About 15 years of Real-Time Java

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- Introduction
- Real-Time Java Solutions
- The Real-Time Java Specification
- RTSJ-Based Solutions
- Java Components-based Solutions
- Distributed Real-Time Java Issues
- High-Integrity Systems
- Conclusions

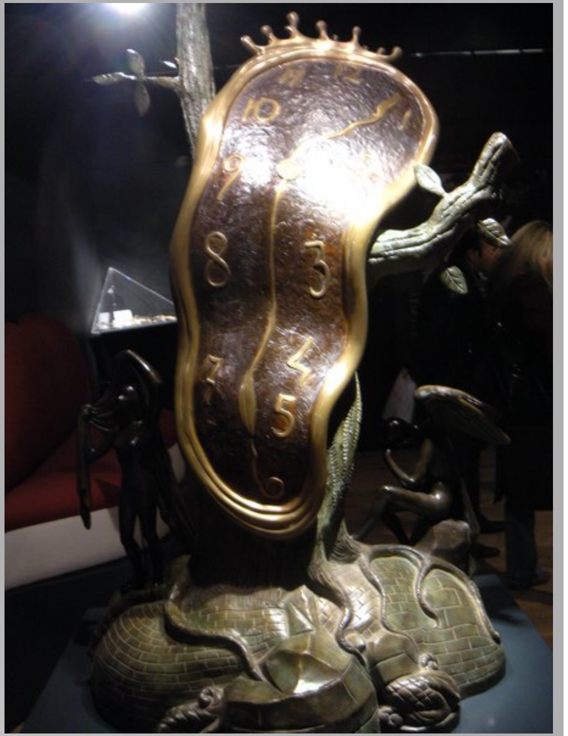
History

- 1995: Java was introduced for Sun Microsystems
- 1997: several research works focus on the limits of Java to execute real-time applications
- 1998: PERC
- 1999: the NIST document
- 2000: the first JSR (Java Specification Request) for RTSJ
- 2002: the JSR-50 for DRTSJ
- 2005: the JSR-282 to enhance RSTJ
- 2006: final release of RTSJ 1.0
- 2006: the JSR-302 for SCJ
- 2011: final draft review of SCJ
- 2011: taken again DRTS

Introduction

Solutions before the NIST document

- 1997-2000
- Real Time Java Threads (Tokuda): provides real task support and synchronization.
- PERC (Nielsen): provides an original API with atomic execution of code and resource negotiation.
- CSP and Transputers: deals with single and multi-processor environments.
- JavaOS: integrates real-time capabilities in a Java-based operating system.
- picoJava: runs the Java bytecodes as its native instruction set.



Real-Time Java Solutions

The NIST document

- Started on december 1999
- A standard Java extension for real-time applications
- API-based solution and profiles
- Two alternatives:
  - The Real-Time Core Extesion fpr the Java Platform (RT-Core)
  - The Real-Time Specification of Java (RTSJ)
    - RT-Core proposses modifications to the Java language, and it was not well accepted
- Profiles: distributed, safety critical, business critical …

Real-Time Java Solutions

Real-time Systems and Java

- The Real-time Specification of Java
- The Distributed Real-time Specification of Java
- The Certiable Safety-Critical Java

The Real-Time Specification of Java (RTSJ) JSR-1 and JSR-282

Problems

- Time values and clocks
- Accessing underlying hardware
- Scheduling
- Synchronization
- Asynchronous event handling
- Dynamic memory management
- Resource management

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RTSJ solutions

- HighResolutionTime class
- RawMemoryAccess class
- RealtimeThread class
- Synchronized keyword
- AsyncEvent and AsyncEventHandler classes
- MemoryArea abstract class and RT-GC
- MemoryParameters and Scheduling Parameters

- Timesys RI
- OVM (Purdue)
- PERC (AONIX)
- Jamaica (AICAS)
- McKinack (SUN)
- Websphere (IBM)
- JOP
- JRate

Implementations

- To avoid the garbage collector we can only use ScopedMemory and ImmortalMemory.
  - objects within the heap or immortal cannot contain references to objects in scoped memory (RTSJ)
  - objects within a scoped region cannot contain external references to objects within a non-outer scoped memory (RTSJ)

- Programing with scoped regions is error-prone
- Still an open research issue in JSR-286

Memory Considerations

- Besides guaranteeing the functional behavior of a specific component, the composition must also guarantee that the communication, synchronization and timing properties of the components are time-analyzable.

