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Cognitive Radio System: Overview of Research Challenge

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Abstract- Cognitive radio system (CRS) is built on the software defined radio, defined by IEEE as 802.22 aimed at using cognitive radio (CR) techniques to allow sharing of unused spectrum as it is aware of wireless environment, its internal state policies. It automatically and dynamically adapt its self from the surroundings and learn from its past experience. Based on software-defined radio, it provides flexibility and also offers much more efficiency for the overall usage of the radio spectrum[1]. CRS has been emerging as a key technology targeted at providing very high spectral efficiency. In this paper we present an overview and challenges of spectrum management for CRS.

Index Terms- Cognitive Radio, Spectrum, Decision, Scheduling

1. INTRODUCTION

The information and communication technology industry is facing a global spectrum crisis. The major problem with the scarcity of spectrum which has came to be a major bottleneck for the development of next generation radio system, developing new services, policies with improved quality of service (QoS) and without any deeper impact to the already existed system. Clearly, there is huge requirement for spectrum efficiency to deal with the problem of spectrum scarcity. Where their is an demand for wireless supply and demands increases day by day. It is an alarm for a spectrum crisis, in which explosive demand from wireless sector like smart phones , WIMAX, CDMA will soon take over the wireless spectrum. The problem arises with the lack of new spectrum available for users. Huge amount of spectrum is required for future to fulfil the growing demands of the next generation.

Cognitive radio divides users into two types: primary users (PUs) and secondary users (SUs). The PU has preemptive priority on channel usage, SU only opportunistically make use of channels that are not occupied by pu. Obviously, spectrum availability for the secondary users is subject to the spectrum occupancy of the primary users.

CRS has been emerging as a key technology targeted at providing very high spectral efficiency. In this paper we present an overview and challenges of spectrum management for CRS. We summarize the status of the balancing approach required to manage the load in the spectrum licensed as well as unlicensed. We point out some key research challenges, especially implementation challenges of cognitive radio (CR). And also for increasing the efficiency without compromising on the QoS. In this paper, we will be reviewing existing approaches previously developed.

This paper consists of four major sections regarding overview research work areas that must be discussed before caring out the research. These are:

1) Introduction
2) Overview
3) Features and Potential of Cognitive Radio network
4) Research challenges
5) Conclusion

2. OVERVIEW

As of an opportunistic radio whose principle is “reuse” of licensed spectrum as shown in Figure 1 where an secondary user (SU) “unlicensed” can be permitted to use licensed spectrum, provided that it does not interfere with any primary users (PUs). In this way, the efficiency of spectrum usage will be improved significantly.

Various measurements and experiments on utilization of the spectrum have shown that spectrum is underutilized, and most of the spectrum is wasted which are occupied by the licensed user in the sense that the typical duty cycle of spectrum usage at a fixed frequency and at a random geographical location is low. This means that there can be possibilities of “holes” in the radio spectrum that could be exploited [3]. Cognitive radio system should be able to exploit these by detecting them and use them in an very opportunistic manner. Because of having an outstanding propagation characteristic in the television bands with strong penetration capabilities, flexible bandwidth with long range capability, it could be used for a brand-new class of services while increasing the limited capacity of existing systems.

But Cognitive Radio System[4] is not only limited to radio spectrum access. but, it also includes heterogeneous networks, where a heterogeneous radio management[5] is performed in that environment.

Here in figure 1 cognitive radio follows the unlicensed path when licensed spectrum is occupied. Current spectrum allocation approaches, does not allow for allocation of frequency bands from different radio access technologies dynamically. However, the cooperation of diverse technologies, which form a heterogeneous infrastructure, have made it possible in managing the spectrum in a dynamic manner. With this there is no more fixed frequency bands guaranteed to be used to a specific RATs, but through intelligent management mechanisms, bands can be dynamically allocated to RATs in such a way that the capacity of each RAT is fully utilised and interference is minimized. Future work, will be considered on the flexible management of the spectrum where operator will use different Radio Accessing Techniques dynamically over time and also have the possibility to acquire spectrum usage rights automatically. This new technology creates many new opportunities [5]. For example, content distribution networks which could benefit from the new spectrum management schemes.

