STATE OF THE ART IN ETSI SDR AND CR RELATED STANDARDIZATION AND PREPARATION OF COMMERCIALIZATION

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ABSTRACT

This paper details the current work status of the ETSI Reconfigurable Radio Systems (RRS) Technical Committee (TC) and gives an outlook on the future evolution. In particular, Software Defined Radio (SDR) related study results are presented with a focus on SDR architectures for Mobile Devices (MD), such as mobile phones, etc., as well as for Reconfigurable Base Stations (RBS). For MDs, a novel architecture is presented enabling the usage of SDR principles in a mass market context. Cognitive Radio (CR) principles within ETSI RRS are concentrated on two topics, a Cognitive Pilot Channel (CPC) proposal and a Functional Architecture (FA) for Management and Control of Reconfigurable Radio Systems, including Dynamic Self-Organising Planning and Management, Dynamic Spectrum Management, Joint Radio Resource Management, etc. Finally, study results are indicated which are targeting a SDR/CR security framework.

Keywords- Cognitive Pilot Channel, Cognitive Radio (CR), ETSI, Software Defined Radio (SDR)

INTRODUCTION

In the past, Software Defined Radio (SDR) and Cognitive Radio (CR) Technologies have been under joint investigation for high-end applications, such as military and public safety products, etc., since the general CR concept had emerged [1]. While CR represents the application side in the sense that a device is (partially/fully) aware of its context (radio context, application context, etc.) and dynamically adapts its parameters such that its operational objectives are reached in an optimum way; e.g., a MD is aware of surrounding Radio Access Technologies (RATs) and selects those which guarantee to fulfill its Quality of Service (QoS) requirements at the lowest cost (in terms of power consumption, etc.). SDR, on the other hand, is considered to be an "enabling technology" introducing the required level of flexibility in order to "enable" a device to adapt to its context. Then, numerous research projects, such as IST-E2R I and II [2], ICT-E3 [3], etc., started to consider the usage of SDR/CR technology in a civil wide area (cellular) and short-range communications context on both the Reconfigurable Base Station (RBS) as well as MD side.

Most recently, these studies have triggered standardization initiatives, such as ETSI Reconfigurable Radio Systems (RRS), IEEE SCC41 [4], etc. In this framework, IEEE SCC41 is developing standards related to dynamic spectrum access networks with a focus on improved spectrum usage. Three Working Groups (WG) are currently active: IEEE P1900.4, IEEE P1900.5, and IEEE P1900.6. The IEEE 1900.4 WG has developed the IEEE standard 1900.4-2009 [4]. This standard defines a management system supporting network-terminal distributed optimization of radio resource usage and improvement in QoS in heterogeneous wireless networks. The WG is currently developing two more standards: P1900.4.1 (detailed description of interfaces and service access points defined in the IEEE standard 1900.4) and P1900.4a (enabling mobile wireless access service in white space frequency bands without any limitation on used radio interface). The IEEE 1900.5 WG is developing a draft standard which will define a set of policy languages, and their relation to policy architectures, for managing the functionality and behaviour of cognitive radios for dynamic spectrum access applications in a vendor-independent fashion. The IEEE 1900.6 WG is developing a draft standard which will define the information exchange between spectrum sensors and their clients in radio communication systems.

The sequel of this paper is organized as follows. Section II presents an overview on the structure of ETSI RRS, followed by details on the overall system vision in Section III. Section IV details the ETSI Functional Architecture and Cognitive Pilot Channel approach, Section V introduces the SDR Mobile

Device vision while Section VI addresses Security concerns. Finally, a conclusion is given.

ETSI RRS – OVERVIEW AND ROLE IN THE EUROPEAN REGULATORY FRAMEWORK

At the inaugural meeting, the ETSI RRS TC created the following four Working Groups (WGs), in which the technical discussions are organized and reports are produced (see Fig. 1):

i) **WG1** focuses on "**System Aspects**" and develops proposals from a system aspects point of view for a common framework in TC RRS with the aims to guarantee coherence among the different TC RRS WGs and to avoid overlapping and gaps between related activities.
ii) **WG2** focuses on SDR technology with a particular interest in "**Radio Equipment Architecture**" and proposes common reference architectures for SDR/CR radio equipments (mobile handset devices, radio base stations, etc.), related interfaces, etc.
iii) **WG3** focuses on "**Cognitive Management and Control**"; the group collects and defines the system functionalities for Reconfigurable Radio Systems which are related to the Spectrum Management and Joint Radio Resource Management across heterogeneous access technologies. Furthermore, the group has developed a Functional Architecture for the Management and Control for Reconfigurable Radio Systems as well as a report on the Cognitive Pilot Channel as an enabler to support the management of the RRS.
iv) **WG4** focuses on "**Public Safety**" and collects and defines the related RRS requirements from relevant stakeholders in the Public Safety and Defense domain. The group defines the system aspects for the applications of RRS in Public Safety and Defense.

