E²R COMMERCIAL RECONFIGURABLE RADIO EQUIPMENTS: FROM ADVANCED RESEARCH TO PROOF-OF-CONCEPT AND STANDARDIZATION

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ABSTRACT

Reconfigurable Radio Equipments are key enablers of End-to-End Reconfigurability. They rely on two key enabling technologies: Software Defined Radio (SDR) and Cognitive Radio (CR), on top of flexible RAT (Radio Access Technique) processing chains.

E²R WP4 (Work Package 4) is evaluating the impacts of SDR and CR capabilities introduction on radio equipments architecture. Both sides of the radio media are considered, i.e. smart terminals and flexible base stations. WP4 is progressing towards a unified architecture description taking into account all the dimensions imposed by SDR, CR and flexible RAT processing. A particular attention is paid on the robustness constraints of highly constrained embedded equipments and their associated security requirements.

This paper presents the refined work assumptions of E2R II WP4 (as of Spring 2006), as well the collective activities conducted in the work-package. A specific focus is being set on the proof-of-concept and standardization objectives.

1. INTRODUCTION

Reconfigurable Radio Equipments are key enablers of End-to-End Reconfigurability : seamless experience across heterogeneous systems, heterogeneous environments and contexts, and heterogeneous devices.

Such Reconfigurable Radio Equipments are relying on two key enabling technologies: Cognitive Radio (CR) and Software Defined Radio (SDR), harnessing and implementing flexible Radio Access Technique (RAT) processing chains.

The SDR dimension is the basic capability to switch a radio equipment from one configuration state (e.g. RAT1) to another one (e.g. RAT2). This imply abstraction of the underlying equipment handled by a reconfiguration framework that effectively triggers and control a reconfiguration process.

Selection of the expected configuration state of an equipment can be realized according to countless considerations and strategies. The CR dimension of the problem has to do with these matters, where context awareness and autonomous/collaborative decision making process are taking place.

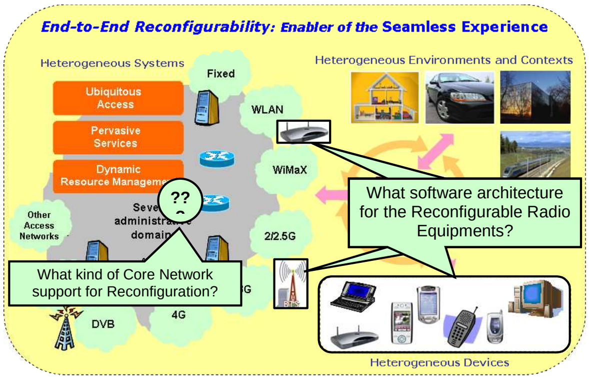

Figure 1 – Key questions about Reconfigurable Radio Equipments architecture research

E2R II WP4 is answering those questions from a general perspective (the architecture work) coupled to the realization of proof-of-concepts (PoC) demonstrations and contribution to standardization. The purpose of this paper is to expose the WP4 initial working assumptions on all those matters.

A reference model is introduced in section 2 to position the architecture areas inside the wide landscape of SDR and CR research. Detailed research topics are identified in section 3, with a refined break-down identifying the major technical concepts of each architecture area. How proof-of-concept demonstrations are derived and a glimpse about the assumptions under investigation are provided in section 4. Finally the related standardization efforts are depicted in section 5.

2. REFERENCE MODEL

A reference notional model (from [2]) is introduced to describe the elements necessary to provide in order to make a SDR Equipment (User Equipment or Base Station) :

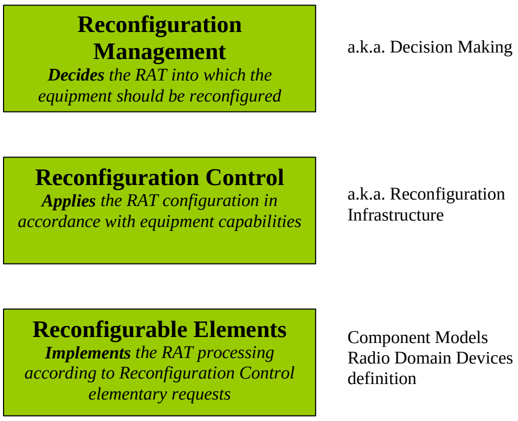

Figure 2 : Reference Notional Model of SDR Equipment Building Blocks

2.1. Reconfiguration Management

Also known as Decision Making, Reconfiguration Management covers all the means inside an Equipment enabling it to contribute to take the appropriate decision concerning the RAT reconfiguration to be applied.
Those means range from very simple (a mere pushbutton on the front panel for the user to switch between one RAT to another) to very complex collaborative expert systems (such as the ones investigated in cognitive radio research).
In E2R context, those are the concepts explored by the RMP (Reconfiguration Management Plane) System Architecture studies and associated implementations, captured under the general Phase 1 wording of Configuration Management Module (CMM).

