Technology Digest

For limited circulation

Monthly bulletin of telecom technology

Issue 5, November 2011

Telecom Regulatory Authority of India

In this issue

STANDARDISATION OF COGNITIVE RADIO SYSTEMS

Cognitive Radio is one of the most discussed topics in contemporary spectrum management. The official definition of **Cognitive Radio Systems (CRS)** developed by ITU-R WP1B in 2009 defines it as a radio system employing technology that allows the system to obtain knowledge of its operational and geographical environment, established policies and its internal state; to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives; and to learn from the results obtained. **Software Defined** Radio (SDR), on the other hand, employs technology that allows the RF operational parameters to be set or altered by software. SDR allows same hardware to be reprogrammed and reconfigured to perform different functions. SDR allows flexibility to handle several standards since radio functions can be changed by software. CRS is therefore build upon the concept of SDR.

Components of CRS

The main components of the CRS are the **intelligent management system** and **reconfigurable radios**. The four key actions of the CRS are obtaining knowledge, making decisions, reconfiguring and learning. The knowledge used by the CRS includes knowledge about operational radio and geographical environment, internal state, established policies, usage patterns, and users' needs. The methods to obtain this knowledge include getting information from component radio systems of the CRS, geolocation, spectrum sensing, access to the CPC, and database access. Using the obtained knowledge, the CRS dynamically and autonomously makes reconfiguration decisions according to some predefined objectives (e.g., in order to improve efficiency of spectrum usage). Based on the decisions made, the CRS adjusts operational parameters and protocols of its reconfigurable radios. Such parameters include output power, frequency range, modulation type, and Radio Access Technology (RAT). Also, the CRS can learn from its decisions to improve its future decisions.

Benefits of CRS

A CRS network can improve spectrum access and utilization significantly, easing the **sharing of spectrum** among different systems. The cognitive radio techniques offer new and more powerful tools for sharing spectrum. The development of cognitive radio techniques can result in new and **more efficient ways of interference management**. Individual techniques developed in the telecommunication research, e.g. smart antennas and power control, offer a good solution for interference suppression and can be further developed for the needs of cognitive radio systems. Another aspect is **the improved flexibility of the network** with the introduction of cognitive radio features. Networks can be enhanced by cognitive techniques to provide capabilities **for self-organization and self-healing**. Moreover, CR techniques increase **interoperability between different standards** and allow systems to support and change their parameters depending on the policy used. CRS can be used **to exploit locally vacant** or unused radio. They can also be used to **negotiate as a broker** on behalf of users with multiple service providers to give network access best matched to the user needs. At the moment efforts are focused on the development of cognitive capabilities to be used in future wireless communication networks, however, similar principles could also be applied to other industry verticals, e.g., smart energy grids and industry automation.

CRS Capabilities

There are three key characteristics associated with CRS:

i) the capability to obtain knowledge regarding operational and geographical environment, established policies, internal state of CRS and usage pattern through information collection, geolocation, spectrum sensing, white space database access and access to a cognitive pilot channel (CPC)

ii) the capability to dynamically and autonomously adjust its operational parameters and protocols, like output power, frequency band and RAT, using an intelligent management system according to the obtained knowledge in order to achieve some predefined objectives. This is the new capability of the CRS, compared to commonly used adaptation methods like power control or adaptive modulation and coding

iii) the capability to learn from the results of its actions in order to further improve its performance.

Types of CRS

Two key types of the CRS can be identified: heterogeneous type CRS and spectrum sharing type CRS.

In the **heterogeneous CRS**, one or several operators operate several radio access networks (RANs) using the same or different RATs. Frequency bands allocated to these RANs are fixed. These RANs may have different types of base stations - legacy, designed to use a particular RAT to provide wireless connection to terminals or reconfigurable, having capability to reconfigure itself to use different frequency bands allocated to the operator and use different Radio Access Technologies (RATs) as specified by the radio regulations for these frequency allocations. The users may have terminals that use a particular RAT or reconfigurable terminal that has capability to reconfigure itself to use different RATs. Such a terminal can hand over between different RANs using different RATs operated by different operators. Optionally, a reconfigurable terminal can support multiple simultaneous links with RANs. The heterogeneous CRS is considered, for example, in the following standards: IEEE 1900.4, IEEE draft standard P1900.4.1, and IEEE 802.21. One example of this deployment scenario is shown in Figure 1.

