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Reconfigurable Radio Systems (RRS); Functional Architecture (FA) for the Management and Control of Reconfigurable Radio Systems

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Contents

Intellectual Property Rights 5

Foreword 5

Introduction 5

1 Scope 6

2 References 6
2.1 Normative references 6
2.2 Informative references 6

3 Definitions and abbreviations 7
3.1 Definitions 7
3.2 Abbreviations 8

4 Motivation, goals, example scenarios 9
4.1 Trends in the wireless landscape and overall requirements for the evolution of wireless systems 9
4.2 Example scenarios 10
4.2.1 Spectrum on demand 10
4.2.1.1 General description 10
4.2.1.2 Evaluations 11
4.2.1.3 Open issues 11
4.2.2 Initial Scan 11
4.2.2.1 General description 11
4.2.2.2 Evaluations 11
4.2.2.3 Open issues 12
4.2.3 Terminal Reconfiguration - Joint Radio Resource Management in B3G networks 12
4.2.3.1 General description 12
4.2.3.2 Evaluations 12
4.2.3.3 Open issues 13
4.2.4 Network (Base Station) Reconfiguration 13
4.2.4.1 General description 13
4.2.4.2 Evaluations 13
4.2.4.3 Open issues 13

5 Requirements for reconfigurable radio systems and entailed functions 14

6 Overview on the Functional Architecture for the Management and Control of Reconfigurable Radio Systems targeting on Radio Resource and Spectrum Efficiency 15
6.1 Scope and overview 15
6.2 High-level description of FA and main functional blocks 16

7 Detailed Functionality 19
7.1 Dynamic Spectrum Management (DSM) 19
7.2 Dynamic Self-Organising Network Planning and Management (DSONPM) 20
7.2.1 Input to DSONPM 21
7.2.2 Output of DSONMP 21
7.2.3 Optimization Process 22
7.3 Configuration Control Module (CCM) 22
7.4 Joint management of radio resources across heterogeneous radio access technologies (JRRM) 23
7.4.1 Access Selection in Idle State 23
7.4.2 Access Selection in Connected State 23

8 Interfaces description 24
8.1 MS interface between DSM and DSONPM 24
8.2 MJ interface between DSONPM and JRRM 25
8.3 MC interface between DSONPM and CCM 25
8.4 CJ interface between CCM and JRRM 25
8.5 JR interface between JRRM and the underlying RATs 25
8.6 CR interface between CCM and the underlying RATs 25

8.7 JJ-TN interface between the JRRM on terminal side and the JRRM on network side 26
8.8 SS interface between different DSM instances 26
8.9 MM interface between different DSONPM instances...26
8.10 JJ-NN interface between different JRRM instances on network side...26
8.11 JJ-TT interface between JRRM instances in different terminals..26
8.12 Example Message Sequence Charts 27

9 Summary and Recommendation for Standardization...29

Annex A: Relationship between IEEE 1900.4 system and ETSI RRS FA 30

A.1 Introduction 30

A.2 IEEE 1900.4 Standard Overview 30
A.2.1 Introduction 30
A.2.2 1900.4 Context 30
A.2.3 Use Cases 31
A.2.4 Architecture..32

A.3 Relationship between IEEE 1900.4 system and ETSI RRS functional architecture 36

Annex B: Relationship between 3GPP standards and ETSI RRS FA 40

B.1 Introduction 40

B.2 Brief overview of 3GPP functionalities of interest...40
B.2.1 SON, ANR 40
B.2.2 Minimization of drive tests...42
B.2.3 Multi-standard radio (MSR)..42

B.3 Relationship between 3GPP standard and ETSI RRS functional architecture......................................43

Annex C: Bibliography...44

History 45

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Foreword

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

Introduction

The present document provides a feasibility study on defining a Functional Architecture (FA) for reconfigurable radio systems, in terms of collecting and putting together all management and control mechanisms that are targeted for improving the utilization of spectrum and the available radio resources. This denotes the specification of the major functional entities that manage and direct the operation of a reconfigurable radio system, as well as their operation and interactions.

