Spectrum Management Using Cognitive Radio Network

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Abstract: ***In recent years, the demand for radio spectrum for wireless communication is growing due to increase in number of users and popularity of data and multimedia services. This has been observed in the recent auctions completed word wide for the vestige of radio spectrum. The radio spectrum has been assigned to different services and it is very much difficult for the emerging wireless technologies to get entry due to rigid spectrum policy and heavy opportunity cost. The inefficient prevailing spectrum management causes the artificial spectrum scarcity. The measurement campaigns conducted worldwide have confirmed this by showing that the considerable amount of radio spectrum is underutilized. Dynamic Spectrum Access (DSA) and the spectrum reframing are the two viable solutions for the problem of spectrum scarcity. In DSA, unlicensed user opportunistically uses the vacant licensed spectrum with the help of Cognitive Radio. Cognitive Radio is a key enabling technology for DSA. In Cognitive Radio paradigm, secondary user (SU) i.e. unlicensed user locate the vacant licensed spectrum of licensed user i.e. Primary user (PU) and uses it without harmful interference to the PUs. The secondary use of licensed spectrum provides efficient use of spectrum. Spectrum reframing means the recovery of spectrum from its existing users for the purpose of re-assignment, either for new uses, or for the introduction of new spectrally efficient Technologies. The aim of this paper to evaluate spectrum management using cognitive radio network.***

Keywords: DSA, SU, PU

1. Introduction

Today's wireless communication networks are regulated by a fixed spectrum assignment policy the spectrum is regulated by governmental agencies and is assigned to license holders or services on a long term basic for large geographical regions. The spectrum usage is concentrated on certain portions of the spectrum remains unutilized. According to federal communications commission (FCC) [1] temporal and geographical variations in the utilization of assigned spectrum range from 15% to 85%.although the fixed spectrum assignment policy generally served well in the past, there is a dramatic increase in the access to the limited spectrum for mobile services in the recent years. This increase is straining the effectiveness of the traditional spectrum polices. Cognitive radio technology is the key technology that enables an xG network to use spectrum in a dynamic manner. The term cognitive radio can formally be defined as follows. A "cognitive radio" is that can change its transmitter parameters based on interaction with the environment in which it operates. From this definition, two main characteristic of the cognitive radio can be defined: Cognitive capability: cognitive capability refers to the ability of the radio technology to capture or sense the information from its radio environment [2]. Re-configurability: the cognitive capability provides spectrum awareness whereas reconfiguration enables the radio to be dynamically programmed according to the radio environment [3]. Cognitive Radio Networks: Wireless communication systems have been widely and successfully deployed all over the world, Day by day, upper layer protocols demand high speed wireless access with very low delay requirements for applications in data, voice, video and other high bandwidth urge multimedia applications. However, the radio spectrum band available to serve the wide variety of all these emerging applications is strictly limited. The regulatory bodies licensed the radio spectrum, implementing strict limitations on operators and manufacturers protecting the radio resource and licensed users. The cognitive radio enables the usage temporally unused spectrum, which is referred to as spectrum hole or white space if this band is further used by a licensed user, the cognitive radio moves to another spectrum hole or stays in the same band, altering its transmission power level or modulation scheme to avoid interference, limitation and congestion due to spectrum sharing

1.2 Problem Definition

Obtain the best available spectrum through cognitive capability and re-configurability and detect the spectrum hole or white space if this band is further used by a licensed user, the cognitive radio moves to another spectrum hole or stays in the same band, altering its transmission power level or modulation scheme to avoid (ISI) inter symbol interference.
Determine the limitation of sharing the spectrum to avoid congestion.
Enhance Energy Detection Sensing Algorithm.

1.3 Objectives

- Study Cognitive Radio Network.
- analyze Cognitive Radio Network techniques
- Spectrum management using Cognitive Radio Network.

1.4 Motivation

- Increasing the capacity of static spectrum to be dynamic.

• Sharing the resources and devices in network.
• Cost reduction.

1.5 Methodology

• Computer model
• Implementation using MATLAB

2. Concept of cognitive radio network

Cognitive radios consist of a variety of users which behave in different ways depending on the environment. The overall goal is for users who are not licensed on their current channel to avoid all licensed users and prevent any interference to them. The licensed users are called Primary Users (PU) because they have primary rights to the channel. Their location is typically known to other users and their transmission characteristics are identifiable but not always the same between primary users due to different applications. These users include but aren't limited to military radios on the military band and emergency help request transmissions on the emergency bands. According to the new FCC rules, the primary users are expected to never receive any interference from unlicensed users. Unlicensed users fall into the category of Secondary Users (SU) since their transmissions are secondary in priority regarding the completion of the transmission. These users may operate on any frequency range which they are permitted by the FCC's new rules. They are expected to scatter and halt transmission immediately upon a PU's appearance as a PU must not experience any interference. These users could be almost anything. A SU can use various tactics to avoid primary users but all of them require an immediate halt to transmissions. If the primary user's behavior makes any further transmissions on that channel impossible, SUs can both change Frequencies and transmit on other channels to avoid the primary user or they can re- route the transmission to another SU node in the network outside of the PU's range. A mixture of both of these may be applied depending on the characteristics of the network. In this investigation node hopping will not be used so the effectiveness will depend on channel hopping.