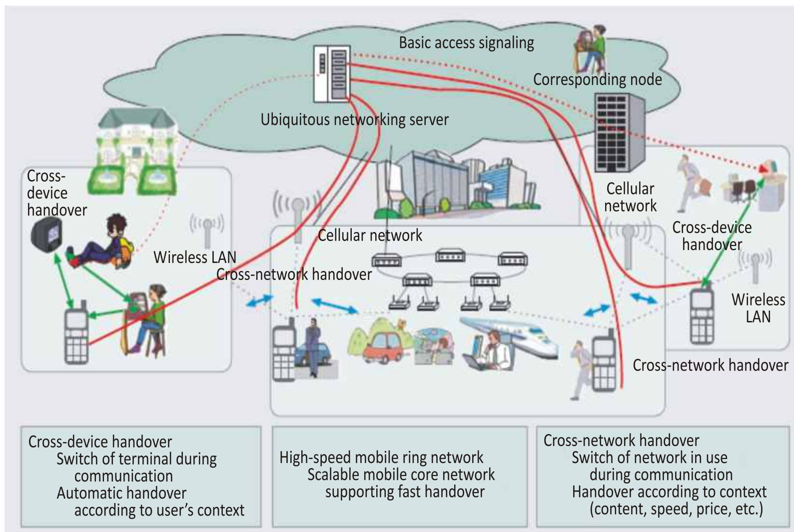


Figure 1 Heterogeneous CRS

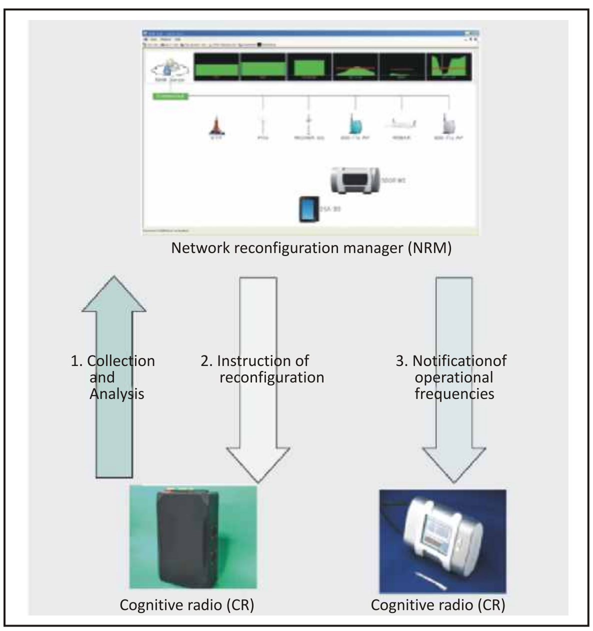


Figure 2 Spectrum Sharing CRS

In the **spectrum sharing CRS** several RANs using the same or different RATs can share the same frequency band. One deployment scenario is when a secondary system operates in the white space of a television broadcast operator frequency band. In such a scenario, the CRS capabilities should provide protection of primary service (television broadcast) and coexistence between secondary systems. Spectrum sharing CRS is considered, for example, in the following standards: IEEE 1900.4, IEEE draft standard P1900.4a, IEEE Dynamic Spectrum Access Networks and the 802 LAN/MAN Standards ETSI, Technical Committee (TC - RRS) ECMA, Task Group 1 f Technical committee 48 etc.

Topics covered in Previous Issues of Technology Digest

1. *Cellular Backhaul Technology, July 2011*
2. *Machine to Machine Communication Standards, August 2011*
3. *Advanced Antenna Systems, September 2011*
4. *Next Generation Optical Access Networks, October 2011*

CRS STANDARDIZATION IN THE ITU

A number of activities relating to CRS are being carried out in ITU-R WP 1B, WP 5A and SG8.

ITU-R Working Party (WP) 1B is currently developing a working document toward draft text on World Radio Conference 2012 (WRC 12) agenda item 1.19 which is "to consider regulatory measures and their relevance, in order to enable the introduction of software-defined radio and cognitive radio systems, based on the results of ITU-R studies, in accordance with Resolution 956 (WRC 07)". WP 1B has developed definitions of the software defined radio (SDR) and CRS. Also, WP 1B has summarized the technical and operational studies and relevant ITU-R recommendations related to the SDR and CRS.