As a feasibility study the present document provides basis for decision making at ETSI Board level on standardization of some or all topics of the FA.

1 Scope

The present document carefully studies the requirements for the improvement of the utilization of spectrum and radio resources in reconfigurable radio systems and proposes a generic architecture, namely the Functional Architecture (FA), which will collect those requirements and propose creative solutions that should be followed during the operation of reconfigurable systems. The FA is outlined in the present document to the extent which is necessary to identify architectural elements (blocks and interfaces) as candidates for further standardization. Since the feasibility of standardization of FA for radio systems also depends on already standardized or ongoing activities on such architectural elements the present document also provides a survey on FA related standardization in other standardization bodies.

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] 3GPP TR 22.811 (Release 7): "3rd Generation Partnership Project; Technical Specification Group Services and Systems Aspects; Review of Network Selection Principles".

[i.2] ETSI TR 122 912: "Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); LTE; Study into network selection requirements for non-3GPP access (3GPP TR 22.912 Release 8)".

[i.3] ETSI TS 123 122: "Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); Non-Access-Stratum (NAS) functions related to Mobile Station (MS) in idle mode (3GPP TS 23.122 Release 7)".

[i.4] ETSI TS 123 402: "Universal Mobile Telecommunications System (UMTS); LTE; Architecture enhancements for non-3GPP accesses (3GPP TS 23.402 Release 8)".

[i.5] ETSI TS 125 304: "Universal Mobile Telecommunications System (UMTS); User Equipment (UE) procedures in idle mode and procedures for cell reselection in connected mode (3GPP TS 25.304 Release 8)".

[i.6] ETSI TS 125 331: "Universal Mobile Telecommunications System (UMTS); Radio Resource Control (RRC); Protocol specification (3GPP TS 25.331)".

[i.7] ETSI TS 136 304: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode (3GPP TS 36.304 Release 8)".

[i.8] IEEE 802.21: "Working Group for developing standards to enable handover and interoperability between heterogeneous network types including both 802 and non 802 networks".

[i.9] IEEE Std 1900.4-2009: "IEEE Standard for Architectural Building Blocks Enabling Network-Device Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Access Networks".

[i.10] "Architecture and enablers for optimized radio resource usage in heterogeneous wireless access networks: The IEEE 1900.4 Working Group", S. Buljore et al. IEEE Communications Magazine, vol. 47, no. 1, pp. 122-129, Jan. 2009.

[i.11] ETSI TR 102 683: "Reconfigurable Radio Systems (RRS); Cognitive Pilot Channel (CPC) design".

[i.12] ETSI TS 136 300: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (3GPP TS 36.300)".

[i.13] RP-090341 (March 2009): "Minimization of drive-tests in next generation networks, 3GPP Study Item Description".

[i.14] RF requirements for Multicarrier and Multi-RAT BS, 3GPP Work Item Description (Sept 2008).

[i.15] Market assessment report on selected cognitive radio systems value propositions ICT-2007-216248/E3/WP1/D1.3.

3 Definitions and abbreviations

3.1 Definitions

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

cognitive radio: radio, which has the following capabilities:

- to obtain the knowledge of radio operational environment and established policies and to monitor usage patterns and users' needs;
- to dynamically and autonomously adjust its operational parameters and protocols according to this knowledge in order to achieve predefined objectives, e.g. more efficient utilization of spectrum; and
- to learn from the results of its actions in order to further improve its performance.

radio system: system capable to communicate some user information by using electromagnetic waves

NOTE: Radio system 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 devices.

software defined multi radio: device or technology where multiple radio technologies can coexist and share their wireless transmission and/or reception capabilities, including but not limited to regulated parameters, by operating them under a common software system

NOTE 1: Examples of the regulated parameters are frequency range, modulation type, and output power.

