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The Next Generation of the Real-Time Specification for Java

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What is the RTSJ?

Support for realtime programming in Java

- importance vs fair scheduling
- determinism vs responsiveness
- timeliness vs throughput
- priority inversion avoidance vs anitstarvation

Support for embedded programming in Java

- device access
- interact with environment

A standard approach to realtime with Java

Constraints

No changes to the language

- same bytecode
- no new language features

Fully compatible with convention Java implementations such as OpenJDK

- Java programs should run correctly on RTSJ implementations that supports the required profile
- Maximize code reuse under time complexity constraints

Why Update the RTSJ?

Environment evolution

- better realtime garbage collection
- Java 1.4 → Java 1.8

Marketing

- support different levels of realtime:
  even for conventional Java implementations
- reduce need for JNI
- deemphisize memory areas
- differencial to Android

RTSJ 1.0.2 Issues

Device memory access inefficient

- Single class for accessing all precision for each of integral and floating types:
  - RawMemoryAccess
  - RawMemoryFloatAccess
- Unclear how I/O memory is address: filters under defined
- Access testing on every access
- Cannot type restrict memory access
- Hard to inline

RTSJ 1.0.2 Issues

Happening ill defined

- No standard way to add new happenings
- Happenings not objects
- Inconsistent with other AsyncEvent types
  - POSIX
  - Clock
  - User triggered
- Too many levels of indirection:
- Happening → AsyncEvent → AsyncEventHandler
- No support for first level interrupt handlers

RTSJ 1.0.2 Issues

No way to define a new Clock

ScopedMemory

- No simple way to use scopes for Producer-Consumer pattern
- No way to manage backing store

Multicore

- no way to assign SOs to processors

Miscellaneous Deficiencies

New Raw Memory Architecture

FactoryBased

- RawMemory class for registration
- RawMemoryFactory for implementation

Interfaces for each access type:
RawInt, RawShort, RawByte, RawFloat, etc.

Concrete classes for

- Memory mapped devices,
- I/O mapped devices, and
- Generic mapped devices.

RawMemory Interfaces

Example

```
Public class IOBusController implements RawShort
{
  private MemoryRawByte command;
  private MemoryRawByte flag;
  private MemoryRawShort address;
  private MemoryRawInt data;

  public int get(short address)
  {
    address.put(address);
    command.put(READ);
    while (flag.get() != DONE);
    return data.get();
  }
...
```

