description

Create an instance of `VTPhysicalMemory` with the given parameters.

See [Section PhysicalMemoryManager](#)

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

size The size of the area in bytes.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given range of memory.

`SizeOutOfBoundsException` when the implementation detects that **size** extends beyond physically addressable memory.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`¹⁹⁹ has been registered with the `PhysicalMemoryManager`²⁰⁰.

¹⁹⁹Section [A.3.1.1](#)

²⁰⁰Section [A.3.3.6](#)

MemoryTypeConflictException when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

IllegalArgumentException when **size** is less than zero.

VTPhysicalMemory(Object, long, long)

Signature

```
public
VTPhysicalMemory(Object type,
                  long base,
                  long size)
```

Description

Create an instance of **VTPhysicalMemory** with the given parameters.

See Section [PhysicalMemoryManager](#)

Parameters

type An instance of **Object** representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is **null** or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (**==**), not by value (**equals**).

base The physical memory address of the area.

size The size of the area in bytes.

Throws

SecurityException when the application doesn't have permissions to access physical memory or the given range of memory.

SizeOutOfBoundsException when the implementation detects that **size** extends beyond physically addressable memory.

OffsetOutOfBoundsException when the **base** address is invalid.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryTypeFilter**²⁰¹ has been registered with the **PhysicalMemoryManager**²⁰².

²⁰¹Section [A.3.1.1](#)

²⁰²Section [A.3.3.6](#)

MemoryTypeConflictException when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

MemoryInUseException when the specified memory is already in use.

VTPhysicalMemory(Object, SizeEstimator)

Signature

```
public
VTPhysicalMemory(Object type,
                  SizeEstimator size)
```

Description

Create an instance of **VTPhysicalMemory** with the given parameters.

See Section [PhysicalMemoryManager](#)

Parameters

type An instance of **Object** representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is **null** or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (**==**), not by value (**equals**).

size A size estimator for this area.

Throws

SecurityException when the application doesn't have permissions to access physical memory or the given range of memory.

SizeOutOfBoundsException when the implementation detects that the size estimate from **size** extends beyond physically addressable memory.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryTypeFilter**²⁰³ has been registered with the **PhysicalMemoryManager**²⁰⁴.

MemoryTypeConflictException when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

²⁰³Section [A.3.1.1](#)

²⁰⁴Section [A.3.3.6](#)

`IllegalArgumentException` when `size` is null, or `size.getEstimate()` is negative.

VTPhysicalMemory(Object, long, SizeEstimator)

Signature

```
public
VTPhysicalMemory(Object type,
                  long base,
                  SizeEstimator size)
```

Description

Create an instance of `VTPhysicalMemory` with the given parameters.

See [Section PhysicalMemoryManager](#)

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is null or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the area.

size A size estimator for this memory area.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given range of memory.

`SizeOutOfBoundsException` when the implementation detects that the size estimate from **size** extends beyond physically addressable memory.

`OffsetOutOfBoundsException` when the **base** address is invalid.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`²⁰⁵ has been registered with the `PhysicalMemoryManager`²⁰⁶.

²⁰⁵Section [A.3.1.1](#)

²⁰⁶Section [A.3.3.6](#)

MemoryTypeConflictException when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

MemoryInUseException when the specified memory is already in use.

IllegalArgumentException when **size** is **null**, or **size.getEstimate()** is negative.

VTPhysicalMemory(Object, long, Runnable)

Signature

```
public
VTPhysicalMemory(Object type,
                  long size,
                  Runnable logic)
```

Description

Create an instance of **VTPhysicalMemory** with the given parameters.

See [Section PhysicalMemoryManager](#)

Parameters

type An instance of **Object** representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is **null** or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (**==**), not by value (**equals**).

size The size of the area in bytes.

logic The **run()** method of this object will be called whenever **MemoryArea.enter()**²⁰⁷ is called. When **logic** is **null**, **logic** must be supplied when the memory area is entered.

Throws

SecurityException when the application doesn't have permissions to access physical memory or the given range of memory.

SizeOutOfBoundsException when the implementation detects that **size** extends beyond physically addressable memory.

²⁰⁷Section 11.4.2.3.2

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryTypeFilter**²⁰⁸ has been registered with the **PhysicalMemoryManager**²⁰⁹.

MemoryTypeConflictException when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

IllegalAssignmentError when storing logic in this would violate the assignment rules.

VTPhysicalMemory(Object, long, long, Runnable)

Signature

```
public
VTPhysicalMemory(Object type,
                  long base,
                  long size,
                  Runnable logic)
```

Description

Create an instance of **VTPhysicalMemory** with the given parameters.

See Section **PhysicalMemoryManager**

Parameters

type An instance of **Object** representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is **null** or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (**==**), not by value (**equals**).

base The physical memory address of the area.

size The size of the area in bytes.

logic The **run()** method of this object will be called whenever **MemoryArea.enter()**²¹⁰ is called. When **logic** is **null**, **logic** must be supplied when the memory area is entered.

²⁰⁸Section [A.3.1.1](#)

²⁰⁹Section [A.3.3.6](#)

²¹⁰Section [11.4.2.3.2](#)

Throws

SizeOutOfBoundsException when the implementation detects that **size** extends beyond physically addressable memory.

SecurityException when the application doesn't have permissions to access physical memory or the given range of memory.