2.2. Reconfiguration Control

Also known as Reconfiguration Infrastructure, Reconfiguration Control covers all the means inside an Equipment enabling it to appropriately take advantage of the reconfigurable elements it is composed of.
Several solutions currently exist to perform some sorts of reconfiguration control, all being based on meta-data descriptors if the target applications (the RAT configuration mode) and the hosting platform (a certain set of reconfigurable elements).
Additionally to the basic configuration control, enhanced features taking into account optimization objectives are being investigated.
In E2R context, the corresponding concepts were identified in Phase 1 as being the Configuration Control Module (CCM).

2.3. Reconfigurable Elements

Two main categories of Reconfigurable Elements are distinguished : the processing units subject to host RAT modules (among which GPP, DSPs, FPGAs), the reconfigurable elements which are reconfigured thanks to parameters adjustments instead of software installation and execution.
In E2R context, the corresponding concepts were identified in Phase 1 as being the Configurable Execution Modules (CEM).

3. RESEARCH TOPICS

E2R II WP4 undertakes efforts on each of the three areas of the reference model : Reconfiguration Management, Reconfiguration Control, Reconfigurable Equipments.
Efforts to produce a coherent reference software architecture, backed by a possible common UML model of the concerned modules, will be undertaken.

3.1. Reconfiguration Management

Based on the findings and architecture definitions of E²R Phase I equipment Reconfiguration Management is covered by the Configuration Management Module (CMM) concept.
It manages the reconfiguration processes according to specified semantics, protocols and configuration data model. CMM is further split into the following sub-modules :

- CMM_Prof: storing, retrieving, updating, and parsing Equipment profile information, such as QoS preferences, price user is willing to pay, technological capabilities, configurations present in memory, etc.
- CMM_MD: monitoring and discovery of RATs, performed at regular intervals. Collects from Rats information such as received signal strength, noise level, bit rate and bit error rate.
- CMM_NS: negotiation and selection, which decides a new configuration (new RAT) based on retrieved information and provides policy variables for the selected configuration to CMM_DMP.
- CMM_Dwnld: manages the download of configuration data provided by operators or manufacturers as well as execution environment software, protocol software and also new security algorithms.
- CMM_Sec: security module namely implements a policy manager to check and store permissions for operations that threads can perform on equipment resources.
- CMM_DMP: collects policies from different stakeholders and combines them in order to dynamically create final policy rules for the device (for the manufacturer, the network operator, and the user).

- CMM_Ifnss: realizes the interaction with network services and the related signalling to trigger other CMM sub-modules.
- CMM_Evnt: communicates configuration control commands from CMMs to CCMs and the related responses in the other direction. This module shall be also used to dispatch to low-level software components in the OS space.
- CMM_Inst: monitors, guides and controls the installation process in CCMs and recovery and/or rollback invocation if necessary. Keeps record of meta-data on what was sent where and its installation status in-case a rollback is needed.
- CMM_MM: this draft entity is entirely responsible for mobility management issues.

The following class diagram summarizes this breakdown:

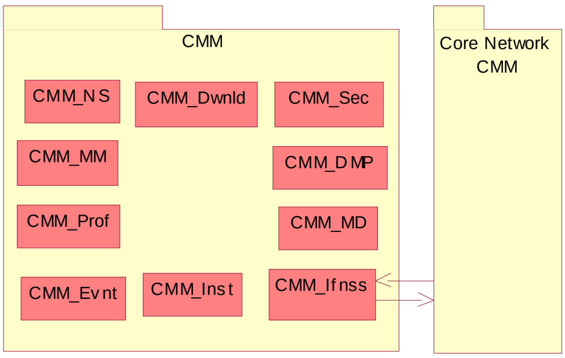

Figure 3 – Sub-modules of Equipment CMM

Efforts to detail the aforementioned structure will be conducted, completed with alignment with studies conducted around Reconfiguration Management Plane System Architecture.