NOTE 2: Common software system represents radio operating system functions.

NOTE 3: This definition does not restrict the way software is used to set and/or change the parameters. In one example, this can be done by the algorithm of the already running software. In another example, software downloading may be required.

software defined radio: radio in which the RF operating parameters including, but not limited to, frequency range, modulation type, or output power can be set or altered by software, and/or the technique by which this is achieved

NOTE 1: Excludes changes to operating parameters which occur during the normal pre-installed and predetermined operation of a radio according to a system specification or standard.

NOTE 2: SDR is an implementation technique applicable to many radio technologies and standards.

NOTE 3: SDR techniques are applicable to both transmitters and receivers.

3.2 Abbreviations

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

ANDSF	Access Network Discovery and Selection Function
ANR	Automatic Neighbour Relation
AP	Access Point
B3G	Beyond 3rd Generation
BS	Base Station
CCM	Configuration Control Module
CFG	ConFiGuration
CPC	Cognitive Pilot Channel
CQI	Channel Quality Indicator
CWN	Composite Wireless Network
DSM	Dynamic Spectrum Management
DSONPM	Dynamic Self-Organizing Network Planning and Management
FA	Functional Architecture
GPS	Global Positioning System
HO	HandOver
ICIC	Inter-Cell Interference Coordination
IP	Internet Protocol
JRRM	Joint Radio Resource Management
KPI	Key Performance Indicator
LTE	Long Term Evolution
MSR	Multi-Standard Radio
NET	NETwork
NO	Network Operator
NRM	Network Reconfiguration Manager
OPEX	OPerational EXpenses
OSM	Operator Spectrum Manager
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
RF	Radio Frequency
RMC	RAN Measurement Collector
RRC	Radio Resource Control
RRM	Radio Resource Management
RRS	Reconfigurable Radio System
RSSI	Received Signal Strength Indicator
SAP	Service Access Point
SDR	Software Defined Radio
SINR	Signal to Interference and Noise Ratio
SON	Self-Organizing Networks
TCP	Transmission Control Protocol
TE	TErminal
TMC	Terminal Measurement Collector

TRC	Terminal Reconfiguration Controller
TRM	Terminal Reconfiguration Manager
UDP	User Datagram Protocol
UE	User Equipment
UMTS	Universal Mobile Telecommunications System

4 Motivation, goals, example scenarios

4.1 Trends in the wireless landscape and overall requirements for the evolution of wireless systems

This clause provides a high level view of the wireless world, emphasizing on reconfigurable radio systems and the overall context, in which the Functional Architecture described in the present document is applied. This is shown in figure 1.