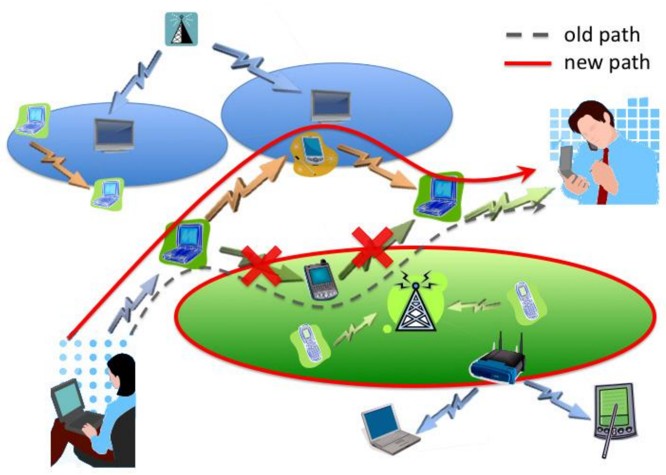

Fig. 1 Cognitive Radio Architecture

3. FEATURES AND POTENTIAL OF COGNITIVE RADIO NETWORKS

The backend station capabilities of cognitive radios system can be classified according to their functionalities. A cognitive radio should be capable(Fig 2) of sensing the environment, analyze it and should be able to learn sensed information (self-organizing capability) and be able to adapt the environment (reconfigurable abilities).

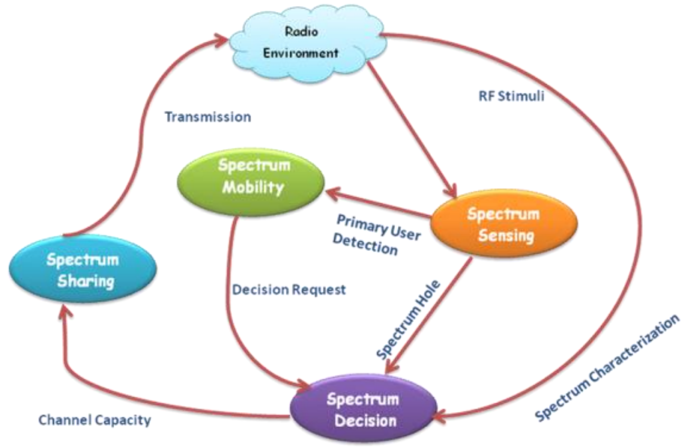

Fig. 2: Cognitive Radio Cycle

3.1 Cognitive Radio System Capability

3.1.1 Spectrum Sensing

A cognitive radio be able to sense spectrum (environment) and should intelligently detect free channels in the spectrum which are those part of spectrum which are currently owned but not used by the Primary user (licensed) or having least interference with them

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3.1.2 Spectrum Sharing

A cognitive radio should be able to embodies a mechanism that would enable sharing of spectrum under the every possible circumstances between a primary user and a secondary user. Users may ultimately be able to negotiate for the use of communication channels on real-time basis, without the need for following constrain based policies between the users.

3.1.3 Location Identification

The ability to determine its Geological location as well as location of other BS and SS stations and applying appropriate operational parameters on it such as the power, bandwidth and frequency requirement at that location. In channels which are used for satellite downlinks are receive-only and do not transmit a signal, location identification technique is appropriate for avoiding interference because spectrum sensing would not be capable in sensing the geographical locations of nearby stations or channels.

3.1.4 Network/System Discovery

A cognitive radio be able to determine the best way to communicate, firstly by discovering available channels around it, through which communication could be possible. These networks could be reached either by directed one hop or by multi-hop network nodes.

3.1.5 Service Discovery

A cognitive radio system should discover the running services and should have the capability to adapt it and use it to fulfil its service requirements.

Software-defined radio (SDR) approach is used to implement the reconfigurations. Also, the CRS can learn from its decisions to improve its future decisions. The results of learning contribute to both obtaining knowledge and decision making.

CRS can be classified into two types: heterogeneous CRS and spectrum sharing CRS. The first 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 QoS. The second type of CRS is sharing CRS, where several RANs using the same or different RATs can share the same frequency band by using the unoccupied subbands in an intelligent and coordinated way. Most of standardization activities are related to this type of CRS.

