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Sensing and Allocation Techniques in Cognitive Networks

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ABSTRACT: The rise of needs of the people has made researchers to look for the solution which can fulfil the demands of the people. The report of FCC had claimed the overcrowded of the spectrum but most of time the spectrum is unused. The spectrum is not utilised and it is wasted. The licensed user is called Primary User (PU) and Secondary Users (SU) which are also called as Cognitive Users (CU) are the unlicensed users. The first step for Cognitive Radio (CR) is sensing where the available spectrum hole has to be identified. In the present study, all types of sensing methods and comparison between them based on different parameters is done. Also the problem faced during the sensing of the spectrum has been studied. The first part of the study contains the allocation of the available spectrum. In the second half implementation of the allocation technique based on Master Slave technique is done. In cooperative spectrum sensing technique Fusion Centre (FU) takes the final decision of the availability of the Primary User in the Spectrum, similarly in allocation Master or the Cluster node takes the responsibility of allocation. The result has been simulated with the help of the MATLAB, where the allocation technique can be visualized.

Introduction

The wireless communication is playing a vital role in people's day to day life with the introduction of modern gadgets like mobile phone, television, gaming, medical, engineering, etc. The era we live in is the era of technology especially wireless technology due to digitalization where notebook is replaced by laptop and mobile phone. Digitalization has led to increase in wireless devices in an exponential rate due to commercialization. More wireless devices like mobile phones, laptop and Internet of things (IOT) have been the daily need of the people; which in turn leads to the overcrowding of the wireless channel and it has become the serious issue. We need to find the solutions to this problem at the earliest before the communication system gets degraded leading to reduce of quality of service (QOS) due to overcrowding of wireless devices. From the survey of FCC (Federation Communication Commission) came with the report about the underutilization of the spectrum by the license users; this gave us the hope to find the way out to

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utilise the available part of the spectrum which remain idle most of the time. This survey report made the researchers to focus on the report of J Mitola in 1999 which described about the software radio. It seems to be becoming a reality today.

The Dynamic Spectrum Access (DSA) gave us the hope of overcoming the spectrum problem by allotting and managing the available spectrum to the users in need of the spectrum with the help of software radio i.e. Cognitive Radio. In Cognitive Radio the licensed users are called Primary Users (PU) and the Users in need of the spectrum are termed as Secondary Users (SU). Cognitive radio (CR) allows secondary users (SUs) to connect with the vacant channel in a constructive manner so that it causes minimum interferences to the License Users [5].It is to be noted that the Secondary Users can use the channel unless and until the Primary Users return to use the channel. At this situation the SU will again go for the available vacant to fulfil the needs. The Cognitive Radio is a new concept which is emerging nowadays and not much protocol has been finalised for the perfect communication. In this thesis work we will go through all the stages of Cognitive Radio and will conclude the best methods for each stage for the Cognitive Radiocommunication.

Operations of Cognitive Radio

From all the available study on Cognitive Radio till March 2019, the operation of Cognitive Radio has 4 different stages to make the concept practical [7]