DMA Support

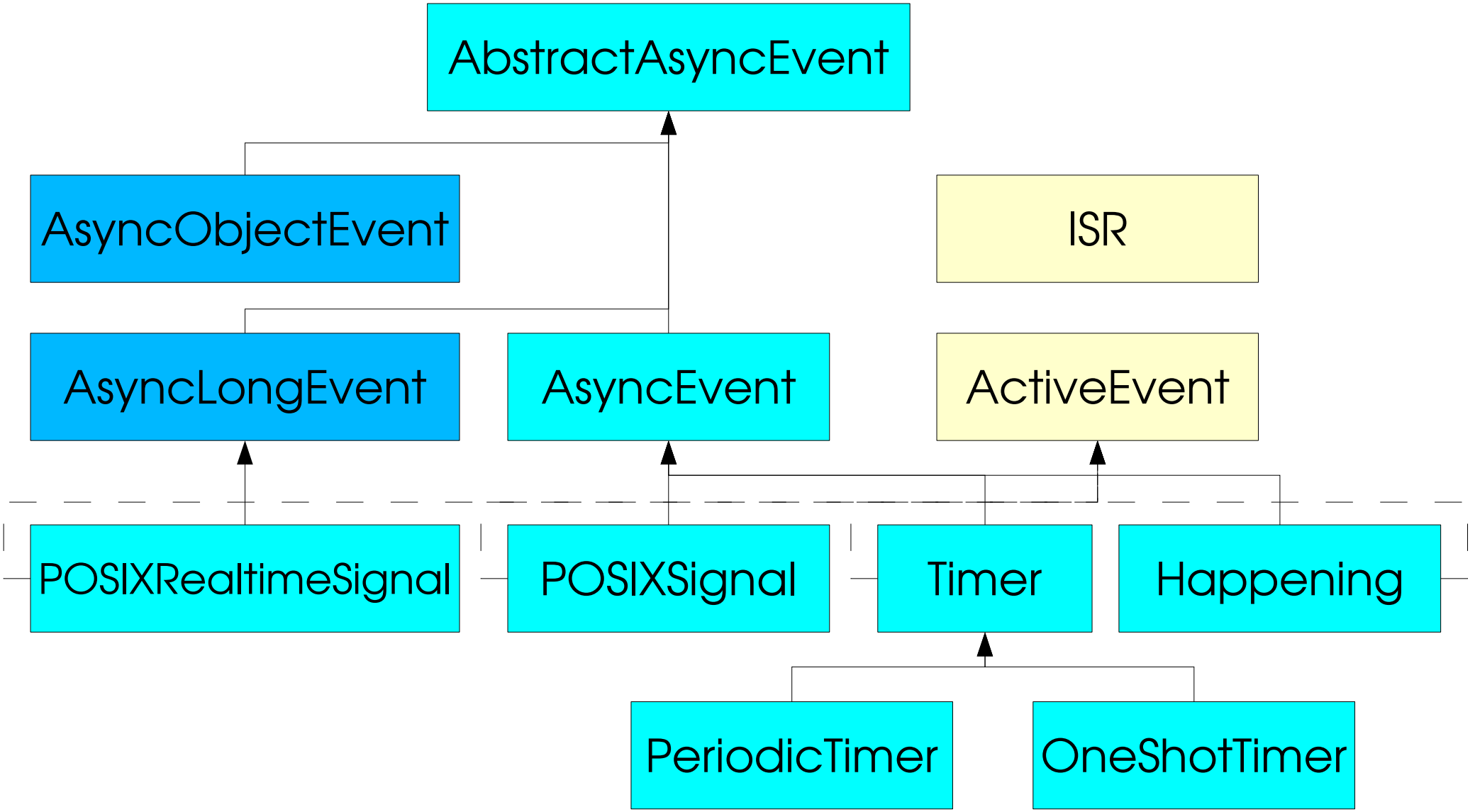
Special factory for direct byte buffer

- Get byte buffer that is visible DMA controller
- Means to get address to pass to DMA controller
- Could be use to implement I/O Channels

