Network and Complex Systems
ISSN 2224-610X (Paper) ISSN 2225-0603 (Online)
Vol.3, No.9, 2013

A Review paper based on spectrum sensing techniques in Cognitive Radio Networks

MOHD Sajid Imam
Dept. of ECE, GEU, Dehradun, Uttarakhand, INDIA

Sheetal Ingle
Dept. of ECE, GEU, Dehradun, Uttarakhand, INDIA

Shabnam Ara
Dept. of ECE, Tulas Institute of Technology, Dehradun, Uttarakhand, INDIA

Abstract

Natural frequency spectrum is scared resource; the efficient use of it can only accommodate the need of future computing world. But efficient use of it is not possible within the existing system, where the allocation of spectrum is done based on fixed spectrum access (FSA) policy. Many survey shows that it leads to under use of spectrum. For efficient utilization of spectrum innovative techniques is needed. using Dynamic spectrum access (DSA) policy we can exploiting the available spectrum, For given purpose Cognitive radio arises to be a tempting solution to the spectral congestion problem by introducing opportunistic usage of the frequency bands that are not heavily occupied by licensed users. This paper presents the study of different spectrum sensing techniques of cognitive radio networks. As we know Cognitive radio is a form of wireless communication where radio transceiver intelligently detects which spectrums are free which are not. After this it occupies the vacant one while avoiding busy one spectrum. Cognitive radios promote open spectrum allocation which is a clear departure from traditional command and control allocation schemes for radio spectrum usage. In short, they allow the formation of “infrastructure-less” collaborative network clusters—cognitive radio networks. However, how to detect free spectrum we have to use the spectrum sensing techniques, here we are describing all the spectrum sensing techniques and Finally concluded that cooperative sensing is better than Non-Cooperative sensing for primary user (PU) signal with low SNR value.

Keywords- CRN, FSA, PU, DSA, SU, SNR..

I. INTRODUCTION

Wireless technology will be the backbone of the future computing world one in which a large number of communicators, mobile devices and sensors are connected to the global Internet and serve as the basic block for many stirring new classes of applications. As we know that natural frequency spectrum is scared resource, the efficient use of it can only accommodate the spectrum demand of future computing world. The existing fixed spectrum access (FSA) policy is not suitable for it as it uses spectrum in very inefficient way. Graph based on Resent survey regarding partial use of spectrum in FSA scheme is show below in Figure1.

Finding of this serve suggest that for efficient utilization of spectrum innovative techniques is needed. One can offer new ways of exploiting the available spectrum by using Dynamic spectrum access (DSA) policy. For given purpose Cognitive radio arises to be a tempting solution to the spectral congestion problem by introducing opportunistic usage of the frequency bands that are not heavily occupied by licensed users as we can see in figure 1.

Now A Cognitive radio is a system that senses its operational electromagnetic environment and can dynamically and autonomously adjust its radio operating parameters to modify system operation, such as maximize throughput, mitigate interference, facilitate interoperability, access secondary markets.” [1]

The rest of the paper is organized as follows: Section II presents the classification of spectrum sensing technique. Section III describes our proposed analysis. Section IV concludes the paper.

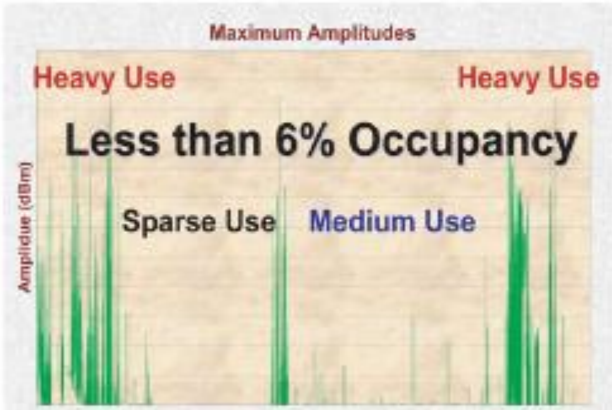

Figure1. Spectrum usage [2]

➢ ***The Functions of Cognitive Radio***

- **Spectrum sensing and Analysing:** Determine which portion of the spectrum is available and detect the presence of licensed users when a user operates in a licensed band.