1. Spectrum Detection
2. Spectrum Decision
3. Spectrum Sharing
4. Spectrum Mobility

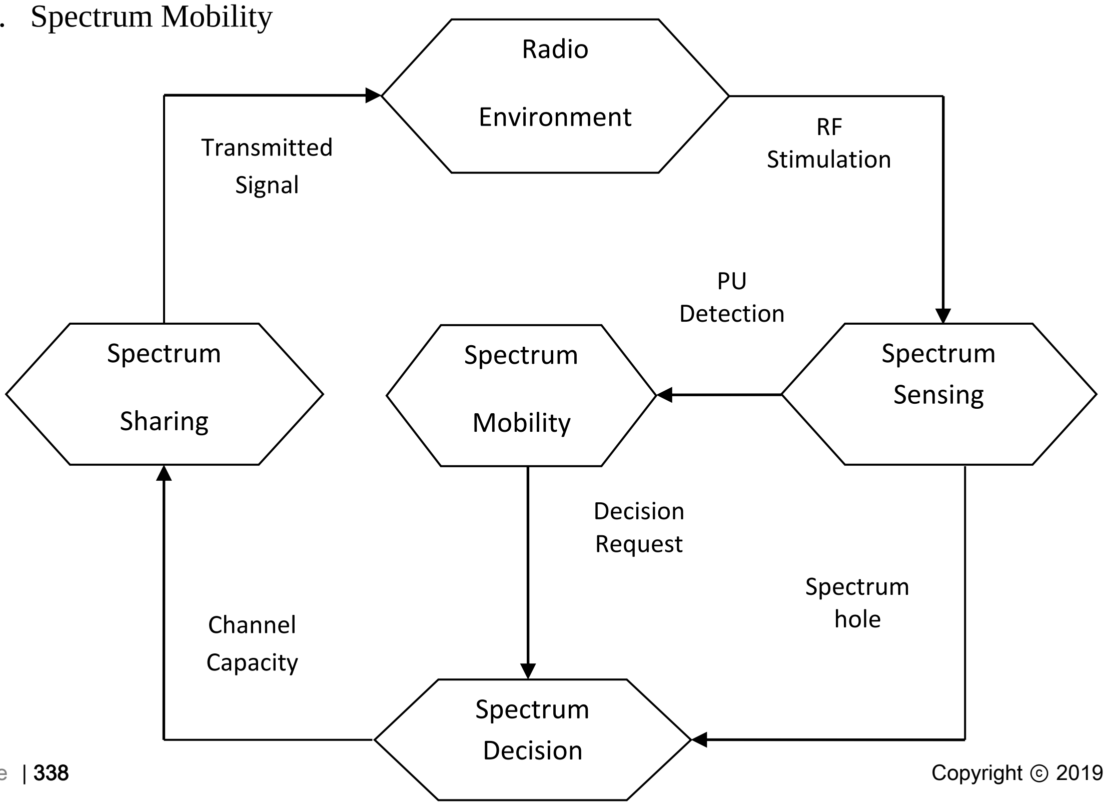

Fig.1 Spectrum measurements

The Fig. 1 shows the Cognitive Radio network cycle where different functions take place to satisfy the operations. It can be seen from the diagram that Cognitive Radio adopts the environment and takes the feedback from different stages of operations.

Spectrum Detection

The most important task of Cognitive Radio is the detection of the spectrum hole or the white space. Spectrum sensing is the method of obtaining the information of the spectrum hole or the vacant channel. It also specifies the existence of Primary Users (PU) in the channel. The information of the Primary Users (PU) can be obtained by different sensing techniques, use of beacons signals, database and geo-location [8]-[10]. More advance information of the sensing can also be achieved like types of signals in the spectrum, waveform, modulation, bandwidth, frequency, etc. Based on the sensing information, Secondary User (SU), it is to be noted that the SU does not causes interference while detecting the spectrum hole. The sensing information is then sent to for spectrum management. We will be analysing the sensing technique in the next section.

Spectrum Decision

Once the available spectrum is been detected by the Secondary User, the spectrum is been utilised for the communication. Here at Spectrum decision, the management of the vacant channel is being done. The decision of selecting the best channel is done to fulfil the quality of service (QOS) [11]. This process can either be done at the local by the SU itself or at the Fusion Centre which we will evaluate further. This decision is forwarded to the spectrum sharing centre so that it can allot the channel for communications. The concept of Spectrum Hole is shown in Fig. 2

