International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 3 Issue 13, December 2016

ISSN: 2394-4404

Cognitive Radio Systems: Conceptual Architectures Cycles Designed Adaptations And Security

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***Abstract:** This paper proposes an integrated cognitive radio conceptual archicteture designed that qualified the radio to be called as an intellegent radio, the radio is classified and defined as promising technology leverage the services of other radio networks and management. The architeture were designed with capabilities to enables and support dynamic spectrum sensing network access systems which cover the operational cycle management. The research work enhance the concept radio architectre of wireless innovative communications forum cognitive radio concepts architectres designe in January 2013. An analysis of radio cognition information processe and functionality of each layer to compliments others in services delivered, also higlighted various stages and evalutions of technical operations parameters in industries standards and regulations policies from differents groups of reserchers in wireless communications. Challeneges and security imlemenatations amongst manfacturers, enteprises and vendors domain. Further more additional processes were added in the exiting and general widely used of cognitive radio definition cycle by Inernational Telecommunication Union (ITU) in respect to the three stages operations process learn, make decision and adjust within its presents environments. A regulations and standards policies on wireless communications concepts with speeds range from 2.3GHz to 2.4GHz for better utilize the radio spectrum standards teachniques IEEE 1900.1to P 1900.7 mobile operations MAC sub layer and PHY layer.*

***Keywords:** Cognitive Radio, Conceptual Architecture, Cognitive Operational Cycle, Security, Standardizations and Regulations*

I. INTRODUCTION

The information and communication technology today have changes our society and the way we live. If take into account from our environments point of view and organisational structures weather profit orientated and non profits making organisations by using information technology infrastructures towards the accomplishments of services delivered through the integrations and implementations of cognition and information process technologist for best practices. In view of the idea and the purposes of this paper focus on cognitive radio conceptual architecture designed and operational executions which consists of computer networks as well as manufacturers vendors operational policies and subsequently the challenges industries were faced to improve the efficiency in services delivered and other various strategies to reduce the impact of the hazardous materials and physical equipments or components on the environments.

All nations' governments agencies small and medium enterprises have realized the need and importance for efficiency not only on the energy domain but also in the spectral domain, because better spectral usage implies less strain on other energy intensive systems which support the ICT. As foretold by the Mitola a cognitive radio is a promising radio network technology to improve better utilization spectrums of wireless communication systems. A cognitive radio is final evolution of software defined the Radio (SDR) framework architectures. A fully re-configurable radio system that changes its communication capability and functionality, depending on network conditions and user demands. Mitola's

 ISSN: 2394-4404

definition on reconfigurability of the system is very generic and only focus here on the reconfigurability of the hardware platform for Cognitive Radio. Software defined radio basically refers to a set of techniques that allow the dynamic re-configuration of a communication system with the help of software alone and without the need to change any hardware element. Terminologist associated in cognitive radio networks regards to the spectrum channels characteristics parameters for primary users and secondary in priority orders. “primary users can be defined as the users who have higher priority or legacy rights on the usage of a specific part of the spectrum. On the other hand, secondary users, which have lower priority, exploit this spectrum in such a way that they do not cause interference to primary users. Therefore, secondary users need to have cognitive radio capabilities, such as sensing the spectrum reliably to check whether it is being used by a primary user and to change the radio parameters to exploit the unused part of the spectrum” (yucek, et al, 2009).

II. COGNITIVE RADIO OPERATIONAL CYCYLE CONCEPT

There are a plethora of definitions of Cognitive radios. The most widely used definition is from International Telecommunication Union (ITU). As per ITU a CRS is a radio system employing technology that allows the system:

- ✓ To obtain knowledge of its operational and geographical environment, established policies, and its internal state (cognitive capability).
- ✓ To dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge, in order to achieve predefined objectives (reconfigurable capability).
- ✓ To learn from the results obtained (learning capability).