4. RESEARCH CHALLENGES

Cognitive Radio covers multiple areas with a large number of research works. The challenges are numerously vast like in opportunistic distribution and implementation, delay overhead, scheduling design, security, less packet drops, QoS requirements and flexible sensing algorithms, .Due to the huge amount of research work and the interdisciplinary nature of the topic, it is incredibly difficult to provide an perfect analysis of all research works available on Cognitive radio Systems. In fig. 3 it provides basic functionalities of structure[8] The purpose is to therefore briefly describe challenges which are yet currently open under observation in the framework of research to these systems.

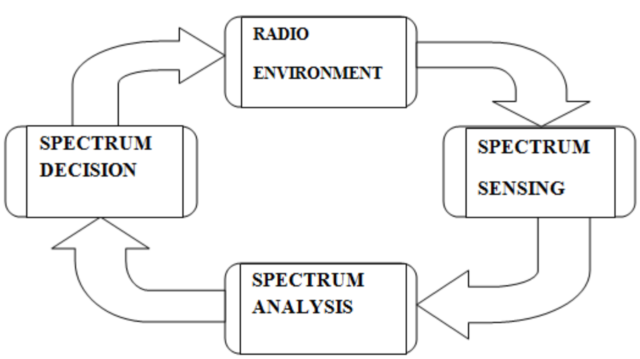

Fig 3: Cognitive Radio Operation

4.1 Decision Making

As these cognitive radio system are focused on decision making, the first appropriate research challenge is to how the decision (e.g., the decision on spectrum availability, number of channels and users, or how to efficiently optimize its performance) should be taken. The first issue is related to implementing it in a centralized or distributed manner. The second issue is of the decision algorithms (e.g., neural networks, genetic algorithms, ant-colony optimization, etc.) which should be customized to fulfil the Cognitive Radio System requirements

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4.2 Learning Process

Research work in machine learning has been grown increasing evolving recently, with substantial quantity and quality of progress. One of the significant part of the learning process mechanisms is whether the learning process performed is supervised or unsupervised. In Cognitive Radio System either technique could be applied. The first challenge of learning is avoiding the wrong choices before an optimal decision, especially under unsupervised learning. The second challenge is to correctly define learning process in the context of Cognitive radio its objectives and contributions.

4.2.1 Supervised Learning

Here the learning algorithms are data driven, i.e. unlike "routine" algorithms it is the data that tells what the result or output is going to be. In **Supervised learning**,the results are *labelled*, means every related output values and the limit. In this learning algorithm knows on what data to perform and the result should be.

4.2.2 Unsupervised Learning

In this type of algorithm the result data are not *labelled*, i.e. you don't have any detailed structure of that data. In this type of algorithm it by itself cannot "invent", but has the capabilty to construct and structure the data in different class, e.g. In a face recognition it could be able to distinguish that face varies, human faces which are very different from monkeys. And these are the most researched topics. For example in the field of web crawler, navigation, etc.

In designing and implementation of algorithms, the cognitive radio functionalities, which are related to networks to learn from their past decisions to improve their forward decisions, are very complex. The design of the decision algorithm itself is a challenge, and decision should be made by learning new issues related to the situation and how to react to them.

4.3 Cross-Layers

With the nature of cognitive radio inter-protocol interaction concept inbuilt in cognitive network to support user and their service needs, has no relevant and comprehensive study is available to measure the performance of the system. The designing and functioning of cognitive or self-managed network is itself a challenging task.

Challenge is also in the design of upper layer including MAC sublayer and network layer, spectrum resource management functions integrated at different layers of the network protocol stack. Different type of devices using multiple frequency bands or different parts of spectrum. As a result, challenges have to be faced in the field of interoperability, coexistence, cooperation and collaboration between devices, and networks with cross-layer interfaces and interlayer signalling are to be resolved.

4.4 Security

The challenges of employing Cognitive Radio Systems include that of ensuring secure operations. Security in this context includes enforcement of policies. Enforcement for static systems is a challenge of how to enforce a secure environment when dealing in a dynamic environment. As the systems are becoming more dynamic, there is an increase in the number of potential interaction that can lead to a violation. Which may lead to a wastage of time and resources during establishment of connections which will amplify the enforcement challenges. Many of the challenges are-

1. Equipment authorization, especially on evaluation criteria and security certification. It becomes even more sophisticated with the employment of self-learning mechanisms. Software and hardware certification will not provide sufficient assurances that the device conforms to the operational envelopes.