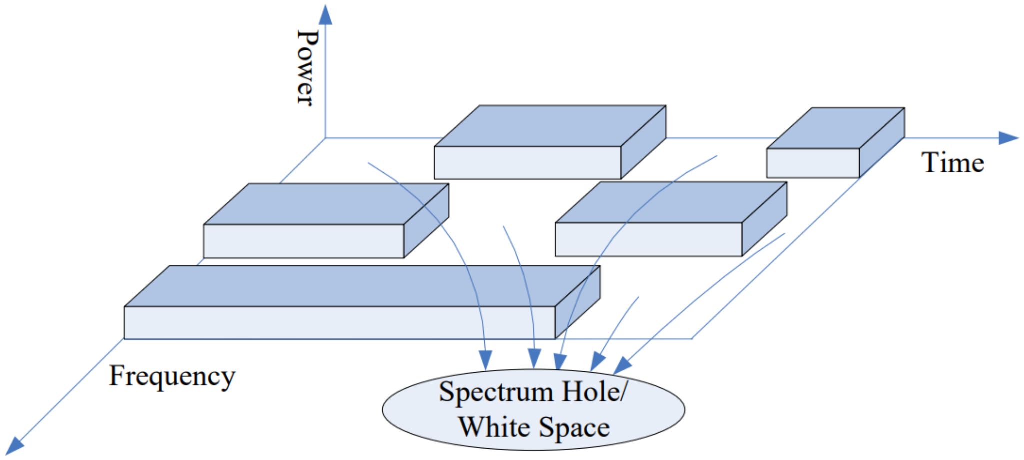

Fig. 2 Concept of Spectrum Hole

Spectrum Sharing

Spectrum sharing is the second most important process in Cognitive Radio. After deciding the best available spectrum is shared with the Secondary Users (SU) for communication. It is ensured that the Cognitive Radio Users gets equal opportunity to use the available spectrum for fulfilling their need of communication [12].

Spectrum Mobility

Spectrum mobility in a Cognitive Radio process refers to the de-allocation of the channel whenever the Primary User returns to use the channel. At this Point the Spectrum Sharing technique will allot a new channel to the Cognitive Radio Users so that it can continue its communications. The summary of the above functions of Cognitive Radio is given in the table below:

Table 1.1: Cognitive Radio Function

Sr.	Functions of CR	Comments
1	Spectrum Detection	Detect the available spectrum which are not utilised by

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		PU
2	Spectrum Decision	Decides among which vacant channels will suits to meet the QOS
3	Spectrum Sharing	Allocating the spectrum to SU
4	Spectrum Mobility	To leave the occupied channel on the arrival of PU and gets new channel for transmission.

Literature Survey

Jun Ma [10] et al. Show the helpful range detecting in light of vitality identification in subjective radio systems. A delicate mix of the watched energies from various psychological radio clients is explored. In light of the Neyman-Pearson model, we acquire an ideal delicate blend conspire that expands the recognition likelihood for a given false caution likelihood. Empowered by the execution pick up of delicate blend, we additionally propose another mollified hard mix plot with no-account overhead for every client and accomplish great trade-offs between location execution and many-sided quality. It shows the helpful range detecting in view of vitality discovery in CR systems. A delicate blend of the watched energies from various CR clients has been explored. In view of the Neyman-Pearson basis, It got the ideal delicate blend (OC) conspire that amplifies the location likelihood for a given false alert likelihood.

TevfikYucek[11] et al. The range recognizing issue has expanded new points of view with subjective radio and spearheading range get to thoughts. It is a champion among the most troublesome issues in mental radio structures. An outline of range identifying frameworks for subjective radio is shown.

JarmoLunden [12] et al. Introduce crafted by a vitality proficient collective cyclostationarig range detecting approach for subjective radio frameworks. A current measurable speculation test for the nearness of cyclostationarity is reached out to various cyclic frequencies and its asymptotic conveyances are built up. Synergistic test measurements are proposed for the fusion of nearby test insights of the auxiliary clients, and a blue pencilling procedure in which just instructive test measurements are transmitted to the fusion centre (FC) amid the collective location is additionally proposed for enhancing vitality productivity in versatile applications. Also, a method for numerical estimate of the asymptotic circulation of the edited FC test measurement is proposed.

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The proposed tests are nonparametric as in no suppositions on information or noise conveyances are required. Furthermore, the tests permit dichotomizing between the coveted signal and obstruction.

