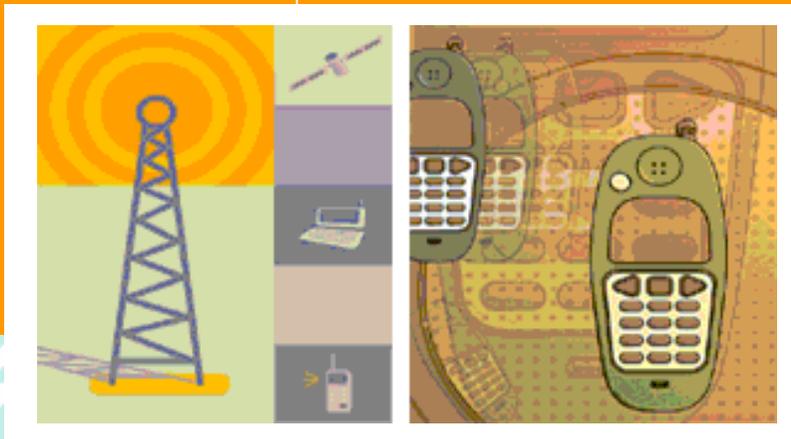


# A Framework for SDR Commercial Equipments: the Reconfigurable Equipment PIM (REP)



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# Presentation Outline



## Problem statement

## Elementary Reconfigurability Architectures

## Formal modelling

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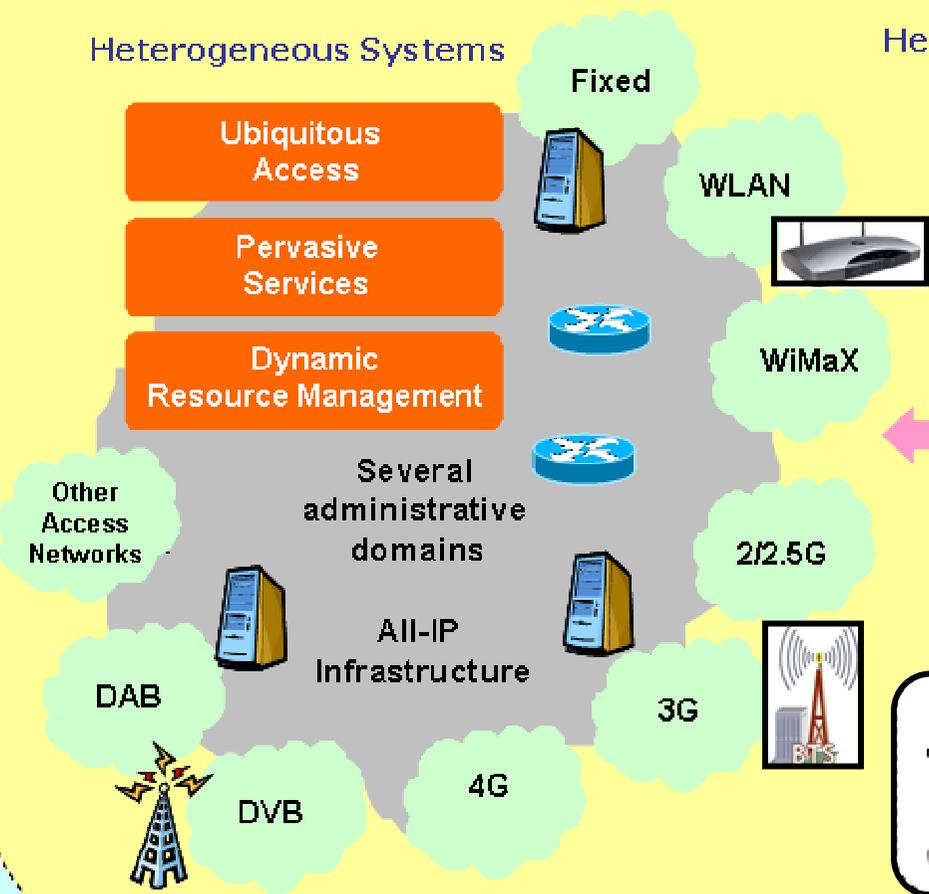