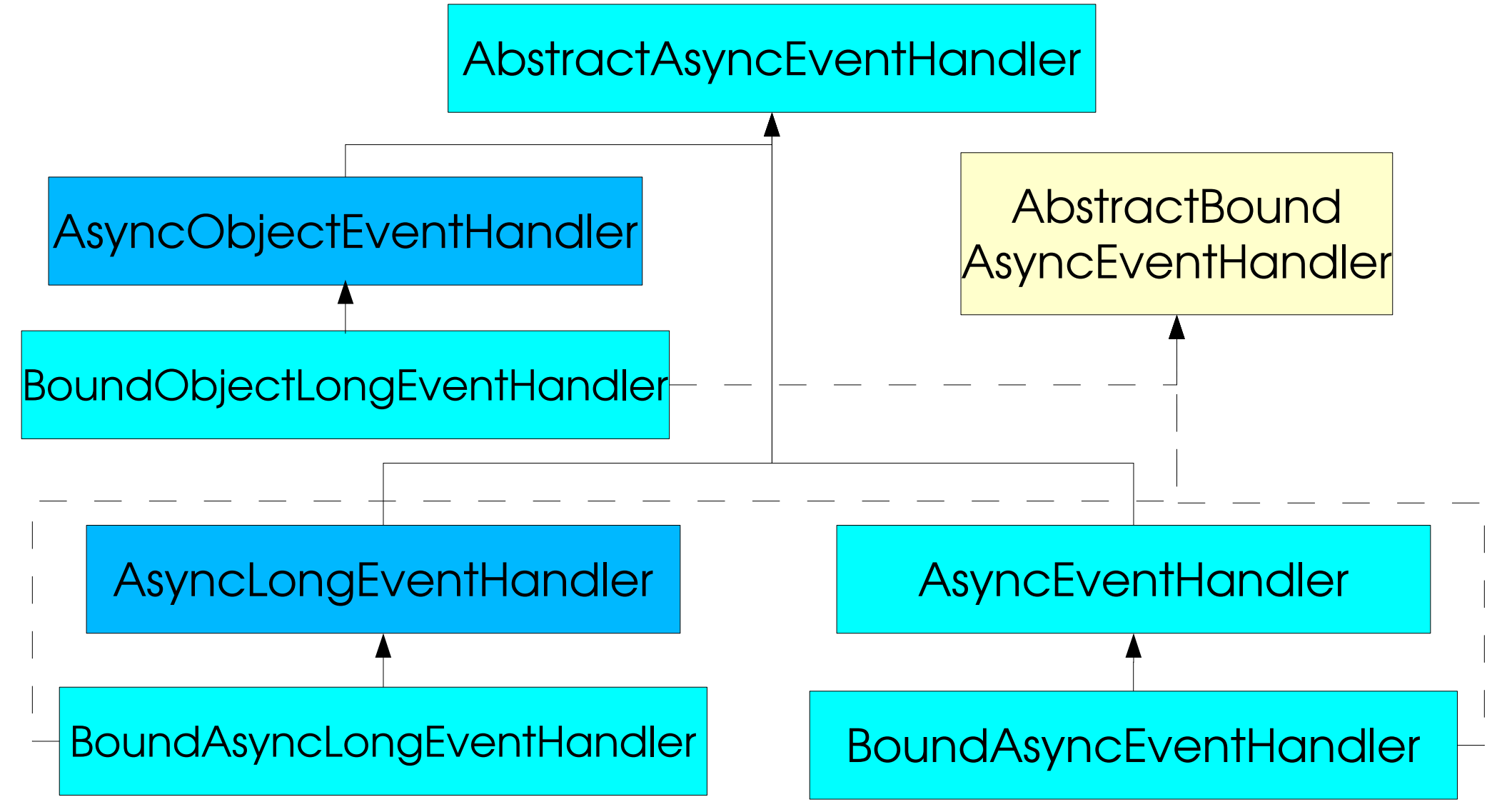
Additional barrier types

- provide write visibility across JNI boundary
- for supporting DMA with direct byte buffers
- Coordinating with Doug Lea
  (JEP 188: Java Memory Model Update)

