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Cognitive Radio Networks: Some Preliminaries

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Abstract: **Cognitive Radio has been explored to bridge the discrepancy between spectrum allocation and spectrum use through its cognitive capability and re configurability. In order to do that it has to first sense the spectrum whether it is available or not and then use the spectrum along with the available users in a dynamic manner without causing harmful interference to the already existing users. This makes security an important issue in CRN since presence of malicious users can easily disrupt the communication in the network. In this paper we present characteristics and the issues in CRN.**

***Keywords*: Cognitive Radio Networks, DSA, terminologies, Challenges**

I. INTRODUCTION

The economical problem with fixed spectrum assignment policy has the suboptimal use of spectrum resource leading to overutilization in some bands and under utilization in others (F.C.C.,(2002), F.C.C.,(2008), C.Bazelon, (2008)).This observation has lead to the recent spectrum reforms by the U.S. Federal Communication Commission (FCC). The Dynamic Spectrum Access (DSA) for enhanced spectrum utilization for adaptive networks is achieved via the CR(I. Mitola, J. and J.Maguire, G.Q., (1999), I.F. Akyildiz, et al,(2006)).CR is an emerging wireless communication technology aims at using DSA to allow the unused ,licensed TV frequency spectrum to be used by unlicensed users on a non-interfering basis(C.R. Stevenson, et al,(2009)). An essential requirement of CRs is that they must rapidly fill the spectrum holes (ie, portions of the licensed band unused spectrum) without causing harmful interference to Primary users. Nowadays, on the one hand, the demands for the RF spectrum are constantly increasing due to the growth of wireless applications, but on the other hand, it has been reported that the spectrum utilization efficiency is extremely low. There are still some other challenges related with CRN.

II. TERMINOLOGIES OF COGNITIVE RADIO NETWORKS

In cognitive radio terminology, a primary user (PU) is defined as a legacy user or a licensed user who has higher priority to access a particular part of spectrum.

Examples of licensed technology are global system for mobile communications (GSM) , (2011, Mouly.M and M. Pautet, 1992), worldwide interoperability for microwave access (WiMax) (2011, Korowajczuk.L, 2011a), and long term evolution (LTE) (Korowajczuk.L, 2011b,2011) while examples of legacy technology are microphone and wireless local area network (WLAN) (Korowajczuk.L, 2011c,2011).

On the other hand, unlicensed cognitive users with lower rights are defined as *secondary users (SUs)*. A SU can access spectral resources of a PU when the PU is not using them. However the SU has to vacate the frequency band as soon as the PU becomes active so that negligible (or no) interference is caused to the PU. Such opportunistic access of the PU resources by the SUs is called as **dynamic spectrum access**.A SU can opportunistically utilize different spectrum holes corresponding to different PUs in order to satisfy its bandwidth requirement without causing interference to the PUs.

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In cognitive radios, secondary users (SUs) opportunistically use the spectrum not used by the primary users as shown in fig.2.1.