The ITU-R WP 5A is currently developing the working document toward a preliminary new draft report, "Cognitive Radio Systems In the Land Mobile Service". This report will address the definition, description, and application of cognitive radio systems in the land mobile service.

ITU-R Study Group 8 (SG8) has published two reports on SDR, which provide basic information on SDR technology and present the application of SDR to IMT-2000 (International Mobile Telecommunication-2000) and to other land mobile systems. SG8 recently also approved a Study Question on "Cognitive Radio Systems in the Mobile Service".

CRS STANDARDIZATION IN IEEE

IEEE DySPAN Standards Committee (formerly IEEE Standards Coordinating Committee SCC41) develops standards for dynamic spectrum access networks. The focus is on improved use of spectrum, including new techniques and methods of dynamic spectrum access, which requires managing interference and coordination of wireless technologies, and includes network management and information sharing. Several working groups have recently published standards on different aspects of CRS:

IEEE 1900.1 "Working Group on Definitions and Concepts for Dynamic Spectrum Access: Terminology Relating to Emerging Wireless Networks, System Functionality, and Spectrum Management" has published a standard IEEE 1900.1 in 2008. This standard creates framework for developing other standards within the IEEE SCC 41.

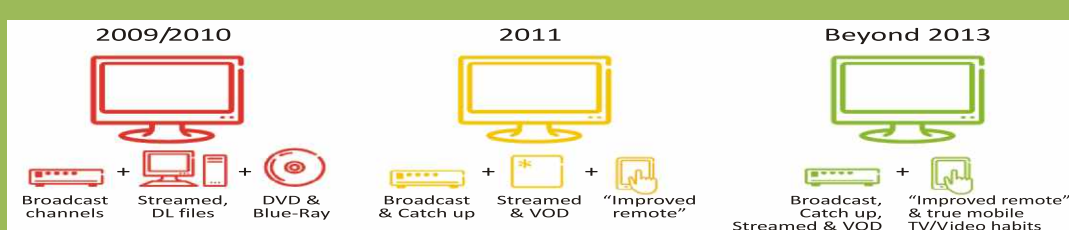
IEEE 1900.2 "Working Group on Recommended Practice for the Analysis of In-Band and Adjacent Band Interference and Coexistence Between Radio Systems" has published a standard IEEE 1900.2 in 2008. This recommended practice will provide technical guidelines for analyzing the potential for coexistence or in contrast interference between radio systems operating in the same frequency band or between different frequency bands.

IEEE 1900.3 "Working Group on Recommended Practice for Conformance Evaluation of Software Defined Radio (SDR) Software Modules" has been disbanded.

IEEE 1900.4 "Working Group on Architectural Building Blocks Enabling Network-Device Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Access Networks" has published standard IEEE 1900.4 "IEEE Standard for Architectural Building Blocks Enabling Network-Device Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Access Networks" in February 2009. IEEE 1900.4 defines the architecture of the intelligent management system of a CRS. Both the heterogeneous and spectrum sharing CRS are supported by the IEEE standard 1900.4. This group is now working on two projects:

> **1900.4a**: Standard for Architectural Building Blocks Enabling Network-Device Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Access Networks - Amendment: Architecture and Interfaces for Dynamic Spectrum Access Networks in White Space Frequency Bands

Future trend of TV and video [Source: Ericsson]



1900.4.1: Standard for Interfaces and Protocols Enabling Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Networks

IEEE 1900.5 "Working Group on Policy Language and Policy Architectures for Managing Cognitive Radio for Dynamic Spectrum Access Applications" is finalizing a standard. P1900.5 defines a vendor-independent set of policy-based control architectures and corresponding policy language requirements for managing the functionality and behaviour of dynamic spectrum access networks. Current status of P1900.5 is that the draft standard is in sponsor ballot process with the intention that it be published by end of 2011.

IEEE 1900.6 "Working Group on Spectrum Sensing Interfaces and Data Structures for Dynamic Spectrum Access and other Advanced Radio Communication Systems" has published a standard in April 2011. ." This amendment provides specifications to allow integrating 1900.6 based distributed sensing systems into existing and future dynamic spectrum access radio communication systems. It enables existing legacy systems to benefit so as to widen the potential adoption of the IEEE 1900.6 interface as an add-on to these systems and to claim standard conformance for an implementation of the interface. In addition it facilitates sharing of spectrum sensing data and other relevant data among 1900.6 based entities and external data archives.

