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"Study of Spectrum Allocation Techniques for Primary and Secondary User in Cognitive Radio Networks"

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ABSTRACT

Cognitive network in an effective technique for utilization of spectrum. In wireless communication one of the most recent advancement is leading to flexibility of spectrum usage. According to licensed spectrum policy, a large part of spectrum remains useless and it is leading to wastage of spectrum. In recent wireless communication, a major demand for this technology is for fair spectrum assignment to unlicensed (secondary) users. This led to the technological development of cognitive radio. Which optimize the spectrum usage. For effective usage of radio frequency spectrum, cognitive radio networks have been proposed and allowing the secondary user to occupy the spectrum whenever the primary user is not using it. To avoid interference with the primary user, secondary user should constantly check the usage of spectrum.Current networking scenario is facing the great scarcity of spectrum and cognitive networks is promising to solve the problem of spectrum.

Key words: Cognitive networks, wireless communication, spectrum, radio frequency, primary and secondary users.

I. INTRODUCTION

Cognitive networks is a new promising wireless communication solution for maximum utilizing the resources of spectrum opportunistically [1,2]This technology enables employing the spectrum in an opportunistic manner. Basically, cognitive networking technology consists of four stages: spectrum sensing, spectrum management, spectrum sharing, and spectrum mobility[3]. In the first stage Spectrum sensing method is used for periodically monitor the specific frequency band, aiming to identify the free licensed spectrums and shares them, while dodge harmful interference with other users. At the second stage: Spectrum management is a process of proper regulating the usage of radio frequencies to promote the efficient use and gain a net social benefit the best available spectrum, which meets user communication requirements, is captured The rapid growth in wireless services over the past decade has illuminated the growing demands for radio spectrum, and we know the potentially-rich spectrum resource is limited. At the spectrum mobility stage,process by which a cognitive-radio user changes its frequency of operation. Cognitive-radio networks aim to use the **spectrum** in a dynamic manner by allowing radio terminals to operate in the best available frequency band, maintaining seamless communication requirements during transitions to better. Finally, the last step provides a fair spectrum scheduling method among coexisting users[3].

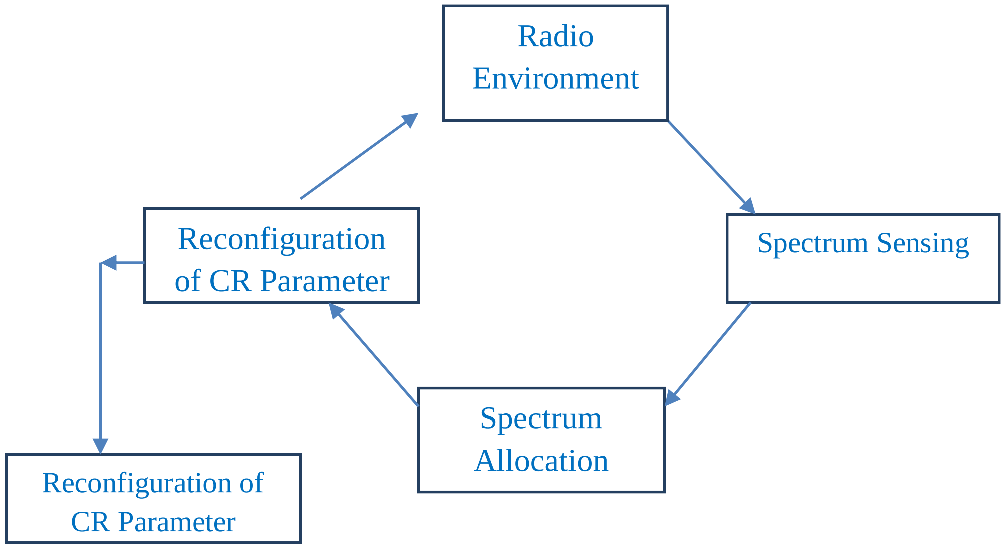


Fig.01: Cognitive radio cycle

The spectrum assignment functionality of cognitive radio network deals with how the secondary user can opportunistically utilize the available frequency band without interference of licensed primary user and leasing basis at every location over the entire spectrum. This inefficient utilization of spectrum necessitates development of dynamic spectrum access techniques (DSA). The DSA[4] allows users without any spectrum license thatcalled secondary users(SUs), for thetemporary use of unlicensed spectrum. DSA will offer the priority to the primary user for spectrum utilization and secondary user will have need to monitor the availability of free spectrum band. After getting the free spectrum, cognitive network will allocate the spectrum to the secondary users but secondary user will have need to reconfigure themselves in order to use the availability of allocated spectrum.