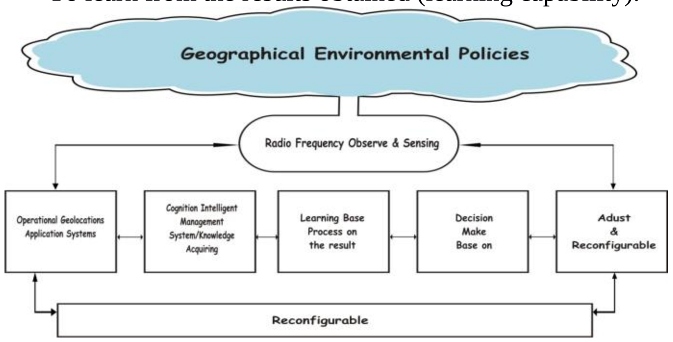

Figure 1

The main components of the CRS are the intelligent management system and reconfigurable radios. CRS are intelligent enough to take actions like making decisions, obtaining knowledge of the system environment, reconfiguration, and learning from its previous experiences. The CRS uses knowledge about operational radio parameters, geographical environment, and internal state of the system, usage patterns, established policies and users’ needs. This knowledge is gathered by getting information from various subsystems of the CRS, sensing of spectrum, access to the cognitive pilot channel (CPC), geographic coordinates, and database access. Using the knowledge gathered, the CRS by itself and dynamically makes reconfiguration decisions on the system according to some set of overall goals, for the purpose of improving efficiency of spectrum usage. The CRS adjusts operational parameters and protocols of its reconfigurable radios based on the decisions made. Such parameters may include frequency range, modulation type, power output and radio access technology protocols. In order to implement CRS with reconfigurations, software-defined radio (SDR) approach is used. Also, the CRS are intelligent enough that it can learn from its decisions to improve its future course of actions from a configuration point of view. Obtaining knowledge and decision making is enhanced by the results of learning. There are two types of CRS: heterogeneous CRS and spectrum sharing CRS. The heterogeneous type uses the network centric approach where one or several operators operate several radio access networks (RANs) using the same or different RATs. Frequency bands allocated to these RANs are fixed. Cognitive network optimizes radio resources and improves the Quality of Service. The second type of CRS is spectrum sharing CRS, where several RANs using the same or different RATs can share the same frequency band by using the unoccupied sub-bands in an intelligent and coordinated way. Most of standardization activities done by ITU are related to this type of CRS.

III. COGNITIVE RADIO CONCEPT ARCHITECTURE

Firstly, the cognitive radio conceptual architecture proposed by groups of researchers for wireless communications forum January 2013, the architecture separate the subsystems into four segment layers in conjunction with open systems interconnections network architecture for efficient services delivered focusing on radio domain, policy domain and user domain addition sub operations policies rules cognitive control systems. Secondly the forum set another of a separate functional layer called a spectrum enabling architecture for dynamic access designed who’s carried several keys operational configurations and systems management. There are two different cognitive radio subsystems layers architecture designed in cognitive radio operations a segment that is makes decision based on the various inputs in regards to flexibilities of software defined radio whose provides a wide range of possible operating modes. A separate spectrum sensing subsystems architectures of cognitive radio is capable to detect signals in its presences environments other services or users. The two subsystems of cognitive radio do not provides any definition of the radio or equipments but often refers to as cognitive radio network that leverage the services of other radios, the two architecture were designed in different dimensions entities.

The proposed integrated conceptual cognitive radio network architecture spell out the cooperative collaboration from the basic concepts and functional OSI layer execution TCP layer, Data Link Layer, MAC Layer and finally Physical Layer which has direct technical operational communications as well as the manufacturers and vendors services policies for best practices. In figure 1 the conceptual cognitive radio architecture consists of four major layers namely are Domain database, Equipments operational Communication Cycle and OSI layer with two sub layers under infrastructures cycle

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operations Gateway and proxy layer with compliments of database domain and full functional application policies.

