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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

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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
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Contents

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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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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.

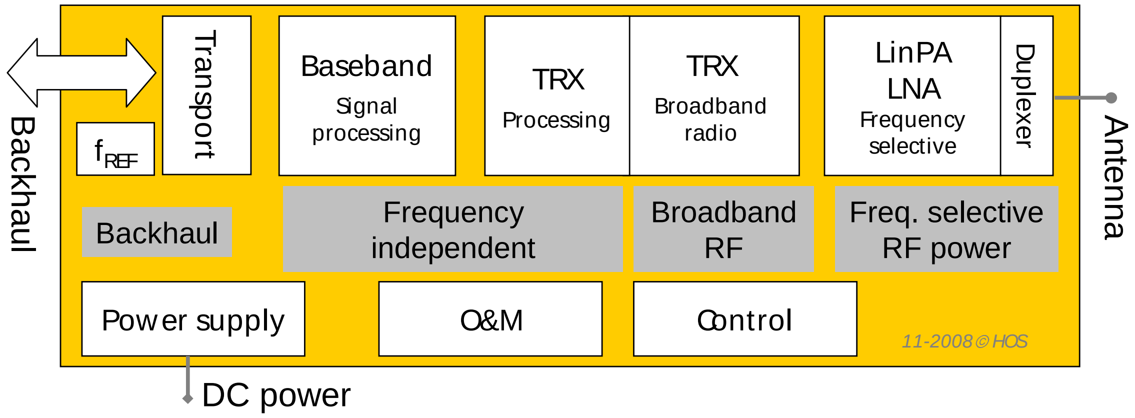

Figure 1: Basic RBS functional blocks

Above RBS block diagram is often split into a system unit and one or multiple radio units. The system unit includes the transport (backhaul) unit, timing, coding, control, multi-radio and multi- antenna processing, control, O&M, etc. The radio unit includes channelization, modulation, all analogue RF processing, power amplifier and filtering. This architecture supports remote radio applications but also multi-antenna solutions like MIMO and beam forming.

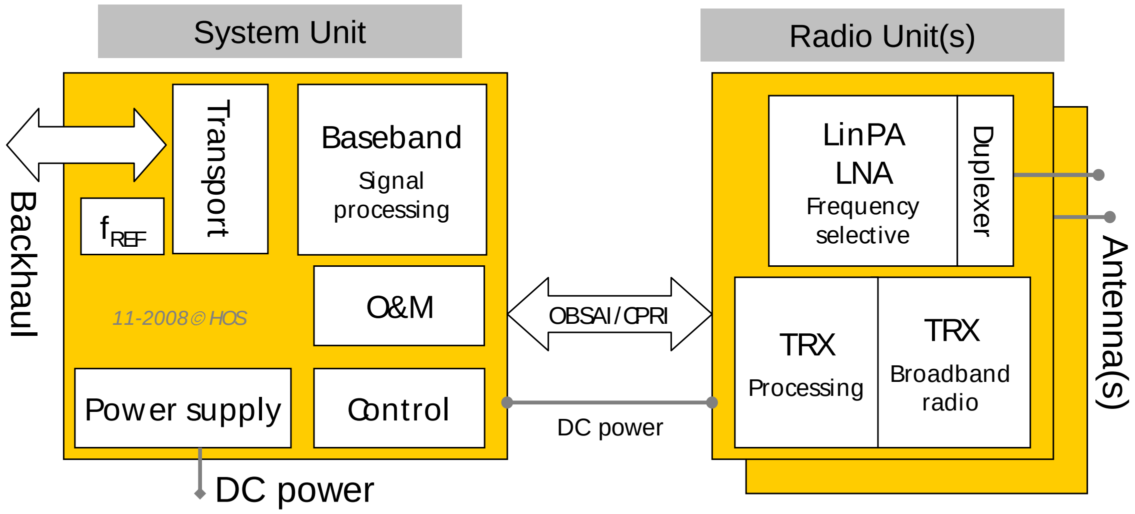

Figure 2: RBS architecture with separate radio units

5.2 Re-configurable radio architecture examples

Several groups made an attempt to define re-configurable radio architectures with different key applications in mind.

5.2.1 Example architecture from E2R and E3 projects

The IST-E^{2}R II project addressed two distinct types of architecture: A *System Architecture* is defined as presented in [i.1], relying on the definition of system-wide functionalities on an abstract plane (the so-called *Self-Ware Reconfiguration Management Plane (SRMP)*). The break-down of these functionalities on the various physical entities is performed in a second step.