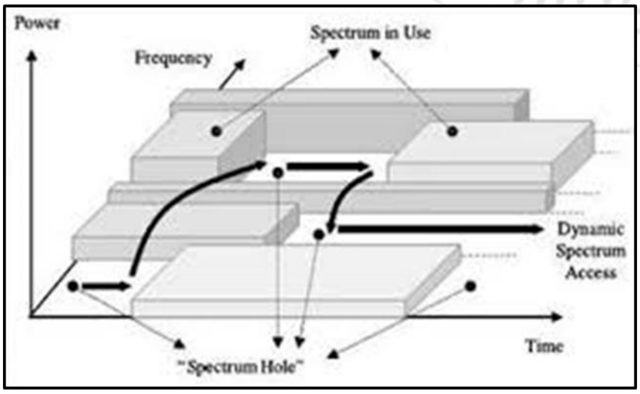

Figure 2.1: Spectrum hole concept [2]

The key enabling technology of xG networks is the cognitive radio. Cognitive radio techniques provide the capability to use or share the spectrum in an opportunistic manner [1]. Dynamic spectrum access techniques allow the cognitive radio to operate in the best available channel. More specifically, the cognitive radio technology will enable the users to determine which portions of the spectrum is available and detect the presence of licensed users when a user operates in a licensed band (spectrum sensing), select the best available channel (spectrum management), coordinate access to this channel with other users (spectrum sharing), and vacate the channel when a licensed user is detected (spectrum mobility).

Once a cognitive radio supports the capability to select the best available channel, the next challenge is to make the network protocols adaptive to the available spectrum. Hence, new functionalities are required in an XG network to support this adaptively. In summary, the main functions for cognitive radios in xG networks can be summarized as follows:

a) **Spectrum sensing:** Detecting unused spectrum and sharing the spectrum without harmful interference with other users.
b) **Spectrum management**: Capturing the best available spectrum to meet user communication requirements.
c) **Spectrum mobility**: Maintaining seamless communication requirements during the transition to better spectrum.
d) **Spectrum sharing**: Providing the fair spectrum scheduling method among coexisting XG users [2].

2.2 Characteristics of Cognitive Radio

The dictionary meaning of word cognition means becoming acquainted with, mental process of knowing through perception or reasoning or intuition or knowledge or we can simply say learning by understanding. Considering these ideas together there are two main characteristics of cognitive radio which is worth mentioning. According to they are cognitive capability and configurability which is describe in detail as follow:

2.2.1Cognitive Capability

The cognitive capability of a cognitive radio enables real time interaction with its environment to determine appropriate communication parameters and adapt to the dynamic radio environment. The tasks required for adaptive operation in open spectrum are shown in Fig. 2.2 [2,4,5] which is referred to as the cognitive cycle. In this section, we provide an overview of the three main steps of the cognitive cycle: spectrum sensing, spectrum analysis, and spectrum decision. The steps of the cognitive cycle as shown in Fig. 2.2 are as follows:

a) **Spectrum sensing**: A cognitive radio monitors the available spectrum bands, captures their information, and then detects the spectrum holes.
b) **Spectrum analysis**: The characteristics of the spectrum holes that are detected through spectrum sensing are estimated.
c) **Spectrum decision**: A cognitive radio determines the data rate, the transmission mode, and the bandwidth of the transmission. Then, the appropriate spectrum band is chosen according to the spectrum characteristics and user requirements.

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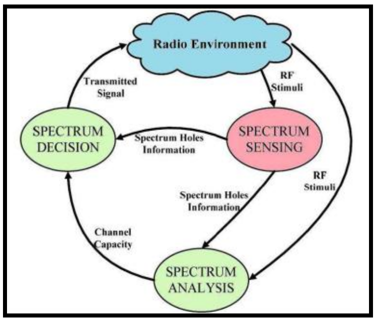

Figure2.2: Cognitive radio cycle [2]

Once the operating spectrum band is determined, the communication can be performed over this spectrum band. However, since the radio environment changes over time and space, the cognitive radio should keep track of the changes of the radio environment. If the current spectrum band in use becomes unavailable, the spectrum mobility function that will be explained in Section 6, is performed to provide a seamless transmission. Any environmental change during the transmission such as primary user appearance, user movement, or traffic variation can trigger this adjustment.