- The development RT components which can be run on different HW platforms is complicate because different timing characteristics of different platforms.

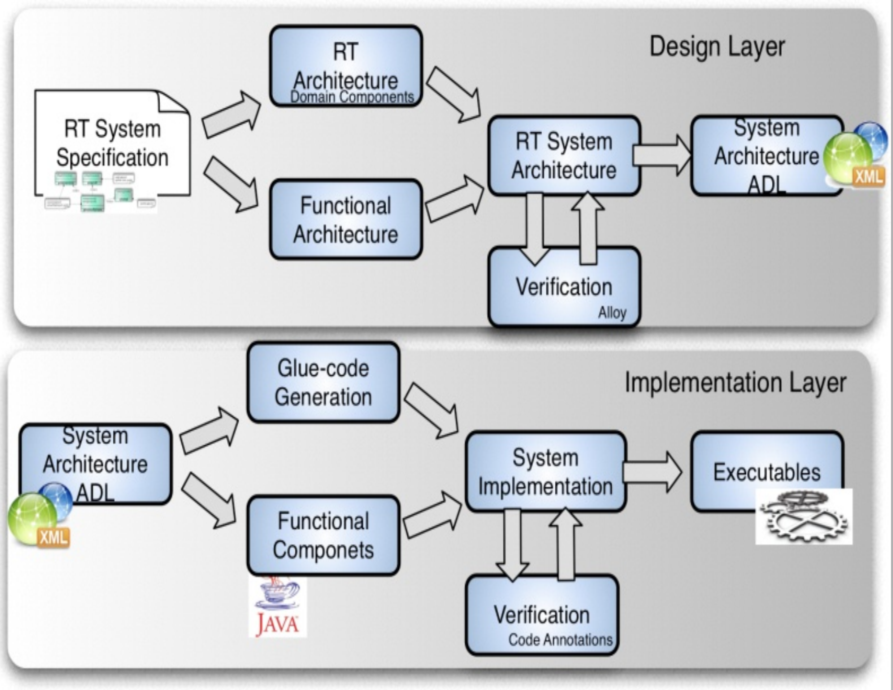
- A RT component should provide the following information:
  - Memory requirements –
  - WCET test cases - WCET for a particular processor family.
  - Dependencies – Describing dependencies on other components
  - Environment assumptions - in which the component operates, for example the processor family.

Real-time Components

RTSJ Components-based Solutions

- Soleil
  (INRIA)
- RTComposer
  (University of Pennsylvania)
- RT-OSGi
  (University of York)