# Problem statement

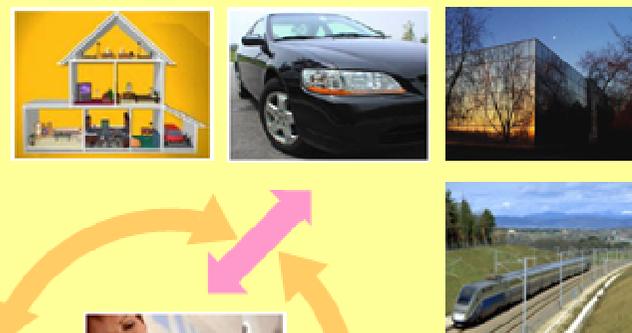


## End-to-End Reconfigurability: Enabler of the Seamless Experience

Heterogeneous Systems



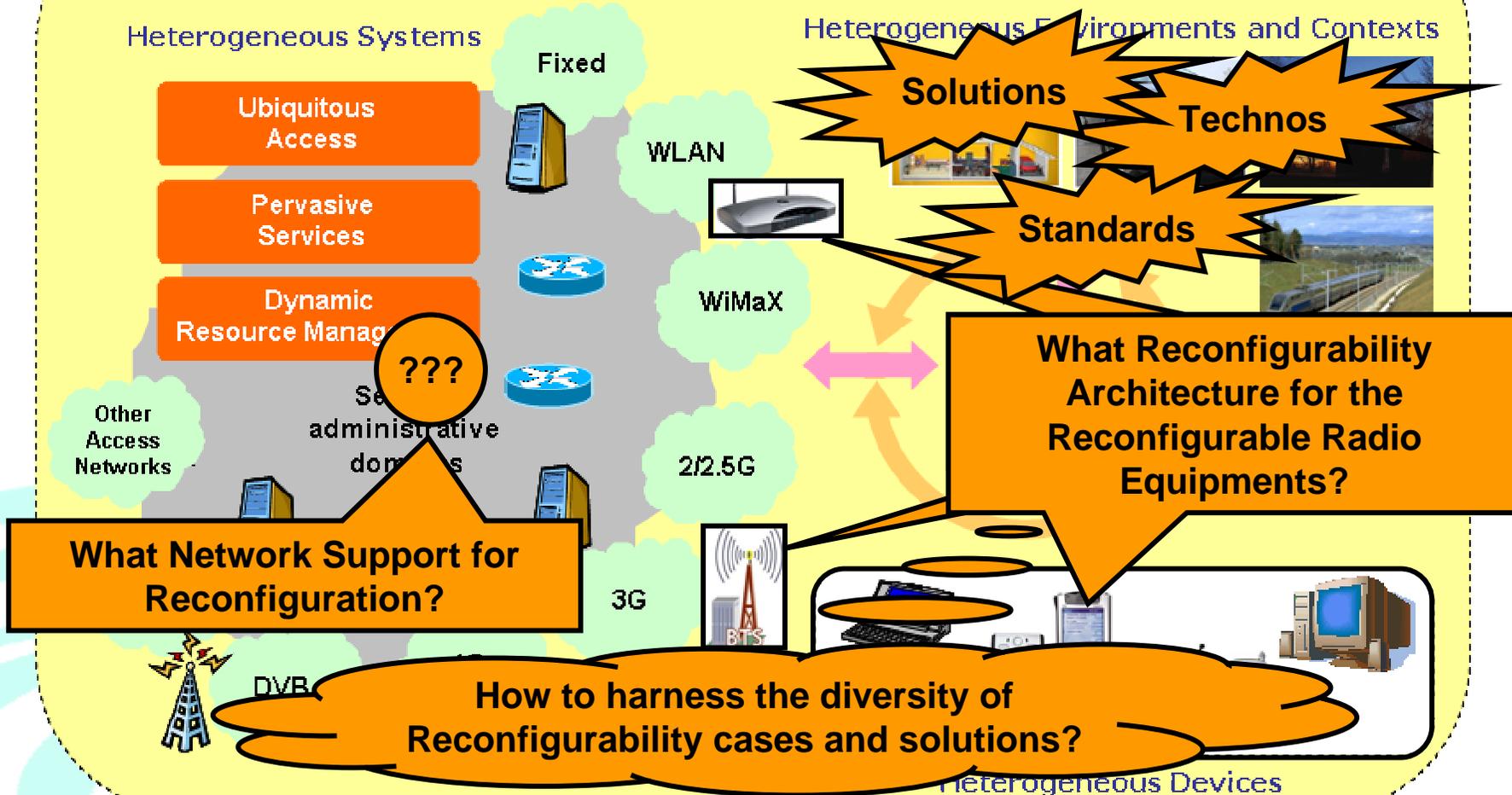
Heterogeneous Environments and Contexts



Heterogeneous Devices

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## End-to-End Reconfigurability: Enabler of the Seamless Experience



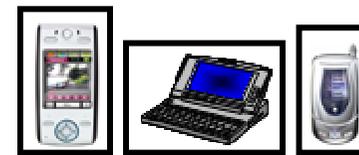
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*Particular Reconfigurable Equipments...*

**Access Equipments**



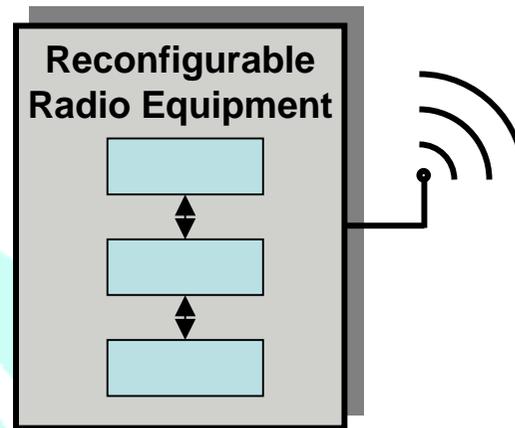
**User Equipments**



*... have their own Reconfigurability Architecture,...*

*... which derives from a common, modular, extensible...*

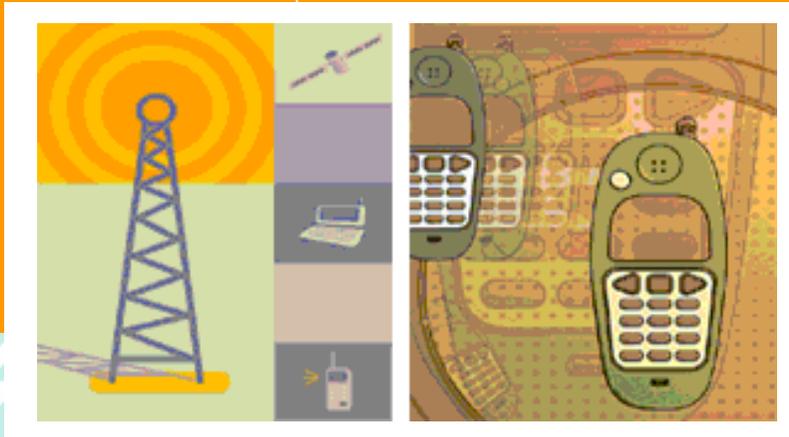
*... Reconfigurability Architecture Framework*

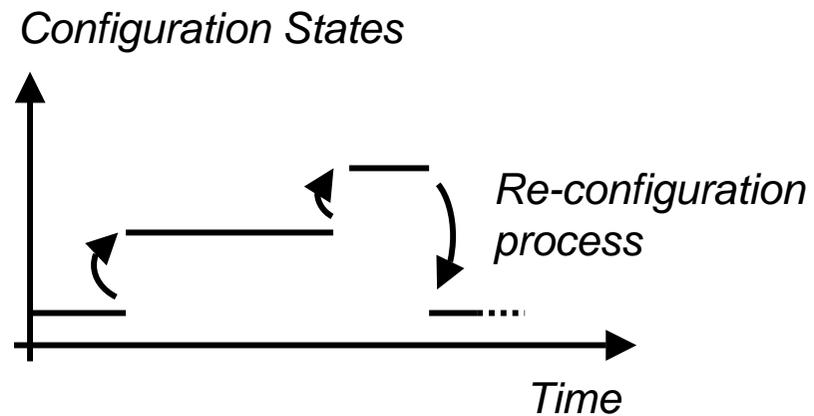


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# Elementary Reconfigurability Architectures