2.2.2Re-configurability

Re-configurability is the capability of adjusting operating parameters for the transmission on the fly without any modifications on the hardware components. This capability enables the cognitive radio to adapt easily to the dynamic radio environment. There are several reconfigurable parameters that can be incorporated into the cognitive radio as explained below [2]:

a) **Operating frequency**: A cognitive radio is capable of changing the operating frequency. Based on the information about the radio environment, the most suitable operating frequency can be determined and the communication can be dynamically performed on this appropriate operating frequency.

b) **Modulation**: A cognitive radio should reconfigure the modulation scheme adaptive to the user requirements and channel conditions. For example, in the case of delay sensitive applications, the data rate is more important than the error rate. Thus, the modulation scheme that enables the higher spectral efficiency should be selected. Conversely, the loss-sensitive applications focus on the error rate, which necessitate modulation schemes with low bit error rate.

c) **Transmission power:** Transmission power can be reconfigured within the power constraints. Power control enables dynamic transmission power configuration within the permissible power limit. If higher power operation is not necessary, the cognitive radio reduces the transmitter power to a lower level to allow more users to share the spectrum and to decrease the interference.

d) **Communication technology:** A cognitive radio can also be used to provide interoperability among different communication systems. The transmission parameters of a cognitive radio can be reconfigured not only at the beginning of a transmission but also during the transmission. According to the spectrum characteristics, these parameters can be reconfigured such that the cognitive radio is switched to a different spectrum band, the transmitter and receiver parameters are reconfigured and the appropriate communication protocol parameters and modulation schemes are used.

2.3 Application of cognitive radio network

a. **Leased network:** The primary network can provide a leased network by allowing opportunistic access to its licensed spectrum with the agreement with a third party without sacrificing the service quality of the primary user [6]. For example, the primary network can lease its spectrum access right to a mobile virtual network operator (MVNO). Also the primary network can provide its spectrum access rights to a regional community for the purpose of broadband access.

b. **Cognitive mesh network:** Wireless mesh networks are emerging as a cost-effective technology for providing broadband connectivity [7]. However, as the network density increases and the applications require higher throughput, mesh networks require higher capacity to meet the requirements of the applications. Since the cognitive radio technology enables the access to larger amount of spectrum, CR networks can be used for mesh networks that will be deployed in dense urban areas with the possibility of significant contention. For example, the coverage area of CR networks can be increased when a meshed wireless backbone network of infrastructure links is established based on cognitive access points (CAPs) and fixed cognitive relay nodes. The capacity of a CAP, connected via a wired broadband access to the Internet, is distributed into a large area with the help of a fixed CRN. CR networks have the ability to add temporary or permanent spectrum to the infrastructure links used for relaying in case of high traffic load.

c. **Emergency network**: Public safety and emergency networks are another area in which CR networks can be implemented [8]. In the case of natural disasters, which may temporarily disable or destroy existing communication infrastructure, emergency personnel working in the disaster areas need to establish emergency networks. Since emergency networks deal with the critical information, reliable communication should be guaranteed with minimum latency. In addition, emergency communication requires a significant amount of radio spectrum for handling huge volume of traffic including voice, video and data. CR networks can enable the usage of the existing spectrum without the need for an infrastructure and by maintaining communication priority and response time.

d. **Military network:** One of the most interesting potential applications of a CR network is in a military radio environment [9]. CR networks can enable the military radios choose arbitrary, intermediate frequency (IF) bandwidth, modulation schemes, and coding schemes, adapting to the variable radio environment of battlefield. Also military networks have a strong need for security and protection of the communication in hostile environment. CR networks could allow military personnel to perform spectrum. Handoff to find secure spectrum band for themselves and their allies.

3. Cognitive radio techniques

3.1 Spectrum Sensing

An important requirement of the xG network is to sense the spectrum holes. The spectrum sensing function enables the cognitive radio to adapt to its environment by detecting spectrum holes. We can categorize spectrum sensing techniques into direct method, which is considered as frequency domain approach, where the estimation is carried out directly from signal and indirect method, which is known as time domain approach, where the estimation is performed using autocorrelation of the signal. Another way of categorizing the spectrum sensing and estimation methods is by making group into model based parametric method and period gram based non- parametric method.