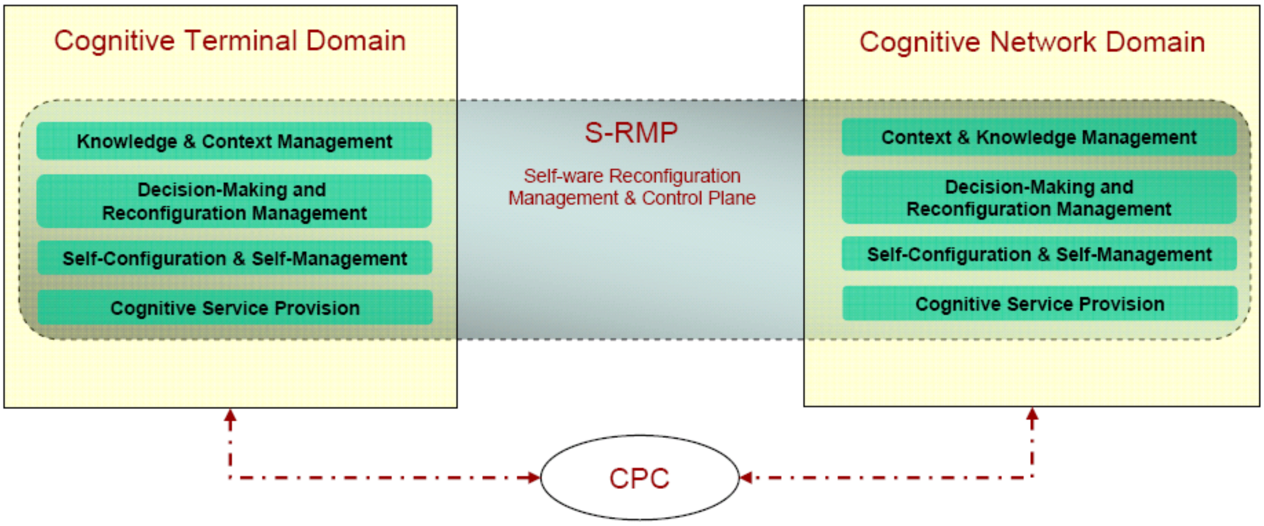

Figure 3: E²R II high-level system architecture for cognitive reconfigurable wireless networks (see [i.1])

As detailed in [i.1], the S-RMP provides elements (terminal equipment, base stations, and routers) with the necessary control and management capabilities so as to be autonomously reconfigured. The SRMP offers the following reconfiguration services:

- over-the-air software-download resulting in upgrade of equipment capabilities;
- dynamic spectrum access and exchange;
- dynamic network attachment and intersystem handover; and
- reconfiguration of hardware resources aiming at the optimization of physical layer performance (e.g. reduced power consumption).

Furthermore, E2R II defines an Implementation architecture detailing the management and control framework of reconfigurable elements. A more detailed description of the inherent definitions of the Configuration Management Module (CMM), the Configuration Control Module (CCM) and the Configurable Execution Modules (CEM) is available in [i.3].

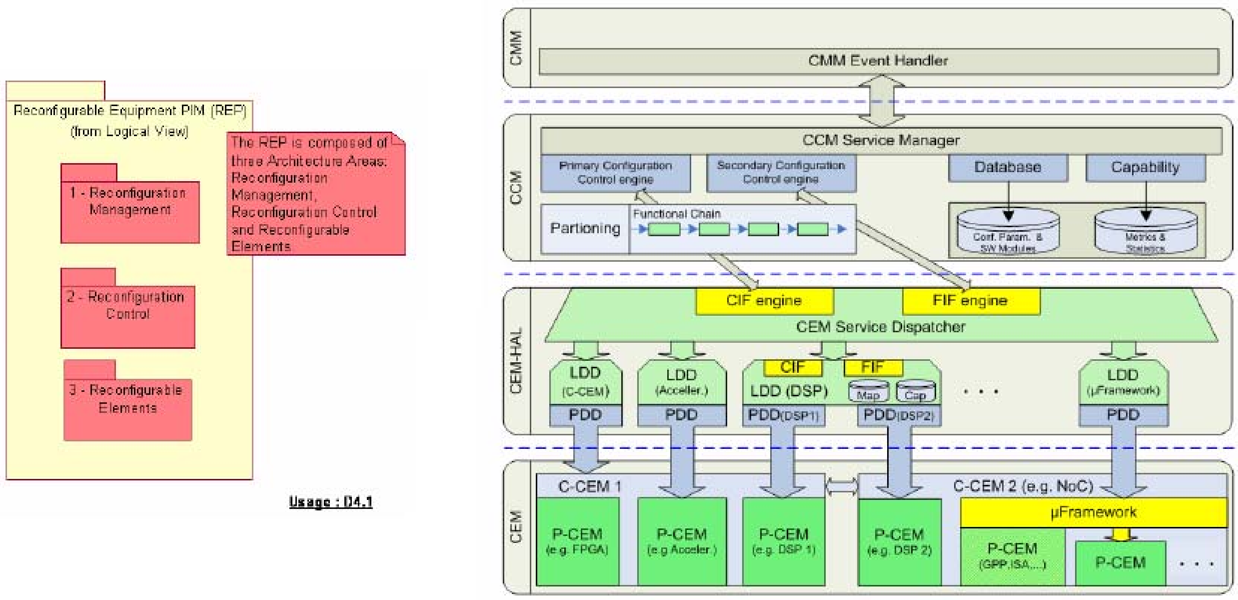

Figure 4: E²R II Implementation Architecture (see [i.2] and [i.3])

In the ICT project E3 the architectural considerations of E2R II have been further developed. A "pillar" model provides a very high level functional view onto heterogeneous radio systems.