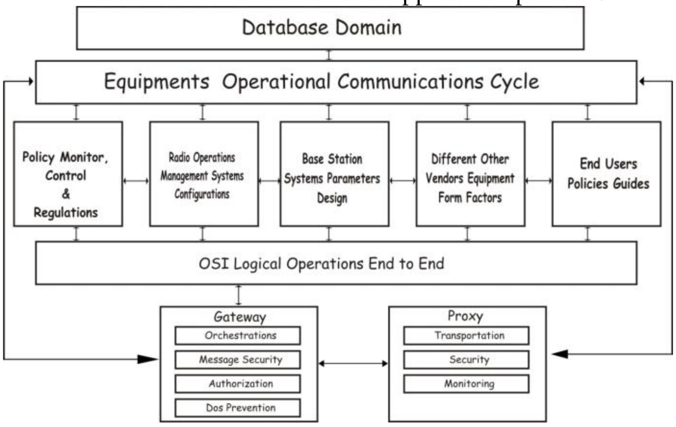

Figure 2

The information that participates in vertical handover is at the intermediate level, or it could be information which can help to make a standard choice, such as a standard detection sensor for instance. The network load of the standards supported by the equipment may also be of interest. It also includes the policies concerning the geography of the location. All human interaction with communicating device is assigned to the highest layer. It is related to everything that concerns the user, his habits, preferences, policies and profile. If a user frequently connects to a video on demand service every evening while coming back home from work by public transport, a CR terminal should be aware of it, to plan all the requirements in terms of battery life, sufficient quantity of credit on his video on demand contract, vertical handover succession depending on each area during the trip, etc. The equipment can be aware of its environment with the help of sensors like accelerometers, microphone, GPS devices, video-camera, bio-sensors, etc. As we are at the early stage of such technology, it is difficult for us to foresee all the possibilities. We can think, for instance, that user's biometric information and/or facial recognition will ensure access control for security purposes. Video-camera could also be used to indicate if the terminal is outside or inside a building. This may impact propagation features, but also the capability or not to receive GPS signals for location awareness. Another example could be given in the context of video conferencing, a separation between the face of the speaker and the background could help decreasing the data rate while refreshing slowly the background of the image.

Note that this classification is also related to three well-known concepts:

- ✓ Context awareness for higher layers,
- ✓ Interoperability for intermediate layers,
- ✓ Link adaptation for lower layers.

All this may be combined to achieve cross-layer optimizations. This is one of the Features of the cognitive engine in our mind. However, due to the high financial Pressure on spectrum issues, CR is often restricted in the research community to spectrum Management aspects. Opportunistic spectrum access approaches are explored to increase the global use of the spectrum resources. FCC (American) has been already opening the door for several years, in the TV broadcasting bands, and permits secondary users (unlicensed) to occupy primary users spectrum when available. More futuristic CR scenarios may also be considered concerning the spectrum management. We may even imagine in the near future a fully deregulated spectrum access where all radio connections features would be defined on-the-go: carrier frequency, modulation, data rate, coding scheme, etc. But this means also to overcome regulatory issues in addition to technological challenges.

IV. CHALLENGES

A large number of researchers have been attracted to Cognitive Radio systems from different domains and the results they have come up with are interesting. The challenges are numerous, they are, distribution of intelligence and implementation, delay/protocol overhead, cross-layer design, security, sensing algorithms, and flexible hardware design. It is very difficult to provide an exhaustive analysis of all research works available on CRS due to the huge amount of published papers and the interdisciplinary nature of the topic. The purpose of this section is therefore to briefly describe challenges which are yet open and current under debate in the framework of research on CRS.

V. DECISION MAKING

CRS is driven by a decision making, the first relevant research challenge is where and how the decision (e.g., the decision on spectrum availability, strategy for selecting channel for sensing or access, or how to optimize radio performance) should be taken. The first issue is directly related to whether the cognitive process should be implemented in a centralized or distributed fashion. This aspect is more critical not only for cognitive networks, where intelligence is more likely to be distributed, but also for cognitive radios, as decision making could be influenced by collaboration between them and also with other devices. The second issue is the choice of the decision algorithms (e.g., neural networks, genetic algorithms, ant-colony optimization, etc. which should be customized to fulfil the CRS requirements.