Basic goal of the framework

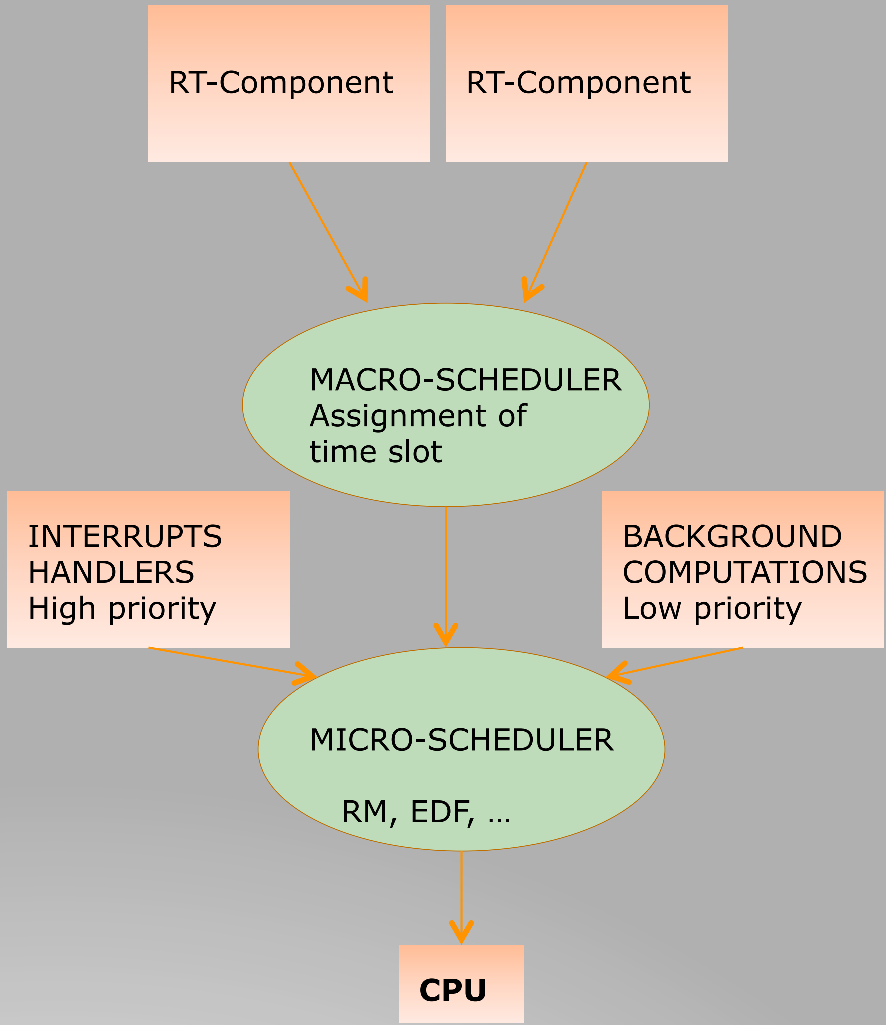


Soleil (INRIA)

- A systematic architecture design
- Automatic generation of RTSJ code
- The *ThreadDomain* component represent the RealTimeThread hierarchy (i.e., RealTimeThread and NoHeapRealTimeThread)
- The *MemoryArea* component represent the MemoryArea hierarchy (i.e., ImmortalMemoryArea, HeapMemory, and ScopedMemory)
- The functional architecture is obtained as a combination of The *ThreadDomain* and *MemoryArea* components.

Hierarchical scheduling approach

- Two scheduling levels:
  - A standard task scheduler is used for inter-slot scheduling
  - An automata-based scheduler is used for intra-slot scheduling



RTComposer (University of Pennsylvania)

Dynamic Configuration

- Combines OGSi and RTSJ real-time thread, priority-based scheduling and real-time GC
- Provides:
  - An admission control protocol.
  - A priority assignment approach supporting temporal isolation.
  - A hierarchical scheduling.
- The combination of these characteristics guarantees safety update of components
- Memory isolation has not been still addressed

RT-OSGi (University of York)

Problems

- RTSJ is focused on centralized
- Since 2000 inactive
- Programming model:
  - *networked* (asynchronous messages)
  - *control flow* (method invocation)
  - *data flow*(publish/subscribe)

The Distributed Real-Time Specification of Java (DSRTJ) JSR-50

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Problems

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- Programming model:
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  - *control flow* (method invocation)
  - *data flow*(publish/subscribe)

DRTSJ extends RMI in RTSJ

- Distributed (multi-node) RTSJ
- Taken again in 2011
- To add end to end timelines:
  - focusses on control flow
  - RMI, events, thread transfer of control, and scheduling

Distributed Real-Time Java

- Profiles for RT-RMI
  (Polytechnic University of Madrid)
- Compadres
  (University of California)
- DREQUIEMI
  (Carlos III University)

Three different profiles:

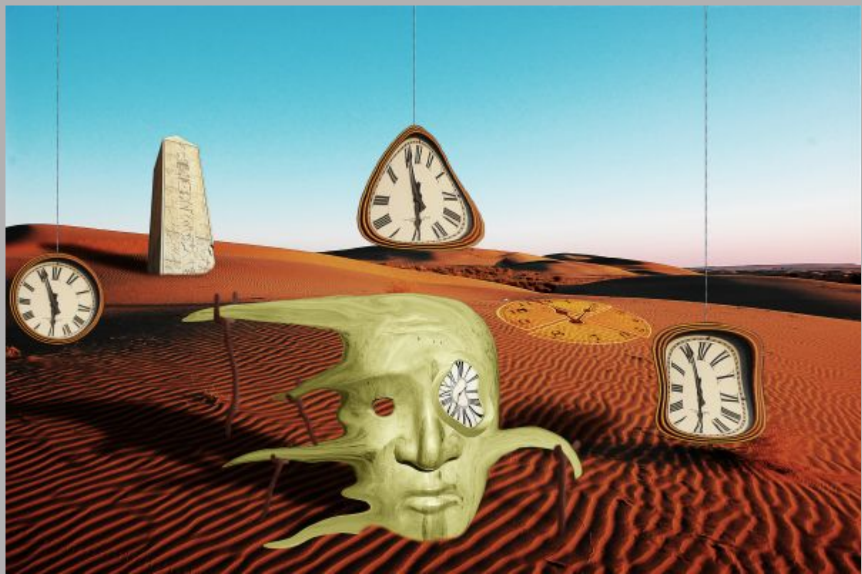
- RMI-HRT for safety critical systems, requires highly deterministic behavior. Deadlines misses can cost human lives or cause fatal errors (i.e., hard real-time systems)
- RMI-Quality of Service for efficient and robust system, which anomalous behavior can cause financial cost (i.e., soft real-time systems)
- OSGi-based solution for flexible business systems (e.g., multimedia systems, ambient intelligent). It considers RT-GC, and does not consider asynchronous interrupt exceptions, nor asynchronous event handling.