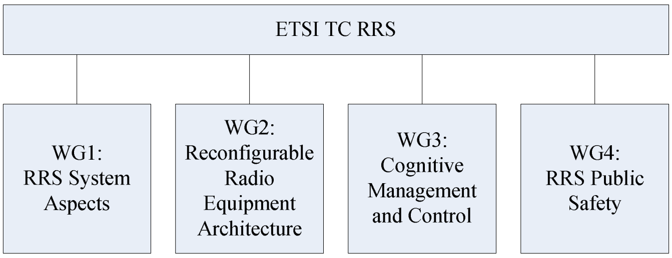

Figure 1: ETSI RRS Structure.

Building on this structure, ETSI RRS will complement ongoing effort in other bodies, such as IEEE standardization bodies, by proposing technological solutions beyond the existing scope (related to SDR interfaces, CR specific Management and Control architectures and interfaces, knowledge management via a Cognitive Pilot Channel and Security solutions); furthermore, ETSI RRS fulfills a key role in the framework of European Regulation, with a focus, among other aspects, on the following:

i) The R&TTE Directive regime in force in Europe is based on declaration of conformity and does include neither type approval nor registration of the equipment nor equipment identifier (in the US, type approval is still necessary). This self-declaration is preferably a reference to a Harmonised Standard to be developed by ESTI RRS.
ii) Protection of TV bands: In Europe, DVB-T does not show a residual carrier as it is the case in the US (the possibility for detection of the US ATSC signal below noise (i.e., at -114 dBm) is made possible thanks to the residual carrier which is present in the ATSC signal).
iii) Broadcasting, wireless microphones and assignment to radio stations are managed in Europe at the national level. Any sharing scheme based on a database will require some level of integration of the national data.

In order to address the above and other European Regulatory aspects, the Electronic Communications Committee (ECC) within the European Conference of Postal and Telecommunications Administrations (CEPT) has set up the SE43 group working on "*Technical and operational requirements for the operation of cognitive radio systems in the 'white spaces' of the frequency band 470-790 MHz*". ETSI RRS is the competence center within ETSI to implement those regulatory requirements.

ETSI RRS SYSTEM ASPECTS – OVERVIEW AND CR VISION

WG1 has conducted feasibility studies on Cognitive Radio Systems (CRS) concept and potential regulatory aspects of CRS and SDR. The technical concept of CRS developed by WG1 includes the following key elements:

i) Objectives;
ii) Spectrum use scenarios;
iii) Technical requirements;
iv) Spectrum management layers;
v) Architectural approaches;
vi) Enabling technologies.

Several objectives have been identified for CRS in order to ensure the provision of more efficient and flexible use of spectrum. For this purpose, CRS performs three key activities: i) obtain knowledge of the radio operational environment and location, ii) decide on the gathered information and act based on this decision, iii) learn from the results obtained.

Enhancing user experience is one of the main objectives of the CRS. Application examples are cross-operator access, user networks, flexible access to future internet, and connecting to smart spaces. CRS is expected to be beneficial for optimization of the mobile operator network. This could include load balancing, spectrum refarming, and radio resource usage optimization.

CRS deployment examples are categorized according to the following four spectrum use scenarios:

i) Dedicated spectrum,
ii) Shared spectrum,
iii) Secondary usage in dedicated spectrum, and
iv) Spectrum dedicated for CRS.

The first category includes such scenarios as autonomous reconfiguration of software defined multiradio, and reconfiguration of terminals and base stations in a composite wireless network. Shared spectrum scenarios consider deployment of CRS in license exempt bands. Secondary usage in dedicated spectrum considers a scenario where CRS shares the spectrum within the current licensed allocations on secondary basis. Spectrum dedicated for CRS scenarios assume deployment of CRS in frequency bands dedicated for CRS.

The overall cognitive radio system concept developed by ETSI RRS is depicted in Fig. 2. The figure covers both centralized and decentralized solutions for CR systems, where the centralized, operator-driven solution is targeted for wide area utilization, and the decentralized solution is targeted for local area ad-hoc/mesh networking.