The scope of the standard is to define the information exchange between spectrum sensors and their clients in radio communication systems Figure 3 shows a scenario where sensing information is exchanged among sensors and their clients. The clients include the Cognitive Engine(CE), Data Archive (DA), and sensors. The CE is defined as the portion of the CRS containing the policy based control mechanism and the cognitive control mechanism, which must have knowledge about the current state and a set of attainable states, and may have knowledge about the cost associated with (state) transitions of the reconfigurable radio platform. The DA is defined as a logical entity where sensing information obtained from spectrum sensors or other information sources, and regulatory and policy information are stored systematically. The sensor can play a client role of another sensor; that is, a sensor can receive sensing information from one or more sensors and forward it to CE or DA.

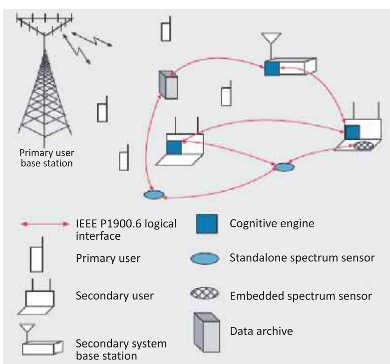


Figure 3 CRS scenario with IEEEP1900.6 interface

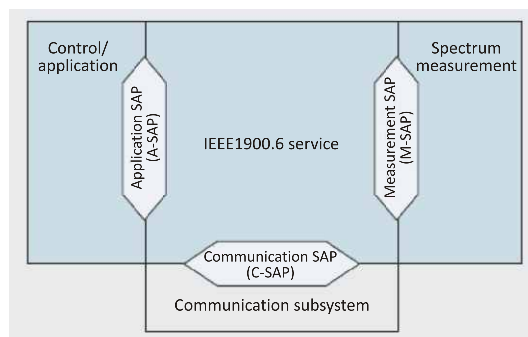


Figure 4 Reference model of P1900.6 standard

To give the industry a guideline on how to implement the logical interface, the WG defines a reference model, shown in Figure 4. Sensors and their clients can have all service access points (SAPs) or a subset of the three SAPs (i.e., application SAP [A-SAP], communication SAP [CSAP] and measurement SAP [M-SAP]. The A-SAP defines a set of generic primitives and data structures to control the P1900.6 entity and/or obtain the sensing results for application purposes. The A-SAP may provide functions to configure these for collaborative sensing, to start the data acquisition and processing (e.g., policy processing), and to obtain the results of P1900.6 processing in order to configure the radio frequency (RF) interface accordingly. The M-SAP is used by P1900.6 entities to access P1900.6 compliant services provided by the station's hardware and/or firmware to control the spectrum measurement module, such as collocated physical spectrum measurement module i.e., analog-to-digital/digital-to-analog converter, and acquire measurement data from these. The C-SAP is used for sensing information (sensing message, sensor message, control message, and regulatory information) exchange between sensors and their clients. The client role can be taken by sensor, CE, and DA.

IEEE 1900.7 "White Space Radio Working Group P1900.7 for Radio Interface for White Space Dynamic Spectrum Access Radio Systems Supporting Fixed and Mobile Operation". Draft standards are under development.

IEEE 802 Standards Committee: IEEE 802 WGs are defining CRSs and components of the CRS. The activity to define CRSs is currently performed in the 802.22 and 802.11 WGs, while the activity to specify components of a CRS is currently performed in 802.21, 802.22, and 802.19 WGs.