3.2. Reconfiguration Control

Based on the findings and architecture definitions of E²R Phase I equipment Reconfiguration Management is covered by the Configuration Control Module (CCM) concept. Functional Description Language (FDL) will be an enabling element of the structure described hereinafter.
Recent achievements enabled to draft an internal breakdown structure of the CCM:

- CCM_FunctionalMapper: maps the functional descriptions of the application towards available RAT modules, possibly developed for heterogeneous processing units.
- CCM_PlatformMapper: resolves the dependencies between the available RAT modules and the existing processing units available on the equipment. This is done in the most straightforward way.
- CCM_SpatialScheduler: an enhancement of the PlatformMapper that is capable to take advantage of profiling informations to oprimize the mappinf of RAT modules onto processing units according to various policies and criteria.
- CCM_Prof: dynamically provides information on available resources of various sorts (available processing power, memory, …) to support Spatial Scheduling.
- CMM_D&C: deployment and configuration applies towards each Reconfigurable Element the appropriate reconfiguration requests, some being software loads and executions, being completed with parameters adjustments on reconfigurable elements.

The following class diagram summarizes this breakdown:

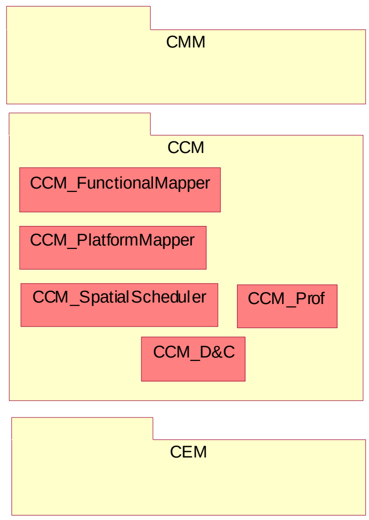

Figure 4 – Sub-modules of Equipment CCM (initial draft)

Efforts to detail the aforementioned structure will be conducted, completed with alignment with studies conducted around Reconfiguration Management Plane System Architecture.

3.3. Reconfigurable Elements

Based on the findings and architecture definitions of E²R Phase I, Equipment Reconfiguration Management is covered by the Configurable Execution Module (CEM) concept.
Research will be focused on Instruction Set Architectures, with approaches centred on software frameworks definitions to enable smart RAT modules reconfiguration, and approaches centred on reconfigurable hardware processor specifically optimized to meet the stringent constraints of the User Equipments.
Strong efforts will be made to articulate the outcome of those both approaches coherently with Reconfiguration Control concepts.

4. PROOF-OF-CONCEPTS

4.1. Approach

The Proof-of-Concept will identify and implement under appropriate facilitating assumptions some of the modules of the reference architecture introduced beforehand.

High attention will be paid in articulating the demonstration scenarios with relevant business level scenarios involving the enabling technologies demonstrated in the PoC.

Such scenarios currently being envisaged :

- Moving hot spot (BS level),
- Load balancing (BS level)
- Mass upgrade (UE level),
- Execution Environment Switching (UE level).

4.2. PoC for User Equipments

The following figure depicts the PoC configuration currently under investigation for User Equipments :

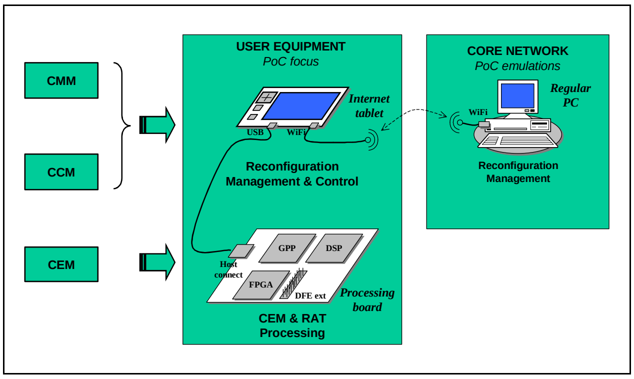

Figure 5: PoC configuration under investigation for User Equipments

The Nokia 770 is proposed to host PoC implementations at User Equipment level of some CMM and CCM modules.

Its Wi-Fi connection would be the bearer for transactions with Core Network CMM modules, while USB would support data transmission with the HW evaluation and processing board which shall embed CEM and RAT processing.

Two paths for CEM & RAT Processing solutions are being investigated :

- A general purpose processing board with DSP and FPGA resource enabling to investigate heterogenous processing environments,
- A board based on SAMIRA processor developed in the work package optimized DSP.

4.3. PoC for Flexible Base Stations

Envisaged Proof-of-Concept (PoC) demonstrators for base stations are focused on the physical layer of a reconfigurable multi standard base station (MSBS), which play an important role in the reconfigurable network scenarios of E2R.