II. COGNITIVE NETWORK

Cognitive network is also known as next generation (xG) networks[5]. Current extremely, high growth of wireless communication is challenging the greater spectrum allocation. We know that the availability of higher resources of spectrum is limited. Now a days the wireless communication traffic is increasing with very high rate. According to the CISCO Visual Networking Index (VNI), mobile vedio traffic is already crossed 50% of the available mobile data traffic.The global mobile data traffic grew 70% in 2012 with strongest growth in countries such as Japan and Korea where 4G penetration is high. According to this Cisco report, the global mobile data traffic is shown to grow steadily at CAGR of 66 percent from 2012 to 2017.Recent spectrum measurement campaigns indicate that most of the licensed spectrum has been under-utilized. Even in the most crowded area near downtown Washington, DC, where both government and commercial spectrum use is intensive, only 38% of the licensed spectrum remains occupied and the rest of spectrum resource, white space/spectrum hole is wasted.

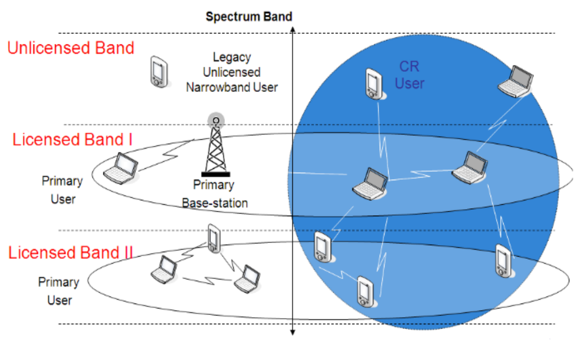


Fig 2: Cognitive network

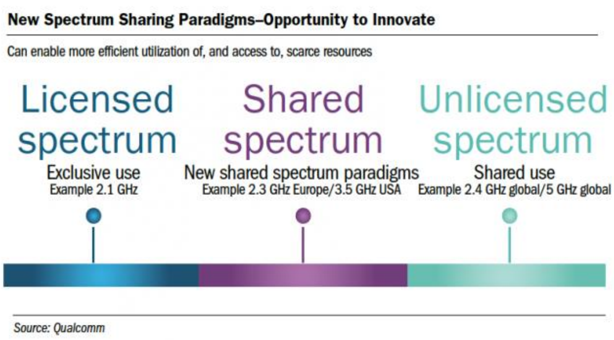
Cognitive radio network consists of primary networks as well as secondary networks. A primary network is accompanies one or greater primary users (PUs) and one or more primary base stations. The PUs having the license for utilization of spectrum and synchronize by the primary base stations. PUs can make communication among the all users via base station. In general there is no availability of CR between PUs and base station.

Primary network is referred to the existing network i.e. cellular or TV broadcast networks. They are infrastructure based networks. The primary networks are formed with the help of primary users and base station. Primary users are having the license to utilize the primary base station. They don't have any need any customization for sharing with xGusers. Primary base station has license to operate in a certain spectrum i.e. base station transceiver system (BTS). Primary usersmust have need to follow the some specific protocols forsharing thespectrum with another users. xG network can be placed as anadhoc networks or infrastructure networks. They can access the spectrum band with higher priority and opportunistic way. It is also known as cognitive radio network or dynamic spectrum access network. The components of xG network are xG user, xG base station and spectrum broker[4].

III. SPECTRUM SHARING

The wireless communication always offer the shared spectrum access. Spectrum is naturally very limited resources and it is shared primary users with the secondary users according to need of accessing. The simultaneous existence of these users creates the lots of challenges in the deployment of cognitive networks. There are some important issues with the spectrum sharing: network architecture, policies for spectrum allocation and spectrum access mechanism.

Fig.3: Spectrum sharing



Architecture [6] – there is two types of sharing networks architectures available: centralized and distributed. In centralized architecture a central authorityis available which is responsible for the spectrum allocation. Firstly, sensing is done individually by the nodes i.e. distributed sensing and then this data is forwarded to the central authority. The allocation map is constructed. This is used to lease the spectrum to the users in a particular location as well as for a particular time interval. In this approach if the centralized authority fails then the whole system collapses. In distributed architecture the allocation is done by the message passing among nodes. This is the process in which all the competing nodes sense the medium and then pass the messages to each other. It degrades the spectrum efficiency. The allocation policy is local or sometimes it is globally followed by all the nodes.