*What is making up the Reconfigurability Architecture of a particular Reconfigurable Radio Equipment?*





*Capability of a Reconfigurable Radio Equipment...*

*...to switch between Configuration States...*

*...as time elapses*

***The Configuration States can be Functional of Physical***

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## Reconfiguration Use Cases

- ✓ Definition: captures the rationale and basic scenario justifying usage of reconfiguration capabilities of a Reconfigurable Radio Equipment
- ✓ Examples
  - ✓ Diagonal handover
  - ✓ Adaptation to the Security Context
  - ✓ Cognitive Radio

## Reconfiguration Capabilities

- ✓ Definition: the technical capability of a certain Reconfigurable Radio Equipment to reconfigure
- ✓ Examples
  - ✓ Software Defined Radio (standard based... or not)
  - ✓ Adaptive Security Framework
  - ✓ Enhanced Frequency Agility

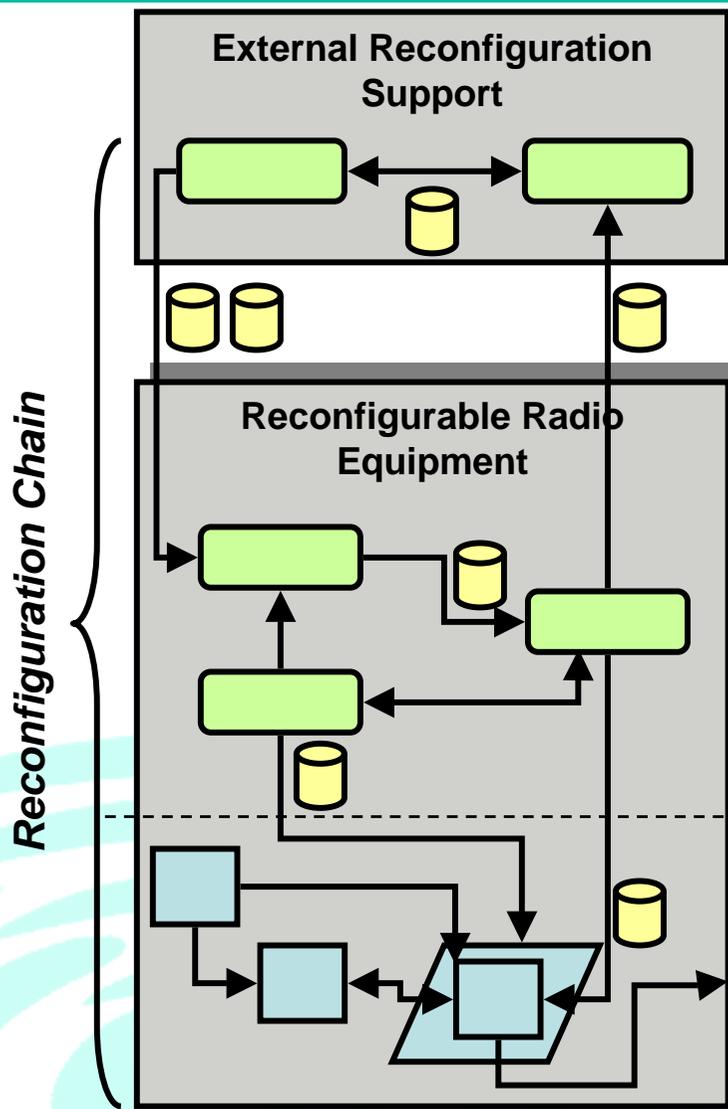
## Definition

- ✓ A Reconfiguration Chain is a complete set of Technical Items contributing to enable a Reconfigurable Radio Equipment to satisfy a certain Reconfiguration Use Case in modifying its Configuration State
- ✓ Some participating items can be external to the considered Reconfigurable Radio Equipment

## Involved items

- ✓ Reconfiguration Modules 
  - ✓ Contribute to satisfaction of the Reconfiguration Use Case
  - ✓ Appropriately reconfigures the Execution Modules
- ✓ Execution Modules  
  - ✓ Contribute to implementation of Configuration States
  - ✓ Various reconfiguration mechanisms: functional / physical, software / hardware, ...
- ✓ Reconfiguration Support Data 
  - ✓ The data exchanged between the items of the chain

**The Reconfigurability Architecture of a given Equipment is the aggregation of the Reconfiguration Chains it features**



*A complete set of Technical Items...*

*...contributing to satisfy a Reconfiguration Use Case*

*Some items can be external...*

*...some are Reconfiguration Modules ...*



*...some are Execution Modules...*



*...some are Reconfiguration Support Data*



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## Context awareness

- ✓ Provides decision making with information on equipment external and/or internal context
- ✓ Examples: Monitoring and Discovery, Load Reporting, Resource Monitoring



## Decision making

- ✓ Contribute to determination of applicable configurations
- ✓ Examples: Negotiation and Selection, Flexible RAT allocation, Functional Mapper, ...