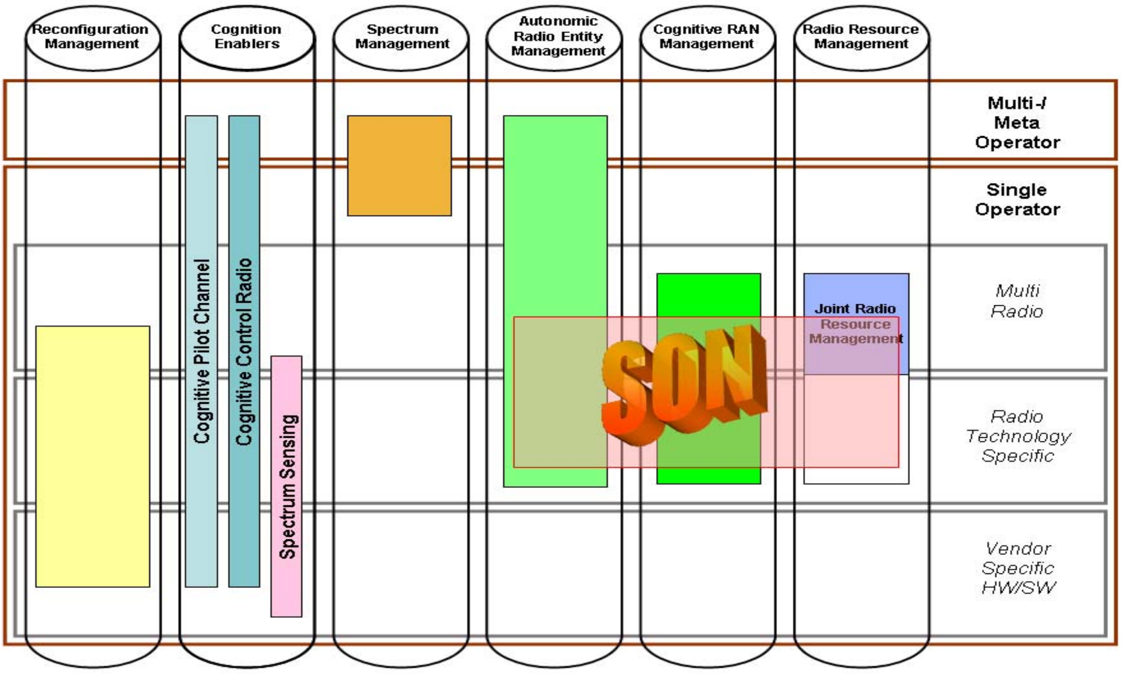

Figure 5: E3 high level functional architecture

The horizontal axis in the figure corresponds to E3 architectural pillars, namely:

- Reconfiguration Management.
- Cognition Enablers.
- Autonomic Radio Entity Management.
- Spectrum Management.
- Cognitive Radio Access Network Optimization.
- Radio Resource Management.

The various deployment cases are outlaid on the vertical axis. Specifically, from top to bottom, the following telecom environment cases are considered:

- Multi/Meta Operator.
- Single Operator.
- Multi Radio.
- Radio Technology Specific Case.
- Vendor Specific HW/SW.

The Reconfiguration Management pillar is of specific interest for RRS. It is assumed that this functionality (it basically is derived from E2R II) is used by the other building blocks as a service that is able to perform reconfiguration actions in the heterogeneous radio equipment. It also has some self-organizing features like self-healing (cases where an urgent - and, therefore, pre-defined - action is required).

The functional entities in figure 6 are seen as composite parts of the reconfiguration management block:

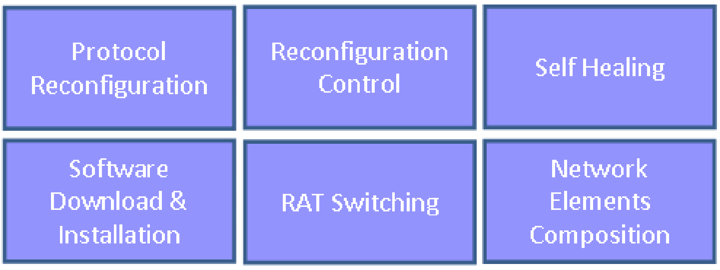

Figure 6: E^3 Reconfiguration Management Entities

5.2.2 Re-configurable architecture from RRS for UE

The following architecture has been proposed in "Reconfigurable Radio Systems (RRS); SDR Reference Architecture for Mobile Device" [i.4]. However, because of the different requirements for UE and RBS, this architecture is considered as not suitable for the RBS.

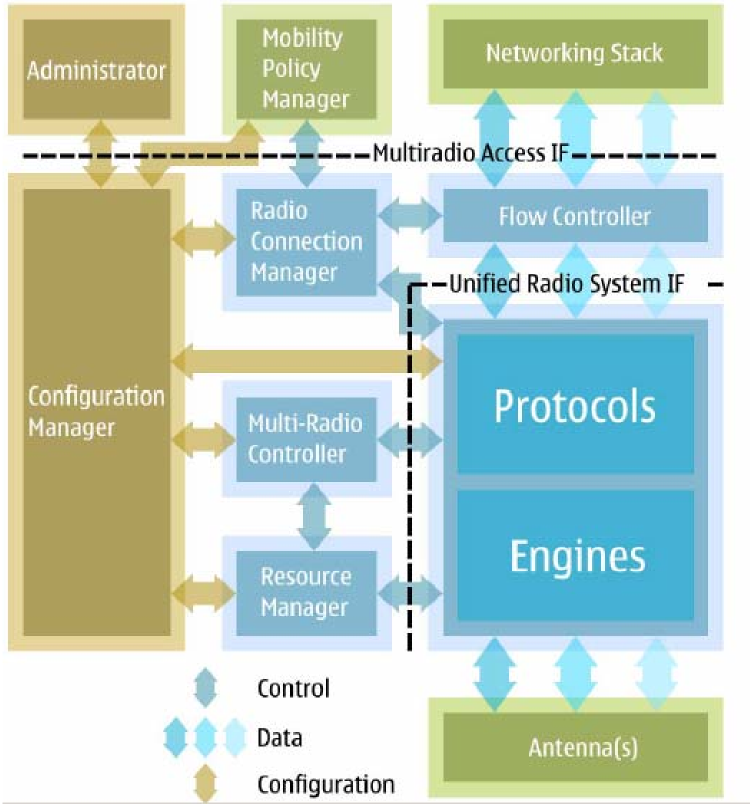

Figure 7: UE example architecture from RRS UE team

The user equipment architecture team identified a unified radio application concept including several key functional block/interfaces:

- MUltiradio access Interface (MURI).
- Handset SDR reference architecture Unified Radio Application Interface (URAI).
- Radio Programming Interface (RPI).
- Reconfigurable RF Interface (RRFI).