Profiles for RT-RMI (Polytechnic University of Madrid)

AComponent Middleware Framework

- Components for Distributed Real-Time Embedded RTSJ
- Components connected by ports that communicate through strongly-typed objects
- Abstracts away RTSJ memory management complexity
- Compiler that automatically generates the scoped memory architecture for components

Compadres (University of California)



A Middleware Framework

- It allows to support the level L1 od DRTSJ
- It incorporates some DRTSJ L2 elements
- It is based on RMI having influences from RT-CORBA
- It offers four services:
  - A stub/skeleton allowing remote object invocation
  - A distributed garbage collector
  - A naming service for white pages
  - A synch/event service for data-flow communication

DREQUIEMI (Carlos III University)

Problems

- Started on 2006
- Safety critical applications
- Validation:
  - standards DO-178B / ED-12B
  - formal models,schedulability analysis
- Requires transformation from bytecodes to target machine Programming model

The Safety Critical Java Specification (SCJS) JSR-302

The Safety Critical Java Specification (SCJS) JSR-302

Problems

- Started on 2006
- Safety critical applications
- Validation:
  - standards DO-178B / ED-12B
  - formal models,
  - schedulability analysis
- Requires transformation from bytecodes to target machine Programming model

A RTSJ Subset for critical system

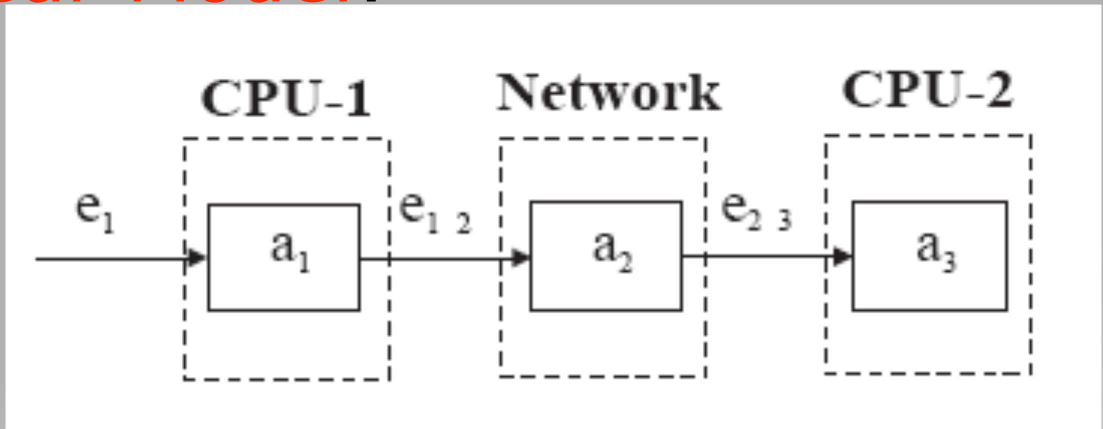
- Finished on 2011
- Minimal set of features:
  - static resource allocation and usage
  - minimal temporal conflicts
  - without dynamic loading
  - Without GC
- It is expected that this JSR will result in an ISO standard