Intranetwork Spectrum Sharing- The spectrum is shared among the cognitive users inside the cognitive network. The resources areshared by the nodes locally they does not cause interference to the primary users.There are various challenges in this particular approach.

Internetwork spectrum sharing[7]- The network is shared by the base stations of different cognitive networks to provide adequate quality of service and to fulfill requirement of stations of their individual network. It is the concept in which multiple cognitive networks share the spectrum in same geographic location.

As the complexities of wireless technologies increase, novel multidisciplinary approaches for spectrum sharing and management are required, with inputs from technology, economics, and regulations. The important characteristics of spectrum sharing methods include identifying the available spectrum resource, deciding on the optimal sensing and transmission time and proper coordination among the users for spectrum access. Recently, cognitive radio technology has come into action to handle the spectrum scarcity problem. In this chapter, we technically overview the state of the art of various spectrum sharing techniques and discuss their potential issues with emerging applications of the communication system, especially to enhance the spectral efficiency. The potential advantages, limiting factors, and characteristic features of the existing cognitive radio spectrum sharing domains are thoroughly discussed, and an overview of spectrum sharing is provided as it ensures channel access without interference or collision with the licensed users in the spectrum. Emerging trends in cognitive radio research[8] and open research challenges related to the cost-effective and large-scale deployment of cognitive radio systems are outlined.

IV. CHALLENGES IN SPECTRUM SHARING

There are various challenges in this spectrum sharing approach: common control channel, dynamic radio range, spectrum unit, location information. Common Control Channel – In cognitive networks it is not possible to maintain a common control channel because when primary user wants a channel it is required to vacate the space immediately. It can be maintained locally like for clustered scenarios. The common control channel is useful for administrative purpose like spectrum sharing and monitoring. Dynamic radio range–In CR networks[9] the radio can change its operating frequency therefore in such case the neighbors are dynamic. It means that whenever frequency changes their neighbor also changes. There is interdependency between operating frequency and radio range. It is very crucial issue and it needs to be resolved. Spectrum unit – The communication channel is considered to be as a spectrum unit. So it is required to be considered in developing algorithms.
Location information – There is an assumption in CR networks that secondary users know the location of primary users as well as their transmission power. But practically this is not always a valid assumption.

IV. SPECTRUM SENSING

In Cognitive Networks Spectrum Sensing and Spectrum Sharing[10] are the most crucial and critical phenomenon to be studied thoroughly and deeply. Certain issues must be kept in mind like maximize throughput, interference and secondary user's existence. The main issues of cognitive radio are sensing, measurement, learning, power allocation, user's requirement, legal issues, operating constraints etc. The scenario of secondary users is like they should not create any type of interference to the primary users who are legitimate and higher priority to the spectrum access. Cognitive radio is used by the secondary users. For this purpose there is a requirement of an algorithm that can monitor such type of operation in the network. Therefore the spectrum sensing is the most important concept in order to establish such type of cognitive networks.

Due to the huge number of diverse wireless devices and technologies, spectacular increases in the number of wireless subscribers, advent of new applications and continuous demand for higher data-rates, the radio frequency (RF) spectrum is becoming more and more crowded. This development calls for systems and devices that are aware of their surrounding RF environment, so they can facilitate flexible, efficient, and reliable operation and utilization of the available spectral resources. Thus, the spectrum sensing is becoming progressively more important to recent and future wireless communication systems for identifying underutilized spectrum and characterizing interference, with the goal of achieving reliable and efficient operation. Cognitive radio is an intelligent radio that is aware of its surrounding environment, capable of learning and adapting its behavior and operation to provide a good match to its surrounding environment and to the user'sneeds. Spectrum sensing is the key requirement and one of the most challenging issues for the cognitive radio system. This chapter presents a comprehensive survey of the physical layer spectrum sensing techniques for cognitive radios.
The major challenges in spectrum sensing are outlined and several techniques for improving spectrum sensing performance are discussed. Further, a hybrid model for non-cooperative spectrum sensing is presented; with this terminology, the proper channelization of the three techniques is introduced, with relevant discussion. This approach helps in detecting the idle spectrum opportunistically, with better spectrum utilization under non-cooperative sensing, resulting in enhanced spectrum efficiency.

