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Technical Report

**Reconfigurable Radio Systems (RRS);
Radio Base Station (RBS) Software Defined Radio (SDR) status, implementations and costs aspects, including future possibilities**

Reference

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Keywords

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Reconfigurable Radio Systems (RRS).

Introduction

The present document provides the results of a feasibility study carried out under the ETSI TC on reconfigurable radio systems (RRS). The target of the study was to investigate the need for standardization within the cellular radio base station to address the requirements resulting from on-situ reconfiguration of future RBS.

The study addresses current radio base station architectures, the possibilities provided by software radio architectures and the requirements of future RBS. The study considers also the impact of re-configurability on the total life cycle energy consumption and the environmental impact of radio base stations.

1 Scope

The scope of the present document is to investigate and assess possible architectures, related qualities and corresponding costs of reconfigurable radio base stations (RBS). It covers public radio systems working on licensed bands (including GSM, WCDMA, LTE, WiMax and similar).

The present document will include expected future technology and cost developments of these architectures. Definition of key possible requirements for SDR applications in RBS, the impact on RBS architecture, network management and equipment certification. It covers reconfigurable RBS on a generic level independent of power classes defined in 3GPP.

2 References

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Not applicable.

2.2 Informative references

The following referenced documents are not essential to the use of the present document but they assist the user with regard to a particular subject area**.** For non-specific references, the latest version of the referenced document (including any amendments) applies.

[i.1] White Paper of the European Project IST-E2R II (June 2007): "End-to-End Reconfiguration Management and Control System Architecture", Zachos Boufidis, Eleni Patouni, Nancy Alonistioti.

[i.2] IST-E2R II Contribution to ETSI Workshop (February 2007): "End-to-End Reconfigurability (E2R II) Management and Control of Adaptive Communications Systems", Didier Bourse, Markus Muck.

NOTE: Available at http://www.etsi.org/website/document/Workshop/SoftwareDefinedRadio/SDRworkshop1-1DidierBourse.pdf.

[i.3] ICT Summit (2006): "E²R SDR Equipments : towards Proof-of-Concept and Standardization", E. Nicollet, Ulf Lücking, Siegfried Walter, Björn Mennenga, Laurent Alimi.

NOTE: Available at http://www.vodafone-chair.com/staff/mennenga/publications/2006/E2RII_35_ICT06_Paper.pdf.

[i.4] ETSI TR 102 680: "Reconfigurable Radio Systems (RRS); SDR Reference Architecture for Mobile Device".

[i.5] SDRF-01-P-0006-V2.0.0: "Base Station System Structure".

NOTE: Available at http://www.sdrforum.org/pages/documentLibrary/documents/SDRF-01-P-0006-V2_0_0_BaseStation_Systems.pdf.

[i.6] ETSI TR 102 530: "Environmental Engineering (EE); The reduction of energy consumption in telecommunications equipment and related infrastructure".

[i.7] Life cycle analysis of communication system, Jens Malmodin, Green Telco 2009.

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

radio application: software application executing in software defined radio equipment

NOTE Radio application is typically designed to use certain radio frequency band(s) and it includes agreed schemes for multiple access, modulation, channel and data coding as well as control protocols for all radio layers needed to maintain user data links between adjacent radio equipments, which run the same radio application.

radio equipment: equipment using radio technology

radio technology: technology for wireless transmission and/or reception of electromagnetic radiation for information transfer

radio system: system, which consists of a number of radio equipments using at least one common radio technology

reconfigurable radio equipment: radio equipment supporting reconfigurable radio technology

reconfigurable radio system: radio system using reconfigurable radio technology

reconfigurable radio technology: radio technology allowing the modification of modulation, frequency or power by S/W, possibly with extensions for cognitive radio

NOTE: Re-configurability includes the typical understanding of SDR like the ability to change RAT (Re-configurable within 3GPP standards like EDGE/ WCDMA/ LTE), re-configurability between all standards, capacity upgrades to match future needs and mixed or flexible spectrum (single or multi-band) usage.

software defined radio equipment: radio equipment supporting SDR technology

software defined radio system: radio system using SDR technology

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

BB	BaseBand
CAPEX	CAPital EXpenditure
CCM	Configuration Control Module

CEM Configurable Execution Modules
CMM Configuration Management Module
CPRI Common Public Radio Interface
CR Cognitive Radio
EOL End Of Life
GSM Global System for Mobile communications
HSPA High Speed Packet Access
IP Intellectual Property
IP Internet Protocol (as in TCP/IP)
JEDEC Joint Electron Device Engineering Council

NOTE: JEDEC Solid State Technology Association.

