Channel Sensing Mechanisms In Cognitive Radio System

J. Divya Lakshmi, Rangaiah L

Abstract: Cognitive radio is an advancement of the wireless technologies in which different licensed and unlicensed users can be accommodated into the same network spectrum. Cognitive radio allows the effective utilization of the network resources and the bandwidth which is idle most of the time if only primary users are allowed. Accommodating secondary unlicensed bands into the network spectrum is a complex process. The first step involved in this process is to sense the channel to check if all the network parameters allow a new user in the unlicensed band. There are several channel sensing mechanisms and approaches that can be used for specific requirements. This paper lists and analyzes several channels sensing approaches and compares the efficiency. Among the channel sensing mechanisms are analyzed for their efficiency in various conditions and requirements. The implementation complexity and accuracy of each approach are analyzed qualitatively. A generic algorithm on how the secondary users can sense the network and transmit the data is also provided. The implementation guidelines can be followed to simulate the channel sensing mechanism in any network tool.

Index Terms: Bandwidth, Channel sensing, Cognitive Radio, Network analysis tools, Network Design, Network performance, QualNet.

1 INTRODUCTION

The spectrum used for wireless communication is crowded on a daily basis. There are various reasons for the same; the number of subscribers is increasing under spectrum has limitations with respect to technical specifications. It is also found that the spectrum is severely underutilized for its capabilities. The wireless spectrum is not utilized in the same way throughout the day. The utilization significantly varies depending on the geographical location of the spectrum. The static allocation of the spectrum and its wireless technologies does not allow the users to utilize every aspect of the spectrum. It is important and necessary that the spectrum is utilized efficiently at all times [1]. It is possible to improve the utilization of spectrum by allowing more channels in the unlicensed band of the spectrum. Several and licensed users can be accommodated in the spectrum which is underutilized to increase the number of channels. The current arrangement in the wireless spectrum is that if a new user wants to use the channel, it is necessary that the existing channel should quit using the spectrum. The concept of cognitive radio has coming to picture to address this issue and use the channel efficiently by accommodating several and licensed users by using the resources efficiently [2].

2 RELATED WORK

The characteristics of cognitive radio present various features that are specifically designed to address the issues in the conventional network spectrum. Various technical aspects and transmission parameters such as frequency can be customized and changed if required when a cognitive radio setup is used.

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One of the major requirements of cognitive radio is that the existing license to band should never interfere when a new and licensed user has to you transferred using the same spectrum. It is also required that the unlicensed band user should be able to quit when a licensed user request. The first step is using cognitive radio spectrum sensing. There a process in which the unlicensed band user census the available spectrum with respect to every technical aspect and then uses the unutilized spectrum. There are various approaches to spectrum sensing [3][4]. The approaches differ in using one parameter that is the most important for a specific type of transmission. The fixed spectrum bands and licensed users in the wireless network setup is a traditional way of using network resources. The resources of the network are utilized by all authorized users in the network. The typical usage of the spectrum is anywhere between 20 % to 80% depending on the location of the network. The concept of introducing secondary users has several advantages over the traditional network system. The capability of the cognitive system depends on how well the information from the surroundings and other network resources have been determined before introducing a secondary user so that there is no interference between the primary and secondary users. The first and the major objective of the cognitive radio are to identify underutilized spectrum and The White spaces which can accommodate the secondary users. The operating parameters should also be matching and the compatibility between the primary and the secondary result should be high. Spectrum sensing is the first step in cognitive radio where the spectrum is analyzed and the parameters are checked before the secondary user can be accommodated [7]. The entire process of using cognitive radio and various steps involved is called a cognitive cycle. The information on the existing network parameters such as frequency, network utilization, and other parameters should be gathered and an algorithm should be followed before the spectrum decisions can be made. The transmission data rate and the bandwidth utilization for also determine before the secondary user can be introduced into the system. The approach called Cooperative sensing is commonly used in cognitive radio set up where the spatial diversity of the cognitive radio users is explored efficiently to change the spectrum for the secondary users. When two or more users are located near to each other geographically the sensing information can be shared among

all the users. It is also possible to share the decisions and certain technical specifications between the users so that the sensing mechanism can be implemented afterward. There are several advantages of cooperative sensing mechanism. The details of the network can be shared, the performance can be improved and the sensing mechanism can be efficient. The signal-to-noise ratio is an important parameter that can be used to detect the signals to check if the secondary user can be accommodated. The sensitivity for determining the SNR ratio is an important parameter because lower intensity signals cannot be detected easily [6]. The complexity of the implementation will increase if the machine detects weak signal. The Cooperative sensing mechanism will address this issue by using multipath fading along with other techniques such as shadowing. The sensitivity of the receiver can be adjusted to you are certain level which is equivalent to the loss occur due to nominal part. This can be implemented without any increase in the complexity for cost of the existing mechanisms. The Cooperative mechanism can also be helpful in improving efficiency using other methods. It is important to reduce the sensing time so that the secondary users can be accommodated immediately into the spectrum and the transmission can begin sooner. The other advantage of this operation is that the throughput can be improved if the sensing mechanism is quick and efficient.