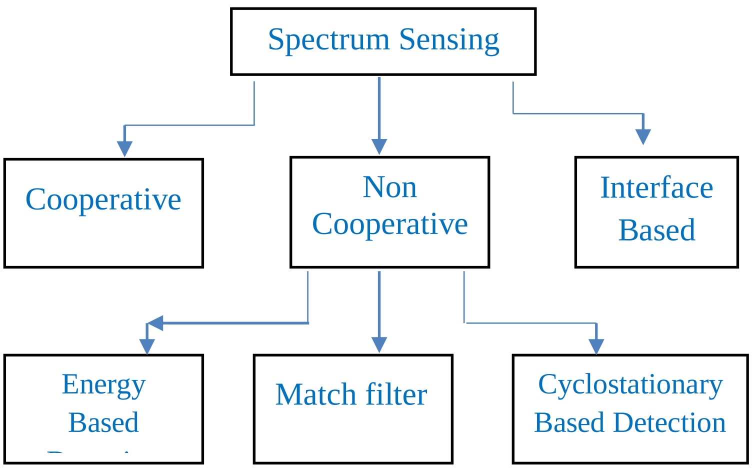


***Fig.3*: Classification of Spectrum Sensing**

We also explore sensing under a cooperative environment. The approach presented aids in opportunistically detecting idle spectrum bands (spectrum holes that are the underutilized sub-bands of the radio spectrum), with better utilization of the spectrum than under non-cooperative sensing, and increased overall spectrum efficiency.

V. SPECTRUM SENSING CHALLENGES

Hardware Requirements- Spectrum sensing in real time is very crucial. It requires very high performance hardware because very complex computations take place in sensing algorithms. For sensing it requires very high sampling, analog to digital conversion, high speed signal processing, channel estimation, power control etc. It requires efficient receivers to cover very wide range of frequencies. Delay is very important aspect while sensing the spectrum therefore it should be minimized. There are two ways to perform sensing single radio and dual radio. In single radio a specific time slot is devoted for the purpose of sensing which is the wastage of precious natural resource i.e. spectrum. But this approach is easy to implement and low cost as compare to dual radio. In dual radio one radio is used for communication and other one is used for sensing. In this approach spectrum efficiency is high as compare to previous approach. In single radio very short time duration is allocated forsensing therefore accuracy is suspected. In dual radio power consumption and cost are increased as well.
Hidden Licensed User Problem- It is due to the many factors like shadowing, multipath fading, it is observed by the unlicensed users while searching for the licensed users in the spectrum.It is similar to the hidden node problem in wireless networks. It causes interference to the licensed user because secondary user is not able to detect the location of primary user but when both transmit at the same time interference occur. Cooperative sensing is one of the ways to handle this particular problem. Sensing Duration and Frequency- In cognitive networks the primary users communicate in their licensed band and secondary users communicate in the band when it is not used by the primary users. But primary users can start communication whenever they wanted to do so it is essential for secondary users to sense the presence of the primary users as soon as possible and switch to another free band. This process requires the frequent sensing of the spectrum for primary users and it is essential to avoid the interference with primary users. It is a great challenge for sensing algorithms.

1) Channel uncertainty: Channel fading or shadowing may cause higher interference. If the primary signal is experiencing a deep fade or being heavily shadowed by obstacles then secondary user may wrongly interpret that the primary user is located out of its interference range. Therefore, cognitive radios have to be more sensitive to distinguish a faded or shadowed primary signal from a white space. This issue may be handled by having a group of cognitive radios (cooperative Sensing) since a single cognitive radio will be unable to achieve this increased sensitivity.

2) Sensing interference limit: The net major challenge lies in the interference measurement at the licensed receiver caused by transmissions from unlicensed users. First, an unlicensed user may not know exactly the location of the licensed receiver which is required to compute interference caused due to its transmission. Second, if a licensed receiver is a passive device, the transmitter may not be aware of the receiver. So these factors need attention while calculating the sensing interference limit [11] .