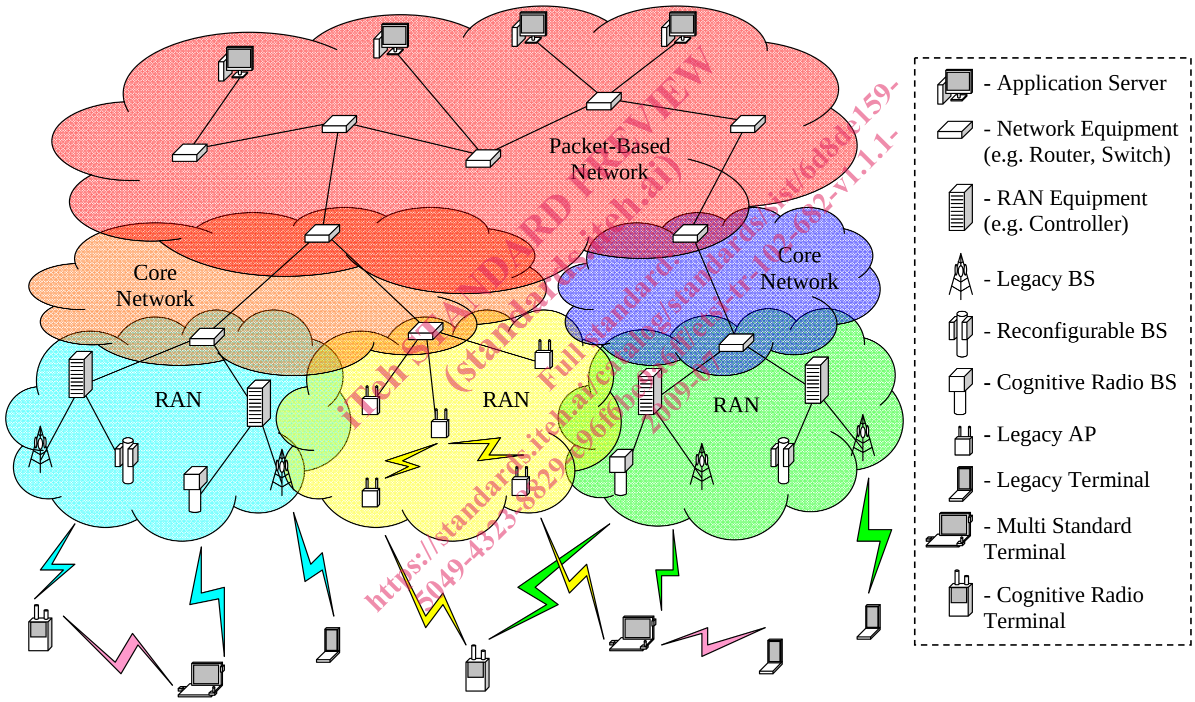

Figure 1: Functional Architecture context

The network and user **equipment** of the wireless environment described in the present document are aligned with the assumptions included in this clause. Specifically:

Different types of terminals operate in this environment. Examples are legacy terminals, multi-standard radio terminals, and cognitive radio terminals. Multi-standard and cognitive radio terminals can be reconfigurable. Moreover, different types of Base Stations (BS) provide wireless access to terminals in this environment. Examples are legacy BSs, APs, Node Bs, etc.; multi-standard reconfigurable radio BSs, and cognitive radio BSs.

The wired network part of this wireless environment, includes RANs, core networks, and packet-based network, and enables the existence of different types of equipment. Examples are legacy RAN management servers, IP management serves, and application serves, as well as, adaptive and reconfigurable RAN management servers, IP management serves, application serves. Furthermore, the reconfiguration of terminals, base stations, and wired network equipment can be managed by the FA as described in the present document. Additionally, different **topologies** can be used in the wireless environment considered.

Terminals can communicate with each other directly or via wireless access service provided by network. Also, terminals can communicate with some application servers. Some terminals can support several active connections in parallel, either with other terminals or base stations.

Base stations can provide point-to-multipoint wireless access service to terminals. Some base stations can serve as wireless relays for other base stations in case of multi-hope communication. Some terminals can also serve as wireless relays to other terminals.

Some operators operate only one RAN with associated core network. Some operators operate several RANs. Each of RANs of one such operator can have separate associated core network or some/all RANs of one operator can have one associated core network. Some part of the wireless environment can reconfigure its topologies. Such reconfiguration can be managed by Functional Architecture described in the present document.

Various **resources** are available for providing services in the wireless environment considered. The available radio resources are shared by RANs and terminals. Depending on RAT, radio resource can be characterized by frequency, time, space, power, and code. In case of reconfigurable radio systems, equipment resources should be also considered. Examples of equipment resources are processing power, storage capacity, number of active connections in parallel, and battery power.

In high data rate transmission wired network resources are also of great importance. In addition to the equipment resources described above, transport capacity of wired links should be considered. In total, the usage of all these resources can be managed by the FA described in the present document.