Elements to be considered for Channel Sensing

There are various elements that need to be understood and analyzed before the spectrum sensing can be implemented. The three important steps in channel sensing mechanism are related to sensing, reports, and fusion of the data. There are certain elements at the fundamental level which include the network specifications and other technical details responsible for the sensing process [8][9].

Sensing model - this the approach used by the network designer to change the channel. The way the secondary users can sense if the white spaces are available and the primary users are underutilizing the network resources is called the sensing model. Network models that involve parallel fusion and other techniques which have been developed from Game Theory and other statistical analysis methods are popularly used in sensing mechanism.

Techniques used - the environment that is busy with radio frequency signals in which certain samples have to be taken to check if the interference is minimum and the secondary users can also be accommodated by using the signal sensing capabilities of the model. The cooperation between the cognitive radio users to alone new users to accommodate the system and then function efficiently without interference determines the efficiency of the technique [12].

Testing - The statistical analysis of the sensing techniques used in the presence and absence of the cognitive user transmitting the radio signals is essential before the system can accommodate both primary and secondary uses. Each secondary user is subjected to different statistical tests to check if the core operations between secondary and primary users are below the threshold for interference and the Cooperative decisions taken by the secondary uses do not disturb the efficient functions of the primary user.

Control mechanism - The channel that uses both primary and secondary uses should be aware of the control mechanism designed to efficiently transfer the information when both of them are functioning simultaneously. The bandwidth and fading concepts are used to accommodate both the channels [11].

Data Fusion - There are several results and design outputs that are applicable to both the uses. It is possible to combine certain results to make a decision that is applicable to both primary and secondary users. The signal combining and other operations allow the design to be efficient in data transmission with high throughput when both the users are transmitting the information with no interference.

Users - It is important to increase the Co-operative gain and decrease the overhead cost when both the users are using the channel. Different user among the available secondary user should be chosen to check if the entire model fits into the required efficiency requirements and can be accommodated within the available space of the spectrum.

Database - The spectrum sensing mechanism can be improved if all the details of the operations are stored securely in a database. It is important that all the details and log are maintained in a secure database because there are several security issues, throughput and other requirements that can be checked and improved when the database is available [10]. Various approaches for spectrum sensing are used in the literature. Various approaches and methods used in spectrum sensing are classified and analyzed. The signal detection mechanism can be classified broadly into coherent and noncoherent types. The basic difference between the coherent and noncoherent mechanisms is that the knowledge of the primary signal and the user transmitting information is checked before the secondary user can be accommodated in a coherent mechanism. No knowledge of the primary user is required in case of a non-coherent signal sensing mechanism. It is also possible to classify the signal sensing approaches using the technical parameters. Wideband and narrowband are the two types of classification when the parameters are considered [12]. This classification is not complete and is only restricted to the most popular mechanism combined using the similarities in the available techniques.

Energy - The research on the detection of the energy of the primary user in order to accommodate the secondary user is vast and extensive. The concept is related to noncoherent detection of but there is no information on the primary users before protecting the energy transmitted. This method is one of the most popular techniques used to detect the channel and sense the parameters. This method is also quick because there is no other parameter used to send the channel but energy. The major disadvantages of this method related to the time, noise, and classification of the users. The energy of the signal is the only parameter, the time taken to detect and calculate the energy is often filed in many cases. If the time taken by the system to determine the energy depends on several other parameters due to uncertainty of the signal transmission, the subsequent channel sensing and transmission corporation also take time. This method will essentially improve the overall time taken for sensing and transmission. It is also possible that there are certain

undesirable noises in the network transmission that will add up when energy parametric is being determined. The energy mechanism does not effectively distinguish between the signals of the primary and secondary users when a set of existing secondary users are already using the spectrum [1].