Event Architecture



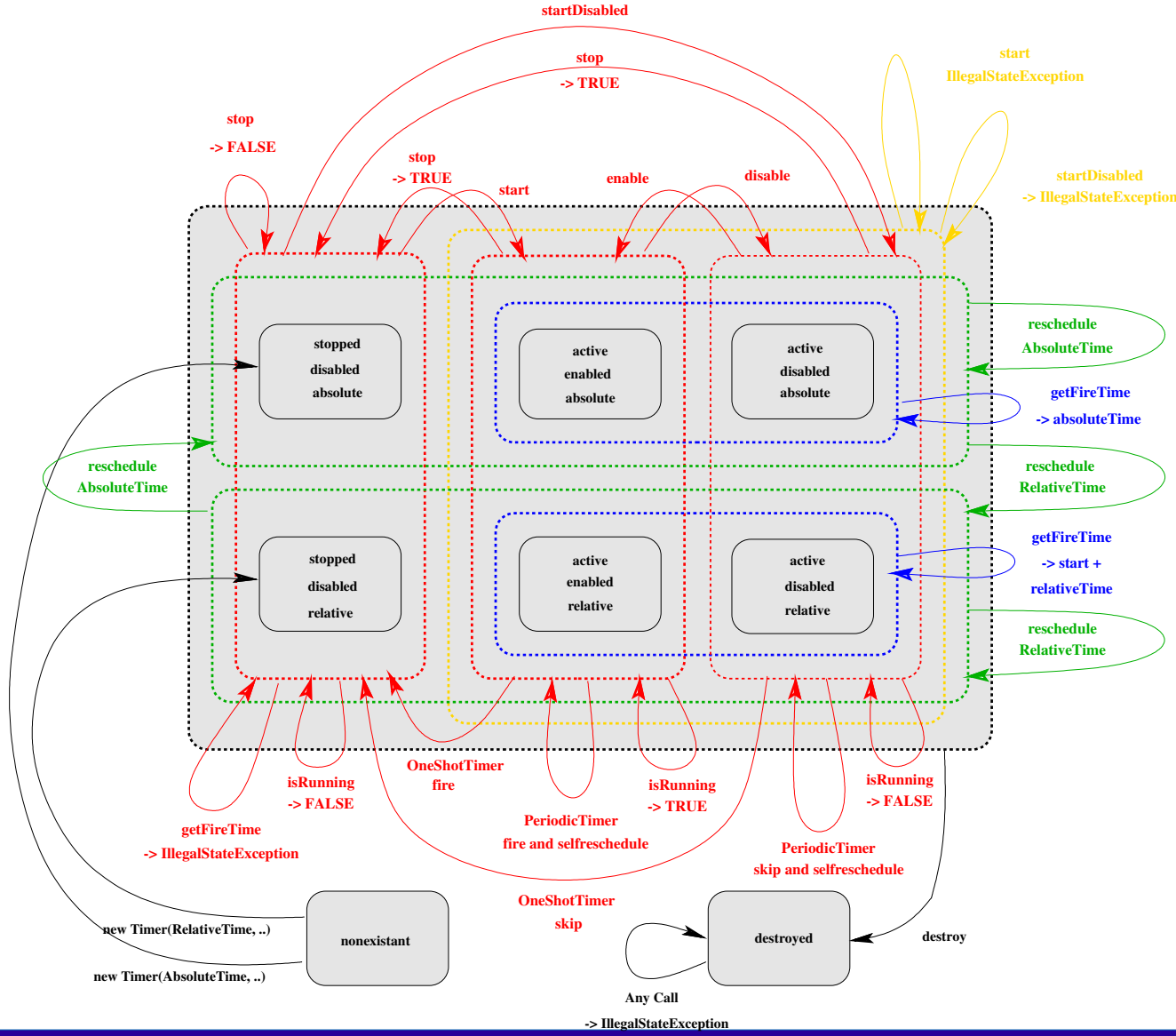
Event Handler Architecture



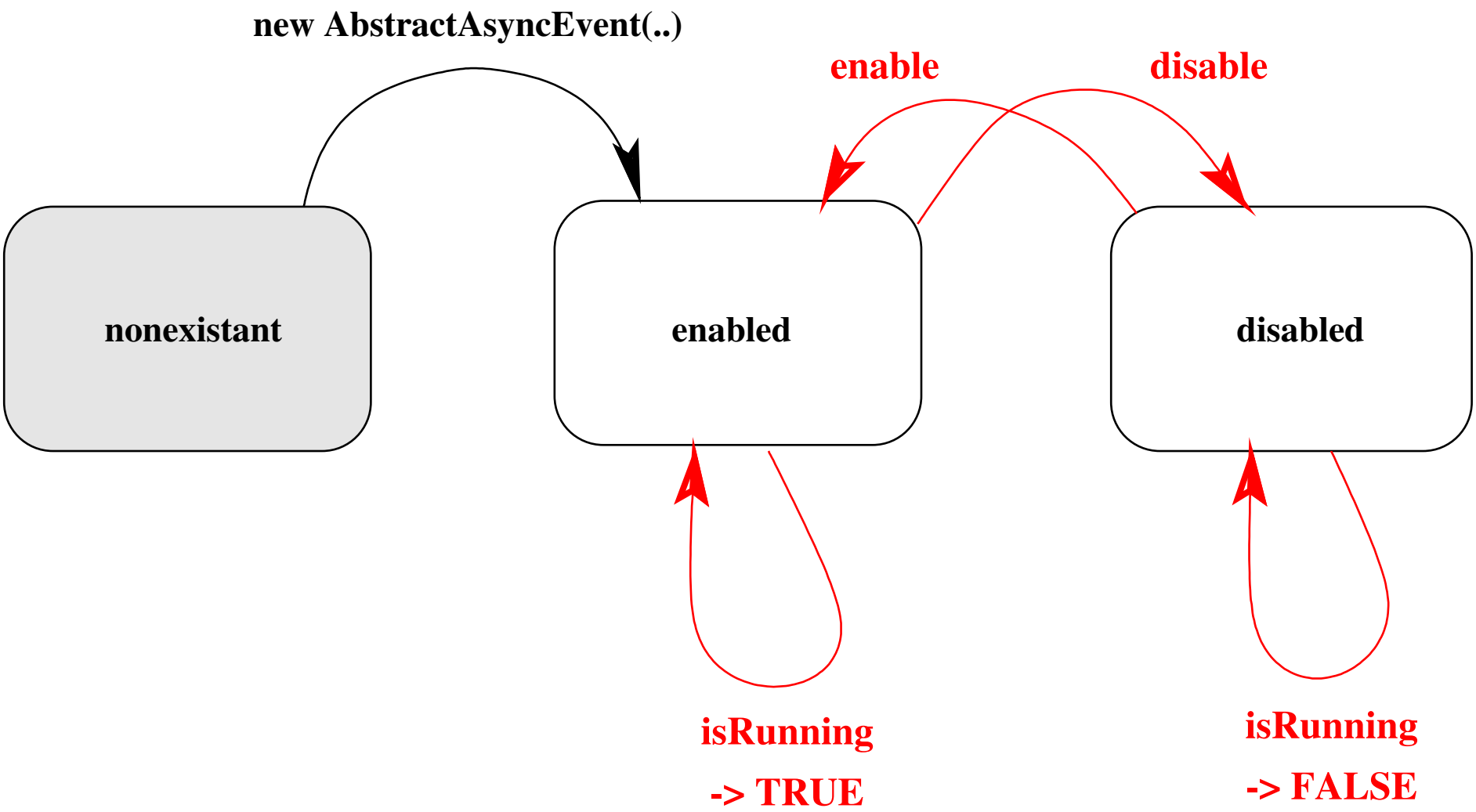
Mix and Match

Types	AsyncEvent	AsyncLongEvent	AsyncObjectEvent
AsyncEventHandler	No payload	No payload	No payload
AsyncLongEventHandler	Event ID	Payload	Event ID
AsyncObjectEventHandler	Event Object	Event Object	Payload