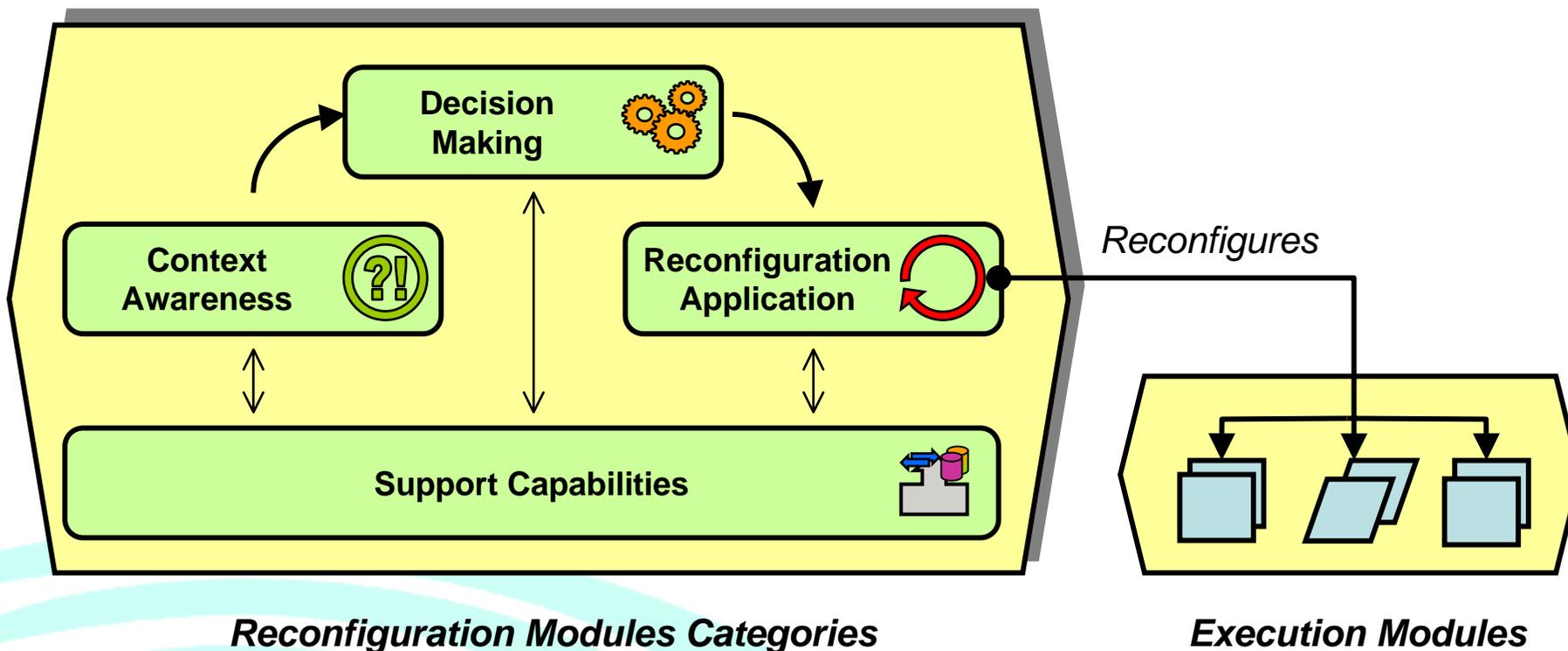
## Reconfiguration application

- ✓ Contribute to application of the selected configurations
- ✓ Examples: Core Framework, Adaptive Security Framework



## Support Capabilities

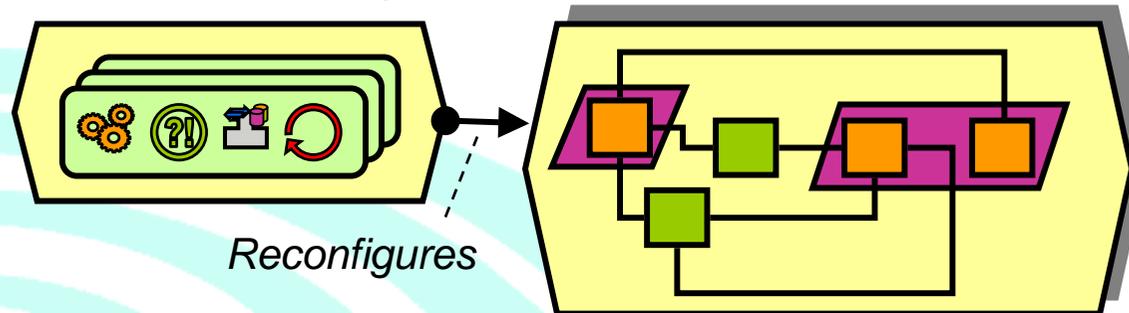
- ✓ Provides capabilities for Support Data management and Support Protocols
- ✓ Examples: files download, profile management, policies management



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- Flexible Hardware**
  - ✓ Hardware elementary parts or sub-systems supporting reconfiguration capabilities
  - ✓ Examples: flexible Transceiver, FFT ASIC accelerator,
- Execution Environment**
  - ✓ Processor, peripherals and software services subject to host diverse software components
  - ✓ Examples: General Purpose Processor, Digital Signal Processor, FPGA, ...
- Software Components**
  - ✓ Executable software components enabling to reconfigure the equipment through execution of diverse software components
  - ✓ Examples: RAT processing software module, Authentication service, ...



**Execution Modules are at Physical level**  
**Some are configurable, some not**



# Reconfiguration Support Data Categories



## Policies

- ✓ Data influencing the behaviour of reconfiguration chain agents
- ✓ Examples: negotiation policy, operating frequencies policy, ...



## Profiles

- ✓ Data serving as inputs / outputs of the reconfiguration chain
- ✓ Examples: user profile, billing profile, available spectrum profile...



## Functional Configurations

- ✓ Description of a Configuration taking no implementation assumption
- ✓ Examples: FDL, RAT PIM meta-data, « RAT UMTS », ...