From the regulatory perspective, spectrum can be divided into several frequency bands. Different spectrum usage rules can be specified to these frequency bands, which may regulate RATs and output power values allowed in particular frequency bands. Also, spectrum sharing, renting, etc can be allowed or not. Primary/secondary relations can be specified for some frequency ranges. Environmental regulations should also be considered.

Various operational objectives can be set by wireless and wired access operators. These objectives can adaptively change. Additional conditions can be set by wired access operators for wireless access operators using their wired access.

From the service quality point of view, different applications can have different QoS requirements. These QoS requirements may include data rate, error rate, delay, and jitter parameters.

Finally, users may have different preferences. User preferences may include preferred operator or RAT, intention to decrease service cost or download time.

All these operational constraints and objectives are considered by the FA described in the present document.

4.2 Example scenarios

This clause presents some indicative scenarios that are envisaged to call for the existence of the functional architecture presented in the present document.

4.2.1 Spectrum on demand

4.2.1.1 General description

In this scenario there are two operators that each has a piece of spectrum where the operator is the primary user. At some time instant operator 1 experiences an increased traffic load and at the same time operator 2 does not fully utilize the allocated spectrum. When this happens the operator 1 temporarily uses the unused spectrum of operator 2 to temporarily increase the system capacity. This is illustrated in figure 2. This scenario assumes that transfer of authorization of spectrum use between operators is authorized (e.g. by regulation) in a way that allows the exchange of spectrum as described below.

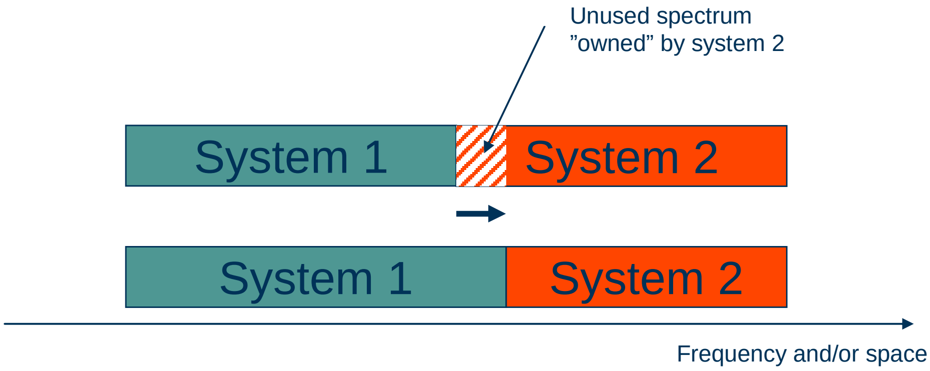

Figure 2: Spectrum allocation for spectrum on demand scenario

This scenario actually consists of a number of sub-scenarios that are qualified by:

- How coordination is done. It can be done either by a broker, by bilateral agreements or in a decentralized fashion.
- The geographic size of the cells. They can either be of approximately the same size or one system can have significantly larger cells. This may for example be the case when System 2 is a broadcasting system and System 1 is a cellular system.
- The number of systems that want to utilize the unused spectrum. There can be one or more systems.
- There are several issues related to the factors above that will have to be further studied.

4.2.1.2 Evaluations

The purpose of these evaluations is to:

- Verify that the suggested methods actually can be used, i.e. ensure that the entire process outlined in this scenario can be performed by the functional architecture.
- Provide simple measures of performance, e.g. the number of messages sent across the interfaces.

4.2.1.3 Open issues

The exact mechanisms used to coordinate spectrum usage among the systems and the details for how it is done still need to be defined.

4.2.2 Initial Scan

4.2.2.1 General description

The main focus of this scenario is when a terminal arrives in a new place (in geography) where the terminal has no knowledge of the environment, i.e. what radio accesses that are available, what services are available and frequencies that are used etc. The terminal then has to find and start using the most suitable (or just a suitable) access.

