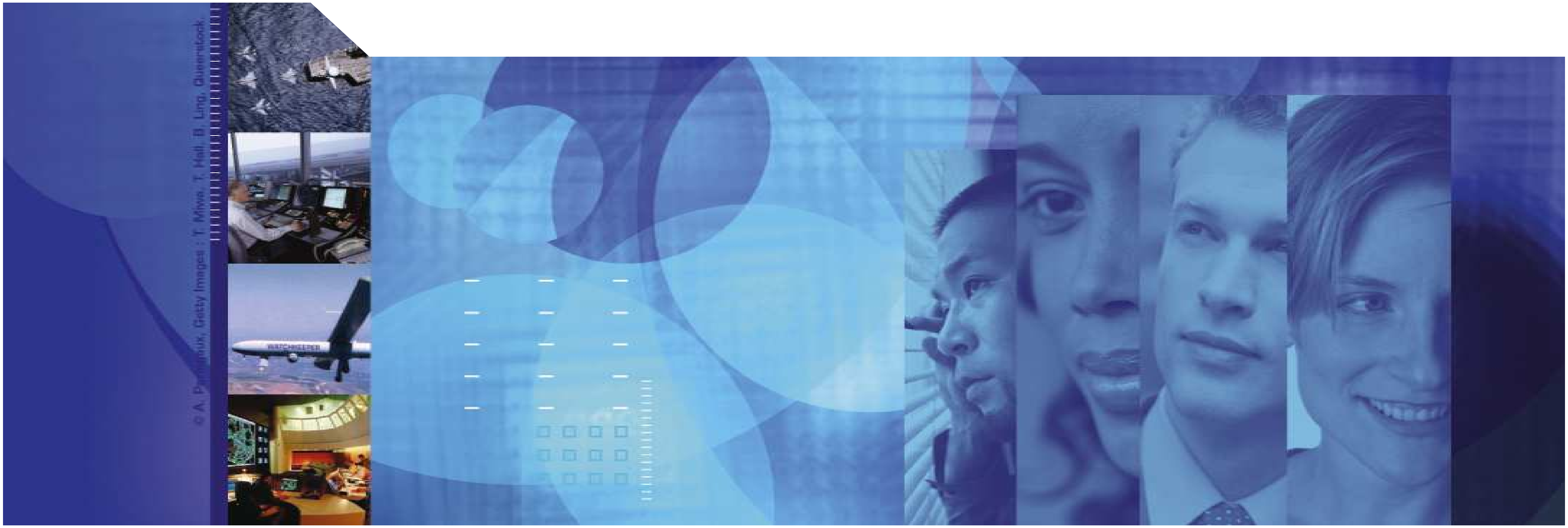

Integration of Flexible Real-Time Scheduling Services in a LwCCM-Based Framework

Authors: O.Hachet JL.Gilbert J.Chauvin (Thales)

M.Gonzales J.Medina P.Lopez (Univ Cantabria)

FRESCOR Project Presentation

- Overview and previous projects
- Project Goals
- FRSH programming model

LightWeight-CCM integration

- Main approach
- Timing requirements
- Components/contract association
- Deployment plan & components assembly

FRESCOR

- Framework for Real-time Embedded Systems based on COntRacts
- Project funded in part by European Union
- Consortium research project following:
  - FIRST: dedicated to flexible scheduling and contract-based techniques
  - COMPARE: CCM applied to RTE systems
  - OCERA: Real-time kernel and components

Objectives

- Develop enabling technology and infrastructure to use the most advanced techniques developed for real-time application
- Higher level programming model used together with RTE systems design methodology (from OS to application)

Industrial products with real-time behaviour should be designed in the following way:

- WCET estimation should be realised
- The whole system doesn't completely needs hard real-time constraints, hard real-time part is small
- Available resources has to be used in adequate manner
- Most of the time no real-time analysis is provided to test the system
  - Timing requirements are "proven" by testing
  - Hard real-time analysis is supposed to be too pessimistic

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Real-time scheduling theory could be useful

- But, needs proper abstraction
- And has to be integrated in the design process

Proposed approach

- API has to be platform independent
- Uses advanced scheduling method coming from real-time theory
  - Built-in analysis
  - Minimum requirements could be guaranteed
- Higher level programming model used together with RTE systems design methodology
- Introduction of Component-based techniques
- Contract-based abstraction
- Resources protection

Specific objectives

- Contract model that specifies application requirements
  - required to be guaranteed
  - usable to increase quality of service
- Underlying implementation manages & enforces contracts
  - integrated resources (processor, network, power, multiprocessor, reconfigurable hardware)
- Adaptive QoS Manager
- Distributed transaction manager
- Performance analysis via simulation
- Component-based framework bridges the gap with design methods
  - tools allow independent analysis
  - tools calculate contract parameters
  - tools obtain timing properties of the overall system
- Test & evaluate on three application domains