## Physical Configurations

- ✓ Description of a Configuration involving the implementation modules
- ✓ Examples: SCA / P<sup>2</sup>SRC meta-data



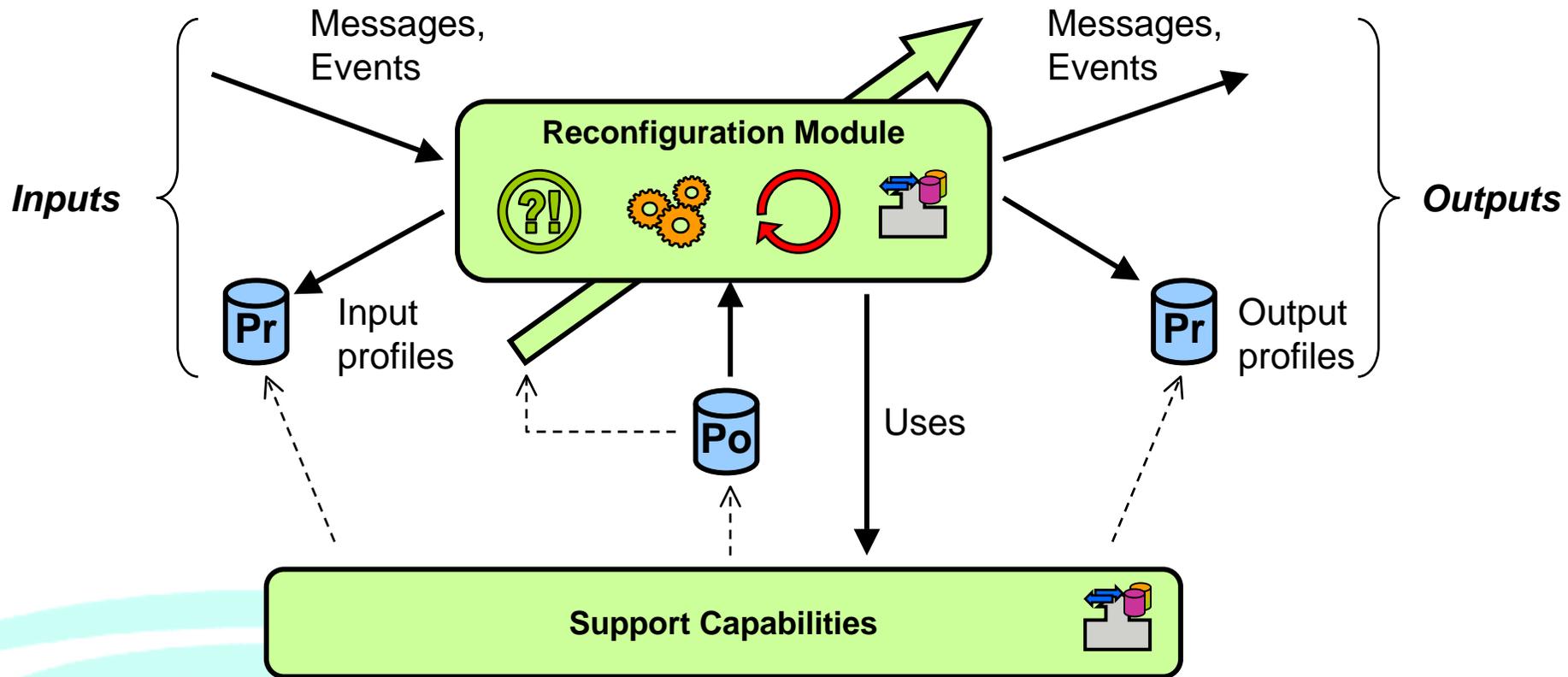
## Object codes

- ✓ Software executable executed to reconfigure using reprogramming
- ✓ Examples: executable dll, COFF file, FPGA bitstream

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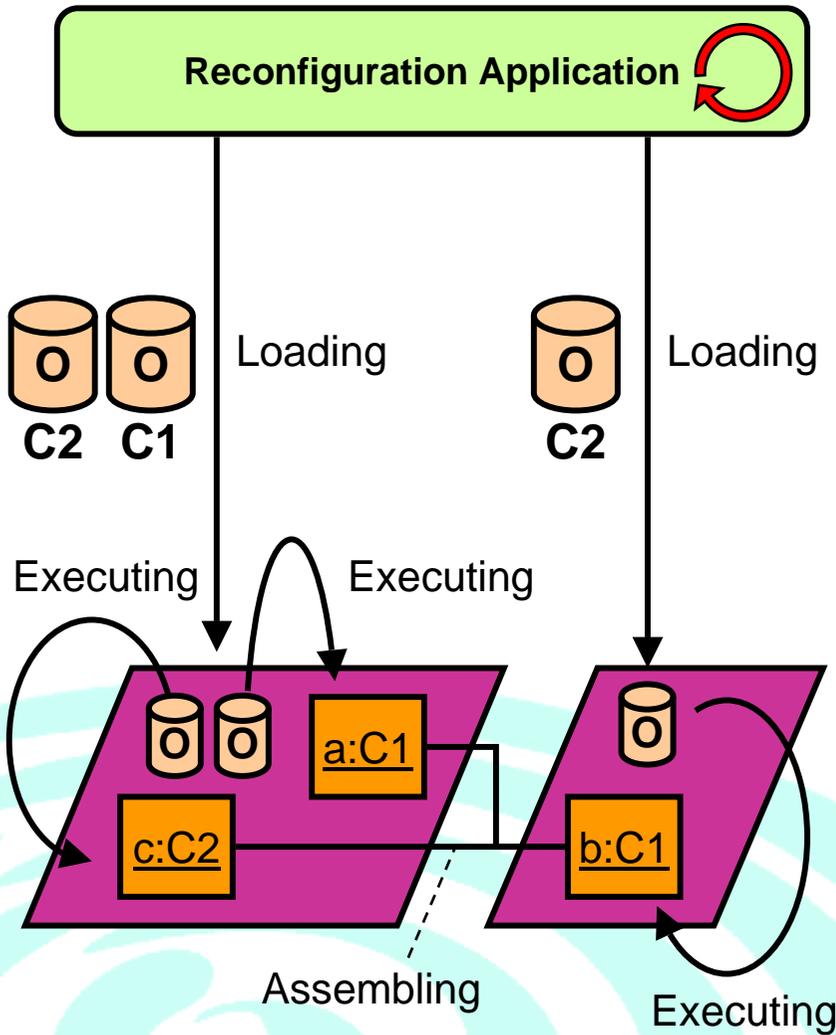




***Profiles and Policies can be handled thanks to Support Capabilities***

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*Executable binary files of various sorts...*