5.2.3 SDR Forum architectures

The SDR Forum describes some RBS architectures in the document "Base Station System Architecture" [i.5]. The Forum separates between single antenna and antenna array architectures. The architectures are basically limited to the RF signal generation and show now details beyond the analogue to digital (RX) and digital to analogue (TX) conversion.

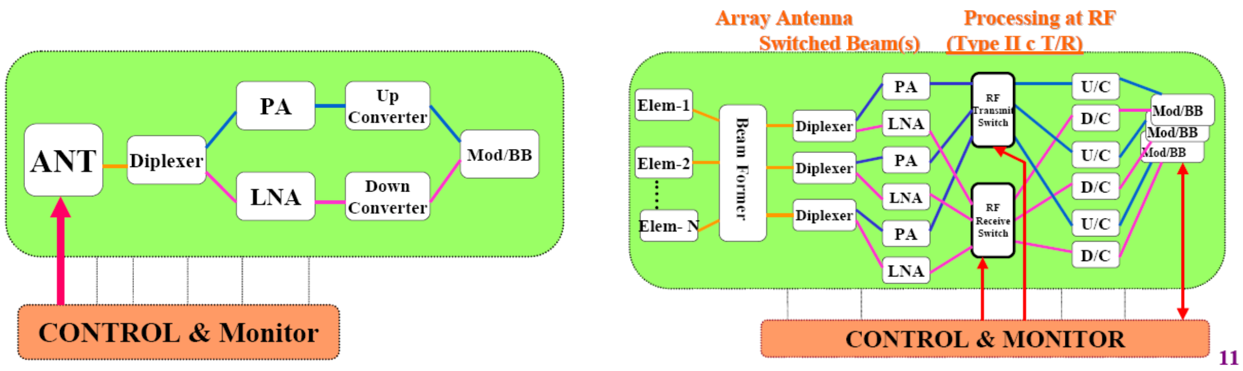

Figure 8: Radio architectures according to the SDR Forum (single and multi-antenna)

5.3 Existing RBS interfaces

There are currently two mayor industry standards in place for cellular radio base stations, CPRI and OBSAI. Both standards allow splitting the RBS as specified in 3GPP into further sub-units, particularly into a system unit and into a remote radio head.

5.3.1 CPRI

The Common Public Radio Interface (CPRI™) is an industry cooperation aimed at defining a publicly available specification for the key internal interface of radio base stations between the Radio Equipment Control (REC) and the Radio Equipment (RE). The Parties cooperating to define the CPRI Specification are Ericsson AB, Huawei Technologies Co. Ltd, NEC Corporation, Nortel Networks SA and Siemens AG.

5.3.2 OBSAI

The OBSAI description and specification documents are developed within the Technical Working Group of the Open Base Station Architecture Initiative Special Interest Group (OBSAI SIG). Members of the OBSAI TWG serve voluntarily and without compensation. The description and specifications developed within OBSAI represent a consensus of the broad expertise on the subject within the OBSAI SIG. The specifications can be downloaded at www.obsai.com.

The OBSAI interface specifications covering the radio base station interfaces for Transport, Clock/Control, Base Band and Radio, together with hardware connection specifications. OBSAI includes also test specifications. OBSAI specifications define a mapping of BTS functionalities onto Control and Clock, Transport, Baseband, RF, and General Purpose blocks for all air interface standards but internal structure of the blocks is not in the scope of OBSAI specifications. The OBSAI interfaces include own interface specifications where needed but apply also standard protocols where suitable, for example XML and Ethernet (RP1).

RP1 covers the timing and control between the Control and Clock and other functional blocks. It supports dynamic multi-mode operation and resource allocation. Multi-mode operation would be controlled by the "Control and Clock Block" function.

RP2 carries the air interface specific data between the Transport block and Base Band Block. Also different air interface standard specific data packets can be sent simultaneously.

RP3 is a high speed serial bus interface mapping the radio carrier specific I/Q data from the Base Band Block to the RF Block. RP3 has enough bandwidth to support multiple standards which enables a simultaneous multi-standard operation. The data format is specified in detail for several different radio standards, such as GSM/EDGE, WCDMA, CDMA 2000, HSPA, LTE, and WiMax.

OBSAI does not mandate how to implement re-configurability, but the interfaces as specified allow reconfiguration of the RBS if the corresponding building blocks support it. Current base station implementations allow already the re-configuration by S/W download for example for WCDMA, HSPA and LTE. A dynamic re-configuration depends on the functionality implemented in the control block but would be supported by the interfaces.

RP3-01 interface is a combination of the RP3 and RP1 interfaces. It allows a distributed RBS or radio head configuration. For example, star and daisy chain configurations of RF heads are supported. The functionality of RP3-01 is basically identical with the CPRI interface but the interface definitions are different.

RP4 is a power supply interface to support the needed supply voltages including control of different power modes (for example standby, high-power, low-power modes).