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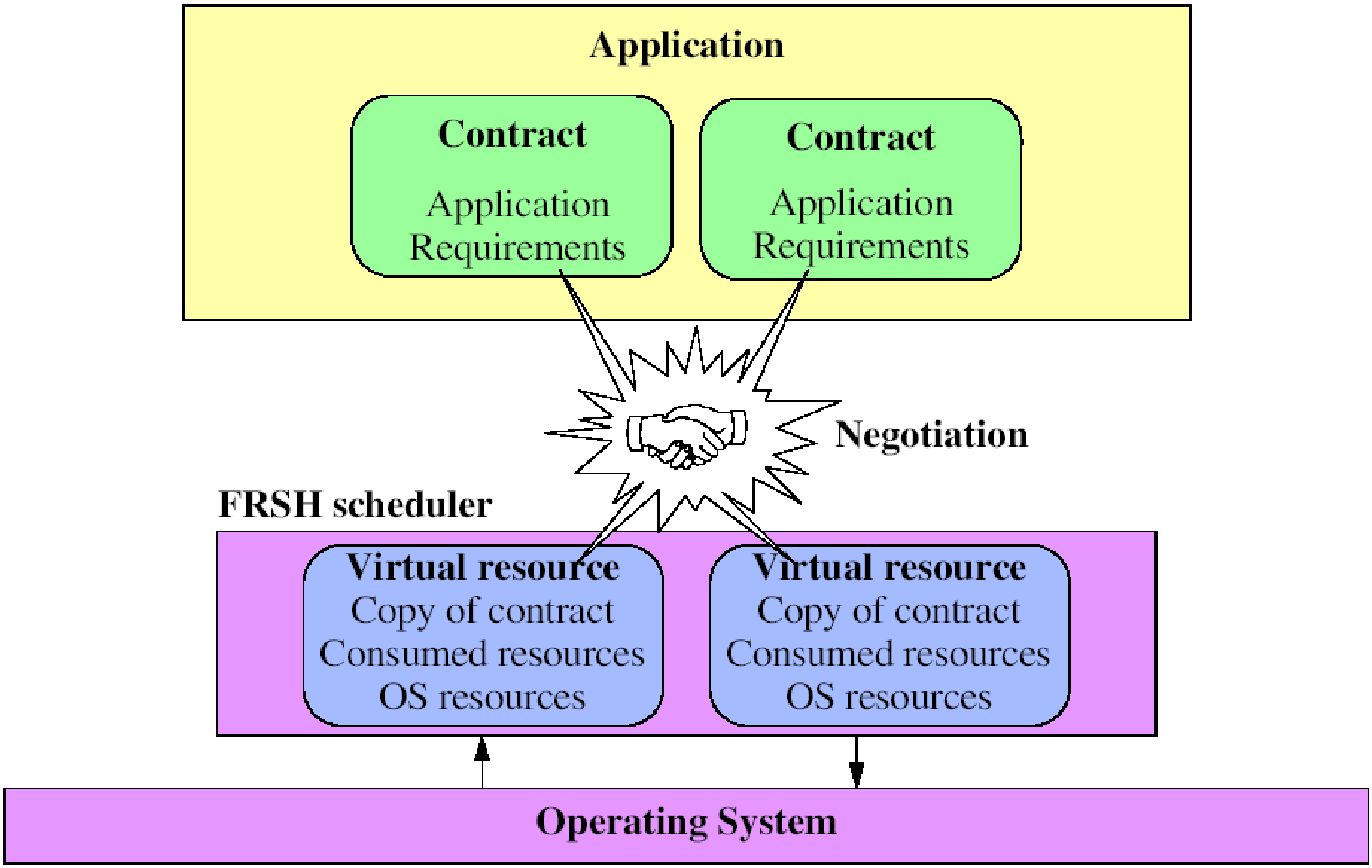
Contract definition



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Contract-based scheduling

Contract specifies

- Minimum requirements for a given resource
- How to make use of any spare capacity

On-line and off-line acceptance tests

Spare resources are distributed according to importance and weight

- Statically or dynamically

Renegotiation is possible

Major features of FRESCOR contracts:

Coverage of application requirements

- mixture of hard and soft real-time

Platform independent API

- independent of OS

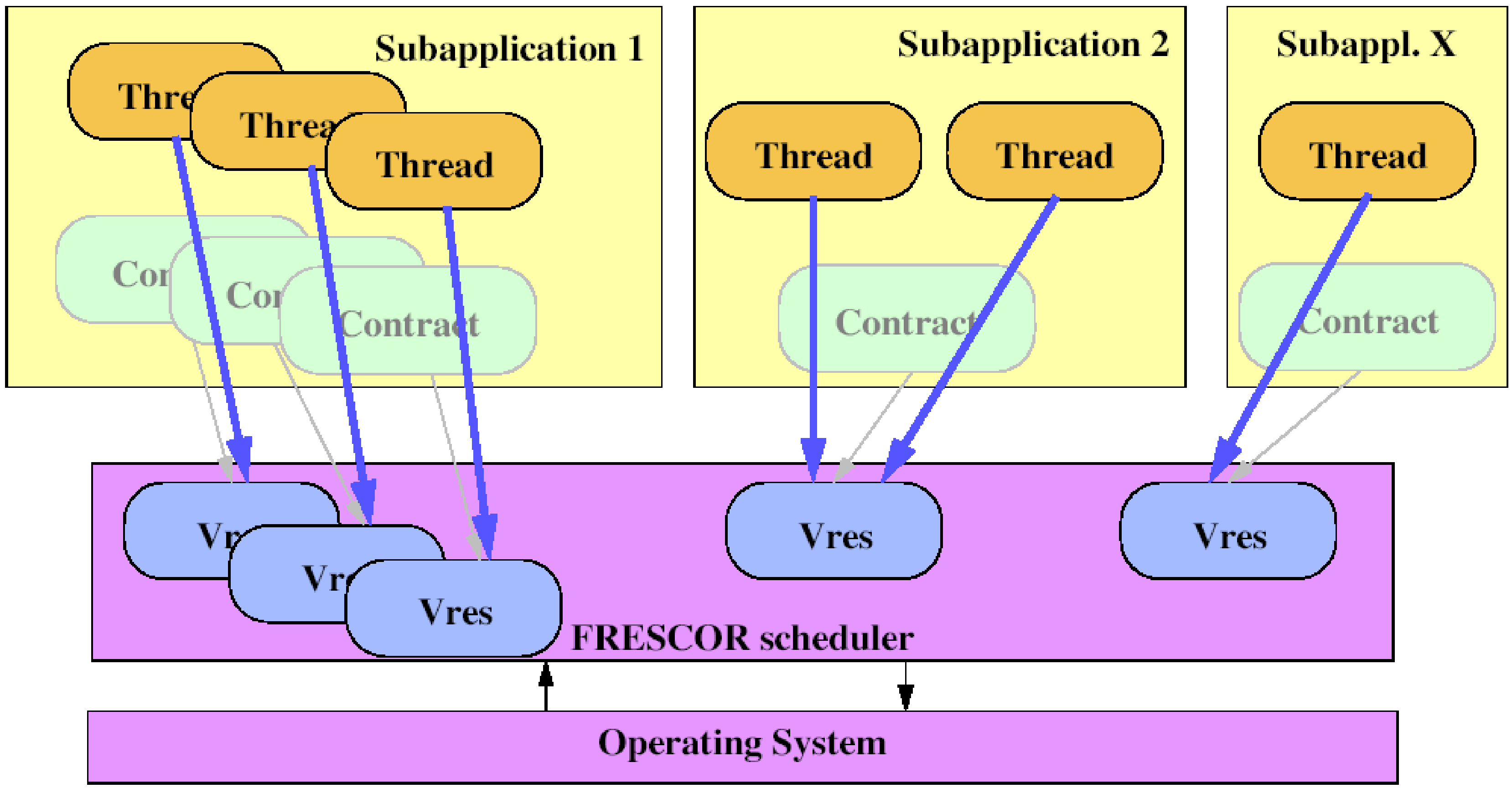
Independent of underlying scheduler

- Support for multiple resources
  - processors, networks
  - memory, energy

Ease of building advanced real-time applications

- by having time and timing requirements in the API

Contract negotiation



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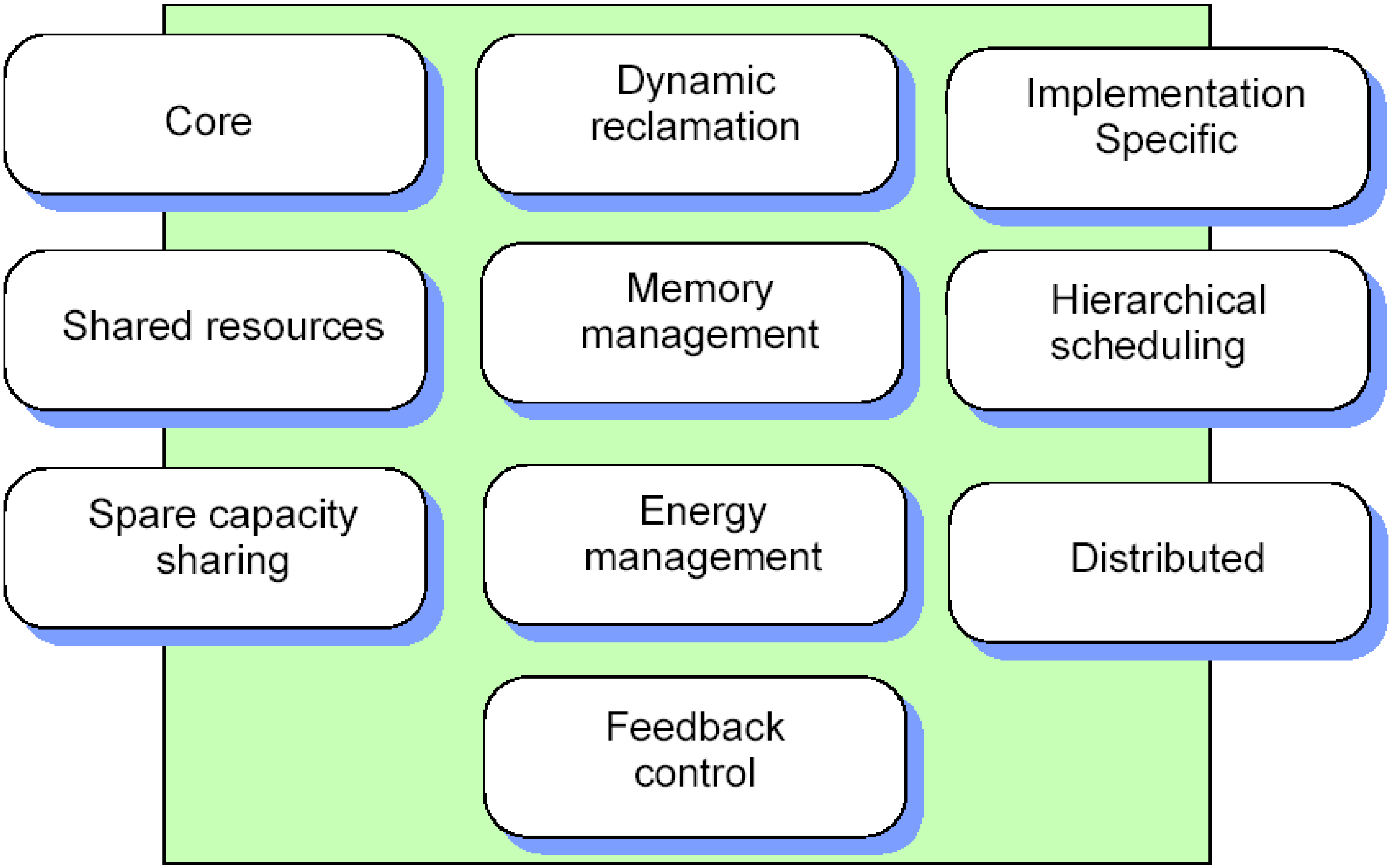
FRESCOR


Core
Dynamic reclamation
Implementation Specific
Shared resources
Memory management
Hierarchical scheduling
Spare capacity sharing
Energy management
Distributed
Feedback control

An API example

With OS API

```
Set priority
Create budget signal handler
create deadline signal handler
create budget timer
create deadline timer
while (true) {
        reset deadline timer
        set budget timer
        do useful things
        reset budget timer
        set deadline timer
        wait for next period
}
```

With FRSH API

```
Create contract with (C,T)
Negotiate the contract
while (true) {
        do useful things
        frsh_timed_wait
}
```