The **draft standard P802.22** is entitled "Draft Standard for Wireless Regional Area Networks Part 22:Cognitive Wireless RAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Policies and Procedures for Operation in the V Bands." It specifies the air interface, including the cognitive MAC and PHY, of point-to-multipoint wireless regional area networks, comprised of a professionally installed fixed base station with fixed and portable user terminals operating in the unlicensed VHF/UHF TV broadcast bands between 54 Hz and 862 MHz (TV white space). The IEEE802.22 standard is targeting at using cognitive radio techniques to allow sharing of the TV spectrum with broadcast service. It aims to bring broadband access to hard-to-reach low-population-density areas like rural areas without causing harmful interference to incumbent operation and low-power licensed devices such as wireless microphones. One of the major challenges in IEEE 802.22 is to detect spectrum availability quickly and dynamically changes transmit parameters, so as not to cause harmful interference to the licensed transmissions. IEEE 802.22 uses geo-location/database and spectrum sensing to understand the spectral environment. In the first method, knowledge of the location of the cognitive radio devices combined with a database of licensed transmitters is used to determine which channels are locally available. In spectrum sensing, the received signals are analyzed to identify which channels are occupied by licensed transmission. An IEEE 802.22 network is able to serve a rural area of typically 30 km or more (up to a maximum of 100 km) in radius from a base station (BS) and up to 255 fixed units of customer premises equipment (CPE) with outdoor directional antennas located at nominally 10 m above ground level. The minimum peak throughput delivered to a CPE at the edge of coverage will be 1.5 Mb/s in the downstream direction (BS to CPE) and 384 kb/s in the upstream direction (CPE to BS).

As the first cognitive radio standard, IEEE 802.22 not only addresses the PHY and MAC layers like other standards, but also a few new functions. At the PHY layer there are two special functions: the spectrum sensing function (SSF) and the geo-location function. These provide necessary functionality to support the cognitive capabilities of the system. At MAC layer, there is also a new function called spectrum manager (SM). To protect wireless microphone, there is also a subgroup (IEEE 802.22.1) standardizing the beacon.

Another standard which emerges is IEEE 802.11af, which will provide services similar to the traditional IEEE 802.11 standard, also known as WiFi when certified by the WiFi alliance. The IEEE 802.11af working group has been set up in Jan 2010 to define a standard to implement White-fi which is a term being used to describe the use of a Wi-Fi technology within the TV unused spectrum, or TV white space. When using systems like white-fi, IEEE 802.11af that use TV white space, the overall system must not cause interference to the primary users. In order for white-fi 802.11af to be able to operate, it is necessary to ensure that the system does not create any undue interference with existing television transmissions. To achieve this there are a number of technologies like cognitive and geographic sensing.

HetNets

Driven by a new generation of devices, like smart phones and netbooks, capacity demand in wireless networks increases faster than spectral efficiency improvement, particularly at hotspots/areas. Also, as services become more data centric, more users operate indoors, which requires increased link budget and coverage extension to provide uniform user experience. Traditional networks optimized for homogeneous traffic face unprecedented challenges to meet the demand cost effectively. Most recently, Third Generation Partnership Project (3GPP) Long Term Evolution (LTE)-Advanced has started a new study item to investigate heterogeneous network (HetNet) deployments as an efficient way to improve system capacity as well as effectively enhance network coverage. Unlike traditional heterogeneous networks that deal with the interworking of wireless local area networks and cellular networks, HetNet is a network containing nodes with different characteristics such as transmission power and radio frequency (RF) coverage area. Low-power micro nodes and high-power macro nodes can be maintained under the management of the same operator. They can share the same frequency band, provided by the operator. In this case, joint radio resource/interference management needs to be provided to ensure the coverage of low-power nodes. In some other cases, the low- and high-power nodes can use discontinuous bands of an operator separately so that strong interference with each other can be avoided. Macro network nodes with large RF coverage areas are deployed in a planned way for blanket coverage of urban, suburban, and rural areas. Local nodes with small RF coverage areas aim to complement the macro network nodes for coverage extension or throughput enhancement. In addition to this, global coverage can be provided by satellites (macrocells) according to an integrated system concept.

Het-Nets target the improvement of overall capacity as well as a cost-effective coverage extension and green radio solution by deploying additional network nodes within the local area range, such as low-power micro/pico network nodes, home-evolved Node-Bs (HeNBs)/closed subscriber group (CSG) cells, and femto and relay nodes.

(Source: IEEE Wireless Communications, June 2011)

Work has only recently started on the IEEE 802.11af standard for white-fi applications in white space TV spectrum. A number of trials have been undertaken with success, although to deploy a scheme of this nature will require careful definition and implementation.

IEEE 802.21 is entitled "IEEE Standard for Local and Metropolitan Area Networks — Part 21: Media Independent Handover Services." It defines extensible media-access-independent mechanisms that enable the optimization of handover between heterogeneous IEEE 802 networks, and facilitate handover between IEEE 802 networks and cellular networks.