Another way of classification depends on the need of spectrum sensing as stated below:

3.1.2 Spectrum Sensing for Spectrum Opportunities

a. Primary transmitter detection: In this case, the detection of primary users is performed based on the received signal at CR users. This approach includes matched filter (MF) based detection, energy based detection, covariance based detection, waveform based detection, cyclostationary based detection, radio identification based detection and random Hough Transform based detection.

b. Cooperative and collaborative detection: In this approach, the primary signals for spectrum opportunities are detected reliably by interacting or cooperating with other users, and the method can be implemented as either centralized access to spectrum coordinated by a spectrum server or distributed approach implied by the spectrum load smoothing algorithm or external detection. Spectrum

c. Interference temperature detection: In this approach, CR system works as in the ultra-wide band (UWB) technology where the secondary users coexist with primary users and are allowed to transmit with low power and are restricted by the interference temperature level so as not to cause harmful interference to primary users.

3.1.3 Classification of Spectrum Sensing Techniques

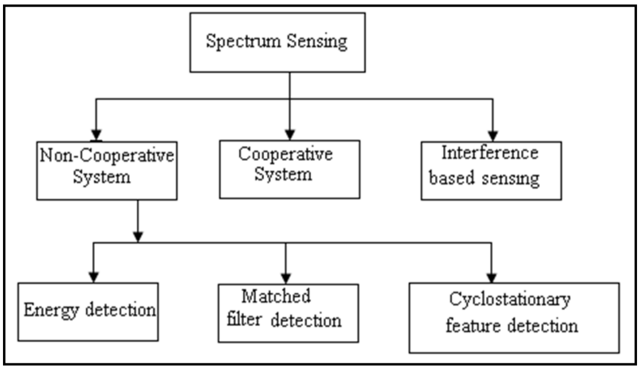

Figure 3.1: Classification of spectrum sensing techniques

Figure 3.1 shows the detailed classification of spectrum Sensing techniques. They are broadly classified into three main types, transmitter detection or non-cooperative sensing, cooperative sensing and interference based sensing. Transmitter detection technique is further classified into energy detection, matched filter detection and cyclostationary feature detection.

a. non-cooperative sensing

1) Energy Detection

It is a non-coherent detection method that detects the primary signal based on the sensed energy. Due to its simplicity and no requirement on a priori knowledge of primary user signal, energy detection (ED) is the most popular sensing technique in cooperative sensing. It is a non-coherent detection method that detects the primary signal based on the sensed energy. Due to its simplicity and no requirement on a priori knowledge of primary user signal, energy detection (ED) is the most popular sensing technique in cooperative sensing.

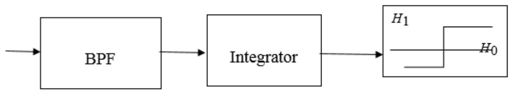

Figure 3.2: Energy detector block diagram

The block diagram for the energy detection technique is shown in the Figure 3.2. In this method, signal is passed through band pass filter of the bandwidth W and is integrated over time interval. The output from the integrator block is then compared to a predefined threshold. This comparison is used to discover the existence of absence of the primary user. The threshold value can set to be fixed or variable based on the channel conditions. The ED is said to be the Blind signal detector because it ignores the structure of the signal. It estimates the presence of the signal by comparing the energy received with a known threshold derived from the statistics of the noise

2) Matched Filter

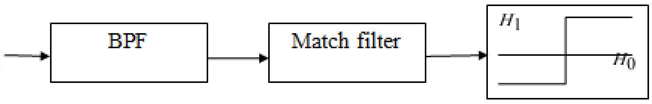

Fig3.3: Block diagram of matched filter

A matched filter (MF) is a linear filter designed to maximize the output signal to noise ratio for a given input signal. When secondary user has a priori knowledge of primary user signal, matched filter detection is applied. Matched filter operation is equivalent to correlation in which the unknown signal is convolved with the filter whose impulse response is the mirror and time shifted version of a reference signal

3) Cyclostationary Feature Detection

It exploits the periodicity in the received primary signal to identify the presence of primary users (PU). The periodicity is commonly embedded in sinusoidal carriers, pulse trains, spreading code, hopping sequences or cyclic prefixes of the primary signals. Due to the periodicity, these cyclostationary signals exhibit the features of periodic statistics and spectral correlation, which is not found in stationary noise and interference. Thus, cyclostationary feature detection is robust to noise uncertainties and performs better than energy detection in low SNR regions. Although it requires a priori knowledge of the signal characteristics, cyclostationary feature detection is capable of distinguishing the CR transmissions from various types of PU signals. This eliminates the synchronization requirement of energy detection in cooperative sensing. Moreover, CR users may not be required to keep silent during cooperative sensing and thus improving the overall CR throughput. This method has its own shortcomings owing to its high computational complexity and long sensing time. Due to these issues, this detection method is less common than energy detection in cooperative sensing. The comparison of different transmitter detection techniques for spectrum sensing and the spectrum opportunities is shown in figure 8. As it is evident from the figure, that matched filter based detection is complex to implement in CRs, but has highest accuracy. Similarly, the energy based detection is least complex to implement in CR system and least accurate compared to other approaches. And other approaches are in the middle of these two.