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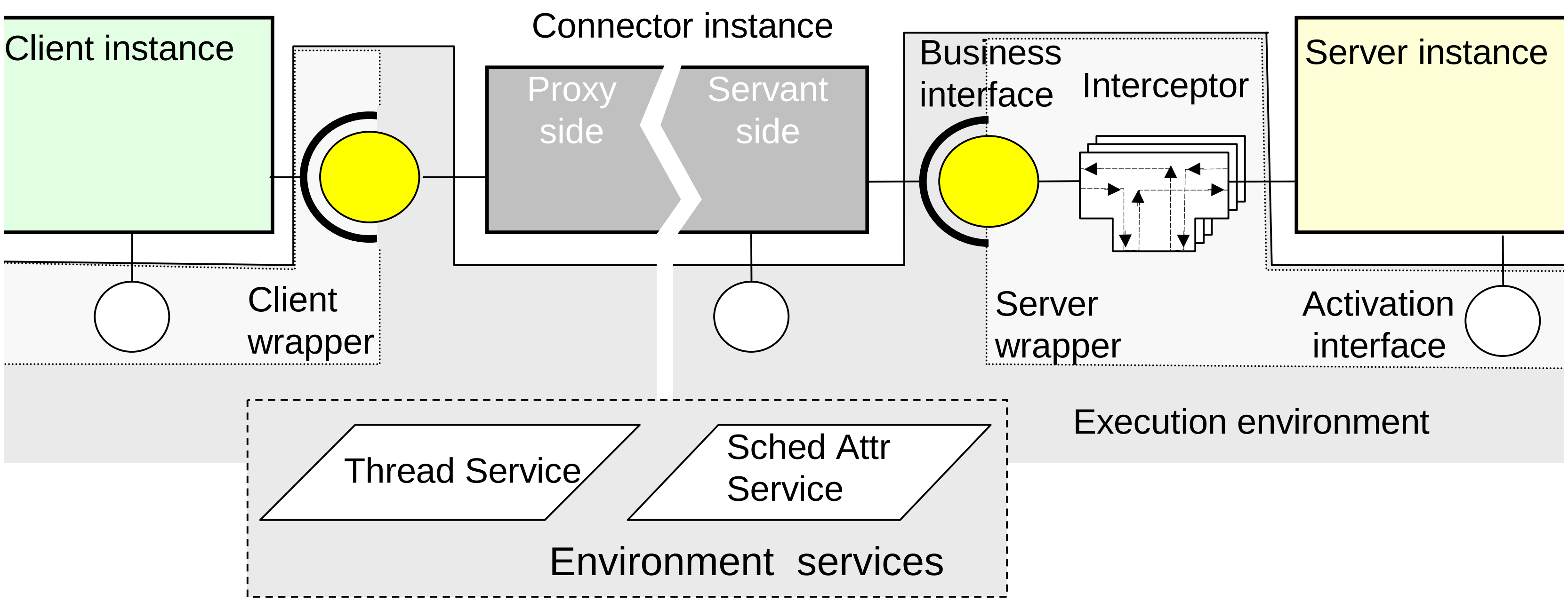
Framework main ideas

- Reusable components with passive operations
- Threads for executing the operations offered and managed by the container
- Connectors used for communication management
- FRESCOR management achieved by interception



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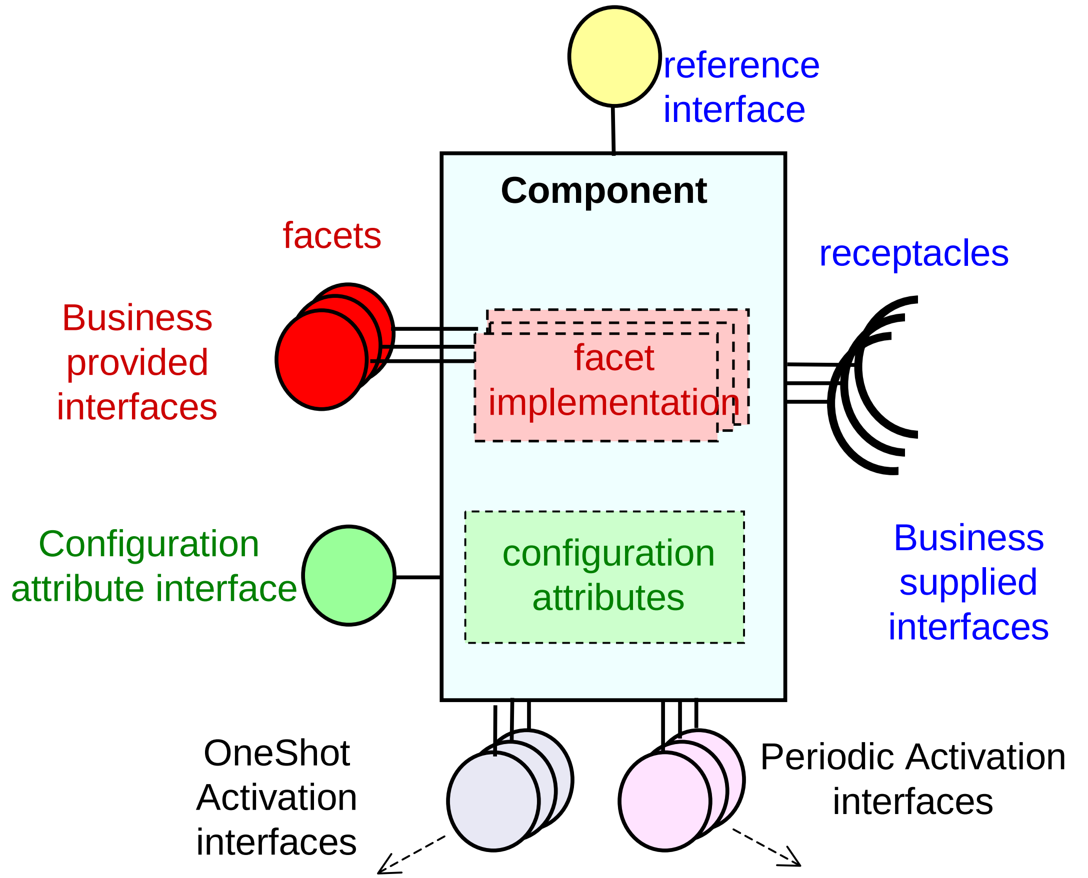
Component Presentation