*...loaded on Execution Environments...*

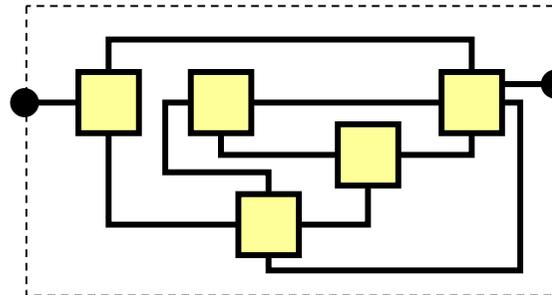
*...to give birth to Software Components when executed...*

*...which are then assembled to finalize deployment...*

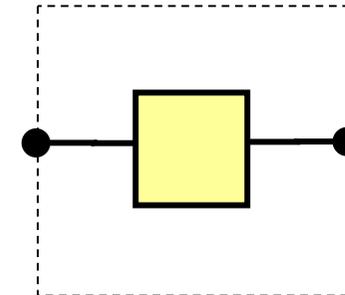


## Functional Configurations

*No implementation assumption  
HW/SW breakdown unknown*

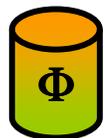


**Fine grain**



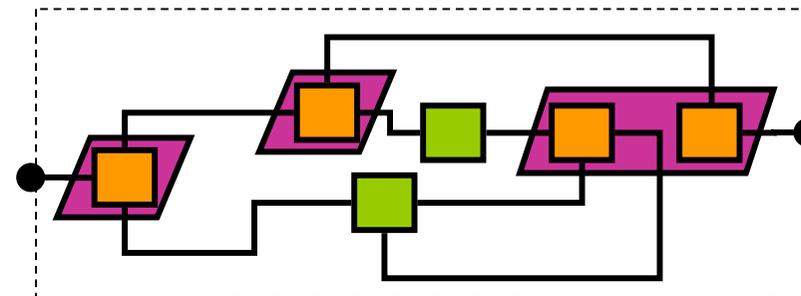
**Coarse grain**

*Variable granularity according to needs*



## Physical Configurations

*Implementation assumption defined  
HW/SW breakdown known*



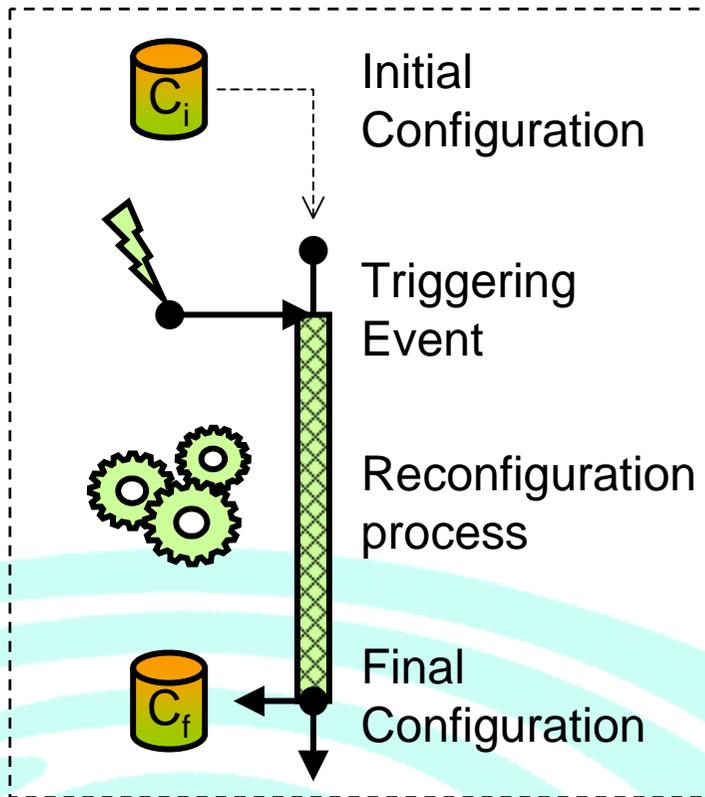
**Implementation grain**

*Physical Configurations are compositions of Execution Modules*

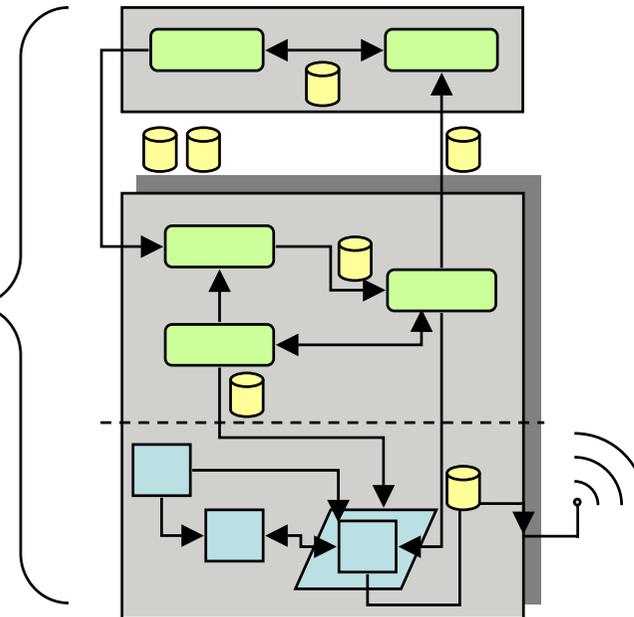
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↑ Illustrates