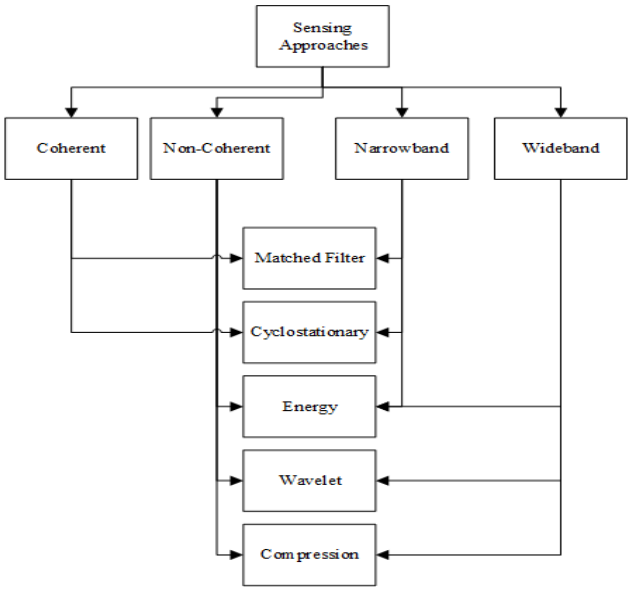

Figure 1. *Classification of Channel Sensing Mechanisms [1]*

Cyclostationary - Technical parameter that can be used to identify the difference between the primary and secondary signals is the periodicity. It is possible to determine certain network parameters so that the signals can be classified at the grass-root level. This method can also be improved by adding several other technical network parameters to determine the signal and also classify them. The major difference is that several parameters can be involved in this method and like the energy parameter used in the previous method. The complexity of this method is high because required that all the network parameters should be determined before employing in this mechanism [1].

Matched Filter - The matched filter mechanism works on taking a particular segment of the network data and matching it with the requirements of the secondary user to check if the channel is free to accommodate the secondary signal without any interference. This mechanism is based on the security principle used in several cybersecurity methods where a particular segment is checked for all the network parameters and functions before they can be classified.

Compressed - The above-described methods function appropriately when Satin network parameters for energy parameter is considered for signal sensing. This method is applicable only if one frequency band has to be determined. These mechanisms are not applicable when multiple bands have to be sensed. The problem intensifies when wideband is considered because the time taken to send the channel will be significantly increased which will deteriorate the efficiency and performance of the channel [9][10]. The concept of compressed sensing is effectively used because the recent compression techniques allowed the signal to be sensed at a compressed state. The primary signals can be sensed in case of white band setting buy sampling and using the matrix operations to check if the primary signal can accommodate a secondary user.

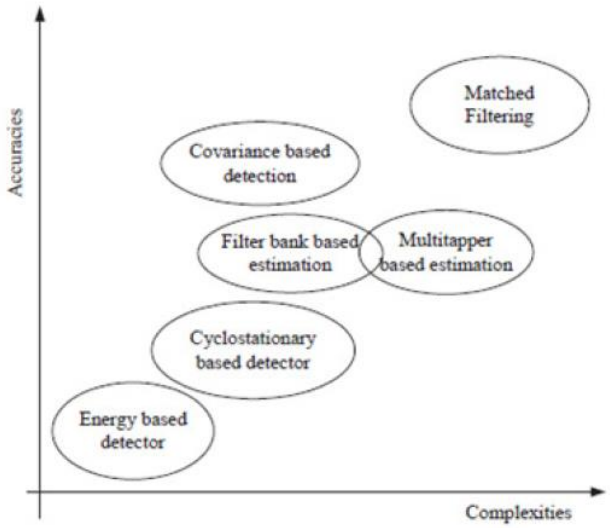

Figure 2*. Comparison of channel sensing mechanisms for complexity and accuracies [7].*

3 DISCUSSION

There are various uncertainties and challenges involved in the spectrum sensing mechanism. These challenges are related to two different network parameters because the perfect channel sensing mechanism does not exist. There are loopholes in every method. The following set of issues should be overcome before a channel sensing mechanism can be enhanced for its efficiency. The accuracies and the complexities are compared for each channel sensing mechanism and are shown in figure 2[7].

Uncertainty of the channel

The various channels sensing mechanism depends on energy, throughput, noise, and other parameters to check if the channel is free for accommodating a new user. However, this channel sensing mechanism does not consider the uncertainty in the channel as a major hurdle in implementing the sensing mechanism. The channel in the spectrum undergoes various operations and also shows the strength of the channel decreases due to shadowing and fading effects. In such cases, the channel sensing mechanism can incorrectly interpret these operations as non-availability of the secondary channel for transmission. It is important to note that the sensing mechanism works only for a very short duration of time. It is not easy to program or determine the exact operations of a signal during its transmission. If the channel is subjected to fading, it is not possible to determine exactly how long the signal strength may be deteriorated. Therefore, it is important that the sensing mechanism considers these operations and signal feeding mechanisms to determine if the channel is not available at all for the uncertainty exist. The other way is also possible when the signal is exhibiting higher levels of suitability and the sensing mechanism considers this specific segment as the property of the entire signal throughout the transmission. In such cases also the sensing mechanism can incorrectly identify the channel and show false positives. The sensing mechanism should effectively

implement two types of operations in which the sensing operation is checked for short and long period of time. The exact duration can only be determined after careful analysis of the channel. If the observation period is long enough the chances of channel sensing operation to detect the channel is high whereas if the sensing period is short, the chances of indifference from the primary user are high[14]. A perfect trade-off between short and long observation period is the skill of the designer based on the network parameters and properties of the spectrum [15].