Draft standard P802.19.1 is entitled "IEEE Standard for Information Technology —Telecommunications and Information Exchange Between Systems — Local and Metropolitan Area Networks — Specific Requirements — Part 19: TV White Space Coexistence Methods." It specifies radio-technology-independent methods for coexistence among dissimilar or independently operated TV band device networks and dissimilar TV band devices.

CRS STANDARDIZATION IN ETSI TC RRS

ETSI standardization initiative ETSI Board created a Technical Committee (TC) for Reconfigurable Radio Systems (RRS) in Jan. 2008. Reconfigurable Radio Systems (RRS) is a generic concept based on technologies such as Software Defined Radio (SDR) and Cognitive Radio (CR) whose systems exploit the capabilities of reconfigurable radio and networks for self-adaptation to a dynamically-changing environment with the aim of improving supply chain, equipment and spectrum utilization. The main purpose is to study the feasibility of standardization activities related to Reconfigurable Radio Systems including SDR and CR. In Oct. 2009, ETSI's RRS Technical Committee released a series of ETSI Technical Reports (TR 102 838) that examine the standardization needs and opportunities. The reports summarize the feasibility studies carried out by the committee and present the recommended topics for standardization. Following the completion of the feasibility studies, standardization of RRS is now getting underway.

ETSI Technical Committee Reconfigurable Radio Systems (TC RRS) is responsible for reconfigurable radio system standardization including cognitive radio systems and software defined radio. The following are the work groups(WG) and their activities:

WG1: System Aspects, Several work items on CRS operations on TV White Spaces(use cases, system requirements, coexistence, RF performance) and mobile systems bands

WG2: Radio Equipment Architecture, Radio reconfiguration related requirements for mobile devices

WG3 – Cognitive Management and Control, Feasibility study on control channels for CRS

WG4 – Public Safety, Use cases for spectrum and network usage among public safety, commercial or military

Technical Reports (TR) published:

WG1 – System Aspects

- ETSI TR 102 802, "Cognitive Radio System Concept," was published in February 2010. It formulates the harmonized technical concept for CRSs. Both infrastructure as well as infrastructureless radio networks are covered. Based on the system concept, the identification of candidate topics for standardization is the target of this study, also including a survey of related activities in other standard development organizations.
- TR 102 803 Potential regulatory aspects of Cognitive Radio and Software Defined Radio systems was published in March 2010. This report summarizes the studies carried out by ETSI TC RS related to the CRS and SDR. In particular, the study results have been considered for items of potential relevance to regulation authorities.
- TR 102 838 Summary of feasibility studies and potential standardization topics summarizes results up to mid 2009, and indicate possible new areas for standardization for SDR and CR.

WG2 – Radio Equipment Architecture

- TR 102 680 SDR Reference Architecture for Mobile Device was published in March 2009. The scope of this study item is proposed to cover functional architecture and interfaces of an SDR equipment, which can operate multiple radios in parallel by sharing the baseband computation, RF and spectrum resources efficiently.

- Such architecture is expected to provide two system-level interfaces: i) Multiradio access interface that provisions all SDR multiradio services such as data communication and reconfiguration to the applications residing in the handset ii) Unified radio system interface for harmonizing the way, in which different and independently standardized radio stacks can operate simultaneously under a common SDR control framework
- TR 102 681 Radio Base Station (RBS) Software Defined Radio (SDR) status, implementations and costs aspects, including future possibilities was published in June 2009. Investigation and assessment of possible architectures, related qualities and corresponding costs. 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. Investigation of architectures facilitating Cognitive Radio (CR).

WG3 – Cognitive Management and Control

- TR 102 682 Functional Architecture (FA) for the Management and Control of Reconfigurable Radio Systems was published in July 2009. It provides a feasibility study on defining a functional architecture for reconfigurable radio systems, in terms of collecting and putting together all management and control mechanisms targeted at 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.
- TR 102 683 Cognitive Pilot Channel (CPC) was published in September 2009. It provides a feasibility study on defining and developing the concept of the CPC for reconfigurable radio systems to support and facilitate end-to-end connectivity in a heterogeneous radio access environment where the available technologies are used in a flexible and dynamic manner in their spectrum allocation context.