As a result CR users need to be tightly synchronized and refrained from the transmissions during an interval called Quiet Period in cooperative sensing.

b. Cooperative Techniques

High sensitivity requirements on the cognitive user can be alleviated if multiple CR users cooperate in sensing the channel. Various topologies are currently used and are broadly classifiable into three regimes according to their level of cooperation.

1) Decentralized Uncoordinated Techniques

The cognitive users in the network don't have any kind of cooperation which means that each CR user will independently detect the channel, and if a CR user detects the primary user it would vacate the channel without informing the other users. Uncoordinated techniques are fallible in comparison with coordinated techniques. Therefore, CR users that experience bad channel realizations detect the channel incorrectly thereby causing interference at the primary receiver.

2) Centralized Coordinated Techniques

In such networks, an infrastructure deployment is assumed for the CR users. One CR that detects the presence of a primary transmitter or receiver, informs a CR controller which can be a wired immobile device or another CR user. The CR controller notifies all the CR users in its range by means of a broadcast control message. Centralized schemes can be further classified according to their level of cooperation as: Partially cooperative where network nodes cooperate only in sensing the channel. CR users independently detect the channel and inform the CR controller which then notifies all the CR users; and totally cooperative Schemes where nodes cooperate in relaying each other's information in addition to cooperatively sensing the channel.

3) Decentralized Coordinated Techniques

This type of coordination implies building up a network of cognitive radios without having the need of a controller. Various algorithms have been proposed for the decentralized techniques among which are the gossiping algorithms or clustering schemes, where cognitive users gather to clusters, auto coordinating themselves [23]. The cooperative spectrum sensing raises the need for a control channel, which can be implemented as a dedicated frequency channel or as an underlay UWB channel

C. Interference Based Detection

In this section, we present interference based detection so that the CR users would operate in spectrum underlay (UWB like) approach.

1) Primary Receiver Detection

In general, primary receiver emits the local oscillator (LO) leakage power from its RF front end while receiving the data from primary transmitter. It has been suggested as a method to detect primary user by mounting a low cost sensor node close to a primary user's receiver in order to detect the local oscillator (LO) leakage power emitted by the RF front end of the primary user's receiver which are within the communication range of CR system users. The local sensor then reports the sensed information to the CR users so that they can identify the spectrum occupancy status. We note that this method can also be used to identify the spectrum opportunities to operate CR users in spectrum overlay.

2) Interference Temperature Measurement

Unlike the primary receiver detection, the basic idea behind the interference temperature management is to set up an upper interference limit for given frequency band in specific geographic location such that the CR users are not allowed to cause harmful interference while using the specific band in specific area. Typically, CR user transmitters control their interference by regulating their transmission power (their out of band emissions) based on their locations with respect to primary users. This method basically concentrates on measuring interference at the receiver.

The operating principle of this method is like an UWB technology where the CR users are allowed to coexist and transmit simultaneously with primary users using low transmit power that is restricted by the interference temperature level so as not to cause harmful interference to primary users.

Here CR users do not perform spectrum sensing for spectrum opportunities and can transmit right way with specified preset power mask. However, the CR users cannot transmit their data with higher power even if the licensed system is completely idle since they are not allowed to transmit with higher than the preset power to limit the interference at primary users. It is noted that

3.2 Spectrum Management

In XG networks, the unused spectrum bands will be spread over wide frequency range including both unlicensed and licensed bands. These unused spectrum bands detected through spectrum sensing show different characteristics according to not only the time varying radio environment but also the spectrum band information such as the operating frequency and the bandwidth. Since xG networks should decide on the best spectrum band to meet the QoS requirements over all available spectrum bands, new spectrum management functions are required for xG networks, considering the dynamic spectrum characteristics. We classify these functions as spectrum sensing, spectrum analysis, and spectrum decision. While spectrum sensing, is primarily a PHY layer issue, spectrum analysis and spectrum decision are closely related to the upper layers. In this section, spectrum analysis and spectrum decision are investigated [2].