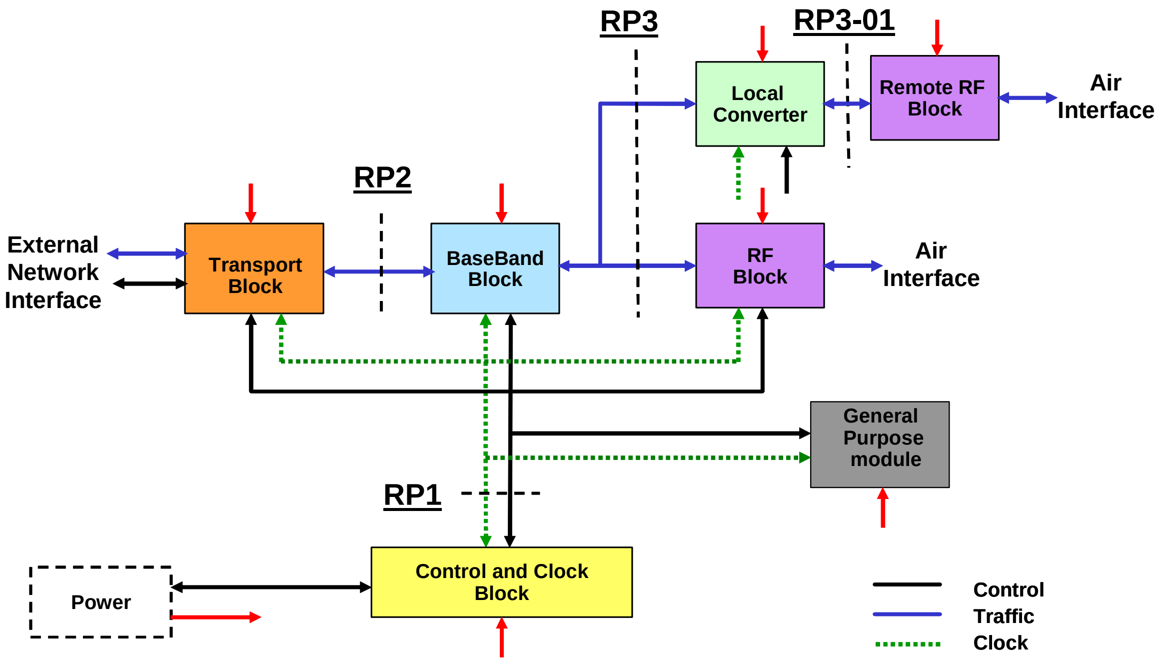

Figure 9: OBSAI reference architecture

5.3.3 Other interfaces

Other interfaces potentially suitable for internal RBS interfaces are Rapid I/O, Ethernet, PCIe, JEDEC, etc. Unlike OBSAI and CPRI these are electrical interfaces and not functional interfaces. For example Ethernet is an interface used within OBSAI.

6 Re-configurable architectures

3GPP investigates currently the harmonization of requirements for several of its current standards. Significant differences in the radio specifications make a reconfigurable GSM/EDGE-WCDMA radio currently economically unattractive. All mayor RBS OEMs announced already WCDMA/HSPA-LTE upgradeable RBS.

WiMax is currently intended for different frequency bands, but radio requirements are otherwise within the range of the above mentioned standards. From a technical point also WiMax could be included within the same frequency band. Once the technical differences are equalized using harmonized radio standards their application would be solely a matter of IPR fees. S/W download and the usage of different characteristics will be therefore an important feature of RRS.

A reconfigurable RBS architecture as outlined in figure 10 is proposed by the RRS WG2.

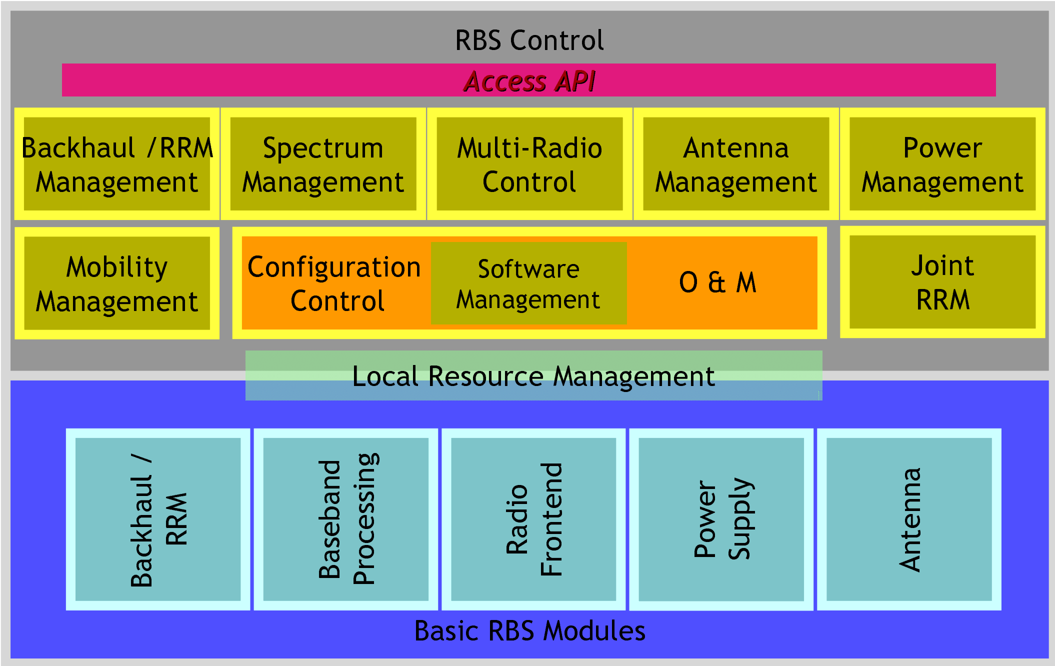

Figure 10: Reconfigurable architecture for radio base stations

The functionality of the different blocks and potential need for standardization is outlined in the following clauses.