WG4 – Public Safety

- TR 102 745 User Requirements for Public Safety was published in October 2009. The proposal is to investigate the application of RRS in the Public Safety and Defense domain, which includes the set of Public Safety organizations and related applications and technologies. The scope of the work is Identification and definition of possible requirements for RRS in Public Safety and Defense domain.

THE INTERNET OF THINGS

In the last few years, a stimulating idea is fast emerging in the wireless scenario: the pervasive presence around us of a variety of “things” or “objects” such as devices, sensors, actuators, and mobile phones, which, through unique addressing schemes, are able to interact with each other and cooperate with their neighboring “smart” components to reach common goals. This novel paradigm, named the “Internet of Things” (IoT), continues on the path set by the concept of the smart environment and paves the way to the deployment of numerous applications with a significant impact on many fields of future everyday life. The IoT paradigm’s feasibility stems from the maturity level reached by several key technologies. From a wireless communication perspective, the IoT paradigm is strongly related to the effective integration of wireless sensor networks (WSNs) and radio frequency identification (RFID) systems. While RFID systems are (mostly) passive nodes that react to solicitations by an RFID reader, enablement of the IoT also requires WSN nodes to be self-reliant for energy. Nowadays, this is possible thanks to the energy harvesting technologies that are becoming ever more efficient in obtaining energy from the surrounding environment. Finally, cooperation between elements of the IoT to provide added value services is possible thanks to application layer solutions derived from web technologies such as SOAP, XML, and REST, all leveraging HTTP, being modified to fit into low-capability IoT nodes. Needless to say, IPv6 is an important transport infrastructure to connect myriad things.

The IoT’s future is bright, although its full deployment must overcome several compelling constraints. The IoT will be composed of a tremendously huge number of nodes; this poses serious scalability requirements on any solution proposed for the IoT. Furthermore, nodes may profoundly differ from one another; therefore, any proposed approach must effectively deal with heterogeneity.

(Source: IEEE Wireless Communications, December 2010)

ETSI Specialist Task Force (STF) 386

Developes cognitive interference mitigation methods for Programme Making and Special Events (PMSE) devices. Purpose is to achieve co-existence of PMSE devices with other radio services.

- ETSI TR 102 799 “Operation methods and principles for spectrum access systems for PMSE technologies and the guarantee of a high sound production quality on selected frequencies utilising cognitive interference mitigation techniques.”
- ETSI TS 102 800 “PMSE - Protocols for spectrum access and sound quality control systems using cognitive interference mitigation techniques.”

CRS STANDARISATION IN SDR FORUM

In September 2008, SDR Forum published a report on “Cognitive Radio Definitions and Nomenclature” (SDRF-06- P-0009-V1.0.0). This report identifies components and collects working definitions for many of the technologies and techniques related to cognitive radios. The Cognitive Radio Work Group (CRWG) under SDR Forum is also working on a report entitled “Quantifying the Benefits of Cognitive Radio”, which is developed for understanding the benefits of using cognitive radio technologies in next generation wireless systems. Since September 2009, the SDR Forum has also started a test and measurement project to develop a set of use cases, test requirements, guidelines and methodologies for SDR/CR unique functions required for secondary access to TV band spectrum. The project addresses critical TV White Space functions, e.g., spectrum sensing, interference avoidance, database performance, and adherence to policy.

CRS STANDARDISATION IN IETF

Internet Engineering Task Force (IETF) Protocol to access white space database (PAWS) draft was released in February 2011. The use of white space spectrum is enabled via the capability of a device to query a database and obtain information about the availability of spectrum/channels for use at a given location. The databases are reachable via the Internet and the devices querying these databases are expected to have some form of Internet connectivity. The databases are also country specific since the available spectrum and regulations may vary. A messaging interface between the white space devices and the database is required for operating a network using the white space spectrum. Cognitive radio and TV white space technology is now in the process of being approved by regulatory bodies around the world. In the US the FCC has already created the regulation and approved a set of database administrators. The interface between the white space devices and databases is over the Internet and uses IP connectivity. The IETF is working to create a common standard for use on a global basis for this interface.

References: There are many to be individually acknowledged, the primary ones are cited here:

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Published by: Telecom Regulatory Authority of India
Editorial responsibility: TDRA Division
Contributions, comments and suggestions: tdra@trai.gov.in, tdra.trai@gmail.com