4.2.2.2 Evaluations

It should be determined how often this scenario happens. I.e. it is necessary to determine if this scenario is a rare exception or if it is an everyday event.

Among the relevant measures to consider is the time from initial power-on to a service is available and the energy used in the process. Another measure is the expected overhead from additional signalling or additional spectrum use.

To see if a suggested solution is actually better, a number of baseline solutions need to be defined. These can include for example scanning all available frequencies.

4.2.2.3 Open issues

In the case the terminal has to select "the most suitable" access it is necessary to define what the terminal considers to be "most suitable".

Methods and solutions need to be outlined further.

4.2.3 Terminal Reconfiguration - Joint Radio Resource Management in B3G networks

4.2.3.1 General description

In this scenario, there is one operator having several heterogeous radio access technologies operating on fixed frequency bands. The terminals considered in this scenario can connect to one or more of these RATs. Considering that the number of users accessing the operators heterogeneous radio access network is varying in time and that the services they consume is highly dynamic, the operator network adapts to these evolving needs to allocate the radio resources. The operator network monitors the radio conditions and decides on the allocation of users to RAT. The terminals reconfigure themselves according to these decisions. Such a reconfiguration can consist in a software download, a modification of the operating RAT for SDR-capable terminals or a selection of the radio interface(s) to use for multi-standard terminals. As an example, figure 3 illustrates the reconfiguration of two terminals due to the arrival of new users in the system: At T=0, each one of these two terminals is connected to two RANs simultaneously. At T=1, due to the increasing load in the network, the two terminals are reconfigured to access only one RAN to ensure proper load distribution across the RANs.

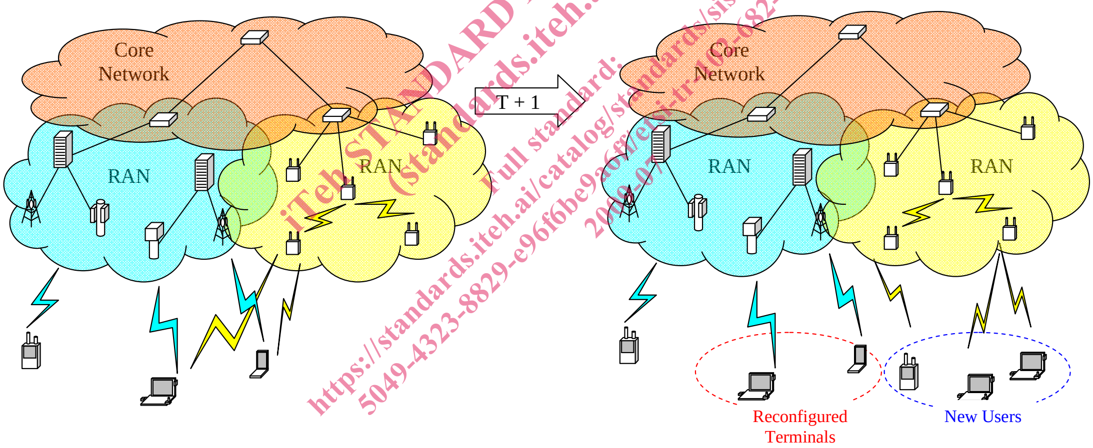

Figure 3: Terminal Reconfiguration - Joint Radio Resource Management scenario

This scenario is also applicable to a situation where the RANs are not owned by a single operator but where several operators cooperate to manage their Radio Resources jointly.

4.2.3.2 Evaluations

The performance of a system designed to support this scenario can be evaluated based on the following criteria:

- Spectrum usage and fair load distribution among RATs: This criterion is relevant from a system-level point of view where the solution for JRRM in B3G networks is beneficial to the spectrum owner/operator since it provides means to manage the distribution of the traffic among the RATs.
- Satisfaction of user needs: This criterion is relevant from a user point of view. It is related to the capability of the system to provide resources that are sufficient for the user to access the network and run services having QoS constraints.