Gongpu Wang [13] ET al. Introduce crafted by a subjective transmission plot for Amplify-and-Forward (AF) two-way relay networks (TWRNs) and research its joint detecting and transmission execution. In particular, we determine the general false alert likelihood, the general identification likelihood, the blackout likelihood of the intellectual TWRN over Rayleigh blurring channels Furthermore, in light of these probabilities, the range opening usage effectiveness of the subjective TWRN is characterized and assessed It is talked about that the littler individual or general false caution likelihood can bring about less blackout likelihood and in this way bigger range gap use productivity for psychological TWRN, and additionally create more obstruction to the essential clients. Strangely, it is discovered that given information rate, more transmission control for the intellectual TWRN does not really get higher range entire use productivity. Besides, it demonstrates that most extreme range entire use productivity can be accomplished through an ideal allotment of the schedule vacancies between the range detecting and information transmission stages. It speaks to an intellectual transmission plot for AF TWRNs and researched its joint detecting and blackout execution. The general false alert likelihood, general identification likelihood, blackout likelihood and range opening use proficiency were determined to assess the execution of the subjective TWRN over level Rayleigh blurring channels. It demonstrates that more transmission control for the subjective TWRN does not really create higher range gap usage productivity. It was additionally demonstrated that most extreme range entire use proficiency can be accomplished through a portion of the schedule vacancies between the range detecting and information transmission stages.

M.P. Wylie-Green [14] In this paper the authors tires to minimize the interference in the received signal of the primary users. The author uses a multi band OFDM to sense the available spectrum. The problem which he arise during this sensing is the when ultra wide band coexist in the narrow band. In such scenario, the unwanted noise is observed in the system. The data of Multi band OFDM signal of the received primary user at power level of -98 dBm. The results of the probability of the miss detection, false alarm being compared with the help of MATLAB simulation and mathematical equation.

Shree Krishna Sharma et al. [15] The authors in this paper broadly discusses about the problems that arises in sensing of the available spectrum. The author focuses on the cooperative radio

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sensing and use of cyclostationary detection to determine the characteristics of the primary users. The authors then uses the TV signals to explain and techniques of sensing using different shift keying techniques. The cognitive radio network is taken as a radius of 100m with the height of the antenna set as 10 meter. The results shows 10%-20 % reduction of interference in the final result and used MATLAB to represent the results.

D. Cabric et al. [17] The sensing techniques is been evaluated in this paper. The author compares three different sensing techniques to explain their findings. The author represents how for the pilot energy detection technique the theoretical design completely as expected but the practical implementation is full of uncertainties with the noise signal. The energy detection techniques was also taking more time in processing of the received signals. The authors also explain how with the help of cooperative sensing technique the gain of the signals can be improved. The use of MATLAB is used for simulations for comparing the techniques.

Xiaofei Chen el al. [18] In this paper the author uses entropy based sensing technique for detecting the spectrum hole in the channel. The noise is also been taken into consideration for the efficient detection of the channel. The author uses the likelyhood ratio test to determine the availability or absence of Primary User in the signal. The results of the entropy of the signal are being used to give the final results. The author amuses that the waveform of the Primary user singal is known to the users to do the calculation in the match filter detection technique for the detection of primary users.

D. Cabric et al. [19] The author explain about the sensing problems that araises in the implementation of the system. It discusses about the critical design problem to detect the primary users presence in the channel. The authors elaborate the signal gain in different technique is sensing to improve the radio sensitivity. Here mainly three digital processing techniques has been studied namely match filter, energy detection and cyclostationary feature detection technique. The author concludes that the cyclostationary technique has the advantages over other two detection technique due to its capability to differentiate the noise signals which reduces the miss detection and the false alarm.

M. Oner et al. [20] In this paper the author uses the cyclostationary features of the signal to detect the presence of the available spectrum hole in the spectrum. Sensing being the most important part of the cognitive radio the author tries to manipulate the received primary user signal. In this technique the properties of the primary signal like cyclostationarity is being taken into consideration. Here the authors explains how the noise has no cyclostationarity behaviour he

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the noise can be differentiated from the original signal. The authors shows the simulation results to show the low SNR ratio signals can also be detected by the use of this method.