VI. LEARNING PROCESS

Research in machine learning has grown dramatically recently, with significant amount of progress. One of the important aspects of the learning mechanisms is whether the learning performed is supervised or unsupervised. In the context of a CRS, either technique may be applied. The first challenge of learning is to avoid wrong choices before a feasible decision, especially in autonomous or unsupervised learning process. The second issue is to concretely define learning process in the context of CRS, its objectives and contributions. In terms of implementation and algorithm design, the cognitive functionalities, which are related to enabling devices or networks to learn from past decisions to improve their behavior, are too much complex. The design of the learning algorithm represents by itself a challenge, and

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measurements which should be employed by learning open new issues related to which measurements to use and how to perform them.

VII. CROSS LAYERS

While the aspect of inter-protocol interaction is included in the concept of cognitive network as means to support user and applications requirement, no relevant and comprehensive analysis is available to address the performance and, in general, the behaviour of applications and networks based on CRS technology. The design of cognitive or self-organized network is itself a challenging task, in particular, the outer and inner loops coordination, the networking middleware for knowledge exchange, and intersystem networking for sharing and cooperation. Challenge is also in the design of high layers including MAC sub-layer and network layer, spectrum management functions integrated at the different layers of the network protocol stack, cognitive radio resource management and coordination, various protocols and routings. Many technologies will be using multiple frequency bands. As a result, challenges in interoperability, including coexistence, cooperation and collaboration for devices, and networks signalling with cross-layer interfaces and interlayer signalling are to be solved. Although many papers deal with the cross-layer design, the issues addressed are still specific and tailored to a given technology with the lack of its general. We need to provide cross-layer designs for more general classes of communications schemes.

VIII. SECURITY

The challenges of employing CRS include that of ensuring secure devices operations. Security in this context includes enforcement of rules. Enforcement for static systems is already a challenge due to the amount of resources necessary to authorize equipment, the requirement of obtaining proof that violations have occurred, and the determination of the violator' identities. As the systems become more dynamic, there is an increase in the number of potential interaction that can lead to a violation. Additionally, this leads to a decrease of the time and special scales of these interactions. Both of these changes will amplify the enforcement challenges. The first issue is on equipment authorization, especially on evaluation criteria and security certification. It becomes even more problematic with the employment of self-learning mechanisms. Software and hardware certification will not provide sufficient assurances that the device conforms to the operational envelopes. Software certification and the security of the software are also challenging area, especially when software provides the control of dynamic systems. The security of that software is critical to ensure that rogue behaviour is not programmed into the devices. The number of combination of interactions is high and the mobility and the agility of CRS is great, so the monitoring mechanisms are challenging tasks. Also, security is to deal at the protocol layer with key exchanges which are very adapted to a highly reliable physical layer and centralized network. However, in CRS with distributed cognitive networks, traditional cryptographic schemes are not adapted.

IX. IMPLEMENTATIONS OF CHALLENGES

Although the theoretical research for CRS is blooming, with many interesting results, hardware implementation and system development are progressing at a slower pace, because of the complexities involved in designing and developing CRS. In this section, the paper present the implementation challenges of CR in the system on chip (SoC) integration's perspective. The first SDR architecture was proposed by Mitola and Maguire, in which the RF and analog processing are reduced to only a pair of data converters, thus providing the maximum flexibility and programmability through the digital processing block. This idealistic approach, however, suffers from the poor tolerance of to the interferers. In many wireless applications, a small desired signal could be accompanied by several large in-band signals created by nearby transmitters of the same communication standard or out-of-band blockers caused by any transmitter. At times, these blockers could be as much as about 100 dB larger than the desirable received signal, which, due to the lack of any filtering in this idealistic approach would demand an impractical dynamic range of about 100 dB on the ADC. This long-term requirement is very far beyond the limits of the technology available as will be shown in ADC/DAC challenges sub-section. Research on high-performances ADC/DAC is going on with significant progress, especially with hybrid-filter bank and time-interleaving architectures. In order to operate on very wide band or multi-bands simultaneously, parallel processing is employed from antennas to analog to digital interfaces. Multi-antennas are necessary for multi-input-multi-output (MIMO) operation and/or multi-bands operation. After antennas, a passive module is used for switching or duplexing, RF filtering, and impedance matching between antennas and power amplifiers (PAs).

