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Design of an Optimum Channel Sensing Mechanism for Cognitive Radios

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Abstract

The radio wave frequency spectrum demanded bands for a large number of users. The limited availability of the spectrum does not allow new users to transmit information. Cognitive radio systems use signal processing and networking techniques to use the unused/unoccupied spaces in the spectrum to accommodate new users in the form of secondary users. Channel sensing mechanism is the first step in implementing cognitive radio systems in which the primary users and the details of their operations are sensed before using the unused spaces. This paper surveys some of the efficient channel sensing mechanisms and proposes a novel method in which the bandwidth and packet drop ratio are used as parameters for transmission by secondary users.

Keywords**:** *Cognitive Radio systems, Channel sensing, Bandwidth allocation, Packet drop ratio.*

1. Introduction

Radio systems and technology has become an integral part of our lives in recent times. The primitive concept and the technology of radio have been around for more than a century in various forms and devices. The radio technology works on frequency places where a large number of users are accessing the same frequency for data transmission. Radio frequencies have become increasingly popular, requiring a large bandwidth to accommodate all the users. The last few decades have proven that radio technologies and frequencies have become exponentially popular and the limited number of frequencies available has become a major hurdle for the growing number of users[1]. There are no frequencies to be accommodated for the new wireless systems that are designed. The platforms used are going to be full of all the frequencies and there are no new frequencies to be allocated. This challenge has been around for a long time and the solution has come up in the form of cognitive radios. The use of various signal processing technologies and approaches in order to accommodate the new users within the available frequency band of radio signals is the concept used in cognitive radios. Therefore, the bandwidth can never be increased but the available resources can be efficient to use so that new users can also be using the same bandwidth. This new concept has set requirements that should be handled appropriately. Degradation of signal quality is the major challenges should be addressed before cognitive radios can be used. The system should also be designed in such a way that a large number of users should be accommodated within the available bandwidth [2].

It is important that the new users are accommodated with no compromise in the quality of performance of the existing users or new users. However, many technical considerations should be taken care of before implementing the cognitive radio setup.

It is important to understand and analyze the cognitive cycle in order to analyze the requirements of the new approach and implement the same for additional users. The cognitive cycle comprises of four important stages in which different signal processing activities are performed in the radio environment.

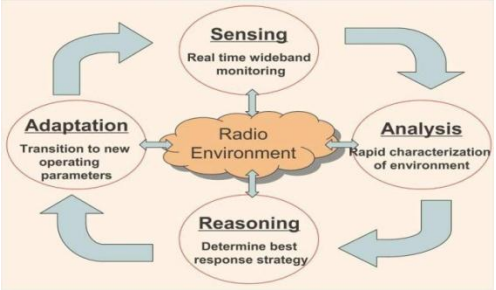

Figure 1: Cognitive Radio cycle

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Sensing is the first and important phase in which the white band of the entire spectrum is monitored in real-time to check for the white spaces that are available for the additional users. White spaces are considered the frequencies that are free from used by the primary users for a limited duration of time. The cognitive radio frequencies will make use of all the available white spaces in the spectrum so that the existing primary users are not disturbed for the performance are transmission in anyway. The sensing phase is followed by an analysis in which the characterization of the entire environment is performed. The white spaces cannot be considered for transmission immediately as there are available but it should be carefully analyzed for all the technical parameters including performance, transmission, signal quality, etc. Before they can be adapted for cognitive radio users. The frequency specifications are available to be read and analyze for all the users so that cognitive users can make the best use of the available bandwidth in order to consider the transmission [7]. The frequency specifications are analyzed by the cognitive users before they can be adapted for the environment. Cognitive radio also has an advantage in using the same spectrum for a large number of Communications. The capacity limitations and the approaches used in cognitive radio set up are different compared to the traditional radio systems. The design and the utilization of the spectrum depending on channels, messages, sharing of the nodes along with the data. In reasoning and adaptation are the next two faces in the cognitive radio cycle that are related to implementation and transmission of the data after careful analysis of the spectrum and the bandwidth available for the users.

2. Related Work

Sensing the channel for the availability of spectrum and bandwidth for accommodating additional users can be done using three simple approaches-overlay, underlay, and interweave.

Underlay is the concept that uses the knowledge of the interference to detect the white spaces so that new users can be accommodated in the cognitive radio system. The interference between the existing frequencies which are called the primary users and the new users called secondary users can be used to detect because of the signal conflicts with the existing ones that can be used to detect the presence of the primary user. The frequencies of the cognitive radio systems are comparatively lower than the frequencies of the primary users. The difference between the frequencies of the primary and secondary users should be below the threshold used in the design of the cognitive radio systems because that maintains the minimum required quality of the signal to the secondary users. There are multiple approaches used for this paradigm. Multiple antennas can also be used to repel the cognitive and non-cognitive signals that are directly connected to the primary and secondary uses of the system away from each other[5]. Wide bandwidth can also be used in order to spread the signals of the cognitive radio setup that should be way less than the signal of the noise band. The threshold level can also be maintained by using a transmitter setup for cognitive signals. Short-range communication can be effectively achieved using the underlay method because the difference between the two types of signals can be easily achieved and the same separation can be maintained using many approaches [3].