3) Noise Uncertainty: The detection sensitivity can be defined as the minimum SNR at which the primary signal can be accurately (e.g. with a probability of 0.99) detected by the cognitive radio and is given by

$$\gamma min = \frac{\mathrm{PL(D+R)}}{N}$$

Where N is the noise power, P is transmitted power of the primary user, D is the interference range of the secondary user, and R is maximum distance between primary transmitter and its corresponding receiver [11]. The above equation suggests that in order to calculate the required detection sensitivity, the noise power has to be known, which is not available in practice, and needs to be estimated by the receiver. Howeverthe noise power estimation is limited by calibration errors as well as changes in thermal noise caused by temperature variations. Since a cognitive radio may not satisfy the sensitivity requirement due to an underestimate of N, γ_{min}should be calculated with the worst case noise assumption, thereby necessitating a more sensitive detector.

4) Spectrum mobility issues: The spectrum mobility in cognitive radio allows the secondary user to change its operating spectrum dynamically based on the spectrum conditions. Spectrum mobility gives rise to a new type of handoff in CR networks, spectrum handoff. Protocols for different layers of the network stack must adapt to the channel parameters of the operating frequency. Moreover, they should be transparent to spectrum handoff and the associated latency. Each time a CR

user changes its frequency of operation, the network protocols may require modifications to the operation parameters. The purpose of the spectrum mobility management in CR networks is to ensure smooth and fast transition leading to minimum performance degradation during a spectrum handoff. An important requirement of mobility management protocols is information about the duration of a spectrum handoff. This information can be provided by the sensing algorithm. After the latency information is available, the ongoing communications can be preserved with only minimum performance degradation[12].

V. SPECTRUM ALLOCATION

The aim of this approach is to limit the interference so that the capacity and performance of the network can be improved. This process is related with spectrum sensing. Spectrum sensing is responsible for finding the available frequency band then spectrum decision or spectrum assignment is based on the parameters like fairness, quality of service requirement, throughput, spectrum efficiency etc. and the constraint is, interference to the primary user as well as secondary users must be avoided. The task of spectrum assignment is carried out by selecting the central frequency and bandwidth (according to requirement) simultaneously. The process of spectrum assignment is divided into three parts. First is define the objective function that is criteria to solve this problem then the suitable modeling is chosen and the third step is the selection of technique that will simplify the SA problem.

Criteria – There are different criteria for assigning the spectrum to the secondary users. Different criteria are as follows.

- Interference/Power – Interference is the main criteria in order to decide the spectrum allocation algorithm. In the past efforts there are three different cases of interference consideration. First is interference experienced by the single secondary user only, second is interference experienced by all secondary users and third is interference experienced by all users including primary and secondary users.

- Interference Temperature Limit - It is the amount of interference at the receiver end. It is the ratio of power at the receiver end to RF bandwidth and boltzman constant. To limit the interference temperature the approach of power control is used. There is a tradeoff i.e. decreasing the power will result in the decrease in the interface but it will result in low SNR.

- Maximize Spectrum Utilization – This is the most basic criteria to design the spectrum allocation algorithm. In this it is require to maximize the number of channels to secondary user or number of secondary users are require to be maximize.

Spectrum Allocation Procedures[13] – There are different procedures of spectrum allocation. Like centralized, distributed, clustered and inclusion of primary user.

- Centralized or Distributed Approach – In this approach a server is used for collecting the information related to the network and it decides the allocation according to predefined criterion. This method contains the reliability and maintain the quality of required services. It depends on the server for the functioning of the network. While in later case the approach is quick and based on cooperation among the nodes but it is not able to preserve the fairness.

- Cluster based – In this approach cognitive network is divided into several clusters and the cluster head is communicating with the base station after collecting the data from cluster members. It is energy efficient and it requires less number of transmissions of control information. In another implementation cluster head itself can take the decision of spectrum allocation after cooperating with other cluster heads.

VI. CONCLUSION

In Cognitive Networks the main focus is to get efficient utilization of spectrum. There are three steps for doing this- (1) Spectrum sensing, (2) spectrum allocation and (3) spectrum handoff or mobility. In this paper, we have studied the cognitive networks, procedures, techniques, sensing, sharing and criterion, for spectrum allocation has been studied and it is understood the challenges that better allocation can drastically improves spectrum utilization. Complete network architecture that can handle the heterogeneities at various levels.

- Environment effects should be considered explicitly.
- Upper layer challenges like congestion, routing, frame errors etc.
- The memory and processing constraints of mobile terminals is required to be considered.

- It is required to develop an architecture that can accommodate the various environments like WLAN, 3G cellular, satellite network, ISM band etc. it facilitate the global roaming of mobile user. It enables the service providers to serve ―Anywhere and Anytime‖.

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