This module is composed of a range of sub modules in order to cover a wide bandwidth or enable simultaneous communications. Then multi-receiver (Rx) and multi-transmitter (Tx) are followed before a multi-ADC/DACs module. A high performance and very flexible digital baseband carries out not only all conventional processing for modulation and demodulation, coding and encoding, and so forth, but also digital filtering, dc offset cancellation, digital automatic gain control, calibration and correction of analog errors and non linearities. Combining with control plane and sensor, a feedback from baseband to RF front-end and transceiver are necessary to boost the performance of the analog part. The challenges of RF front-end and transceiver in the short-/midterm are to reduce the off-chip and passive components, increase their frequency-agility, minimize the power dissipation, and reduce area. CR needs to adapt transmission and receiver parameters to avoid causing interference to PUs and maximize spectral efficiency. To avoid causing interference, numerous techniques can be used and combined such as frequency tuning (adaptive frequency hopping, dynamic frequency selection and RF band switching), OFDM sub-channelization, channel aggregation, time multiplexing, power control, modulation and coding for QoS adaptability, beam-forming, and space-time coding for MIMO. To maintain link in adverse conditions, wide dynamic range especially for analog-to-digital converter (ADC) and high sensitive receiver with rapid adaptation to changes in interference temperature are required. CR will be also based on strong cross-layer interactions. For example, the cognitive spectrum management involves intelligent use of spectrum based on anticipating the demand for spectrum by the user and previous observation of user behavior. Another cognitive behavior is to monitor the environment in which the CR is operating and then manage the resource intelligently based on expectations or experiences.

X. REGULATIONS AND STANDARDIZATIONS

A. REGULATIONS

The European and US telecom and communications regulatory agencies are developing rules for the unlicensed use of TV White Spaces. In the US the work is being done by the FCC and in UK by Ofcom and the Electronic Communications Committee (ECC) of CEPT in Europe. The FCC in 2010 provided the rules for TV White Spaces which are nothing but unused areas in the TV broadcast spectrum. The use of the 2.36GHz to 2.4GHz band for medical area networks is being worked out. To better utilize the radio spectrum other opportunistic spectrum access beyond TVWS is being contemplated. A great deal of work has been done by Ofcom and they came out with the first consultation in 2009 for developing regulations for the TVWS. In 2011 they released a statement for white space devices and implementation of location based databases. The ECC studied the requirements for operation of CRS in the white space in the Ultra High Frequency broadcasting band of 470 to 790 MHz and that work is being used as the stepping stone for regulatory activities in the ECC.

B. STANDARDIZATIONS

At present international standardization of CRS is done at different levels (IEEE, ETSI, ITU and ECMA). Multiple deployment and business directions are being experimented. ITU has worked on the definition of SDR and CRS and their relationship and summarized the technical and operational studies, and relevant recommendations. Radio services and regulation implications in different SDR and CRS usage scenarios has been considered. A working group is currently looking at the description, definition and application of CRS in the mobile service which are land based. The 802 Working Groups (LAN/MAN) of IEEE is very active in CRS, the definition activity for CRSs is currently being done in the 802.11 and 802.22, while the specification activity for components of a CRS is being done in 802.19, 21, and 22. 802.11y is an update for 3650–3700 MHz frequency band for operations in USA, these define new regulatory classes, dynamic frequency selection for 802.11 to share frequency bands with other users and transmit power control. In order to meet the legislative requirements for coexistence and channel access in the TVWS the existing standards namely 802.11 physical (PHY) layers and medium access control (MAC) layers have been modified in a draft standard know as the P802.11af which is an update for TVWS operations standard. In order to optimize the handover between heterogeneous IEEE 802 networks and for facilitating the handoff between IEEE 802 networks and cellular systems the IEEE 802.21 standards the media independent handover was developed. The P802.19.1 draft was developed for TVWS methods for coexistence. The draft standard P802.22 is on policies and procedures for operation in the TV bands. It specifies the air interface, including the cognitive MAC and PHY, of point-to-multipoint wireless regional area networks, operating in the unlicensed TV bands between 54 MHz and 862 MHz. Draft standard P802.22.1 is to enhance harmful interference protection for PUs operating in TV bands. The draft standard P802.22 focuses on procedures and policies for operation in the Television bands. This standard specifies the air interface, including the cognitive MAC and Physical, of point-to-multipoint wireless regional area networks, operating in the unlicensed TV bands between 54 MHz and 862 MHz Draft standards P802.22.1 was developed to improve harmful interference protection for Primary Users operating in Television bands. The standards committee first developed IEEE P1900 standards and subsequently developed the IEEE DySPAN standards for radio and spectrum management with the spotlight on enhanced use of spectrum. The standards numbered from 1900 range is used for dynamic spectrum access (DSA), for its methods and techniques which also requires coordination of wireless technologies, managing interference and includes information sharing and network management.