3.2.1 Spectrum Analysis

In xG networks, the available spectrum holes show different characteristics which vary over time. Since the xG users are equipped with the cognitive radio based physical layer, it is important to understand the characteristics of different spectrum bands. Spectrum analysis enables the characterization of different spectrum bands, which can be exploited to get the spectrum band appropriate to the user requirements. In order to describe the dynamic nature of xG networks, each spectrum hole should be characterized considering not only the time-varying radio environment and but also the primary user activity and the spectrum band information such as operating frequency and bandwidth. Hence, it is essential to define parameters such as interference level, channel error rate, path-loss, link layer delay, and holding time that can represent the quality of a particular spectrum band as follows [2]:

a) **Interference:** Some spectrum bands are more crowded compared to others. Hence, the spectrum band in use determines the interference characteristics of the channel. From the amount of the interference at the primary receiver, the permissible power of an xG user can be derived, which is used for the estimation of the channel capacity.

b) **Path loss**: The path loss increases as the operating frequency increases. Therefore, if the transmission power of an xG user remains the same, then its transmission range decreases at higher frequencies. Similarly, if transmission power is increased to compensate for the increased path loss, then this results in higher interference for other users.

c) **Wireless link errors**: Depending on the modulation scheme and the interference level of the spectrum band, the error rate of the channel changes.

d) **Link layer delay**: To address different path loss, wireless link error, and interference, different types of link layer protocols are required at different spectrum bands. This results in different link layer packet transmission delay.

e) **Holding time:** The activities of primary users can affect the channel quality in xG networks. Holding time refers to the expected time duration that the xG user can occupy a licensed band before getting interrupted. Obviously, the longer the holding time, the better the quality would be. Since frequent spectrum handoff can decrease the holding time, previous statistical patterns of handoff should be considered while designing xG networks with large expected holding time.

3.2.2 Spectrum Decision

Once all available spectrum bands are characterized, appropriate operating spectrum band should be selected for the current transmission considering The QoS requirements and the spectrum characteristics. Thus, the spectrum management function must be aware of user QoS requirements. Based on the user requirements, the data rate, acceptable error rate, delay bound, the transmission mode, and the bandwidth of the transmission can be determined. Then, according to the decision rule, the set of appropriate spectrum bands can be chosen In [12] five spectrum decision rules are presented, which are focused on fairness and communication cost. However, this method assumes that all channels have similar throughput capacity. In [10] an opportunistic frequency channel skipping protocol is proposed for the search of better quality channel, where this channel decision is based on SNR. In order to consider the primary user activity, the number of spectrum handoff, which happens in a certain spectrum band, is used for spectrum decision [11]. Spectrum decision constitutes rather important but yet unexplored issues in xG networks, which are presented in the following subsection.

3.3 Spectrum Mobility

In a radio network consisting of primary users (licensed users) and cognitive users (unlicensed users), the primary users do not always fully utilize their spectrum. The cognitive users may therefore temporally occupy the unused sub-bands. However, the cognitive users need to vacant these sub-bands when primary users want to use them. When this occurs, the affected communication links of the cognitive users will be lost. But if the cognitive users can sense idle sub-bands they can reconstruct the communication links to them. This is called spectrum handoff. The protocols for different layers of the network stack must adapt to the channel parameters of the operating frequency. Moreover, they should be transparent to the spectrum handoff and the associated latency. In general, according to the decision timing for selecting the target channels, spectrum handoff mechanisms can be categorized into [2]:

a) **Proactive-decision spectrum handoff:** make the target channels for spectrum handoff ready before data transmission according to the long-term observation outcomes.

b) **Reactive-decision spectrum handoff:** determine the target channel according to the results from on-demand wideband sensing. Each time an xG user changes its frequency of operation, the network protocols are going to shift from one mode of operation to another. Take the situation of four sub-carriers as an example: Fig.3.4 shows the sub-carriers handoff process when spectrum holes shift with time (t1<t2<t3). The squares denote spectrum which be occupied by licensed users, while empty slots denote spectrum holes that used by cognitive users.

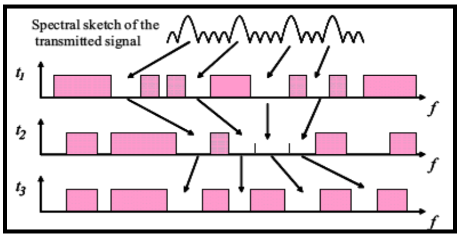

Figure 3.4: spectrum mobility and handoff

The purpose of spectrum mobility management in xG networks is to make sure that such transitions are made smoothly and as soon as possible such that the applications running on an xG user perceive minimum performance degradation during a spectrum handoff. It is essential for the mobility management protocols to learn in advance about the duration of a spectrum handoff. This information should be provided by the sensing algorithm. Once the mobility management protocols learn about this latency, their job is to make sure that the ongoing communications of an xG user undergo only minimum performance degradation. Consequently, multi-layer mobility management protocols are required to accomplish the spectrum mobility functionalities. These protocols support mobility management adaptive to different types of applications. For example, a TCP connection can be put to a wait state until the spectrum handoff is over. Moreover, since the TCP parameters will change after a spectrum handoff [2], it is essential to learn the new parameters and ensure that the transitions from the old parameters to new parameters are carried out rapidly.