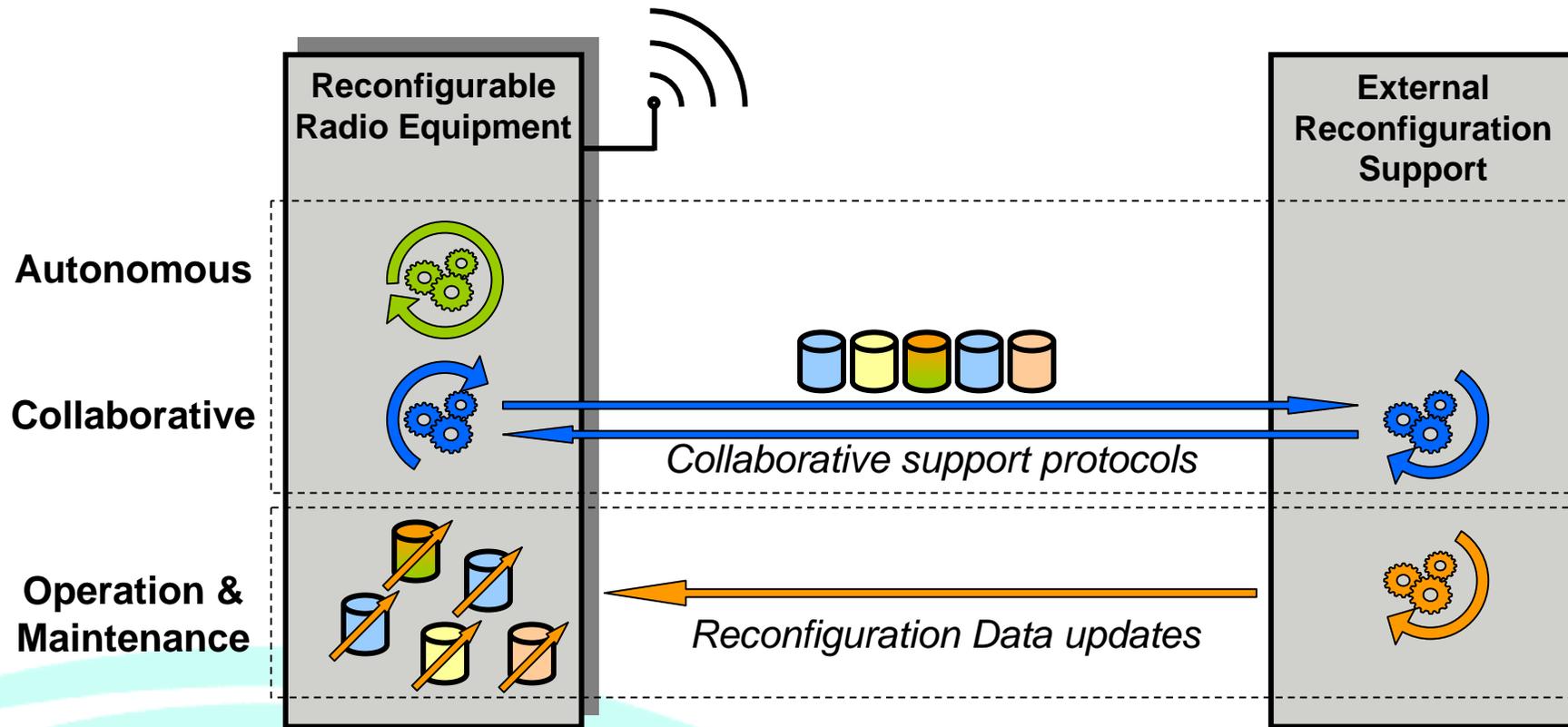
Involves



*Reconfiguration scenario encompass the whole Reconfiguration Chain  
The considered Configurations can be either Functional or Physical*

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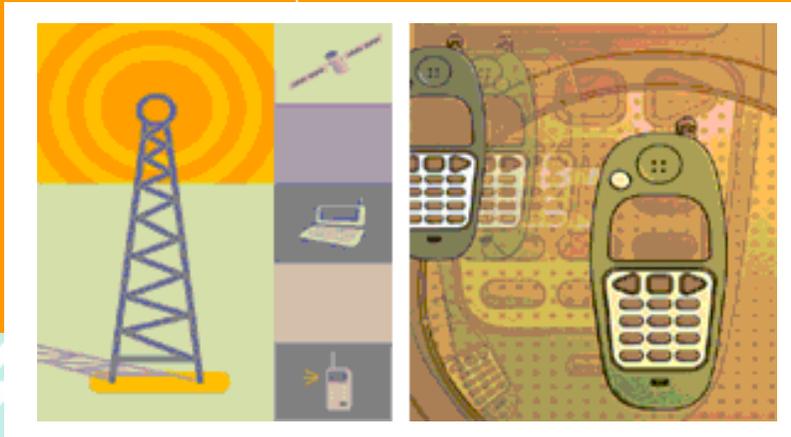


- ✓ Autonomous: no external Reconfiguration Support
- ✓ Collaborative: external Reconfiguration Support
- ✓ Operation & Maintenance: updates protocols (esp. Policies and Profiles) for Reconfiguration Data

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# The Reconfigurability Architecture Framework

*Formally capturing what is  
of common interest*

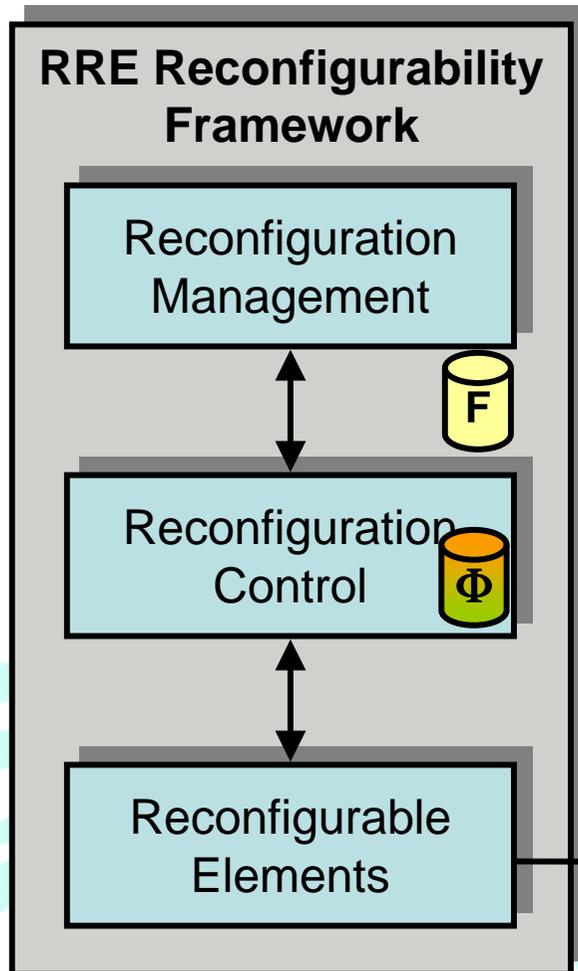


## Architecture Areas

- ✓ Organization artifacts / repositories
- ✓ Are sub-division level of the Architecture Framework
- ✓ Are coherent groupings of the common concepts of the Framework
- ✓ Those common concepts are Architecture Items