6.1 Configuration control

- Provides interface for triggering re-configuration actions.
- Ensures consistent state of all RBS parts at all time.
- Involves SW management into re-configuration actions where necessary.
- Implements roll-back actions.
- Implements fast reactions in case of RBS failures (e.g. re-organizing in case of partial equipment failure).

6.2 S/W management

- Implements SW download procedures.
- Knows what SW modules are currently installed in the RBS.
- Knows potential SW constellations.
- Can activate/de-activate SW in the RBS.
- RBS SW can be handled as monolithic SW block or as set of independent applications.
- Can rely on many SW Management approaches (e.g. fixed mapping onto the RBS processing units or flexible mapping like in SCA, i.e. autonomous - with restrictions - SW distribution inside RBS).

6.3 Operations and maintenance

- Has access to all relevant configuration parameters in the RBS.
- Controls activation/de-activation of measurement.
- Collects and summarizes measurement results (collection and summarization schemes are flexible and can be re-configured).
- Multiple clients can subscribe for delivery of measurement results and/or configuration parameter values (delivery schemes are flexible and can be re-configured).
- Serves external and internal clients.
- Protects the RBS in case of too many data collection requests.

6.4 Backhaul management

- Physical transport configuration: (Giga-) Ethernet, Cupper, Fiber, SDH, µwave, (multi-connectivity, mapping to the supported standards/RANs, etc.).
- Logical transport configuration: TCP/IP, SDH-Frame, S1/X2 associations, (mapping to the supported standards/RANs, limitations, etc.).
- Configuration of internal to the standards RRM algorithms for autonomous (fine-)tuning.

6.5 Spectrum management

- Assignment of spectrum bands and spectrum usage policies
- Planning/management of spectrum usage in supported cells (if policies allow for): algorithms, assignment period, thresholds, interference between cells.
- Provides features for cognitive radio.

6.6 Multi-radio control

- RBSs should be efficient from the "green aspects" point of view (e.g. power consumption and related issues).

6.7 Antenna management

- Antenna radiation pattern, antenna gain, antenna direction, etc.
- Sector configuration (3x1, 1x1, etc.).
- Physical Antenna type (Multi-pad, MIMO, SIMO, MISO, SISO, etc.).
- Usage of RX-/TX-Diversity, according split of antenna cabling.
- Mechanical tilt, Electrical tilt, tilt parameters, Azimuth height.

6.8 Power management

- Max. TX power, RAT spec. TX power, per cell, per sector, per antenna, etc.
- Specific power schemes (day, night, event, power saving, etc.).
- Alignment with RAT spec. efficiency measures (clipping, pre-distortion, feed-forward correction, etc.).

6.9 Mobility management

- Handover parameter configuration (thresholds, timers, hysteresis, etc.).
- Horizontal handover procedures (hard, soft, softer, etc.).
- Vertical handover procedures (3GPP - WiFi - WiMAX, etc.).

6.10 Radio resource management

Support Access Selection of a terminal based on:

- Requested QoS (Bandwidth, Max. delay, Realtime/non-realtime).
- Radio conditions (e.g. abstracted signal strength/quality, available bandwidth).
- Access Network conditions (e.g. cell capacity, current cell load).
- User preferences.
- Network policies.
- Neighbourhood Information Provision for efficient discovery of available accesses.
- Cell location (longitude/latitude).
- Cell size (e.g. radius of the cell).
- Cell capabilities (support of e.g. real-time, non-real-time services).
- Cell capacity.
- Dynamic data like current cell load.
- Uses CPC-like communication towards terminals.

7 Technology development

Flexibility increases the need for signal processing. It is expected that Moore's law continues, resulting in smaller, cheaper and less power consuming digital devices. However, the analogue RF technology like low noise amplifiers, power amplifiers and filters, develops on a different pace. Although digital components support analogue functions, high performance radio equipment like a cellular base station is heavily dependent on analogue components.

The sole reason and basic need for introducing filter functions in a radio communication link is to provide a high degree of frequency selectivity:

1) in order to improve link quality by suppressing out-of-band interferer; and

2) limiting the spectral pollution that can act detrimental to neighbouring radio systems.

Hence, the receiver filter has to pass as narrow a bandwidth as possible around the intended frequency band of operation, while attenuating the undesired signals in all other frequency bands, which otherwise would interfere with the receiver, either by degrading the signal to noise/interferer ratio or, even worse, block the receiver by causing it to saturate.

The transmitter filter has to, in a similar fashion, only pass the intended transmit frequency band of operation, attenuating all the frequency bands outside of the transmit band, where the transmitter to some extent still would effect by its noise and/or spurious signals.

In order to allow for a flexible frequency deployment of a radio communication system, the transmit and receive filters would have to provide the same flexibility in term of where the corresponding pass-band spectra are positioned. In general, this flexibility could either be implemented by a selection of the proper band from a finite number of pass-bands, or by re-tuning the filter within a specific bandwidth.

Alternatives, bank of switchable filters or the re-tuneable filter, has limitations to its performance in terms of RF-performance (insertion loss, attenuation, BW, return loss, power handling etc) as well as size, cost and complexity/reliability.

The frequency dependence in a filter stems from reactive components; inductances and capacitances. In order for these properties to be tuneable, different physical parameters like length, permittivity and/or permeability have to be changeable.

Different approaches to apply these changes in physical properties can be by use of actuators (stepper motors, piezo-electric actuators, MEMS, etc.) or by electronic control of capacitance (e.g. by varactors or ferroelectric material).