The centralized CRS concept is represented by the Composite Wireless Network (CWN) including Cognitive Network Management System (C-NMS). C-NMS contains such key components as Operator Spectrum Manager (OSM) and Joint Radio Resource Management (JRRM). The decentralized CRS concept is represented by the Cognitive Mesh Network (CMN) controlled by the Cognitive Control Network (CCN).

WG1 has also identified key *enabling technologies* for CRS. They include software defined radio and multiradio, reconfigurable base stations management, spectrum sensing, cognitive pilot channel, cognitive control radio and networking, geolocation, primary protection database, and distributed decision making.

FUNCTIONAL ARCHITECTURE FOR MANAGEMENT AND CONTROL OF RECONFIGURABLE RADIO SYSTEMS

The network and user equipment of the wireless environment described in sequel are aligned with the following assumptions (see Fig. 4):

i) Different types of terminals operate in this environment. Examples are legacy terminals, multi-standard radio terminals and cognitive radio terminals;
ii) Multi-standard and cognitive radio terminals can be reconfigurable;
iii) Moreover, different types of Base Stations provide wireless access to terminals in this environment. Examples are legacy BSs, APs, Node Bs, etc.;
iv) Multi-standard reconfigurable radio BSs, and cognitive radio BSs are deployed in the heterogeneous context.

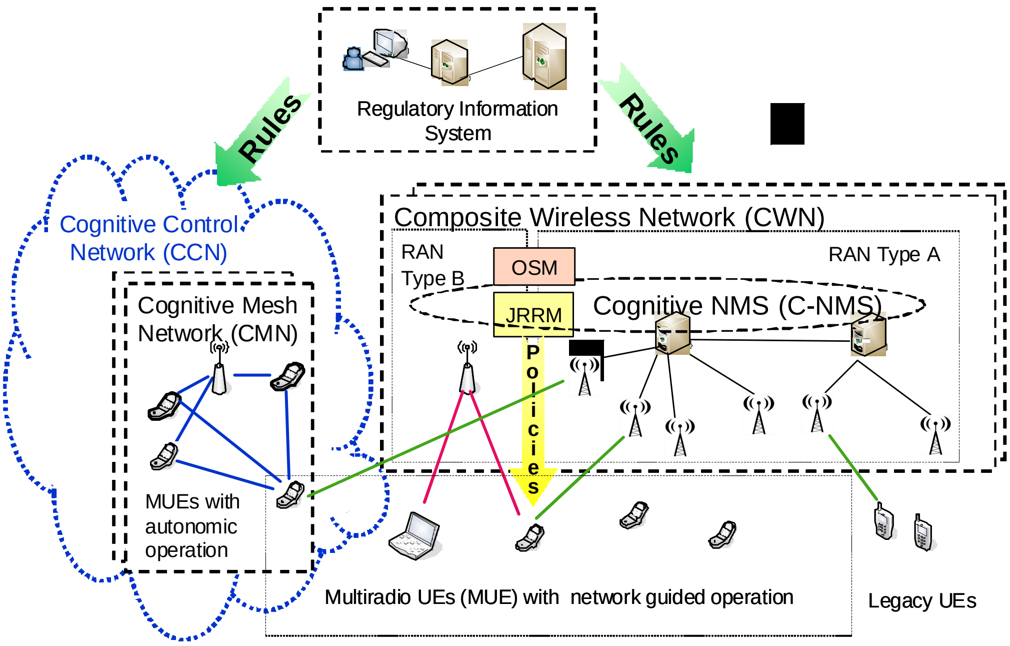

Figure 2: Centralized and Decentralized CR System Concepts.

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 Functional Architecture as defined by ETSI RRS.

In this framework, the availability of context information is key. For this purpose, ETSI RRS defined a Cognitive Pilot Channel (CPC) as a channel which conveys the elements of necessary information facilitating the operations of CRS [5-9]. The CPC provides information on which radio accesses can be expected in a certain geographical area. This information includes operator information, RAT type as well as used frequencies. Exemplary scenarios where the CPC is seen as useful are:

i) The CPC is used to support a terminal during the start-up phase in an environment where the terminal does not yet know the available RATs and corresponding used frequencies.

ii) In the context of a secondary system, the CPC is used to exchange sensing information between terminals and base stations in order to perform collaborative/cooperative sensing facilitating the searching of white spaces to start communication.

iii) The CPC is used for an efficient level of collaboration between a network and the terminals by supporting Radio Resource Management (RRM) optimisation procedures.