- **Spectrum management and Handoff:** It selects the best available channel (frequency) for communication.

- **Spectrum sharing and Allocation:** It coordinates fair spectrum access to this channel with other users.

- **Spectrum mobility:** Vacate the channel when a licensed user is detected while still maintaining seamless communication requirements during the transition to a better piece of spectrum.

➢ ***Approaches for accessing Licensed Spectrum***[Figure2]

Three main approaches have been developed for cognitive radio, regarding the way a secondary user accesses the licensed spectrum:

- Through opportunistic spectrum access (OSA), also known as interweave scheme, according to which a secondary user accesses a frequency band only when it is detected not being used by the primary users [14].

- Through spectrum sharing (SS), also known as underlay scheme, based on which the secondary users coexist with the primary users under the condition of protecting the latter from harmful interference [15-16]

- Recently, a third hybrid approach was proposed, aiming to increase the throughput of the two aforementioned schemes, in which the secondary users initially sense for the status (active/idle) of a frequency band (as in the OSA) and adapt their transmit power based on the decision made by spectrum sensing, to avoid causing harmful interference (as in SS) [19].

Whatever the approach is, it is clear that spectrum sensing is the key for all of them. Thus we can say that without highly accurate and accomplished spectrum technique it is very difficult to make competent Cognitive radio system.

In this paper our discussion will revolve around different spectrum sensing techniques and their advantages as well as disadvantages.