3.4 Spectrum Sharing

Spectrum sharing is mainly located in the MAC layer and is used to schedule spectrum assignment among secondary users. Spectrum sharing involves with spectrum allocation, spectrum access and spectrum mobility (switch from one spectrum to another). Spectrum sharing plays a key role in DSA, since its design greatly affects the performance of DSA networks. Spectrum sharing process consists of five major steps [2]:

a) **Spectrum sensing:** An xG user can only allocate a portion of the spectrum if an unlicensed user does not use that portion.
b) **Spectrum allocation:** Allocation depends on spectrum availability and determined based on internal (and possibly external) policies.
c) **Spectrum access:** Access should be coordinated in order to prevent multiple users colliding in overlapping portions.
d) **Transmitter-receiver handshake:** A transmitter-receiver handshake protocol is essential for efficient communication in xG networks.
e) **Spectrum mobility:** If a licensed user requires the portion of the spectrum in use, the communication needs to be continued in another vacant portion.

4. Spectrum Management Using Cognitive Radio

4.1 Proposed Model

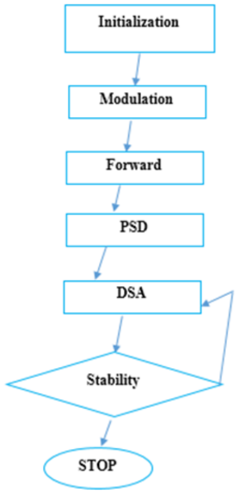

Fig. 4.1: Proposed model for DSA using CRN

Initialization: 4Carrier Frequency Bands for Users, Message Frequency and the Sampling Frequency are initialized
Modulation: Modulates user data over the respective frequency band.
FORWARD: Addition of all the modulated signals to produce a transmitting signal
PSD: To estimate the power spectral density of received signal.
DSA:
- **ADD Slot Allocation:** New User is allotted to the first spectral hole when he arrives.
- **Emptying a slot:** Asked user to empty a specific slot if all the slots are engaged.

Test Stability
It happen through
- **Addition of noise:** Amount of Noise to be added
- **addition of Attenuation:** Percentage of Attenuation is introduced

4.2 Results and Discussions

The cognitive radio system continuously searches the spectrum hole where primary users is not present and is determined by the method of energy detection. When it finds out the spectrum hole, immediately it allots to the Secondary User (SU) and whenever Primary User (PU) wants to occupy the slot, Secondary User immediately leaves it For 4(Four) signals, the carrier frequencies are 1MHz, 2MHz, 3MHz and 4MHz and sampling frequency is 12MHz used for simulation. Power Spectrum Density (PSD) of signal is calculated, compared with the predefined threshold value and determined the presence of primary user signal. In this paper, it has assumed that 1st, 3rd primary users are present and 2nd and 4th primary users are not present. Then, the following results are obtained which are shown below:

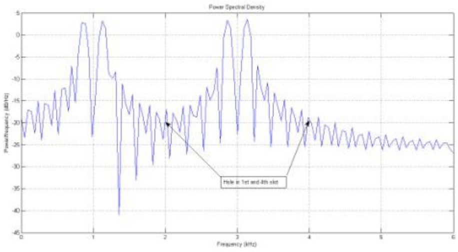

Figure 4.2: 2nd and 4th primary user are not present

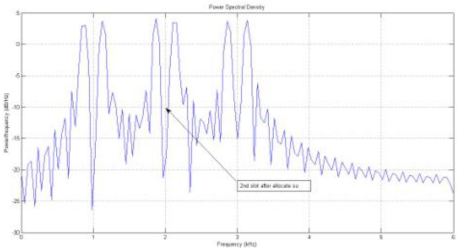

Figure 4.3: allocate 1st secondary user in the 1st hole

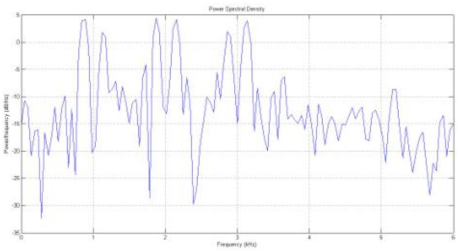

Figure 4.4: add noise after 1st secondary user allocation

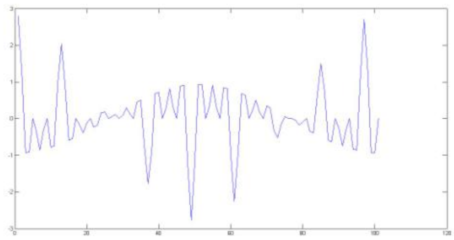

Figure 4.5: add attenuation after 1st secondary user allocation

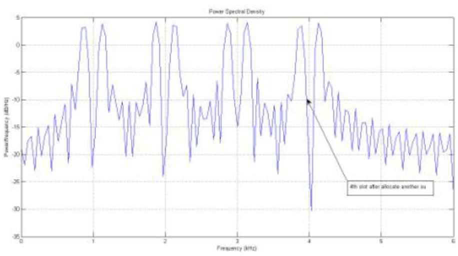

Figure 4.6: allocate 2nd secondary user in the 2nd hole

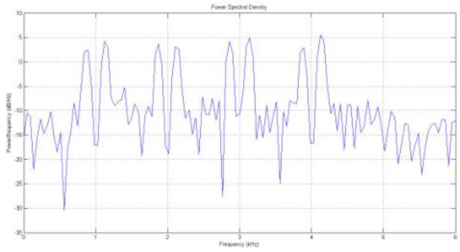

Figure 4.7: add noise after 2nd secondary user allocation

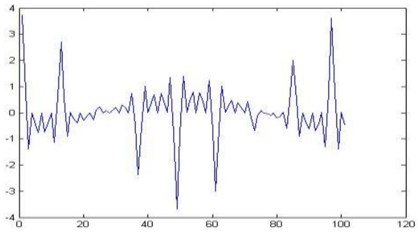

Figure 4.8: add attenuation after 2nd secondary user allocation

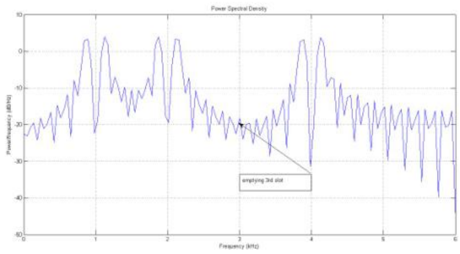

Figure 4.9: emptying 3rd slot to allocate new secondary user

5. Conclusion

The approach was to take the decisions in this paper on the basis of power spectral density of the channel which can be used cognitively to search the available spectral holes those can be used to new incoming users (SU) thus improving the overall channel's throughput. In this work the energy detection spectrum sensing. It has been shown that how the cognitive radio works dynamically with changing the frequency band from one to another and successfully demonstrated in simulation result. The stability of system it done through adding noise and attenuation that's lead to the Spectrum Access in Cognitive Radio demonstrated successfully without interfering with the other frequency bands used by the primary user (PU).

Reference

[1] FCC, ET Docket No 03-222 Notice of proposed rulemaking and order, December 2003.

[2] http://itec.hust.edu.cn/~heixj/phd_net11fall/CRN/06-NeXt%20generation=dynamic%20spectrum%20access=cognitive.PDF

[3] F.K. Jondral, Software-defined radio-basic and evolution to cognitive radio, EURASIP Journal on Wireless Communication and Networking 2005.

[4] S. Haykin, Cognitive radio: brain-empowered wireless communications, IEEE Journal on Selected Areas in Communications 23 (2) (2005) 201–220.

[5] R.W. Thomas, L.A. DaSilva, A.B MacKenzie, Cognitive networks, in: Proc. IEEE DySPAN 2005, November 2005,pp. 352–360.
[6] J.A. Stine, Spectrum management: the killer application of ad hoc and mesh networking, in: Proc. IEEE DySPAN 2005, November 2005, pp. 184–193.
[7] I.F. Akyildiz, X. Wang, W. Wang, Wireless mesh networks: a survey, Computer Networks Journal 47 (4) (2005) 445–487.
[8] D. Maldonado, B. Lie, A. Hugine, T.W. Rondeau, C.W. Bostian, Cognitive radio applications to dynamic spectrum allocation, in: Proc. IEEE DySPAN 2005, November 2005, pp. 597–600.
[9] [9] R. Murty, Software-defined reconfigurability radios: smart, agile, cognitive, and interoperable, Technology@Intel Magazine, July 2003
[10] V. Kanodia, A. Sabharwal, E. Knightly, MOAR: a multichannel opportunistic auto-rate media access protocol for ad hoc networks, in: Proc. IEEE BROADNETS 2004, October 2004, pp. 600–610.
[11] S. Krishnamurthy, M. Thoppian, S. Venkatesan, R. Prakash, Control channel based MAC-layer configuration, routing and situation awareness for cognitive radio networks, in: Proc. IEEE MILCOM 2005, October 2005.

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