The following figure depicts the PoC configuration envisaged for Flexible Base Stations :

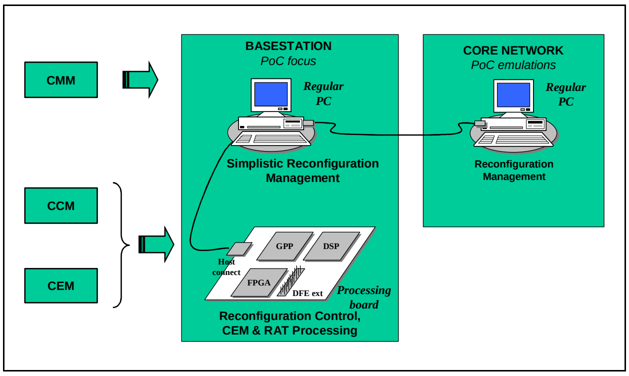

Figure 6: PoC configuration under investigation for Base Stations

As working platform, a state-of-the-art multicore processing system will be used comprising GPP, DSPs, and HW-accelerators on a SoC, supported by FPGAs and interface logic.

Starting from an existing legacy dedicated air interface implementation, where the whole operation code including RTOS is loaded as one 'firmware' bulk without any possibility of reconfiguration, a primary configuration control engine (PCC) will be developed as the CCM_D&C. It will manage the RAT deployment by accordingly configuring the processing devices. Further references can be found in [5] and [6].

The PoC shall on the one hand validate the mechanisms partly derived from the OMG Platform Independent Model (PIM) as reliable and economic Platform Specific Model (PSM) solution for RAT deployment and on the other hand allow the demonstration of selected scenario. The deployment of supplementary air interfaces is envisaged.

5. FORESEEN STANDARDIZATION OUTCOMES

For the sake of WP4 areas of interest, identified standardization opportunities have so far been identified at two levels : Open Mobile Alliance (OMA) and Object Management Group (OMG).

OMA activity will be concentrated around two activities of the OMA :

- Device Management,
- Data Synchronisation.

OMG activity will be concentrated around two Software Based Communications Domain Task Force:

- PIM and PSM for Software Radio Components (P^2SRC) (a.k.a. SWRadio Spec),
- Digital IF (Digital Interface).

5.1. OMA Device Management

The goal of the Device Management (DM) Working Group is to specify protocols and mechanisms that achieve management of devices. Management includes:

- Setting initial configuration information in devices
- Subsequent installation and updates of persistent information in devices
- Retrieval of management information from devices
- Processing events and alarms generated by devices

5.2. OMA Data Synchronization

The goal of the Data Synchronization (DS) Working Group is to continue development of specifications for data synchronization, and to develop other similar specifications, including but not limited to SyncML technology. These specifications will include conformance specifications and a set of best practices that describe how to use the data synchronization technology specifications within the OMA Architecture.

5.3. OMG P²SRC

P²SRC is complex specification that encompasses most aspects necessary to come up with a Reconfigurable Equipment.

Concerning CCM_D&C; possibility to take advantage of existing OMG Core Framework specification items (meta-data structure, interfaces, properties, general concepts) could avoid redefinitions of equivalent concepts in the reference software architecture. These possibilities will be traded off against existing backgrounds and achievements from Phase 1, with proprietary Primary Configuration Engines implementations and existing interfaces to access the CEM.

Concerning CEM, efforts to define a Platform Specific Model (PSM) adapted to the highly constrained processing units such as DSPs will be realized.

5.4. OMG Digital IF

Digital IF effort will be focused in contributing to revised submission so as to have a baseline set of interfaces coming from an existing standard to characterize the dependency of the RAT software towards Transceiver implementation.

This is expected to be a key enabler of future integration of the PoC demonstrations into E²R Integrated Reference Prototype.

6. CONCLUSION

This paper has presented the overall approach of E2R II WP4, as once established to guide the activities. An important focus is set on the reference architecture, the expected PoC demonstration and standardization perspective.

It shows that the research activity conducted on reference software architecture for SDR equipments will be backed by important efforts to achieve proof-of-concepts and significant contribution to community standardization efforts.

The content is depicted the assumptions as identified in Spring 2006. Since then, significant results and inflexions have been obtained, some of them being described in [7] (Reconfigurable Radio Equipment PIM) and [8] (Transceiver APIs).

ACKNOWLEDGMENT

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7. REFERENCES

[1] End to End Reconfigurability Phase II (E2RII), IST-2003-507995 E2R, http://www.e2r.motlabs.com

[2] E. Nicollet, E²R and P²SRC : some fruitful research opportunities? http://www.omg.org/registration/SDR-webcast.htm

[3] Don Kretsch, Sun Studio Engineering Director, December 15, 2005, ‘Beware: Concurrent applications are closer than you think!’

[4] The Open Group, http://www.opengroup.org/

[5] E²R Deliverable D4.4 ‘Configuration Control Module Architecture and Interface Specification’.

[6] E²R Deliverable D4.6 ‘Operational Environment’.