Ian Frasch et al. [21] The author has described how the spectrum can be accessed dynamically and how the spectrum holes can be used for cognitive radio users for the transmission of their signals. He works on the implementations of the sensing in cognitive radio with the help of design, implementation, and analysing of a wideband spectrum holes detector. The detection algorithm like energy detection technique, match filter technique and cyclostationary are been compared and have been implemented to get the better sensing results. The author performs the series of experiments to analyse the practical issues that arises in sensing of the widespread spectrum.

Nhan Nguyen-Thanh et al. [22] In this paper the author works on to test the sensing capability by fitness test with the use of Anderson-Darling (AD) test. The author verify that the AD test outperform the energy detection test in terms of spectrum sensing. The authors performs series of test on simulation and find that the AD test is better than energy detection test only when the Primary User signals are static in nature. The primary user signals are rarely static which means that this test on AD is not sufficient for sensing purpose. Hence the author comes to the conclusion that the standard and classical method is better in terms of sensing in practical nature.

Sensing Techniques in CR

In the functioning of cognitive Radio, the first task is to find is to find the vacant hole in the spectrum. Sensing of a network and finding optimal result about the availability is not an easy task. The fig. 3 shows the overview of spectrum sensing.

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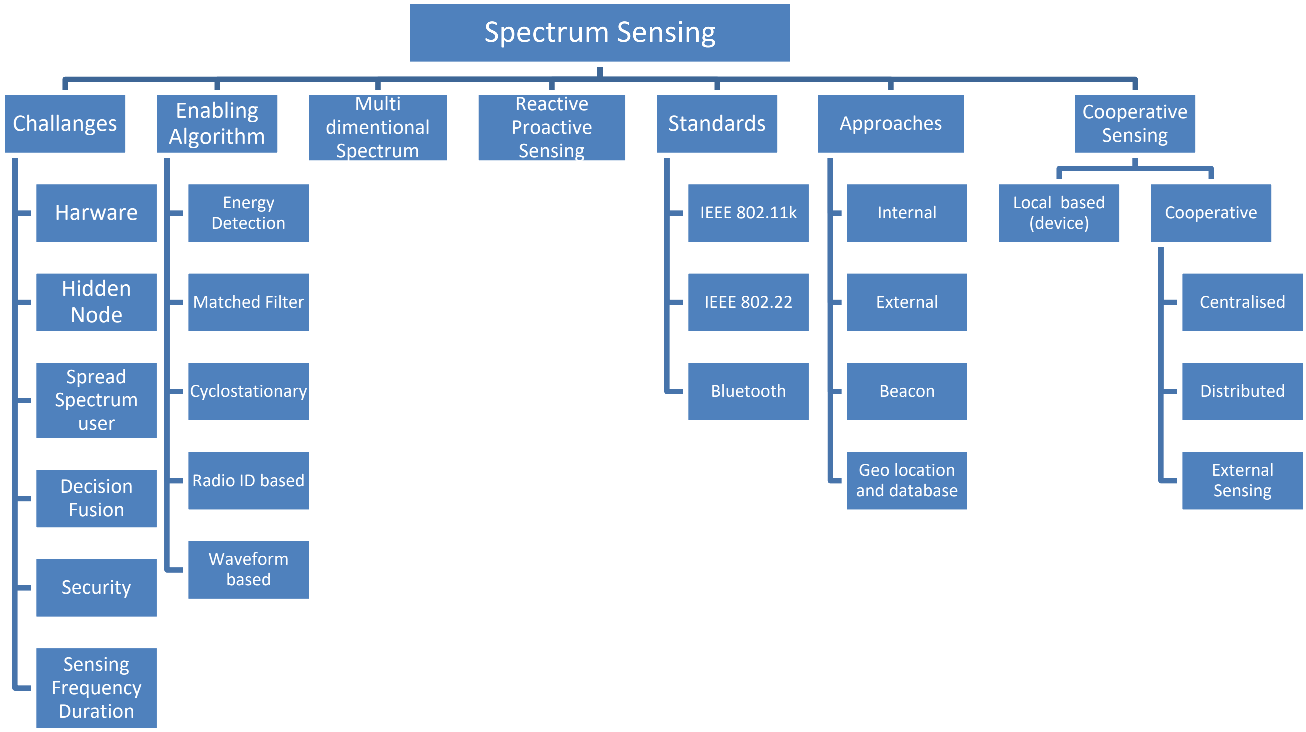