Realization of switchable filter banks is not very practical for high power macro RBS applications, which would require air cavity filters and mechanical coaxial switches. At lower power level applications the filter banks could be realized by SAW, BAW or ceramic filters, and MEMS technology could be used for the switches.

However, even though theoretically possible, the practical aspects of implementing RF filters for SDR applications make this to be the most challenging area within the SDR design.

8 Energy consumption aspect of re-configurability

One of the greatest threats to our future society is global warming. A dramatic cut in greenhouse gas emissions is needed to keep the temperature increase on an expectedly save level of < 2 degrees. Power consumption of radio networks is therefore not only an essential economic requirement. The European Parliament and governments of other countries made clear, that a failure of the industry to react decisively will result in serious legislation to reduce energy consumption.

Energy efficiency affects directly the power consumption of a radio base station and is therefore of uppermost importance not only from an environmental point of view but also as a significant OPEX factor for telecom operators. However, if we want to assess the overall environmental impact we have to consider the complete lifecycle of a radio base station. This includes the impact of materials, production, installation, maintenance, operations and end-of-life/decommissioning.

The power consumption during the use phase has naturally a direct impact on the ecological footprint (CO_2 emission) of the RBS. There is a wide range of possible H/W implementations and flexibility has typically its own penalty compared to dedicated solutions. Flexibility on the other hand might increase the lifetime of the H/W and reduce the environmental impact of production and EOL.

Reconfigurable radio systems have mostly been discussed under the aspect of flexibility and their ability to match further requirements and new radio standards with a minimum of required CAPEX. Recent discussions about global warming and particularly rising energy cost placed OPEX and the operators' electricity bills into the focus.

Flexibility offers a very valuable tool to match power consumption of a radio system to the actual traffic and can deliver significant energy and OPEX savings if properly implemented. Flexibility has also a power penalty on the implementation level and is limited to where it provides a proven benefit.

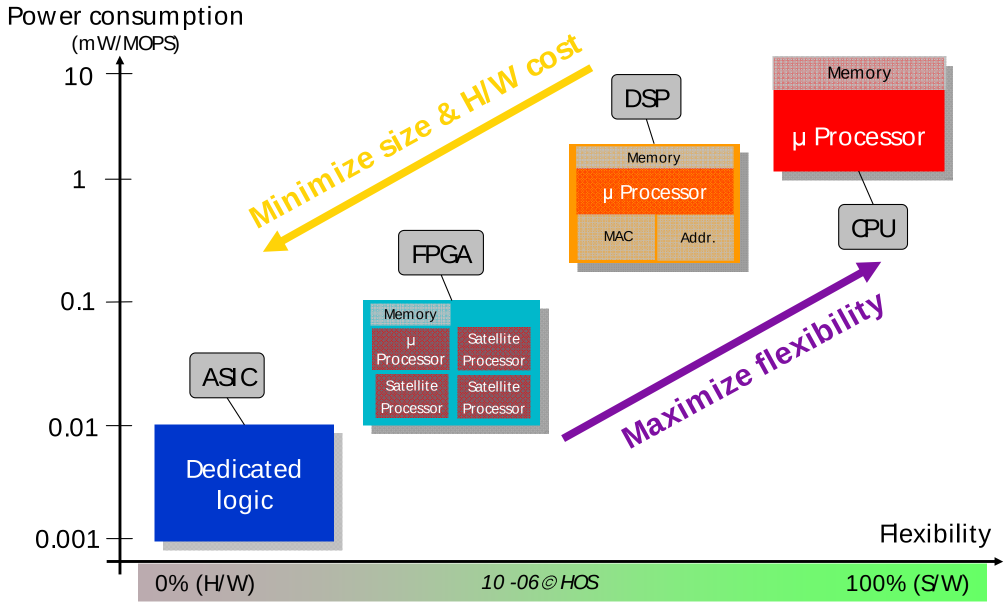

Figure 11: Power consumption versus flexibility on a circuit implementation level

A life cycle analysis of telecom infrastructure and in particular radio base stations is a pretty tedious work and depends on several assumptions. Different methods and assumptions revealed that approximately 90 % of the total energy consumed results from the actual use phase of the RBS. This factor depends naturally on the life time of the RBS (typically > 10 years) and is much lower for most consumer products like for example for the short lived telecom user equipment like mobile phones. As a rule of thumb we could state that the embedded energy from RBS manufacturing is approximately equivalent to one year of operation.

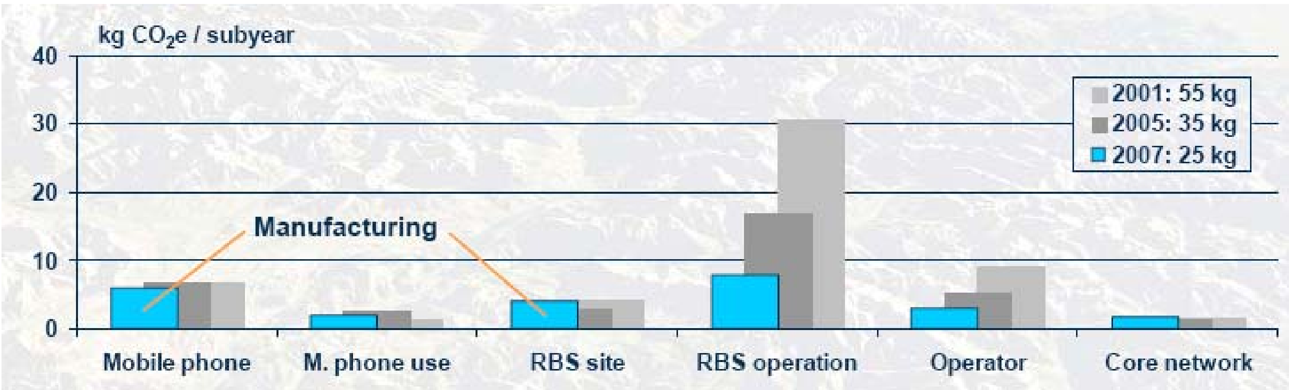

Figure 12: Lifetime analysis results for mobile network equipment [i.7]