Noise - the determination of noise in the secondary channel is used commonly for sensing the spectrum. The sensitivity of the channel is determined by using the signal to noise ratio of the cognitive radio users. It is essential to know the exact noise value before the sensitivity of detection can be determined. The estimation of the noise power provides the details of several other parameters to ensure that the secondary channel is free for transmission. Sensitivity detection is a complex process that has several network parameters.

Interference - a major factor that determines the efficiency of the cognitive radio set up is interference. The channel sensing mechanism is the first step in determining if a secondary user can be accommodated into the channel where the primary user is transmitting information without any interference. Interference is a parameter that depends on other parameters such as noise, fading, throughput, delay, etc. Aggregate interference is the value which is determined by calculating the overall interference from all the users in the network band. The major requirement is that the interference between the primary and secondary users should be minimum. However, the value of the aggregate Indifference can interfere with the secondary users and cause uncertainty. In such cases, calculation of the sensitivity and other parameters has to be repeated to ensure that the interference will not cause major issues. The secondary user is not allowed to disturb or interfere with the operations of a primary user as per the principles of cognitive radio. Therefore, importance should be given to interference and other parameters before the sensing mechanism can detect a space for secondary users. As mentioned before, the Network operations in a cognitive radio setup are highly uncertain. The measurement of the interference provides appropriate results only if the primary user is using the network resources to the maximum level. If the network is idle when the sensitivity and interference measurements are performed by the secondary user, the result will be inaccurate. It is also possible that the licensed primary user is a passive entity that will be active only for a certain amount of time and inactive otherwise. This issue can be overcome only if the right amount of duration can be calculated for which the sensing mechanism has to be implemented [14].

Frequency Band and synchronization - Determining the best frequency band available for the secondary uses in the cognitive spectrum is a challenging task. There are two approaches to sensing the right frequency band - proactive and reactive. The proactive system keeps checking the frequency band at regular intervals of time to determine if the secondary user can be accommodated. The reactive system works only if the parameters related to primary users are favorable and the sensing mechanism can be executed. When there is a transmission between two secondary users, several parameters have to be considered because the target spectrum band should not be utilized by any other users and all the network parameters should accommodate the hand-off operation. The designer should ensure that the synchronization between different secondary users and between the primary and secondary user is always high [15][16].

4 IMPLEMENTATION

The channel sensing mechanism and the cognitive radio setup can be simulated using different network tools. The basic steps involved in the general algorithm for implementing a channel sensing mechanism are explained as follows.

1. The network parameters such as packet drop ratio, route to next hop, faults, traffic, and bandwidth are considered to select the channels for transmission.
2. A set of network parameters are assigned values in a generic sense (are based on the exact calculation and design). The threshold for the packet-drop ratio can be set to 0.5 so the drop ratio is minimum and does not cause the interference.
3. The fault value can be set to less than 5 packets for 1000 packets to ensure that the efficiency of the system is high.
4. The value of traffic to be set determines how efficiently the bandwidth is utilized during network operation. The average value of background traffic can be set to approximately 40% and the value of Band would be used at all times for communication can be set to 50%.
5. Given the parameters, the Sensing mechanism is executed and all the channels are scanned for the given values of network parameters.
6. The values of each parameter are stored in the tool for every channel so that all the channels can be compared.
7. If a channel sensing mechanism detects a channel that fulfills all the requirements using the network parameters, a flag value one to mark that the destination is reachable.
8. If the network parameter values do not match the requirement, the above-described steps are repeated until a channel is found.
9. Once the channel is selected. The propagation of signals in that selected channel follows first in first out order.
10. All the data packets should be sent to the new channel or until at least 80% of the bandwidth of the new channel is utilized.

5 CONCLUSION

Among the various spectrum sensing techniques, coherent and noncoherent Systems have been analyzed in this paper. The classification of channel sensing mechanisms can be different when other parameters are considered. The parameter used in this classification is the knowledge of the previous channel available for the channel sensing mechanism. Different parameters that fall under coherent and noncoherent mechanisms are also analyzed. There are various parameters that determine the efficiency and throughput of the secondary user in a cognitive radio setup. These parameters should be carefully designed and

implemented in a simulation tool before they can be tested in Real world conditions. This study can be extended to involve the technical details and derivation of the network parameter values to provide a Framework for channel sensing mechanism.

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