Timer States



AbstractAsyncEvent States



Happening: Kind of AsyncEvent

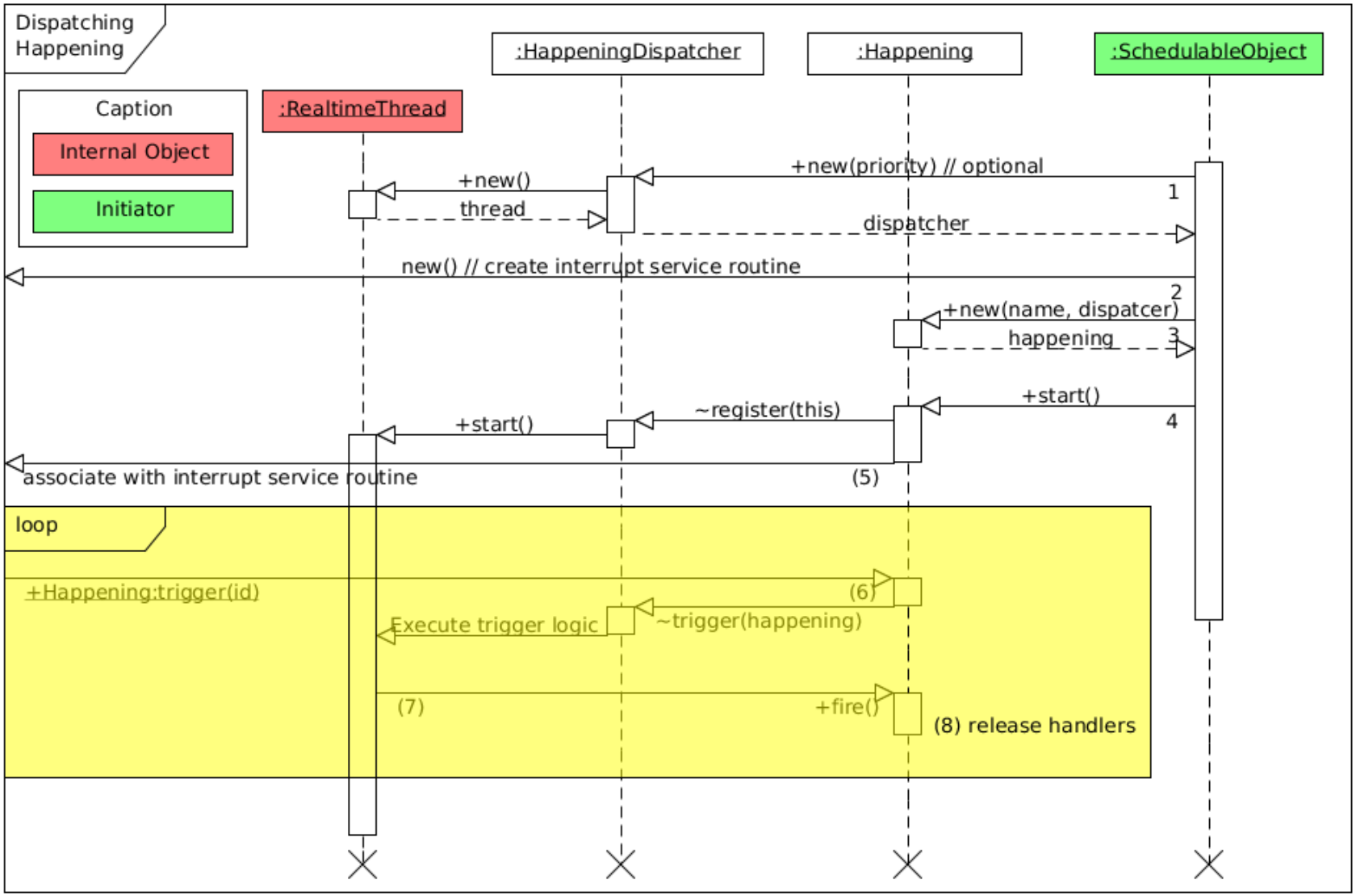
AsyncEvent

- Passive (fire mechanism)
- Runs all associated event handlers
- User definable

Happenings

- supports active behavior too (trigger mechanism)
- Can have (needs) dispatcher to manage activity
- Can be triggered from outside the VM