- Business code formulated as passive operations
- Two kinds of operations can be executed by environment threads on a component:
- Activation operations: One Shot or Periodic
  - Formulated as ports offering “special” interfaces
- Invocations received in a facet. Different execution modes:
  - Synchronous or asynchronous
    - Defined at specification level (IDL)
    - Managed by the connector
  - Client controlled or Global Activity controlled
    - Defined in the deployment file
    - Managed by interceptors




```
interface OneShotActivation{
  void run();
};
```

```
interface PeriodicActivation{
  void update()
raises(EndActivationException);
};
```

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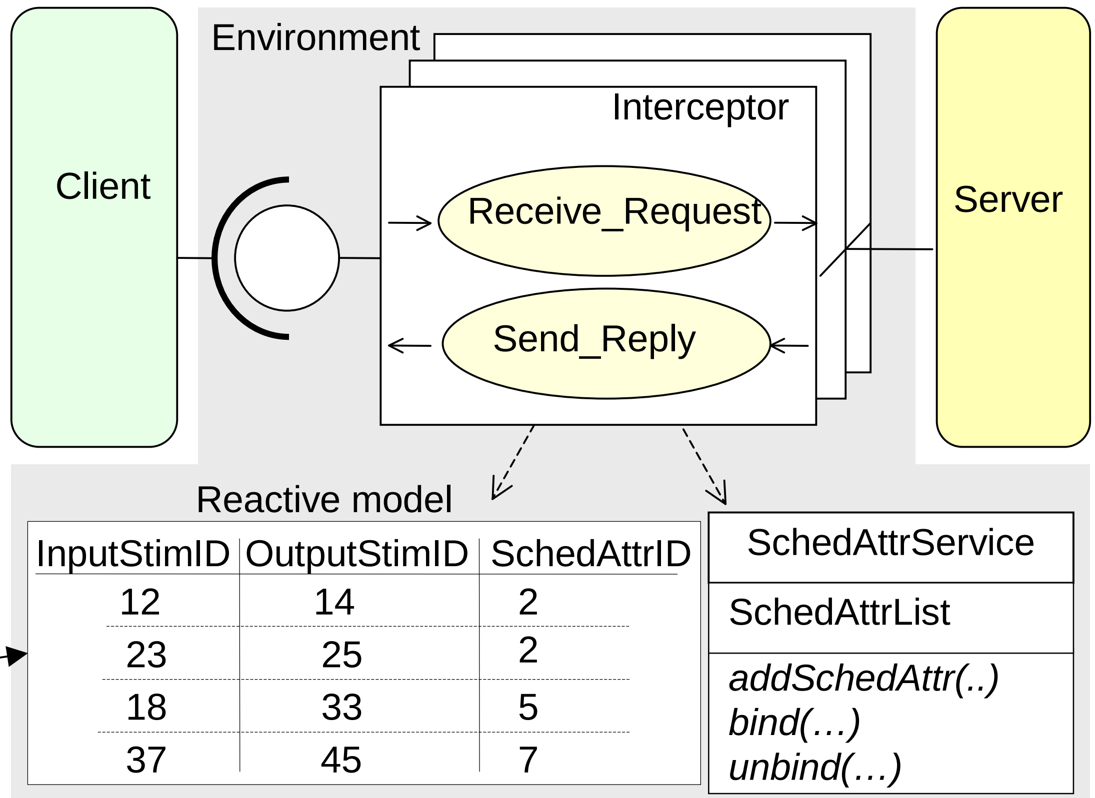
Support the real-time model:

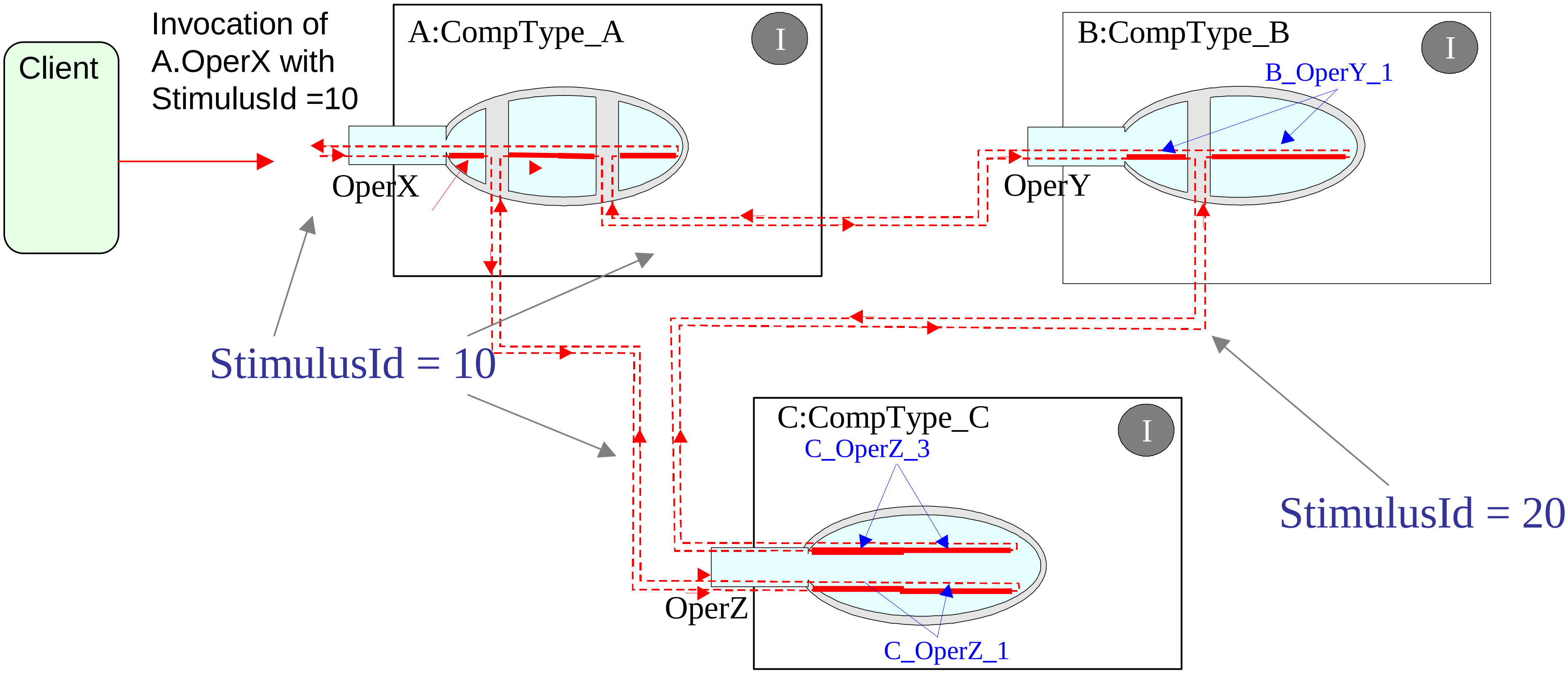
- Assign scheduling attributes to invoking threads
- Differentiates invocations based on global activities