The underlay method has been popular and used by the various user who would like to accommodate the secondary users between the primary users in the licensed band. One important parameter is the interference temperature that can be effectively used to measure the difference between the two types of signals. The power of the radio frequency can be measured using antennas so that the threshold level and the power ratings can be calculated. Another approach is to measure the signal to noise ratio to check if the secondary user can be accommodated within the same band as a primary user.

Overlay –Overlay is the method in which both the cognitive and non-cognitive users can be accommodated simultaneously. There is no interference even when both the users are transmitting the data. This method also allows the data of one user to be hidden from the other in case both of them are transmitting the information. The interference between cognitive and non-cognitive users can be avoided by using encoding techniques. The encoding should be directly related to the cognitive user because then non-cognitive signals are the primary users who have already been accommodated using the available bandwidth. There are many practical issues including interference that may arise if the proper encoding has not been used between cognitive and non-cognitive signals. There could be delays or communication failure if the interference becomes higher than the threshold.

Interweave - This approach requires both the cognitive and non-cognitive signals to transmit information together but without the interference. There are a large number of applications that this method for cognitive radio applications. The interference is caused by various channels when the proximity of the channels increases. This could also lead to the degradation of the quality of the signal. The cognitive signal should be transmitted over the gaps between the non-cognitive signals without any degradation or interference using this interweaving technique. It is a common phenomenon to observe higher levels of noise both primary and secondary users are transmitting the signals. The data transmitted through non-cognitive signals is not constant throughout the transmission duration. It is important to understand that there are variations in the signal with respect to quality, strength, power, amplitude, noise ratio, etc. These fluctuations should be considered and the detection method for cognitive bands should be designed in such a way that they consider the fluctuations and avoid false negatives of false positives.

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Sensing of the Spectrum - The design of the cognitive radio systems can be initiated only after the channel sensing and analysis stages are completed. Channel sensing can be performed using different mechanisms after selecting one of the three above-described techniques. Sensing of the spectrum essentially means that the gaps in the spectrum and the presence of the user should be detected. The detection using spectrum interference temperature is a technique that uses the temperature rise due to the presence of the primary user. It is possible that there is no interference during network transmission due to the limited power of the transmitted signals. Limiting the frequency will also result in the loss of power which is not preferable for signal quality. Interference may also appear due to any undesirable noises of the frequencies that are transmitting the data [4].

The comparison between different channel sensing methods offers the technical reasoning required to select the right method for each application. The underlay method is used when certain technical parameters such as interference temperature and signal power can be measured, for the primary users. The overlay method considers the issues with encoding between the primary and secondary users. This method requires expertise for design and implementation. The applications using an overlay mechanism requires encoding requirements. The interweave method considers the quality of the signal as it considers the quality and noise levels. The most important difference between the methods is the nature of the application and how they can be chosen for their highlighted parameter.

Channel sensing mechanism – Channel sensing with respect to cognitive radio is a complex process and several aspects should be considered before the channel is detected and the cognitive users are implemented. One of the major parameters is related to the sensing model that is used to design the channel. The channel sensing model is related to how the white spaces are detected in the network band using all the network resources in order to accommodate the cognitive uses. There are several techniques including the statistical methods and the concepts from game Theory that are popularly used in channel sensing. Another aspect to be considered during cognitive radio design is to check if the interference is lesser than the threshold value for all the secondary users to be accommodated, the efficiency of the technique depends on how the cognitive radio users can allow the new users without any interference for signal degradation. Statistical analysis methods are extensively used to test the sensing techniques and their efficiency because the system is dynamic and the parameters change randomly. The statistical methods are used to check the likelihood of interference when the secondary users start transmitting the network data. The cooperation between primary and secondary users should be below the threshold value and the secondary users are not allowed to cause any additional interference to the primary uses during transmission [11].

The control mechanism, data fusion, user behavior, and database are the other factors that can significantly influence the performance of cognitive radio systems [8]. The control mechanism used to efficiently transmit the information when both primary and secondary users are sending data should be designed to use all the resources effectively [6]. There are certain network resources that are often shared by both primary and secondary users [11]. The cooperative game and overhead of the Internet work when both primary and secondary users are busy transmitting information should be considered for making any decisions. The data transmitted also required certain techniques for fusion because some of the data is transmitted and used by both users [7].

Energy detection has also been a topic of research on cognitive radius because the primary' users and secondary users have different levels of energies that should be considered used during the design of the cognitive model.

