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Comparative Analysis of Different Spectrum Sensing Mechanism: A Review

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Abstract- Due to increase in number of modern cellular devices and wireless data communications in the recent years, demand of radio spectrum has been increased but current radio spectrum is a scarce natural resource due to static allocation of the spectrum bands to certain services like TV satellites, mobile fixed broadcast etc, so the efficient utilization of radio spectrum is a crucial task. Cognitive radio helps in removing this problem through proper utilization of radio spectrum. Cognitive Radio is a new emerging technique in which the free spectrum bands are identified to be used by non-licensed users for their instant communication. Cognitive Radio helps in finding the occupied frequency spectrum bands over a time interval by spectrum sensing methods. Spectrum sensing plays a vital role in Cognitive Radio systems. In this paper, various spectrum sensing techniques like energy detection, Matched filter, Cyclo-stationary are discussed with their advantages and disadvantages. Work proposed by various authors on spectrum sensing in cognitive radio has also been discussed.

Keywords--Cognitive radio, Spectrum sensing, Energy detection, Matched filter, Cyclo-stationary detection.

I INTRODUCTION

Increase in wireless devices and applications lead to the demand of effective utilization of radio spectrum and current radio spectrum is underutilized due to static allocation, as this allocation makes it inflexible to operate in a certain frequency band. So to remove underutilization of radio spectrum cognitive radio technology has been employed. Cognitive radio technology provides effective utilization of the radio spectrum and reliable communication among all the users of the network. Cognitive radios are made so intelligent that it has the capability to sense the external radio environment and change its parameters according to the situation. To improve the spectrum efficiency, it can also access underutilized radio spectrum dynamically without interfering the primary users. Spectrum sensing have a very prominent role in cognitive radio for efficient utilization of current radio spectrum. The primary task of every cognitive radio user is to keep track of primary users whether they are present or not and this process is known as spectrum sensing. Spectrum sensing techniques may be categorized as: Frequency domain approach and time domain approach.

In frequency `domain method, computation is carried out directly from signal whereas in time domain approach, computation is performed using autocorrelation of the signal.

II COGNITIVE RADIO

Cognitive radio may be defined as part of radio systems that perform spectrum sensing in a continuous manner which identify spectrum holes (unused radio spectrum) dynamically and then perform operation in a time domain when it is not used by primary users. "A cognitive radio may be defined as a radio that is aware of its environment and the internal state and with knowledge of these elements and any stored pre-defined objectives can make and implement decisions about its behavior"[1].

Cognitive radio has four main functions which are:

1) Spectrum sharing
2) Spectrum Management
3) Spectrum Mobility
4) Spectrum Sensing

Spectrum sharing: Spectrum scheduling is done in this method. This method will decide which secondary user of the cognitive radio network can have the access to unused portion of the radio spectrum at some particular time. Spectrum Management: Spectrum management may be defined as the process of choosing the optimal available spectrum band among the radio spectrum so as to fulfil the requirement of user for proper communication.

Spectrum Mobility: Spectrum mobility is the process in which one secondary user interchanges its frequency of operation with other secondary user present in network.

Spectrum Sensing: Spectrum sensing is the process which is used to detect unused portion of radio spectrum and shares it by estimating the interference level of the primary user.

Advantages of Cognitive Radio:

1) Efficiency and utilization of spectrum is improved.
2) Reliability of link is enhanced.

3) Capable of finding open frequency for accessing the spectrum.
4) Helps in improving the performance of SDR (software defined radio) techniques.
5) Enhancement in user throughput and system reliability leads to improve the wireless data network performance.
6) General and selective spectrum access issues are solved by using Cognitive radio.

Disadvantages of Cognitive Radio:
1) Security in a cognitive radio is a major concern and lot of work is to be done to achieve security in cognitive radio.
2) Software reliability is not there in cognitive radio.
3) It is difficult for cognitive radio to keep up with higher data rates.
4) More efforts needs to be put forward so that we can implement cognitive radio in real world.

III SPECTRUM SENSING

The most important and crucial task of cognitive radio is to detect the unused portions of the radio spectrum. Cognitive radio has a characteristic that it can sense the spectrum holes and shares it with another secondary users without affecting the work of primary user. In spectrum sensing, secondary users keep track of primary users to find spectrum holes which is also known as spectrum bands. Spectrum holes can be classified as: temporal spectrum holes and spatial spectrum holes. In temporal spectrum holes, primary user does not use spectrum for the transmission for that particular amount of time so at that time secondary user can use the spectrum for transmission whereas in spatial spectrum holes, primary user activities is bound to a particular area and secondary user can use the spectrum outside that area. So in cognitive radio, to detect the presence or absence of the primary user various spectrum sensing techniques of cognitive radio such as Matched filter detection, Cyclo-stationary Feature detection, Energy detection, Higher order statistics, Waveform based sensing, and Eigen value based have been deployed but the performance of every spectrum sensing technique is different in different scenarios.