Fig. 3 Spectrum Sensing Overview

Hypothesis Sensing

Before we work on the spectrum sensing method we must first start with the hypothesis testing which will be used in the equation further.

The objective of the sensing is to detect the availability of Primary Users (PU) in the spectrum. To detect, we will be using binary values to denote the presence and absence of the Primary Users. Let H0 (null hypothesis) is the representation that the Primary user is absent in and the cognitive radio receives only noise. H1 is the representation that primary user is active in the channel and in the output the noise and the signal of the primary users will be received.

The representation of the binary hypothesis under the influence of additive white Gaussian noise (AWGN) is represented by the equation below [13]:-

$$x(t) = \begin{cases} n(t)H0 \\ hs(t) + n(t)H1 \end{cases} \qquad \text{...} (1)$$

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In the above equation$x(t)$ is the signal sensed by Secondary User (SU),$n(t)$ is a noise and h$(t)$is the channel gain and s$(t)$is the signal of the Primary User

On the basis of the above probability, the sensing is done in cognitive radio is done.

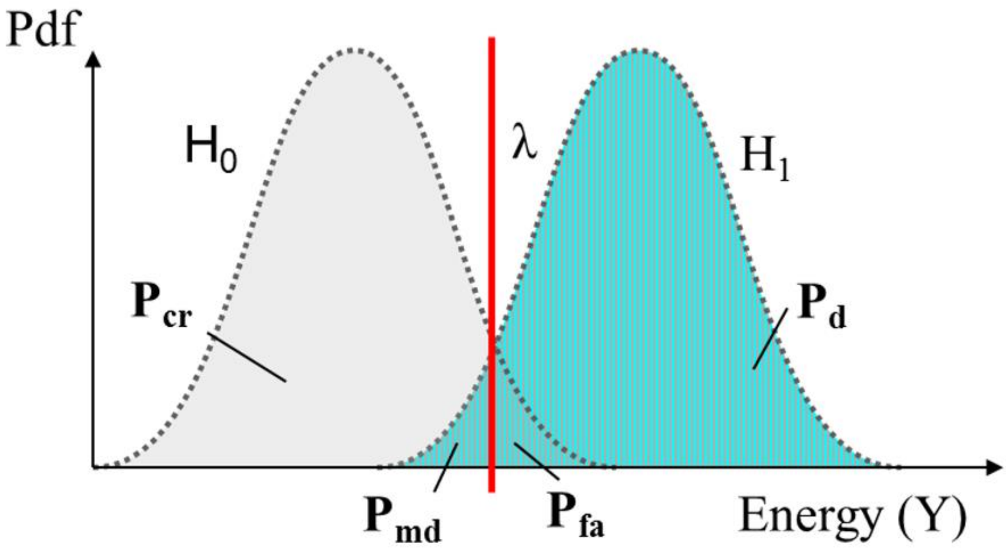

Figure.4.2 Probability of false alarm and miss detection

Here from the above comparison the trade-off between the miss detection and false alarm can be compared. From the picture, we can easily figure out that how miss detection is happening during trade off. The miss detection happens when the probability of the detection is kept high on the other hand the false alarm happens when the probability of detection is kept low. Here the miss detection leads to underutilization of the spectrum where available spectrum is missed.

