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

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Presentation Outline

Problem statement

Elementary Reconfigurability Architectures

Formal modelling
Problem statement
Reconfigurable Radio Equipments in the E²R landscape

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

Heterogeneous Systems
- Ubiquitous Access
- Pervasive Services
- Dynamic Resource Management

Heterogeneous Environments and Contexts
- Fixed\n- WLAN\n- WiMax\n- 2/2.5G\n- All-IP Infrastructure\n- 3G\n- 4G\n- Several administrative domains\n- Other Access Networks

Heterogeneous Devices

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The questions asked

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

- Heterogeneous Systems
  - Ubiquitous Access
  - Pervasive Services
  - Dynamic Resource Management

- Heterogeneous Environments and Contexts
  - Fixed
  - WLAN
  - WiMAX

Solutions

Technos

Standards

What Reconfigurability Architecture for the Reconfigurable Radio Equipments?

What Network Support for Reconfiguration?

How to harness the diversity of Reconfigurability cases and solutions?
Defining an architecture Framework

Particular Reconfigurable Equipments...

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

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

Reconfigurable Radio Equipment

Access Equipments

User Equipments

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Elementary Reconfigurability Architectures

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

Reconfigurable Radio Equipment

Configuration States

Re-configuration process

Time

Capability of a Reconfigurable Radio Equipment…

…to switch between Configuration States…

…as time elapses

The Configuration States can be Functional or Physical
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**.
Reconfiguration Chain (II)

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
Reconfiguration Modules

Categories

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
The Reconfiguration Modules
notional loop

Context Awareness

Reconfiguration Application

Decision Making

Support Capabilities

Reconfigures

Reconfiguration Modules Categories

Execution Modules

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Execution Modules Categories

- **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 / P²SRC meta-data

- **Object codes**
  - Software executable executed to reconfigure using reprogrammation
  - Examples: executable dll, COFF file, FPGA bitstream
Profiles and Policies can be handled thanks to Support Capabilities
Object codes

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 and Physical Configurations**

**Functional Configurations**
No implementation assumption
HW/SW breakdown unknown

**Physical Configurations**
Implementation assumption defined
HW/SW breakdown known

**Fine grain**
Variable granularity according to needs

**Coarse grain**

**Implementation grain**
Physical Configurations are compositions of Execution Modules
Reconfiguration scenario

- **Initial Configuration**
- **Reconfiguration process**
- **Final Configuration**

The considered Configurations can be either Functional or Physical.

Reconfiguration scenario encompass the whole Reconfiguration Chain.
Autonomous and Collaborative Reconfiguration Chains

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

**Reconfiguration Support**

**Collaborative support protocols**

**Reconfiguration Data updates**
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
The 3 Main Architecture Areas

RRE Reconfigurability Framework

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
## Responsibilities

- Determining Functional configurations
- Ultimately decides of applicable functional configurations

## Main Interactions

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

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

Main interactions

✓ Towards Reconfiguration Control
✓ Between Reconfigurable Elements
Formal modelling: the Reconfigurable Radio Equipment PIM

Stereotypes
Framework structure
Stereotypes Definitions for 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
Stereotypes definitions for Reconfiguration Modules

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
Stereotypes definitions for Reconfiguration Support Data

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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