InputStimID	OutputStimID	SchedAttrID
12	14	2
23	25	2
18	33	5
37	45	7

Automatically generated according to deployment data

Concept of activity and stimulusId



C_OperZ_1 is executed with StimulusId =10 ➔ Contract 1 (SchedAttr = 1)

C_OperZ_3 is executed with StimulusId = 20 ➔ Contract 2 (SchedAttr =2)

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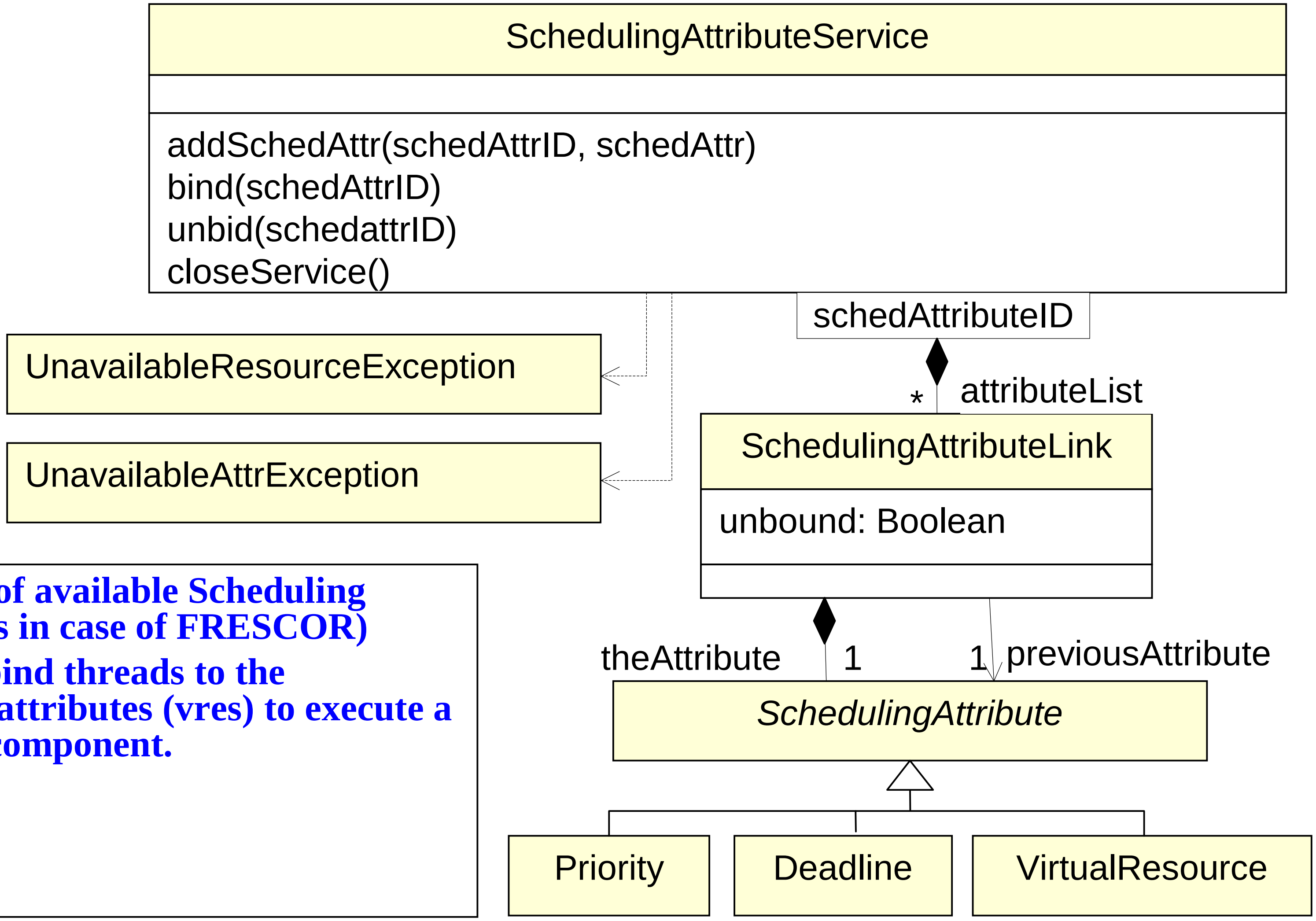
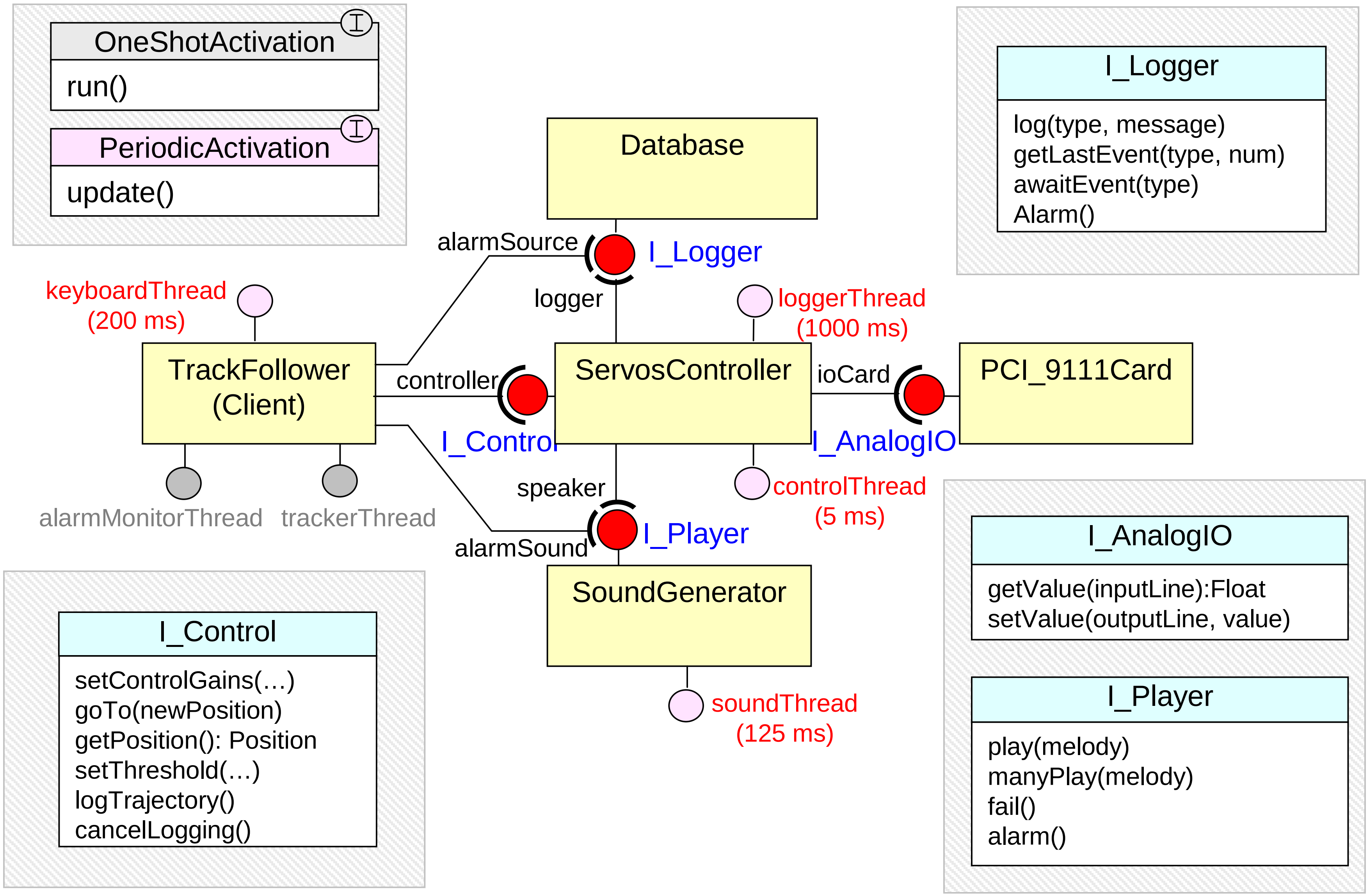
Scheduling Attribute service