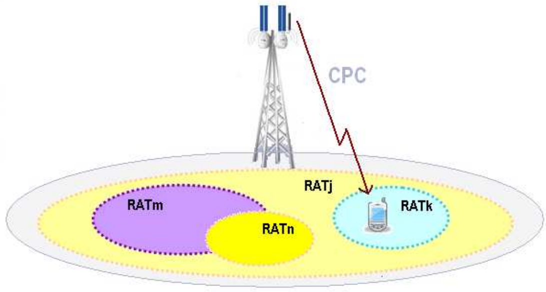

Figure 3: The CPC in a Heterogeneous RAT Environment.

A SDR ARCHITECTURE APPROACH FOR MOBILE DEVICES AS A BASIS FOR FUTURE SDR STANDARDS

ETSI RRS has identified a set of requirements related to an SDR MD architecture [10], including i) general architectural requirements, ii) capability requirements, iii) operational requirements, iv) interface requirements and v) other requirements. The capability requirements are highlighted below:

i) **Multiradio configuration capability:** SDR equipment in mobile device is expected to install, load and activate a radio application while running a set of radio systems already.

ii) **Multiradio operation capability:** SDR equipment in mobile device is expected to execute a number of radio systems simultaneously;

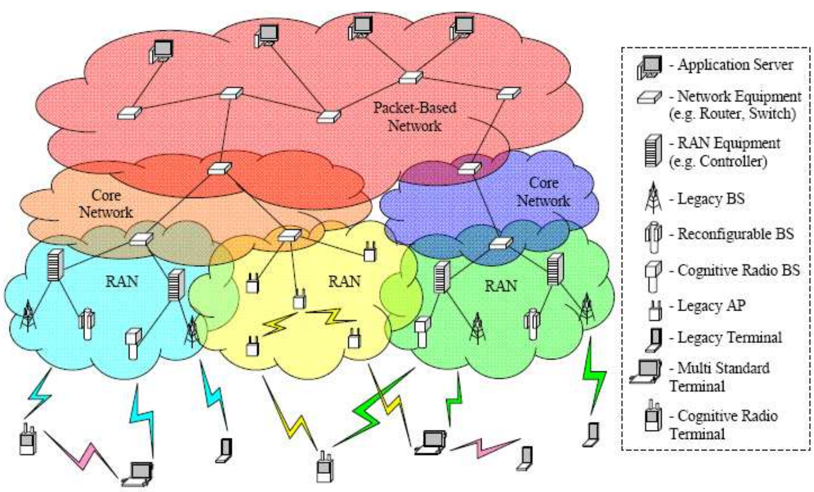

Figure 4: Functional Architecture Context [11].

iii) **Multiradio resource sharing capability:** SDR equipment in mobile device is expected to execute a number of radio systems simultaneously by sharing resources.

The outcome of the study consists, among others, of the presentation of a functional architecture for SDR equipment as detailed in Fig. 5:

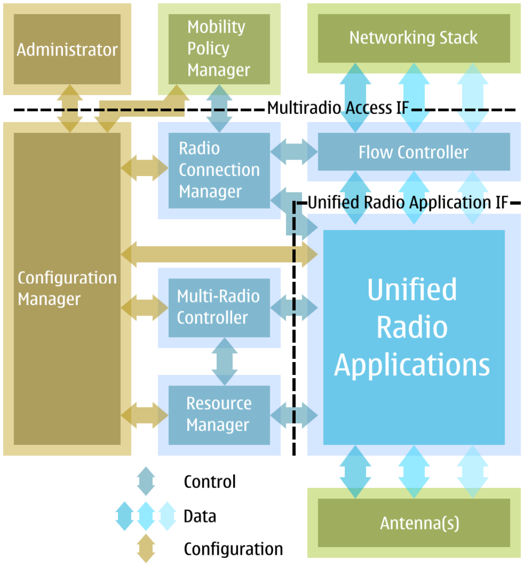

Figure 5: Functional Architecture of SDR Equipment.