Happening Sequence



User Defined Clocks

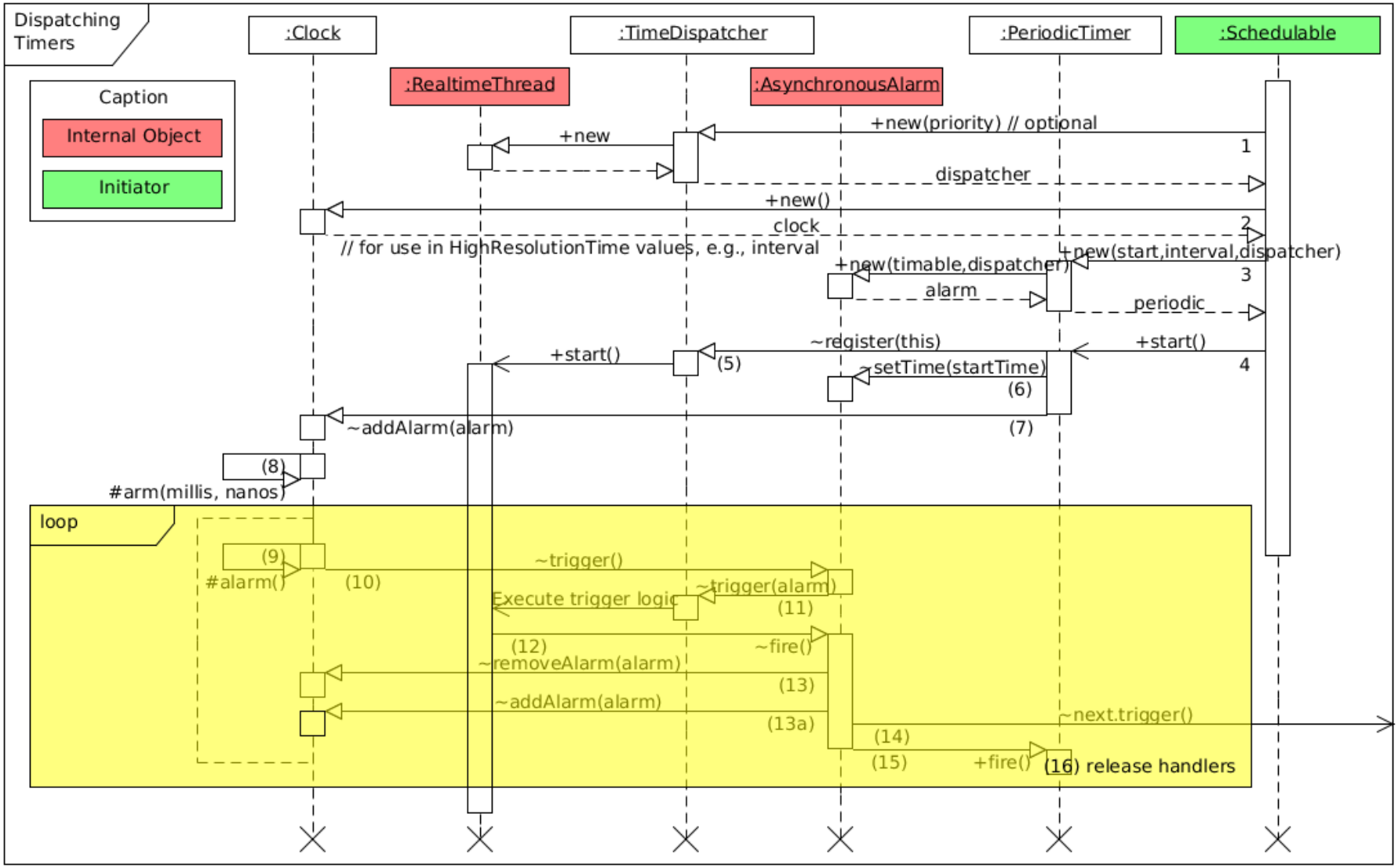
Like an ISR

- no active thread
- just triggers associated Timers

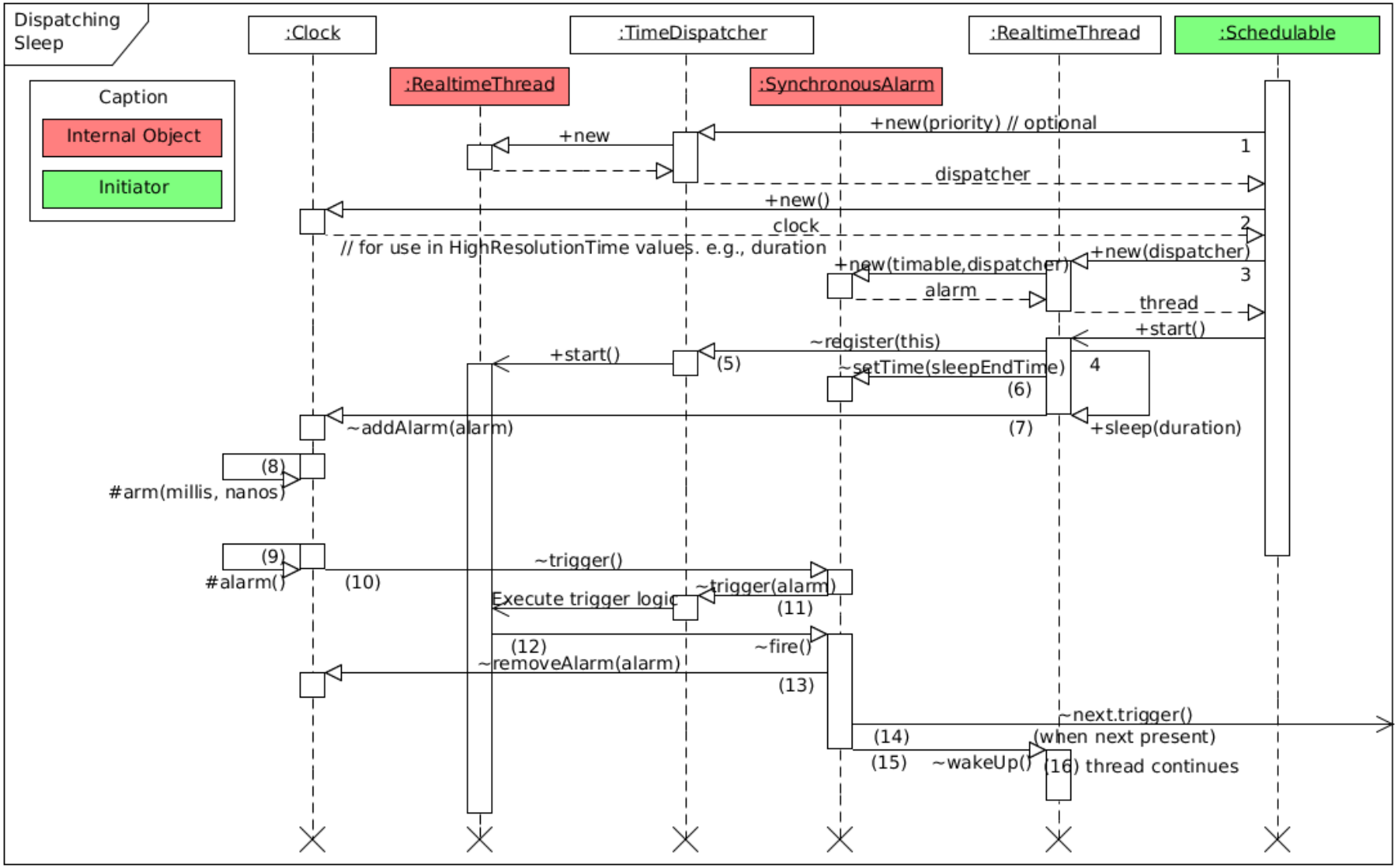
Manages Trigger Queue

- next set of Timers (in priority order) to trigger
- time ordered set of Timer sets
- constant trigger time for top next Timer
- bound adding and deleting

Clock Sequence Diagram



Sleep with Application Clock



Affinity

Multicore control

- enable pinning Threads and AsyncEventHandlers to a subset of processors.
- support collective pinning w/ ProcessingGroupParameters
- find out what processors and processor subsets are available for pinning
- pinning to single processors is always supported.
- orthogonal to all other RTSJ classes

Entering MemoryAreas

Provide for passing arguments

- use lamda and closure
- can be optimized to prevent allocation

Provide a return value

- Use Supplier API
- adds many methods
  - five types: Object<T>, int, long, double, and boolean
  - enter, executeInArea, joinAndEnter, and joinAndEnter with timeout
  - 10–20 new methods!

New ScopedMemory Areas

PinnedMemory

- subclass of ScopedMemory
- similar to LT Memory except supports pinning

StackedMemory

- subclass of ScopedMemory (supports SCJ Model)
- similar to LT Memory but reserves backing store
- backing store from parent when StackedMemory
- enterable only from MemoryArea where created
- resize to max reserved (when no sub area)

StackedMemory Example

Small Change

RealtimeThread

- add waitForNextRelease() and release()
- for aperiodic processing

AsyncEventHandler

- memory area entered on each release
- old behavior obtained by using PinnableMemory

ReleaseParameters

- add blocking factor to support feasibility analysis

Small Change

PreallocatedThrowable

- ThrowBoundryException
- OutOfMemoryException