Sensing Technique

The Secondary Users (SU) will constantly sense for the spectrum hole so that it can used it for its communication purpose. The SU will then switch to available channel, hence the sensing plays a vital role in communicate in Cognitive Radio. Many spectrum sensing techniques have been used to search for the spectrum hole in the spectrum like energy detection, match filter, cyclostationary technique, and wave-form based sensing technique is technique.

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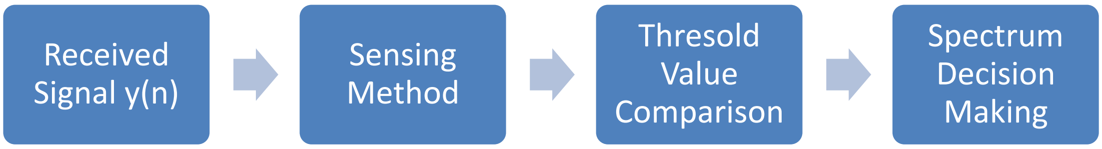

4.3 General Spectrum Sensing Model

Energy Detection Technique

Energy detection technique is the most common and widely used technique due to simplicity. In energy detection no prior information of the Primary Users (PU) required, it constantly senses the energy of the primary User and compared with the threshold value that has been defined before. The threshold is kept fixed to avoid the false alarm in the sensing. The few problems faced during energy detection technique are it require to threshold value, incapable to differentiate the nose under low SNR and the signal of the primary users (PU) [14]. As the technique is easy to use less expensive and simplicity makes it a widely used sensing technique. Also it is incapable to sense the signal of the spread spectrum signals.

Let the received signal be represented as,

$$x(n) = s(n) + w(n) \text{.......................................} (2)$$

In the above equation s(n) is the additive Gaussian noise and w(n) is the signal that is been detected. The condition when the Primary user is not transmitting, then s(n) = 0.

The decision of the presence of the Primary User (PU) can be obtained by comparing decision vector M with the fixed threshold value λE. On the other hand the threshold value λE has to be set at an optimal position, where it can balance between Pd and Pf. It is not easy to balance the value of threshold as it requires lots of knowledge about the received signal and the noise.

Match Filter

Match filter is gives better output in detection of the primary user when the information about Primary user signal is known [16]. Match filter gives the probability of the miss detection and false alarm in a short duration of time. It works on the principal to correlation of the unknown signal of the Primary User and the known signal. The technique of match filtering works best where the noise in the environment is stationary i.e stationary Gaussian noise which results in the maximization of the SNR of the signal received.

The prior information of the Primary Single like operating frequency, modulation technique, frame diagram, and precise coordination of the Secondary User is required for better performances of this technique[17]-[19]. We should understand that information is not easily available to Secondary User (SU) in Cognitive Radio. IF we are planning to get the information of the signal, it will make the system costly to build such detectors, complexity will also increase. Hence this technique will not be suitable for cognitive radio network.

Conclusion

In future the size of network can be increased and other parameters like time of delivery of information, network security can be checked. Following are the parameter which can be worked upon in future for better and efficient communication.

1). **Network Security:** Lot can be explored in the region of security to the Secondary Users. Cognitive Radio manipulates the spectrum and gathers information of the Primary Users operation time. We know that the Secondary User has to evacuate the channel as soon as the Primary Users starts its communication; what if the Secondary Users continues to transmit the data? Such action may leads to increase in nose to the channel.

2). **Improve QOS:** The Qos is directly associated with the security, sensing methods and allocation.If we are able to provide better and promising channel for communication to the Secondary Users. This can be achieved with improved mechanism and algorithm.

3). **Transmission time (latency):** In this work, the transmission time is not been studied. If we are able to calculate the latency, the actual scenario can be understood. By this we will be able to increase QOS of the communication.

4). **Increased Network size:** Here we have discussed about the network size of 25 Users (nodes). If we are able to replicate this for a bigger network at some geographical location, the scarcity of the spectrum will reduced drastically and better and improved services can provide to the users.

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