The components of this framework have different responsibilities as follows:

i) **Configuration Manager:** (de)installation and (un)loading of radio applications into radio computer as well as management of and access to the radio parameters of those radio applications.

ii) **Radio Connection Manager:** (de)activation of radio applications according to user requests and overall management of user data flows, which can also be switched from one radio application to another.

iii) **Flow Controller:** sending and receiving of user data packets and controlling the flow.

iv) **Multiradio Controller:** scheduling the requests on spectrum resources issued by concurrently executing radio applications in order to detect in advance the interoperability problems between them.

v) **Resource Manager:** management of radio computer resources in order to share them among simultaneously active radio applications, while guaranteeing their real-time requirements.

The ETSI RRS WG2 SDR handset reference architecture report [10] identifies four candidate interfaces for standardization:

i) **Multiradio Interface** as the uniform interface for network protocol stacks and other user domain entities to access services of the radio computer;

ii) **Unified Radio Application Interface** at the boundary between the common radio computer platform and the specific radio applications;

iii) **Radio Programming Interface** including software development-time concepts and run-time interfaces between radio software entities and radio computer platform.

iv) **Interface to the Reconfigurable RF Transceiver** to support multiple radio applications, even concurrently.

Among these interfaces, the **Multiradio Interface** has most potential for standardization, and is currently under further studies in ETSI RRS. It is expected to enable an easier integration of radio platforms into handsets that benefits both chipset vendors and device manufacturers; moreover, it offers significant functionality on top of SDR.

The deployment of the **Multiradio Interface** is expected to proceed in phases with platform capability advancing, starting from legacy radio access technologies, gradually moving towards a full SDR:

i) Radio applications use pre-defined fixed resources. Radio applications come from a single source, and a list of concurrently supported radios is provided;

ii) Radio applications have fixed resource requirements. Instead of fixed resources, a worst-case resource consumption budget is attached to each radio;

iii) Radio applications have dynamic resource requirements. In addition to phase 2 capabilities, the resource demand of radios varies based on their type of activity (for instance power-save vs. active data link);

iv) Radio applications come from third-party vendors. This stage mostly affects the security requirements on the platform, as well as the tools to create radios.

The **Multiradio Interface** is described with a static information model and signaling diagrams for dynamic behavior. This is organized in an UML model to allow formal definitions on a rather abstract level, and extension and specialization of the desired elements later on. This is the current focus in ETSI RRS SDR standardization.

SECURITY

The activity of research and standardization of RRS security must resolve a broad range of issues, which spans from software assurance, conformance to spectrum regulations and certification. As a general rule, RRS must validate the communication security requirements of conventional communication systems like Data Confidentiality and Privacy, Availability, Registration, Authentication and Authorization. This is a consequence of the general conformance to standards and regulations already defined for the wireless communication systems, with which RRS must interoperate. For example, if RRS is used in the context of the public safety domain, it must support the type 1 security requirements defined in the TETRA standard. A major security issue introduced by RRS is the consequence of its reconfiguration capability (see also [12]). Theoretically RRS terminals should be able to download from the air interface new configuration profiles or software modules. Once activated, the new profile or software module will change the RRS radio transmission parameters like frequency, power and modulation types. RRS can use this capability to improve the spectrum usage efficiency and interoperability with the Radio Access Technology (RAT) present in the area. This capability presents two main security issues: i) who guarantees that the downloaded profile or software module comes from a trusted source and can be activated on the RRS terminal ? ii) who guarantees that the downloaded profile or software module will behave as expected ? One inherent requirement is that ETSI RRS needs to adopt the concept of Software Assurance in Information Technology, requiring i) a certification processes to guarantee that the software modules to be downloaded and activated will behave as expected, ii) a secure download mechanism, which guarantees the authenticity of the downloaded software. This should be completed by components in the RRS terminal to verify the software modules, iii) a secure execution environment in the RRS to guarantee that only trusted software can be activated and executed, iv) a component to ensure that spectrum regulations will be validated regardless of the software modules running on the RRS terminal.

In the military and public safety domain, there is the additional consideration that RRS can be used to remove or mitigate the interoperability barriers among the organizations involved in emergency crisis or natural disasters. This application of RRS was evaluated in the FP7 WINTSEC project [13]. Using the capability of RRS technology to communicate with different RATs using the same platform, it is theoretically possible to create interoperable “bridges” across public safety organizations, which use different communication systems.

CONCLUSIONS

This paper has illustrated the SDR and CR framework that is elaborated by ETSI RRS for a heterogeneous wide area (cellular) and short range system scenario. Key elements, such as context provision via a CPC, resource control and management by the proposed FA, a harmonized SDR architecture, security features, etc. are expected to provide the basis for a broad market acceptance.

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