- **Keep the list of available Scheduling Attributes (vres in case of FRESCOR)**
- **Bind and unbind threads to the corresponding attributes (vres) to execute a method of the component.**

Example: Track follower



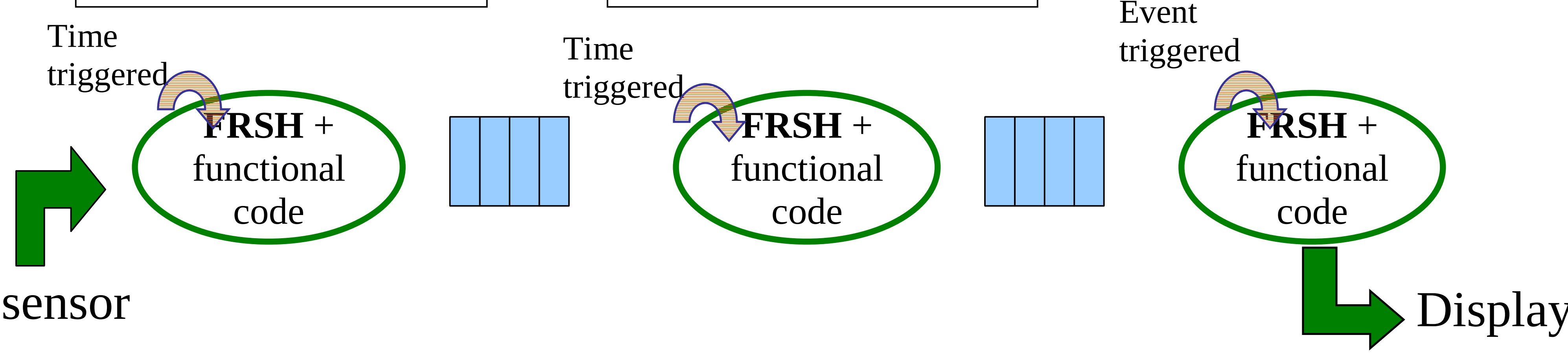
FRSH usage example

MPEG2 decoder showing spare capacity usage

Bmax: maximum budget to allocate to use spare capacity
Pmin: Minimum period to enforce

Bmin: minimum budget (execution time)
Pmax: Maximum period to enforce (maybe equal to deadline)