High-Integrity Systems

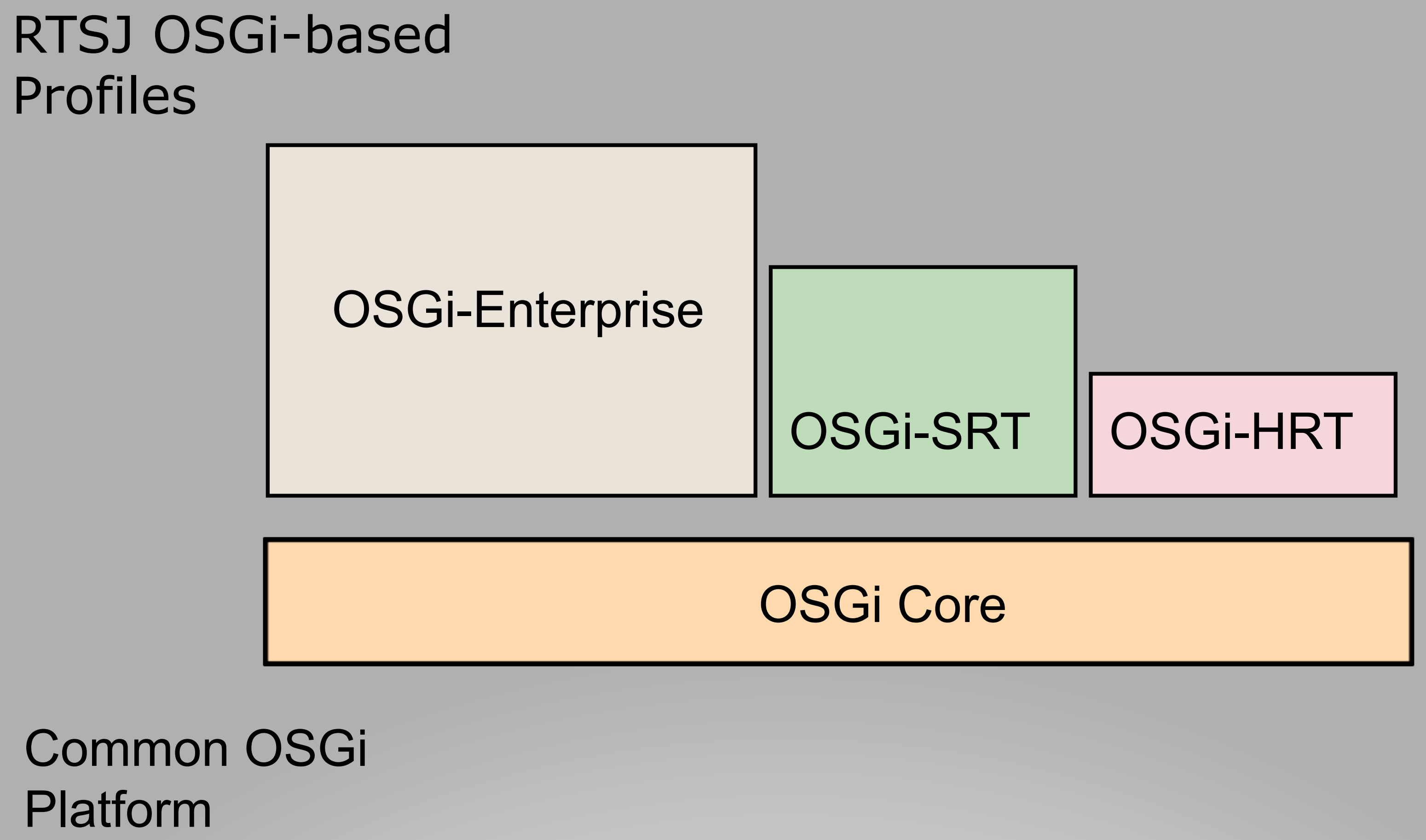
- RMI-HRT Profile (HIJA)
- PERC and OSGi

- Computational Model based on HRTJ:
  - based on pre-emptive priority-based scheduling
  - threads or event handlers (periodic or sporadic)
  - priority ceiling inheritance protocol
  - two phases: initialization and mission

- Linear Model:



RMI-HRT Profile (HIJA)



PERC and OSGi

- RTSJ is the standard Java extension adding real-time capabilities to the Java environment
- It introduces the MemoryArea class; an original mechanism that combines pre-allocates spaces with the GC.
  - Scoped memory present some difficulties regarding their use
- The DRSJ profile supports the development of distributed Java programs with real-time restrictions
- RT Embedded systems interact with the real-world
  - must be dynamically adaptive
  - must be capable of being modified and updated at run-time
- We give an overview of existing RTSJ components based solutions
- The SCJS profile supports the development of programs that must be certified. This specification includes annotations and rules to check statically the semantic program.

Summary and Conclusions