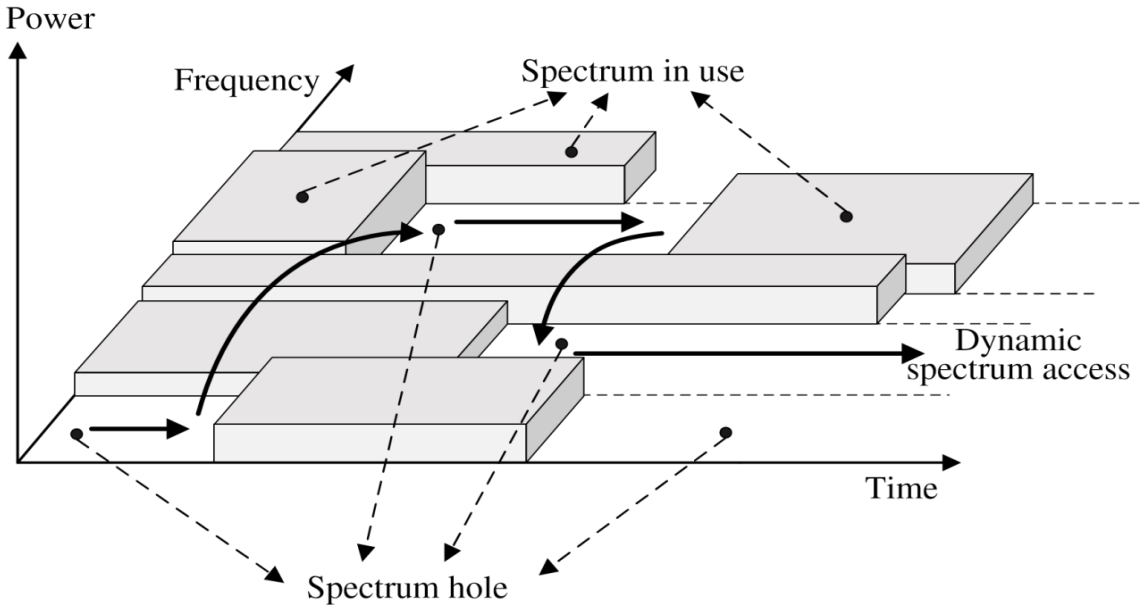

Figure 2.1: Illustration of spectrum holes and the concept of dynamic spectrum access (I. Akyildiz,2008).

III. CHALLENGES IN COGNITIVE RADIO NETWORKS

The main challenges in the design and operation of CRN comes from cognitive capability and reconfigurability, dynamically changing and open wireless medium for communication. Some of the challenges of cognitive radio networks are (Zhongshan Zhang et al, 2013, Prabhjot Kaur et al, 2011):

1. Security:

The security of communications in cognitive radio network is very important, especially in military applications. Open and shared access medium, resource constraints, incumbent coexistence and self-coexistence, PU mobility, trusting on other nodes for proper functioning of the network are some of the characteristics of these networks that pose substantial challenges in security design. Also the security threats are mainly related to the two main characteristics of radios: Cognitive capability and reconfigurability. The presence of these unique characteristics explains the need for security solutions for CRN to achieve secure data communication, protection against security attacks and desirable network performance. (Alexandros.G et al, 2013).

2. Energy Management:

"Energy management is defined as the process of managing the sources and consumers of energy in nodes or in the network as a whole, in order to enhance the life time of the network". Most of the existing methods simply model the energy consumption in sensing, sleeping and transmission/reporting as fixed values. The energy efficiency in these operations depends on so many factors like varying transmitter power levels, channel conditions, sensing techniques, sensing interval etc. Hence more accurate energy model considering all these factors taken into account is needed.

3. Interference management and resource allocation:

An improvement in spectrum utilization is achieved by permitting a secondary user to access a spectrum hole unoccupied by the primary user at the right location and the right time. The major problem in cognitive radio scenario is how to deal with minimizing interference while optimizing capacity of the spectrum. Hence, an efficient interference management strategies should guarantee maximum data rates while avoiding harmful degradation to the primary system.

4. Distributed Collaborative Communications:

In the context of cognitive radio with a primary network licensed user of the spectrum and a secondary network operating in an opportunistic way over the available bandwidth under minimum interference constraints, we need to analyze the potential gain from considering collaborative communications.

5. Radio resource management:

Another thrust areas in this technology is to recognize the techniques and algorithms for radio resource management which includes addressing problems of designing a device or algorithm for detecting the unused but allocated licensed or unlicensed frequencies. After detecting the spectrum, algorithms need be defined which trace for white space. These white spaces are to be used following designed spectrum allocation scheme.

Seamless mobility i.e. shifting the frequency band from one to another as soon as the licensed user wants to use its allocated frequency should be considered. At the same time Switching from one application to another should also be seamless. Parameters such as traffic, data rates and processing speed are important and significant parameters while designing the algorithms for spectrum assessment and manipulation.

6. Regulatory Policies:

One of the basic concerns for coexistence of heterogeneous wireless devices is autonomy vs. regulation. Licensing is found to be best suited for high duty cycle traffic whereas opportunistic access is optimal for low duty cycle traffic. Thus, there is a need to find how much licensing is optimal for which traffic.

7. QOS Tradeoff:

Two important but conflicting requirements for the standard being developed are satisfaction of QoS parameters and at the same time providing reliable spectrum sensing which is a tedious task. Optimum solution need be found for accurate sensing in minimum possible duration. Also the access delay, throughput and BER have to be in tolerable limits for successful communication. In addition, the numbers of handovers have to be seamless and optimized. Thus, there is a need to focus on detailed specifications and analysis of protocols supporting CR and its architecture.

8. Mac Strategies For Crns:

CR MAC protocols are conventionally classified by considering either the spectrum access scheme (i.e., to divide the spectrum access as random access, time slotted access, or hybrid access) or spectrum sharing architecture (i.e., either centralized or decentralized). Besides, self-organization features are extensively observed in the decentralized spectrum sharing protocols and have been proven to be capable of achieving cost-effective spectrum access and management.