The standards for terminology and concepts is numbered IEEE 1900.1 and it was published in 2008. In 2009 IEEE 1900.4 was published it specifies the methodology to assist improvement in QoS and network-terminal distributed optimization of radio resource usage in heterogeneous wireless networks. The architecture and interfaces for DSA networks in TVWS id defined by the IEEE 1900.4a working group. For policy language requirement and architecture the IEEE 1900.5 standard was developed. For spectrum sensing interfaces and data structures the IEEE 1900.6 standard was developed. For white space dynamic spectrum access radio systems supporting fixed and mobile operation the draft standard IEEE P1900.7 was developed. This standard also supports to avoid harmful interference to authorized users in the white space frequency bands of radio systems supporting fixed and mobile operation for their MAC sub-layer and PHY layers. The P1900.4a supports white space management whereas the P1900.6 is used to specify the accessing and exchange of sensing-related information. An Ad hoc standard for radio interface for vehicular communications has been developed due to the high interest among users in evaluating feasibility in this area.

XI. CONCLUSION AND DISCUSSION

This research paper on cognitive radio conceptual architecture designed and operational policies presented the cognitive radio operational cycles and actions within its presents environments. Also looked at the various standards and regulations groups developed which enhanced the operational parameters of wireless communications equipments speeds and capacities globally for best practices, it highlighted the full operational cycle definition processed and execution as an intelligent radio. Cognitive radio will bring about a revolution in spectrum management because it uses three vital capabilities namely learning capability, cognitive capability and reconfigurable capability. If CRS is implemented using SDR technology, then because of the reconfigurable nature of the radio system, it can provide better efficiency in spectrum usage. The CRS can also use white spaces or spectrum holes of licensed spectrum bands with the constraint that it does not disrupt the functioning of primary users of spectrum. Heterogeneous radio access networks can be dynamically managed with respect to spectrum usage if we incorporate CRS in them. Allocation of frequency bands to RATS can be done dynamically so as to reduce interference and increase the capacity of each RAT. The acquisition and exchange of spectrum usage rights and deployment of different RATS in frequency/location/time can be done by the operator. Dynamic adaption to the different heterogeneous radio access networks can be done by autonomously by the cognitive devices. The challenges that face CRS encompass multiple domains and it attracts a good number of researchers who have produced interesting results. The implementation of CRS is limited by physical possible bounds. Some of the challenges that remain to be resolved are distribution of intelligence, cross-layer design, security, delay/protocol overhead, flexible hardware design and some more. Future standardization, usage model and decoding of signal in the presence of noise and the signal bandwidth are some of the limitations. If innovations in semiconductor devices happen in parameters like linearity, selectivity and agility then we will be moving closer to making CRS a reality soon. Any additional cost in deploying new device technologies can be compensated by innovative design techniques and high density CMOS based systems. The technical challenges can be overcome and the timeframe for CRS deployment is dependent on business and return on investment models that will have to be worked out.

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