LTE Long Term Evolution
MEMS Micro Electro-Mechanical Systems
MIMO Multiple Input Multiple Output
MURI MUlti-Radio access interface
OBSAI Open Base Station Architecture Initiative
OPEX OPerational EXpenditure
PCle Peripheral Component interconnect express
RAT Radio Access Technology
RBS Radio Base Station
REC Radio Equipment Control
RF Radio Frequency
RPI Radio Programming Interface
RRFI Reconfigurable RF Interface
RRS Reconfigurable Radio System
RX Receiver
SCA Service Component Architecture
SDR Software Defined Radio
SON Self Organizing Network
S-RMP Self-ware Reconfiguration Management and control Plane
TCP Transport Control Protocol
TM Trade Mark
TX Transmitter
URAI Unified Radio Application Interface
WCDMA Wideband Code Division Multiple Access

4 RRS RBS requirements

Re-configurability requirements are partly different for user equipment and RBS. In clause 4.1 we list general requirements based on different use cases. In clause 4.2 different requirements based on telecom operator needs and telecom infrastructure equipment manufacturers are listed.

4.1 Re-configurability requirements from use cases

4.1.1 Generic requirements for reconfigurable RBS

- Transition from one standard to a new (example GSM=> WCDMA, WCDMA=>LTE, etc.).
- Multi-standard use, frequency re-farming.
- Spectrum trading.
- Secondary spectrum usage.
- Dynamic capacity optimization depending on load (energy saving).
- Network planning and adaptation, antenna tuning.

- Backhaul reconfiguration for flat architecture.

These use cases above require the re-configurability of:

a) Modulation and BW.

b) Frequency allocation (existing bands and future bands, cognitive radio).

c) Dynamic spectrum allocation.

d) Multi-standard operation.

e) Power levels, capacity, efficiency.

f) FDD/TDD operation change.

g) Network architecture modifications.

4.1.2 Potential additional requirements for Femto/home-RBS

It is expected that there will be a future market for reconfigurable Mobile Devices that offer the possibility to either operate as a standard Mobile Device entity providing voice/data service access to end-users and/or as a Femto-Base-Station (Femto-BS). In order to enable an efficient implementation, such "Dual Mode" devices require the following:

- The Femto-BS mode of the corresponding "Dual Mode" device should build on a standard architecture typically applied for Reconfigurable Mobile Devices, for example such as it is defined in TR 102 680 [i.4]. Suitable extensions to such available architectures need to be defined.

- The corresponding device is expected to build on reconfigurable hardware, typically exploiting SDR principles.

4.2 Stakeholder requirements

The following requirements are collected from the needs of current stakeholders. The requirements are separated according to the different stakeholders. A requirement is mentioned in multiple sections if it applies for several stake holders.

4.2.1 Operator requirements

The development of different systems which coexist temporally and geographically requires to manage at the same time and in the same area, two or more systems in order to adapt the network to the characteristics of the traffic and optimize the resource usage. Typically, said problem rises for an operator who has already an installed network and wants to add a new network related to a new generation system (e.g. to add an LTE network to a 2G-3G network already deployed). Moreover, the operator wants to be able to manage dynamically the hardware resources dedicated to the existing system and to the new generation system, according to the traffic variation that insists on the cells of a certain area.

Considering a cell set in a certain area, it is possible that the traffic of different services on a specified system (or different systems), changes from one area to the other according to the day period. Moreover it could happen that some cells may be congested (high call blocking percentages) in some particular area while surrounding cells are less loaded or characterized by low blocking percentages. In addition, in case of deployment of two or more RATs in the area, the traffic from different services on each deployed RAT could also be differently distributed in time with respect to the other deployed RATs.

In this context, the availability of reconfigurable nodes in the networks (i.e. nodes whose hardware and processing resources can be reconfigured in order to be used with different RATs, frequencies, channels, etc.) will give the network operators the means for managing in an overall efficient way the radio and processing resource pool, with the aim to adapt the network itself to the dynamic variations of the traffic offered to the deployed RATs and to the different portions of the area. Besides of that, possible OPEX and CAPEX reduction could be obtained in network deployment.