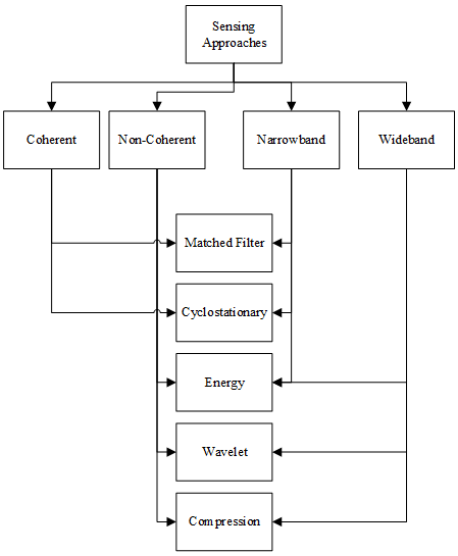

Figure 2: Classification of channel sensing mechanisms

3. Design

Channel sensing mechanism can be designed using All the above-described parameters in the following steps,

1. The selection of the channels for data transmission requires various network parameters such as the route to next hop, traffic, data quality, and signal strength, etc. to be considered.

2. Each of the network parameters considered in the design is assigned with certain specific values. Statistical analysis and calculation of each parameter is an important step so that the threshold value for or packet drop should be set to minimum and it should be taken interference should not be a problem [10].

3. 5 packets can be considered reasonable value for faults for every thousand packets in order to ensure that the efficiency is height throughout the transmission. The traffic value and the utilization of the resources related to

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the bandwidth of the system directly contribute to the deficiency of the network. Background traffic should be approximately 35% compared to the available bandwidth. Maximum bandwidth that can be utilized during transmission can be set to around 50%.

4. It is essential to scan all the channels for the network parameters. The design of the system should be considered and preceded only if all the network values are within the threshold value of the design. Any large deviation of the parameters will only result in the degradation of the quality and inefficiency of the cognitive systems.

5. The values of each of the network parameters should be stored within the tool so that the design changes can be made instantly without changing the entire architecture. The optimum values within which the deviations can occur should be entered in the network tool[16].

6. The channel sensing mechanism is implemented to detect a channel that can successfully fulfill all the requirements of the network resources and parameters. If a channel is detected if the flag value is set to high in order to mark that the network destination is optimum and can be reached.

7. If there are no matching network values with respect to the requirements of the system, all the steps are repeated until the optimum values are found that match the requirement.

8. First In First Out (FIFO) order to send the signals if the channel has been selected.

9. The network transmission is said to be completed only if all the data packets have been sent to the new channel. Another condition that can complete the transmission is the bandwidth utilization which can be set anywhere between 60% to 80%.

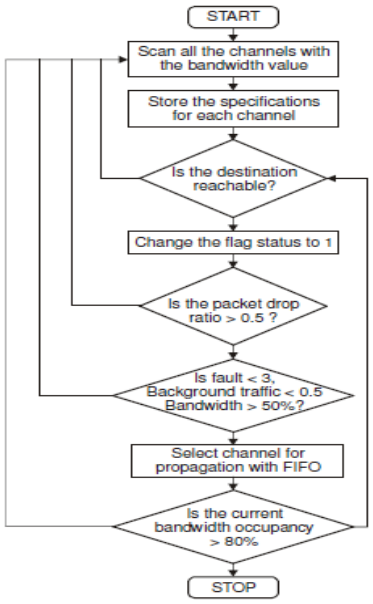

Figure 3: Flowchart of channel sensing mechanism

The design of the system is as shown in figure 3. The process can be described as follows. The first step is to scan all the channels with the available brand value. The bandwidth value can be set in the network tools which and are the result of the analysis methods [11].The bandwidth values should be scanned across all the available channels in order to find the right channel. The specifications of each channel should be stored in the network tools so that the optimum level within the minimum deviation can be checked. There actability of the destination is then considered only after the specifications and the bandwidth is found to be within the limits. The network implementation is preceded only after the decision on the destination is successful [12]. It is important to mark that the destination is reachable in the network tool so that all the other parameters can be fixed during the transmission. Flag status can be used for this purpose in which the status of the flag will indicate every network parameter and the tool that the network has been successfully implemented. Packet drop ratio, fault, background traffic, and bandwidth values are checked in a particular sequence in order to ensure that the data transmission can be successful [14].Channel is then selected after all the parameters are found to be optimum [15]. First, in first out order is used for data transmission in the selected channel. The data is transmitted until the bandwidth is reached to 80%.It is not possible to use all the bandwidth because there are certain restrictions on the use of the bandwidth and the network resources for optimum performance. This process is repeated for as long as all the parameters are within the optimum range.

4. Conclusion

This research paper has presented the details on the channel sensing mechanism and approaches used for data transmission in the cognitive radio systems. There are various approaches used for sensing the channel capacity based on the network resources and various technical parameters. The approaches used different statistical methods and parameters within the specification in order to ensure that the performance is optimum. The paper also provides details on how much a novel sensing mechanism can be implemented using an optimal design That considers various network parameters and resources.

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