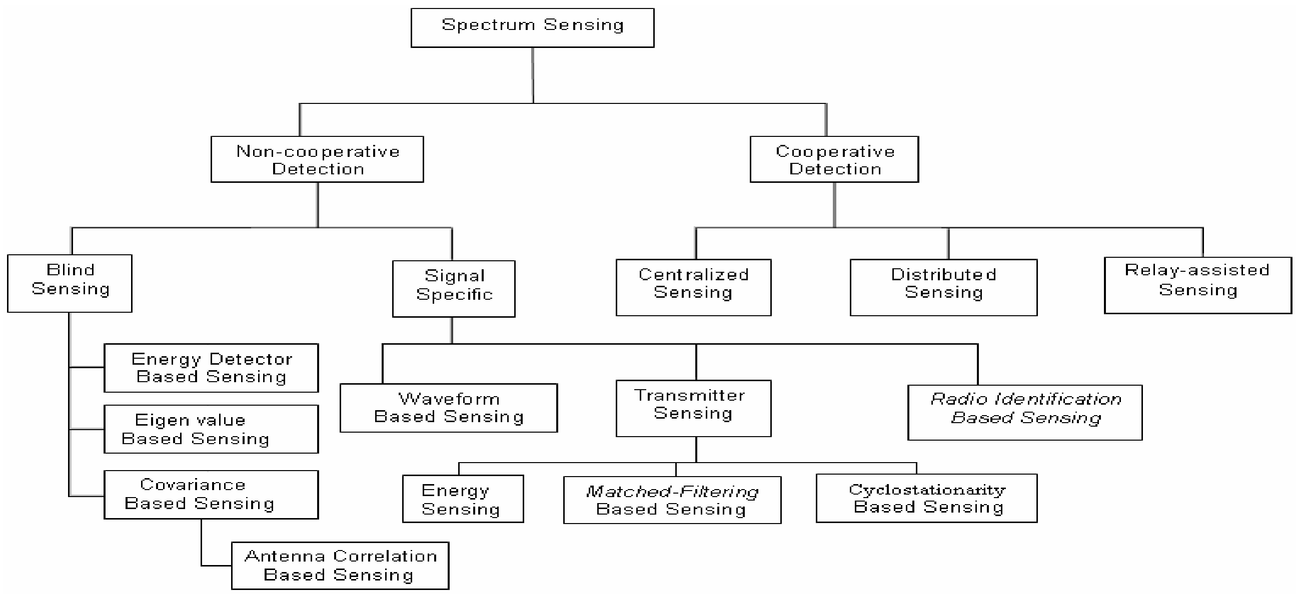

Figure 3. Spectrum sensing techniques

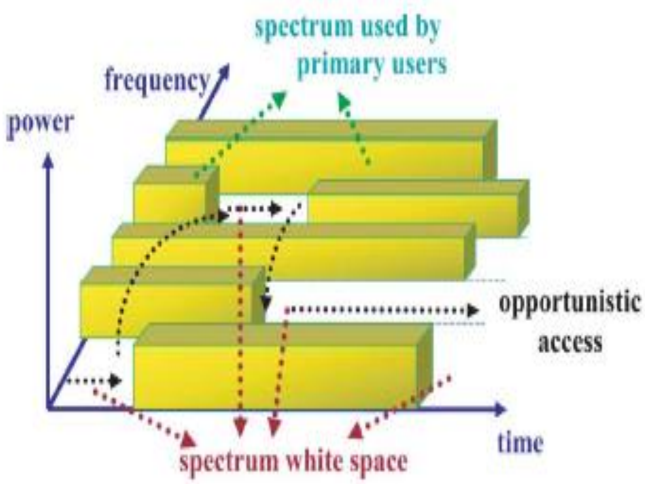

Figure 2. Illustration of spectrum white space [2]

II. CLASSIFICATION OF SPECTRUM SENSING TECHNIQUE

We can broadly divide spectrum sensing techniques under two categories.

1. *Cooperative Detection Technique.*
2. *Non-cooperative Detection Technique.*

1. Cooperative Detection: In this method group of CR's share sensing information so as to get a more efficient result. In this process group of secondary user (Su) collect the information regarding channel occupancy and maintain this information into spectrum map represented by bit-vector. Su periodically transmit it to the Central Coordinator as part of control message. Central coordinator takes bitwise-OR of spectrum maps, to determine the set of UHF channels available at all of the nodes. After that Coordinator select the best available channel and broadcast it back to Su. This technique exploits the spatial diversity intrinsic to a multi-user network. It can be accomplished in a centralized or distributed fashion.[5]

There are broadly three approaches for cooperative spectrum sensing:

a) Centralized approach: In this approach to cognitive radio cooperative spectrum sensing, there is a node called fusion center (FC) or central processor controls within the network that collects the sensing information from all the sense nodes or radios within the network. It then analyses the information and determines the frequencies which can be used.[8]

b) Distributed approach: In this approach distributed approach for cognitive radio cooperative spectrum sensing, no one node act as fusion center (FC) or central processor controls. Instead communication exists between the different nodes and they are able to share sense information. However this approach need individual radios to have a much higher level of autonomy, and possibly setting themselves up as an ad-hoc network.[9]

c) Relay-assisted cooperative: Besides centralized and distributed cooperative sensing, the third scheme is relay-assisted cooperative sensing. Since both sensing channel and report channel are not perfect, a CR user observing a weak sensing channel and a strong report channel and a CR user with a strong sensing channel and a weak report channel, for example, can complement and cooperate with each other to improve the performance of cooperative sensing. When the sensing results need to be forwarded by multiple hops to reach the intended receive node, all the intermediate hops are relays. Thus, if both centralized and distributed structures are one-hop cooperative sensing, the relay-assisted structure can be considered as multi-hop cooperative sensing.

2. Non-Cooperative Detection: In this Detection technique Individual radios act locally and autonomously to carry out their own spectrum occupancy measurements and analysis. [10]

There are broadly three approaches for cooperative spectrum sensing:

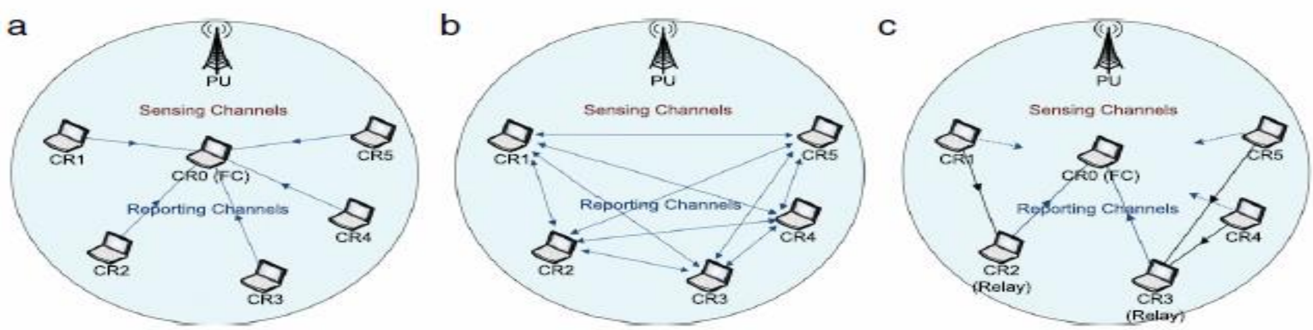

Figure 4. Classification of cooperative sensing: (a) centralized, (b) distributed, and (c) relay-assisted [18]