In a Basic scenario we consider a mature network evolution example. We assume a residual GSM and UMTS infrastructure and starting LTE deployment: all standards within the operator's licensed spectrum. Currently the access nodes are configured manually by Operator. In the future we expect that the access nodes are configured by the network automatically. All RATs implemented (e.g. by software) in the RBS are fully compliant with the current existing standards (e.g. GSM, UMTS, LTE, WIMAX, etc.) and related regulatory restrictions (bands, frequencies, power levels, spectrum masks).

Basics requirements for network planning:

- Availability of a tool to make a coverage forecast considering different self configuring radio access network scenarios.

Basic requirements for Radio network deployment:

- Reduced surface/volume radio nodes.
- Standardization of mechanical aspects of equipment installation like cabinet, number type and position of RF, power, data and alarm connectors.
- Standardization of RF connection between access node and antennas (passive RF elements, duplexer, combiners).
- Standardization of link between access node and core network (only one physical link to manage different standards links).
- RBSs are completely compatible with the current deployed network elements; this means that RBSs should use common standardized interfaces (new or existing modified ones) that guarantee a transparent introduction in the current networks.
- RBSs are deployed and configured by the Operator according to its needs, e.g. exploiting current and future standardized SON capabilities.

Basic requirements for Network operation:

- RBS is able to be reconfigured in both hardware (e.g. both BB and RF) and radio resources for each supported RAT.
- RBSs should be multi-standard reconfigurable nodes.
- The percentage of hardware/processing resources devoted to each supported RAT can be dynamically modified.
- The number of frequencies/channels assigned to each supported RAT can be dynamically modified.
- RBSs are able to be reconfigured taking into account the experimented network and users conditions (e.g. traffic and/or interference conditions).
- RBS should be able to receive and execute reconfiguration commands coming from entities that manage the reconfiguration of the network via common standardized interfaces; such entities should be located e.g. in access or in core network or in O&M nodes, considering also flat architectures (e.g. HSPA+ and/or LTE based).
- The reconfiguration phase of a RBSs are performed in real-time and/or in the fastest way without the necessity to shut down and restart the device (e.g. in case of Multi-RAT operations/reconfigurations).
- RBS could be able to manage both operator's and other possible available spectrum to provide subscriber demands, considering behaviour of standard/services (coverage, capacity, mobility) in different frequency bands.
- RBSs should be efficient from the "green aspects" point of view (e.g. power consumption and related issues).
- Reduced power consumption according to TR 102 530 [i.6].
- Improved temperature operating range.

Maintenance requirements:

- Reduced number of different spare parts required for maintenance purposes: increasing compatibility degree (mechanical, electrical, protocol level) between the building blocks of every node for every supplier, reduce the number of building blocks of every node and making sure that building blocks will not need a hardware upgrade for new standards.

4.2.2 OEM requirements

The growing number of radio standards, frequency allocations and RBS classes dramatically increase the number of product variants. Re-configurability is considered to ease product logistics:

- Customer requirement/competition.
- S/W upgrade of existing products (GSM=> EDGE, WCDMA=>HSPA), capacity upgrade.
- Maintenance (O&M and other support system).
- Limited number of test cases.
- Certification.
- Reliability (H/W & S/W reliability).
- Product roadmap management.

4.3 Power efficiency and energy consumption

Energy consumption should be considered for the complete life cycle of the RRS (materials, production, delivery, operation, end of life).

Lifetime energy consumption (energy consumed during operations).

Power efficiency is defined as RF power divided by DC input power for a given use pattern.

Embedded energy (materials, components, production, EoL).

5 Architectures for current RBS

The present document covers the part of the network which is typically called "radio base station" (RBS, NodeB, eNodeB, etc.). It includes all elements of a RBS including:

- RBS control and reconfiguration control.
- Radio front-end (frequency selective part).
- Signal processing part.
- Network processor, RNC functionality, etc.
- RRS core network solutions are included in many SDR discussions. This is considered beyond the mandate of the work item.

5.1 Basic RBS architecture

The RBS as considered above can be divided into high level functional blocks. The transport and baseband functions are purely digital signal processing and provide the largest potential for S/W re-configurability. The TRX block contains radio frequency components, which poses a basic H/W limits, also today's broadband technologies allow a wide range of configuration. The final RF part is frequency selective and power limited by its H/W implementation. It poses the biggest challenge regarding configurability.