## Architecture Items

- ✓ Can be out-of-the-box **Common Items**
  - ✓ A particular Reconfigurability Architecture can use them as they are
  - ✓ Generally standard implementations (formal standard / *de facto*)
  - ✓ Example: Core Framework, OMA DM implementation, CORBA...
- ✓ Can be **Items Facilities** for dedicated Modules definition
  - ✓ A particular Reconfigurability Architecture will derive its Modules from the facilities Building Blocks (templates, algorithms, APIS, protocols...)
  - ✓ Example: API building blocks, Transceiver



## Reconfiguration Management → Modules **CMM**

- Determining applicable Configurations
- Autonomous or collaborative mechanisms
- The determined Configurations are Functional

## Reconfiguration Control → Modules **CCM**

- Transforming Functional Configurations into Physical Configurations
- Applying the Physical Configurations through reconfiguration of Reconfigurable Elements

## Reconfigurable Elements → Modules **CEM**

- Supporting the Reconfiguration capabilities
- Addressed through reconfiguration interfaces
- Software Components, Execution Environments, Flexible Hardware



# Reconfiguration Management



## Responsibilities

- ✓ Determining Functional configurations
- ✓ Ultimately decides of applicable functional configurations

## Main Interactions

- ✓ Towards Reconfiguration Control
- ✓ Possibly with external Cognition Support (collaborative chains)

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# Reconfiguration Control



## Responsibilities

- ✓ Mapping Functional configurations into Physical configurations
- ✓ Enforcing Configurations towards Reconfigurable Elements

## Main interactions

- ✓ Towards Reconfiguration Control
- ✓ Towards Reconfigurable Elements
- ✓ Possibly with external Cognition Support (collaborative chains)

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# Reconfigurable Elements



## Responsibilities

- ✓ Executing the reconfiguration capabilities
- ✓ Capturing sub-set of the Execution Modules

## Main interactions

- ✓ Towards Reconfiguration Control
- ✓ Between Reconfigurable Elements

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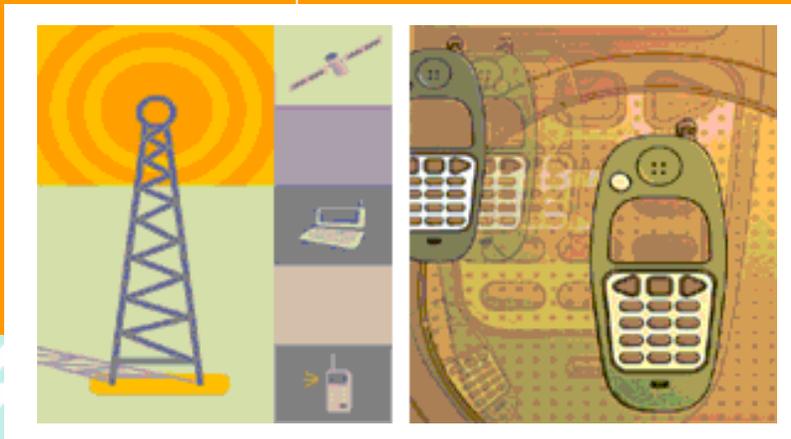
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# Formal modelling: the Reconfigurable Radio Equipment PIM



*Stereotypes*  
*Framework structure*

## Architecture Area

- ✓ Applicable to packages
- ✓ Such packages shall contain Architecture Items
- ✓ 3 defined so far: Reconfiguration Management, Reconfiguration Control, Reconfigurable Elements

## Architecture Item (virtual)

- ✓ Applicable to packages
- ✓ Such packages shall be sub-packages of Architecture Areas
- ✓ Virtual stereotype

## Common Item

- ✓ Inherited from « Architecture Item »
- ✓ Such package shall contain modelling artifacts of the Common Item

## Item Facility

- ✓ Inherited from « Architecture Item »
- ✓ Such package shall contain modelling artifacts of the Item Facility

## Reconfiguration Module (virtual)

- ✓ Applicable to a modelling artifact of an Architecture Item
- ✓ Inherited from standard « **Control** » stereotype



## Context awareness

- ✓ Inherited from « Reconfiguration Module »
- ✓ Applicable to context awareness controls of an Architecture Item



## Decision making

- ✓ Inherited from « Reconfiguration Module »
- ✓ Applicable to decision making controls of an Architecture Item



## Reconfigurability Application

- ✓ Inherited from « Reconfiguration Module »
- ✓ Applicable to decision making controls of an Architecture Item



## Support Capability

- ✓ Inherited from « Reconfiguration Module »
- ✓ Applicable to decision making controls of an Architecture Item

## Reconfiguration Support Data (virtual)

- ✓ Applicable to a modelling artifact of an Architecture Item
- ✓ Inherited from standard « Entity » stereotype



### Policy

- ✓ Inherited from « Reconfiguration Support Data »
- ✓ Applicable to context awareness entities of an Architecture Item



### Profile

- ✓ Inherited from « Reconfiguration Support Data »
- ✓ Applicable to decision making entities of an Architecture Item



### Functional Configuration

- ✓ Inherited from « Reconfiguration Support Data »
- ✓ Applicable to decision making entities of an Architecture Item



### Physical Configuration

- ✓ Inherited from « Reconfiguration Module »
- ✓ Applicable to decision making entities of an Architecture Item



### Object Code

- ✓ Inherited from « Reconfiguration Module »
- ✓ Applicable to decision making entities of an Architecture Item

# Thank you for your attention !

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