Frame Input		Frame Decoder		Frame Output
Bmin: 1ms Pmax: 5ms	Bmax: 3ms Pmin: 7ms	Bmin: 1ms Pmax: 7ms	Bmax: 3ms Pmin: 10ms	Bmin: 1ms Bmax: 3ms



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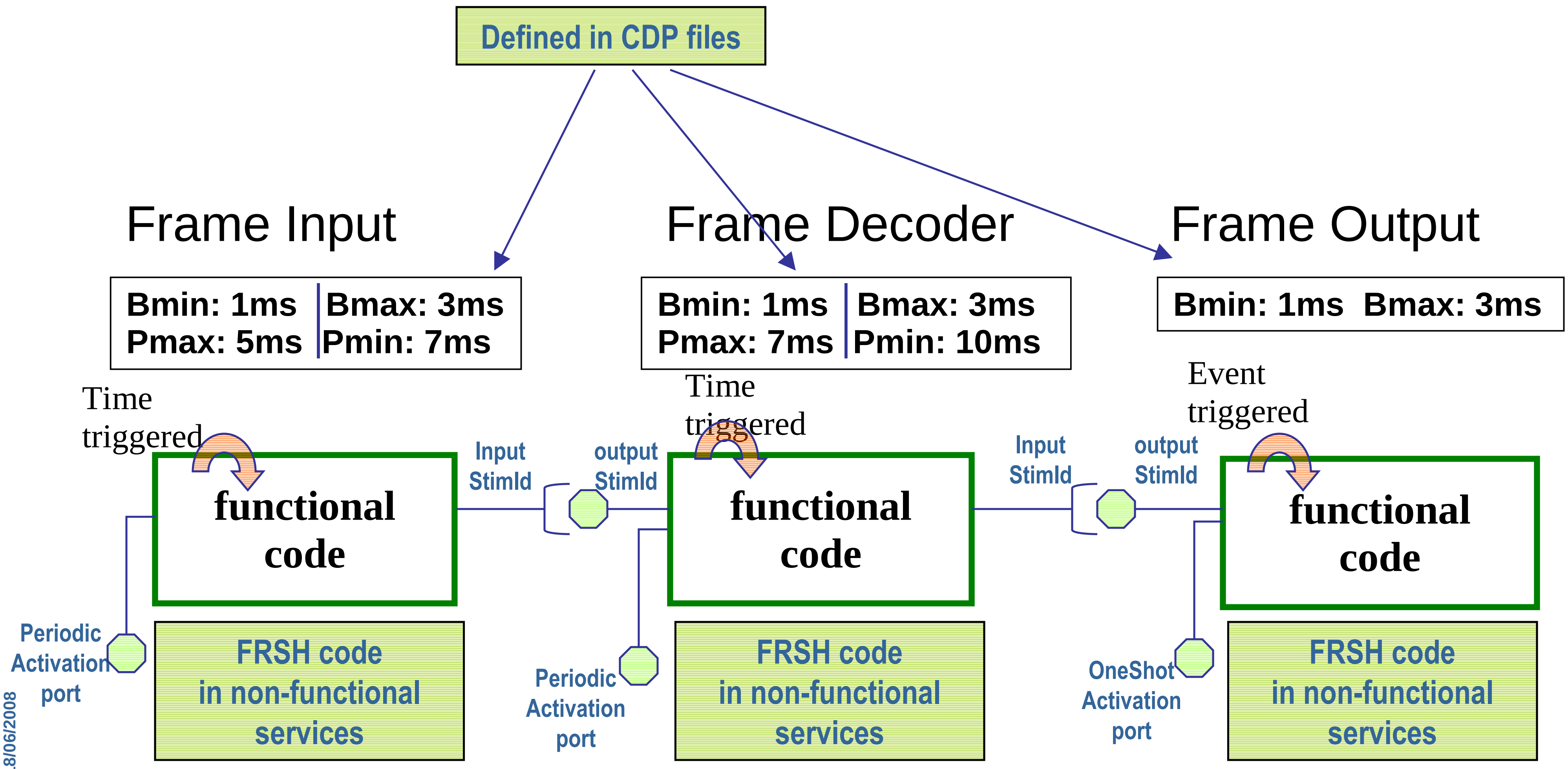
Component-FRSH usage example

MPEG2 decoder showing spare capacity usage



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Includes the aspects that are application-dependent: i.e., the scheduling parameters

```
<DnCedm:DeploymentPlan>
  …
  <instance name="theSpeaker" node="node1" …>
    <!– Property to configure the Periodic Activation -->
    <property name="soundThread">
      <value>
        <periodicActivationProperty period ="0.005" schedAttrId ="1"
      </value>
    </property>
    <!– Property to configure invocation modes of operations-->
    <environmentProperty portname="I_Player_Port"
                         operation="play">
      <executionData inputStimId="10" outputStimId="10"
                     schedAttrId="2"
                     executionMode="TransactionControlled"/>
      <executionData inputStimId="50" outputStimId="60"
                     schedAttrId="3"
                     executionMode="ClientControlled"/>
    </property>
    ….
  </instance>
  …
< DnCedm:DeploymentPlan>
```

```
<DnCedm:TargetDataModel>
  …
  <node name="node1"  …>

    <schedulingAttribute id="1">
      <value>
        <contract contractId ="1"
                  contractParams ="…"/>
      </value>
    </schedulingAttribute>

    <schedulingAttribute id="2">
      <value>
        <contract contractId ="2"
                  contractParams ="…"/>
      </value>
    </schedulingAttribute>
  …
< DnCedm:TargetDataModel>
```

Conclusion and Future Work

Conclusion

- FRSH API allows to encapsulate several scheduling policy
- New programming model leverage development of Real-time application with soft and hard constraints
- Used together with Components technology permits to modelize the behaviour of an RT application
- LightweightCCM enable RT constraints enforcement via contract definition and activities

Future work

- Distribution of contract techniques on network
- Contract parameters evaluation via simulation tools
- Reconfiguration via on-line scheduling analysis
- Use-case assessment

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