OffsetOutOfBoundsException when the **base** address is invalid.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryTypeFilter**²¹¹ has been registered with the **PhysicalMemoryManager**²¹².

MemoryTypeConflictException when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

MemoryInUseException when the specified memory is already in use.

IllegalAssignmentError when storing **logic** in **this** would violate the assignment rules.

VTPhysicalMemory(Object, SizeEstimator, Runnable)

Signature

```
public
VTPhysicalMemory(Object type,
                  SizeEstimator size,
                  Runnable logic)
```

Description

Create an instance of **VTPhysicalMemory** with the given parameters.

See Section [PhysicalMemoryManager](#)

Parameters

type An instance of **Object** representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is **null** or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (**==**), not by value (**equals**).

²¹¹Section [A.3.1.1](#)

²¹²Section [A.3.3.6](#)

size A size estimator for this area.

logic The `run()` method of this object will be called whenever `MemoryArea.enter()`²¹³ is called. When **logic** is `null`, **logic** must be supplied when the memory area is entered.

Throws

SecurityException when the application doesn't have permissions to access physical memory or the given range of memory.

SizeOutOfBoundsException when the implementation detects that the size estimate from **size** extends beyond physically addressable memory.

UnsupportedPhysicalMemoryException when the underlying hardware does not support the given type, or when no matching **PhysicalMemoryTypeFilter**²¹⁴ has been registered with the **PhysicalMemoryManager**²¹⁵.

MemoryTypeConflictException when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

IllegalArgumentException when **size** is `null`, or `size.getEstimate()` is negative.

IllegalAssignmentError when storing **logic** in this would violate the assignment rules.

VTPhysicalMemory(Object, long, SizeEstimator, Runnable)

Signature

```
public
VTPhysicalMemory(Object type,
                  long base,
                  SizeEstimator size,
                  Runnable logic)
```

Description

Create an instance of `VTPhysicalMemory` with the given parameters.

See Section `PhysicalMemoryManager`

²¹³Section 11.4.2.3.2

²¹⁴Section A.3.1.1

²¹⁵Section A.3.3.6

Parameters

type An instance of `Object` representing the type of memory required (e.g., *dma*, *shared*) - used to define the base address and control the mapping. When the required memory has more than one attribute, **type** may be an array of objects. When **type** is `null` or a reference to an array with no entries, any type of memory is acceptable. Note that **type** values are compared by reference (`==`), not by value (`equals`).

base The physical memory address of the area.

size A size estimator for this memory area.

logic The `run()` method of this object will be called whenever `MemoryArea.enter()`²¹⁶ is called. When **logic** is `null`, **logic** must be supplied when the memory area is entered.

Throws

`SecurityException` when the application doesn't have permissions to access physical memory or the given range of memory.

`SizeOutOfBoundsException` when the implementation detects that the size estimate from **size** extends beyond physically addressable memory.

`OffsetOutOfBoundsException` when the **base** address is invalid.

`UnsupportedPhysicalMemoryException` when the underlying hardware does not support the given type, or when no matching `PhysicalMemoryTypeFilter`²¹⁷ has been registered with the `PhysicalMemoryManager`²¹⁸.

`MemoryTypeConflictException` when the specified base does not point to memory that matches the requested type, or when **type** specifies incompatible memory attributes.

`MemoryInUseException` when the specified memory is already in use.

`IllegalArgumentException` when **size** is `null`, or `size.getEstimate()` is negative.

`IllegalAssignmentError` when storing **logic** in **this** would violate the assignment rules.

A.3.3.13.2 Methods

²¹⁶Section 11.4.2.3.2

²¹⁷Section A.3.1.1

²¹⁸Section A.3.3.6

toString

Signature

```
public  
java.lang.String toString()
```

Description

Creates a string representing this object. The string is of the form (VTPPhysicalMemory) Scoped memory # num where num is a number that uniquely identifies this VTPPhysicalMemory memory area.

Returns

A string representing the value of `this`.

A.3.3.14 WaitFreeDequeue

Inheritance

```
java.lang.Object  
  javafx.realtime.WaitFreeDequeue
```

Description

A `WaitFreeDequeue` encapsulates a `WaitFreeWriteQueue` and a `WaitFreeReadQueue`. Each method on a `WaitFreeDequeue` corresponds to an equivalent operation on the underlying `WaitFreeWriteQueue` or `WaitFreeReadQueue`.

Incompatibility with V1.0: Three exceptions previously thrown by the constructor have been deleted from the `throws` clause. These are:

- `java.lang.IllegalAccessException`,
- `java.lang.ClassNotFoundException`, and
- `java.lang.InstantiationException`.

Including these exceptions on the `throws` clause was an error. Their deletion may cause compile-time errors in code using the previous constructor. The repair is to remove the exceptions from the `catch` clause around the constructor invocation.

`WaitFreeDequeue` is one of the classes allowing `NoHeapRealtimeThreads` and regular Java threads to synchronize on an object without the risk of a `NoHeap-RealtimeThread` incurring Garbage Collector latency due to priority inversion avoidance management.

Deprecated since RTSJ version as of RTSJ 1.0.1

A.4 Rationale

These are interface and classes that have been shown to be less the ideal. They have been replaced by interfaces and classes that better fulfill the requirements. Compatibility can be provided by implemenations that use existing facilities so there is not reason to continue requiring their inclusion new implementations.

Appendix B

Bibliography

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