To minimize the impact of the embedded energy from the materials, manufacturing and transport of the RBS an extended lifetime, for example by S/W reconfiguration, of existing H/W seems to provide obvious benefits. However, the fast development of semiconductor technology makes newer equipment not only directly more power efficient but also allows new, more efficient architectures. The typical energy consumption of an RBS has been dramatically reduced during the recent 5 years to 8 years, which is mostly a result of H/W improvements and only partly based on S/W features.

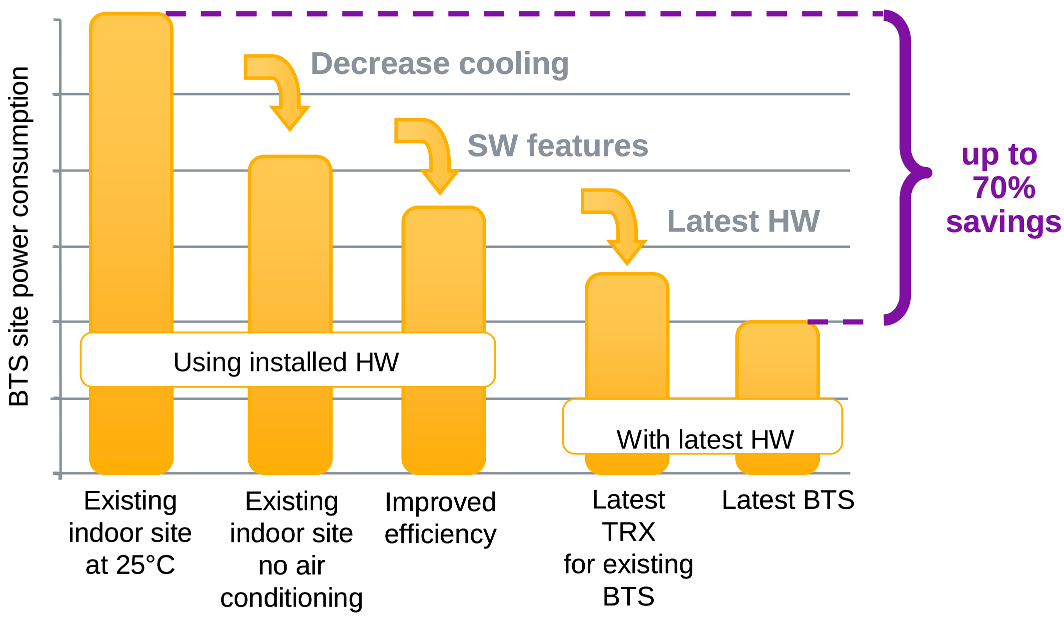

Figure 13: Reduction of RBS power consumption

Obviously, a prolonged operation of technically obsolete hardware has a severe impact on the energy consumption and CO2 emission of the radio network.

9 Recommendations

The need for reconfigurable radio base stations and their requirements have been collected and analyzed. Telecom operator requirements stated a need for reconfigurable radio base station, in order to achieve:

- Fast network planning and update according to capacity and coverage needs.
- Fast and cost efficient network deployment and commissioning.
- Flexible network operation especially with respect to technology migration, spectrum reuse.
- Maintenance optimization.

Also from telecom OEMs a need for reconfigurable RBS has been identified, mainly to:

- Efficiently follow different customer requirements.
- Reduce number of product variants and allow efficient product management.

At a first stage, from the collected requirements a potential standardization item could be derived on the topic of open and standardized interface(s) in order to manage fast and flexible network planning and operation, and related resource management. However, the study has been limited to SDR architectures, without taking additional possible requirements from e.g. Cognitive Radio (CR) into account. Therefore further activity is envisaged to support more specifically the related standard development. Requirements originating from extended functionalities, as e.g. CR, are likely to further impact the standardization of related aspects.

The new SDR technology network devices should fully meet the requirements and technical specifications of the 3GPP standards, thus also guaranteeing the complete interoperability among them. In addition, standardized interfaces should ensure soft evolution and software upgrade of deployed SDR technology radio access networks to new standards.

RBS architectures of current products and proposals from different international research activities have been considered for their usability in RRS. Several RBS internal industry standard interfaces already exist. The most prominent are CPRI for remote radio heads and OBSAI, which includes several RBS internal interfaces and a remote radio head interface. While each of these interfaces found their supporters, none of those industry standards managed to reach a dominating position. In this context, standardized interfaces could reach a higher acceptance thanks to the larger consensus built inside ETSI standardization fora.

The working group developed a high level reconfigurable RBS reference architecture and described the basics of the ten most relevant interfaces for this architecture. Several of the described functionalities and interfaces could have potential for standardization.

The concept of a dual mode mobile device/home RBS has been presented. It has been proposed to standardize a mobile device/home RBS architecture and inherent interfaces. However, possible requirements and details for such a device are not covered in this work item.

History

Document history		
V1.1.1	June 2009	Publication