a) Blind Sensing: In this approach to cognitive radio cooperative spectrum sensing, there is a node called fusion center (FC) controls within the network that collects the sensing information from all the sense nodes or radios within the network. It then analyses the information and determines the frequencies which can be used.

1. Energy Detector based sensing: If a receiver cannot gather sufficient information about the primary user's signal, such as in the case that only the power of random Gaussian noise is known to the receiver, the optimal detector is an energy detector. Energy detection is simple and can be implemented efficiently by using a Fast Fourier Transform (FFT) algorithm. However, there are some drawbacks for energy detection. First, the decision threshold is subject to changing signal-to-noise ratios (SNR's). Second, it can not distinguish interference from a user signal. And third, it is not effective for signals whose signal power has been spread over a wideband [17].

2. Eigen value based Sensing: The eigenvalue of the covariance matrix of the received signal can also serve the purpose of primary detection. With the help of random matrix theory, the ratio of the maximum eigenvalue to the minimum eigenvalue is quantized, and one of the quantized values is chosen as detection threshold is. [3,4]

3. Covariance based Sensing: As a matter of fact statistical covariance matrices of the received signal and that of noise are normally different. By utilizing this difference we can differentiate the desired signal component from background noise.[6,7]

- **Antenna Correlation Based Sensing:** Antenna correlation based detector by extending the covariance based detector from time domain to space domain via exploiting the correlation among antennas. Obtaining threshold level to achieve required probability of false alarm due to the approximate in the derivation which is helpful in order to sense spectrum.

b) Signal Specific: This sensing technique requires prior knowledge of Primary User (PU) signal.

1. Waveform based Sensing: This method is only applicable to systems with known signal patterns which could be preambles, midambles, regularly transmitted pilot patterns, spreading sequences and etc. It is termed as waveform-based sensing or coherent sensing. It is shown that waveform based sensing outperforms energy detector based sensing in reliability and convergence time. Furthermore, it is shown that the performance of the sensing algorithm increases as the length of the known signal pattern increases. [11-13].

2. Transmitter Based Sensing: Here, the cognitive radio attempts to discern areas of used or unused spectrum by determining if a primary user is transmitting in its vicinity. This approach is predicated on detecting not the strongest transmitted signal from a primary user, but the weakest. The idea is that the weakest signal producing primary transmitter would ideally be the one furthest away from the cognitive radio, but still susceptible to RF interference from the radio. The basic hypothesis for transmitter detection as:

$$x(t) = \begin{cases} n(t) \ H_0 \\ hs(t) + n(t) \ H_1 \end{cases}$$

Here, x(t) is the signal received by the cognitive radio, s(t) is the transmitted signal of the primary user, n(t) is all white Gaussian noise (AWGN) and h is the amplitude gain of the channel. H0 is a null hypothesis, which states that there is no licensed (primary) user signal in a certain band. H1 is an alternative hypothesis, which indicates that there exists some licensed user signal. The three main detection techniques which rely on this hypothesis for transmitter detection are described below.

- **Energy Sensing:** If a receiver cannot gather sufficient information about the primary user's signal, such as in the case that only the power of random Gaussian noise is known to the receiver, the optimal detector is an energy detector. Energy detection is simple and can be implemented efficiently by using a Fast Fourier Transform (FFT) algorithm. However, there are some drawbacks for energy detection. First, the decision threshold is subject to changing signal-to-noise ratios (SNR's). Second, it can not distinguish interference from a user signal. And third, it is not effective for signals whose signal power has been spread over a wideband.