2. 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.

3. Policy Threats is the main concern in which an attacker spoofing private information, can capture and extract useful statistics from it. By manipulating the RF the radio uses, an attacker can then use these statistics to appear in the knowledge base of radio and can rupture the system by providing faulty information. By understanding how a algorithm work, an attacker can manipulate them according to his needs. Since these evaluations are done based on raw RF values, there is no way to apply cryptography to secure them, as it is obviously done to prevent typical communications attacks. We call this as sensory manipulation attacks since they rely on observing and knowing the working to provide fake output.

4. Learning Threats are same threats as policy threats, where an attacker provides false input. However, a learning system uses all its past experiences to create a database of understanding experiences, making the attack much more dangerous and powerful.

The number of combination of interactions is high and switching between different channels makes monitoring mechanisms a challenging task. However, in Cognitive Radio Systems in distributed environment, traditional cryptographic schemes are not adapted.

4.5 Scheduling Algorithm

As of cognitive radio systems are a software defined radio. There are two important goals of cognitive radio is to provide reliable communication and utilize the radio spectrum effectively [2]. Most cognitive radio systems make use channels which are temporarily not used by licensed users to make full utilization of the licensed radio spectrum, cognitive radio should be able to detect it and use it and whenever primary user wants to use cognitive radio system should quit the occupation. Thereby, utilizing these "dynamic" resources effectively to provide reliable communication. In order to make resource allocation dynamic there must be an effective packet scheduling algorithm, which serves different traffic queues based on the QoS levels of each traffic queue and the variation of available spectrums. Hence, the proposed algorithm inclines to the real-time traffics when there are not enough resources to use to maintain the QoS level of real-time traffics. Simulation results show that, compared with traditional packet scheduling algorithms, the proposed algorithm provides not only better QoS guarantee for heterogeneous cognitive radio traffics, but also higher system access capacity and spectrum efficiency.

4.6 Implementation Challenges

Although the theoretical research for CRS is developing at a fast pace, with many interesting results, hardware implementation and system development are progressing at a much slower pace, because of the complexities involved in designing and developing CRS [6]. Focusing on the challenges of implementation of Cognitive Radio system from hardware perspective.

The SDR architecture was first proposed by Mitola [7], in which the RF and analog processing are reduced to only a pair of data converters, which provides the maximum flexibility through this digital processing. And also provides much for effective programmable approach to the radio system. This futuristic approach, suffers from poor tolerance. In a wireless applications, a small desired signal could be conducted by several large signals produced by nearby transmitters for the communication of the same standard. At many occasions, the blockers coming from another outside transmitter could go upto 50 dB larger than the required, with the lack of filtering would impose an impractical signal demand of about 50 dB on to the ADC. These requirements are far from the technological limits available as of now. Research for ADC of high efficiency is being carried out, focusing on filters and time-interleaving architectural design.
There is a necessity in designing the hardware for testing in a heterogeneous environment that have yet to be discovered. Which could be used for development, diagnostics and manufacturing purposes.

5. CONCLUSION

This paper presented an overview and challenges of Cognitive Radio Systems which focuses on implementation of cognitive radio. We summarized the status of some key research challenges, especially implementation challenges related to sensing and scheduling. Having capabilities such as sensing, reconfigurable, and dynamic learning capability.

Cognitive Radio has the potential of being a disruptive force within spectrum management. Using SDR for implementing dynamically reconfigurable radios and also provides additional flexibility and offers improved efficiency to overall spectrum use. It can exploit the spectrum holes of licensed spectrum bands provided that it does not cause harmful interference to any primary users in order to significantly improve the efficiency of spectrum usage. The cognitive devices may autonomously and dynamically adapt to the diverse heterogeneous radio access networks. The challenges remain numerous, namely, intelligence distribution and implementation, security, delay/protocol overhead, cross-layer design, flexible hardware design, and so forth. The timeframe to make this happen is more linked to the economical and business model for CRS than real technological issues.

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