Phasing control for periodic schedulables

- when start() called after absolute start time
- now, phased, all past, & exception

PhysicalMemory

- Update documentation to improve clarity.
- Separate from RawMemory

Small Change

RelativeTime

- add compareTo0()
- add scale(int factor)

Timed

- add reset() method
- better support for watchdog timers

PriorityCeilingEmulation

- now required in base module

Small Change

Consistency

- provide for firing an AsyncEvent (or release an AsyncEventHandler) on all resource limit errors.
- new methods as necessary to provide both a returned object and one that takes a destination, e.g., to reuse HighResolutionTime objects
- update semantics for cost enforcement to permit a schedulable's CPU use to be bound by its cost parameter in each period
- soft cost enforcement

Modularization Goals

Provide useful subsets of the RTSJ

- with and without a realtime GC
- with and without device support

Encourage more implementations

- Hard realtime, e.g., for control systems
- Soft realtime, e.g. for system monitoring
- No realtime, e.g., for development

Modules

Base

- Schedulables
- Priority Inheritance
- Clock
- ...

Device

- Happenings
- RawMemory
- ...

Memory Area

- immortal
- physical
- scoped

Advanced Options

- ATC
- ISR

Conclusion

A common API for realtime Java

- provides for realtime sceduling and control
- support interaction with environment
- reduce need for external code

Base for a dynamic cyberphysical platform

- robust basis
- resource control
- recognizes realtime requirement

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JSR 282

Current specification:
https://www.aicas.com/cms/en/rtsj

Java Project Page:
http://java.net/projects/rtsj-2

Mailing List:
jsr282-feedback@aicas.com

Discussion:
http://www.linkedin.com/groups/RTSJ-8147216

Twitter:
@realtimejava #RTSJ