- **Matched Filter Sensing:** The matched filter works by correlating a known signal, or template, with an unknown signal to detect the presence of the template in the unknown signal. Because most wireless network systems have pilots, preambles, synchronization word, or spreading codes, these can be used for coherent (matched filter) detection. A big plus in favor of the matched filter is that it requires less time to achieve a high processing gain due to coherency. The main shortcoming of the matched filter is that it requires a priori knowledge of the primary user signal which in a real world situation may not be available.

- **Cyclostationary Based Sensing:** Because modulated signals are coupled with sine wave carriers, repeating spreading code sequences, or cyclic prefixes all of which have a built-in periodicity, their mean and autocorrelation exhibit periodicity which is characterized as being cyclostationary. Noise, on the other hand, is a wide-sense stationary signal with no correlation. Using a spectral correlation function, it is possible to differentiate noise energy from modulated signal energy and thereby detect if a primary user is present. Cyclostationary feature detection is a promising option especially in cases where energy detection, described next, is not so effective. However, cyclostationary detection requires a large computational capacity and significantly long observation times.

3. Radio Identification Based Sensing: This method veers from the typical study of interference which is usually transmitter-centric. Typically, a transmitter controls its interference by regulating its output transmission power, its out-of-band emissions, based on its location with respect to other users. Cognitive radio identification-based detection concentrates on measuring interference at the receiver. The FCC introduced a new model of measuring interference referred to as interference temperature. The model accounts for cumulative RF energy from multiple transmissions and sets a maximum cap on their aggregate level. As long as the transmissions of cognitive radio users do not exceed this limit, they can use a particular spectrum band. The major hurdle with this method is that unless the cognitive user is aware of the precise location of the nearby primary user, interference cannot be measured with this method. An even bigger problem associated with this method is that it still allows an unlicensed cognitive radio user to deprive a licensee (primary user) access to his licensed spectrum. This situation can occur if a cognitive radio transmits at high power levels while existing primary users of the channel are quite far away from a receiver and are transmitting at a lower power level.

III. PROPOSED ANALYSIS

As we know cognitive radio network is future technology and very few works are done in this field so far. Through this paper we have tried to give an idea based on spectrum sensing techniques in order to utilizing the spectrum band. As we have discussed the Spectrum sensing techniques with tree diagram in Figure 3. In cooperative all the radio nodes are working together for spectrum sensing while for Non-cooperative each and every radio nodes are working individually. So using figure 5, we can say if we have High (Signal to Noise Ratio) SNR the probability of primary user detection is approximate same for both the detection scheme (Cooperative as well as Non-cooperative) But low value of SNR, performance of non-cooperative as well as cooperative detection is decreasing while cooperative detection is better as compare to Non-cooperative detection.

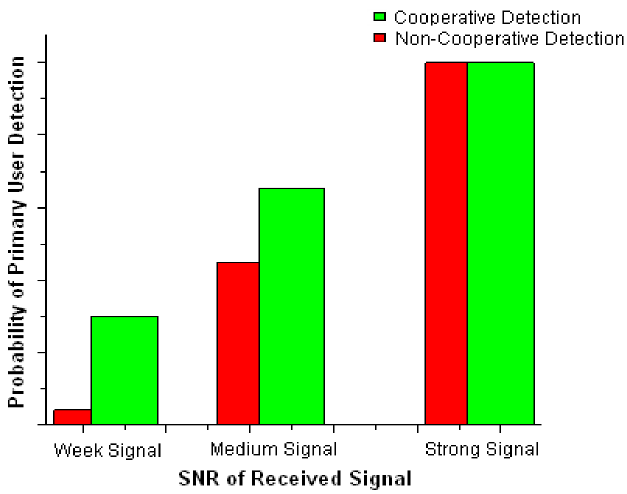

Figure 5. Probability of Primary User Detection Vs SNR of Received Signal

IV. CONCLUSION

In this paper, we have proposed a review paper based on cognitive radio network related to spectrum sensing techniques. It described the four primary functions of a cognitive radio: spectrum sensing, spectrum management, spectrum sharing, and spectrum mobility. After that in this paper we are focusing over spectrum sensing techniques as well as different approaches used for accessing licensed spectrum by secondary user. Finally we purposed a compared graph between cooperative and non-cooperative sensing technique on the basis of their ability to recognize or sense primary user with SNR of Received Signal. In Future we will try to improve the performance of existing spectrum sensing techniques.

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[FIGURE 4]

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