9. Control Channel Management In Crns:

Since Cognitive Radio exhibits the unique characteristics such as cognitive capability and reconfigurability effective spectrum sharing and utilization can be obtained. This will reduce the interference between users or wireless technologies sharing the same spectrum bands. Designing multichannel MAC protocols is assumed to be the first step in the development of CR MAC protocols in unlicensed adhoc scenarios.

Since the number of channels available at each CR user varies with time and space in CRNs, the timescale of operation should also be varied with interference constraints. Therefore, different methodologies should be implemented to form a separate control channel for transmitting spectrum sensing results among CR users as well as sharing the channel allocation information.

10. Adaptive Routing:

There are so many factors that are interdependent while routing nodes in CRN. They are node mobility leads to dynamic characteristics of wireless signals, dynamic changes of available spectrum in CRNs depending on that connectivity between the nodes will be decided. The time-variant channel attenuation, dynamic changes of the spectrum and frequency/space domain characteristics of the radio environment , all these facts affect the QoS of CR nodes.

Also adaptive re-routing must also be implemented after spectrum awareness to adapt to spectrum fluctuations to maintain CR routes. Trade off between minimization of interference along with delay and optimization of throughput or load balancing should also be considered while designing routing algorithms for CRNs.

11. Heterogeneity induced challenges:

The heterogeneity of the CRNs, especially that exhibited in a multiuser environment with coexistence of CR users and primary users, introduces new challenges to the spectrum management and sharing. Besides, the heterogeneous spectrum comprising both licensed and unlicensed bands for different purposes imposes additional challenges CR techniques.

Multichannel spectrum sensing: Since CR users may neither occupy a spectrum band for a long time period nor satisfy their requirements by utilizing a single spectrum band, multiple noncontiguous spectrum bands can thus be simultaneously sensed and utilized by CR users for purposes of improvement in throughput and communications reliability. However, designing a cost-efficient multi spectrum sensing approach in heterogeneous CRNs is still a challenging task.

12. Network operation and maintenance:

Cooperative spectrum sensing: The effective combination of cooperation and self-organization in spectrum sensing is worthy of further investigation, and a totally distributed CRN (i.e., cooperation is performed without relying on the coordination of CR base stations or permanent cluster heads) would be a promising solution in terms of cost reduction in network operation and maintenance.

13. Spectrum mobility challenges:

Limited packet loss and delay need to be maintained during the spectrum mobility process, and this requirement raises new challenges in terms of seamless data transmission, priority-based channel management, and QoS guarantee.

14. Self-organization paradigms in CR functionalities:

Since self-organization paradigms are totally based on local behavior of individuals, the decentralized control may raise new challenges:

• Self-organization may not necessarily lead to an optimum solution;
• In order to minimize human intervention, the control decisions as well as data measurement/probing/processing should be operated autonomously. Therefore, a tradeoff between the reliability and the signaling overhead of self-organization methods must be addressed.

15. Reliability:

QoS of CRN –WRAN cells degrades due if spectrum sensing is interrupted. The Dynamic Frequency Hopping technique where data transmission and sensing are handled parallel is used to countermeasure this degradation. But this technique is inefficient for bigger cluster cells where co-ordination among the cells plays a vital role. Thus proper co-ordination mechanisms are to be introduced for better QoS and throughput performance.

16. Flexible radio circuits:

A key fundamental problem in radio circuits is their non linearity and time variant nature. So, along with wanted signals, many unwanted harmonics and sidebands are also produced. Further, white space will usually not be concentrated in one particular area of spectrum. A more likely scenario is a spectrum, with a number of medium to narrowband white segments. Dynamic access of unused spectrum via cognitive radio asks for flexible radio circuits that can work at an arbitrary radio frequency. A powerful solution should focus on using several white segments in parallel.

IV. SUMMARY

Cognitive Radio Networks have some unique characteristics that differentiate them from other wired and wireless networks such as Cognition capability, reconfigurability, constrained resources, limited device and physical security. The characteristics of CRN make it essential for future generation communication networks, but they also present challenges such as energy management, scalability, and Quality-of-Service. The unique characteristics, namely a shared broadcast radio channel, an insecure operational environment, lack of association, limited resource availability and physical vulnerability, make such networks highly vulnerable to security attacks compared to wired networks or other wireless networks. This paper has investigated the major challenges of Cognitive Radio Networks.

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