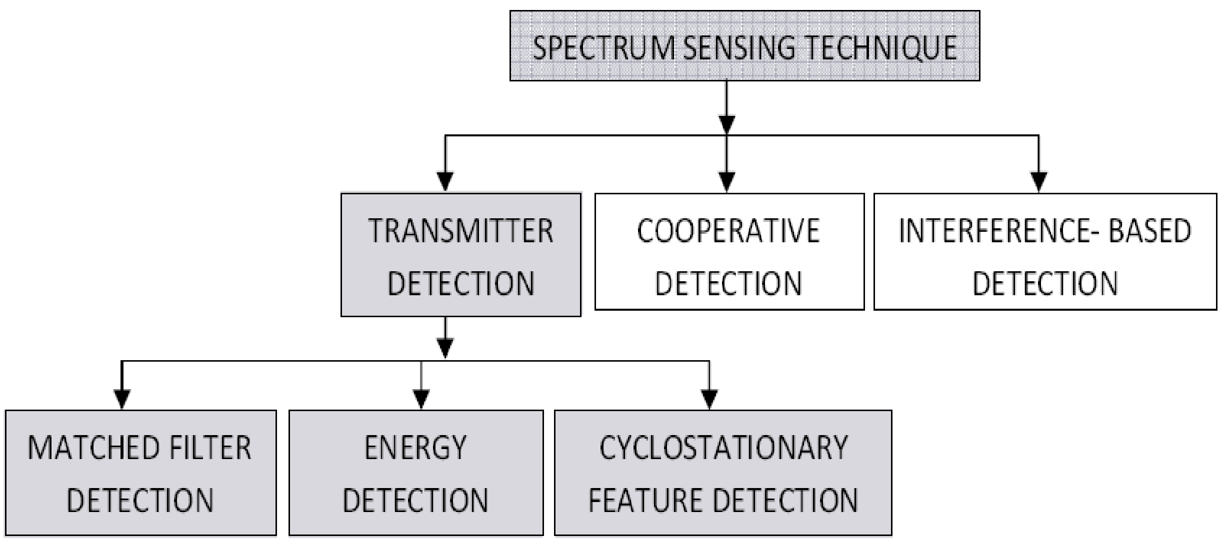

Figure 1. Different Spectrum Sensing techniques.

IV RELATED WORK

Work proposed by Subhashri G. Mohapatra et al. [2] focuses on spectrum sensing techniques, their performance, and effectiveness under different transmission conditions. It is based on energy based detection and Cyclo-stationary detection. Simulation results of different techniques are compared and these techniques detect the presence of primary signal under low SNR condition. In this work, two methods i.e. Energy detection and Cyclo-stationary based detection are compared and from the simulation results it is observed that if sufficient information about primary user signal is not gathered by receiver, but the power of random Gaussian noise is known to the receiver then Energy detector is optimally suited for this case but this Energy detector doesn't give better performance in case of uncertainty in noise power as well as fading channels.

Work proposed by Shipra Kapoor et al. [3] focuses on hybrid model technology in which proper channelization of three techniques i.e. energy detection, matched filter detection, Cyclo-stationary detection have been presented for detecting unused spectrum bands i.e. underutilized sub bands of radio spectrum for better utilization of spectrum for increasing spectrum efficiency.

Work proposed by Waleed Ejaz et al. [4] introduced a new local spectrum sensing scheme I3S (Intelligent spectrum sensing scheme) to improve the utilization efficiency of radio spectrum with increasing reliability and decreasing sensing time. In this proposed work, either combined energy detector and Cyclo-stationary detector is used or match filter detection based on power and band of interest. Then in this proposed I3S is compared with existing detection techniques, and this system gives more reliable results with less mean detection time.

Work proposed by Anirudh M. Rao et al.[5] discusses the simulation of the energy detection spectrum sensing algorithm for Cognitive Radio under low SNR condition. The energy detection algorithm is known for its simple implementation but the method to calculate the threshold value lacks in both clarity and defined steps. So in this paper author made an effort to enhance the traditional energy detection technique by fusing it with the statistical Principal Component Analysis (PCA) technique .This methodology is used for different range of SNRs, different values of Pf and frequencies of interest.

Work proposed by Juei-Chin Shen [6] suggested that the Cyclo-stationary feature can be used in performing the spectrum sensing for detecting the performance of primary user. The most prominent approach for Cyclo-stationary detection is second order statistical approach in which a group of time lags is used for testing. This method requires knowledge of the 4th-order cyclic cumulate of PUs" signals, which can be a burden in practice. So in this paper, authors presented a new idea for lag set selection which reduces the above mentioned burden. Simulation results shows that the performance of the proposed method is comparable to the optimal one in the low signal to-noise ratio region.

V SPECTRUM SENSING TECHNIQUES

A. Energy Detection

In this technique [2] [7] [4], primary signal based on sensed energy is detected. This technique is best suited for detecting independent and identically distributed signals in high SNR conditions, but not optimal for detection of correlated signals. This method of spectrum sensing is very simple to implement as in this prior knowledge of primary signal is not required .but this method requires proper knowledge of noise power and hence it is vulnerable to noise uncertainty. Three parameters defined in spectrum sensing for calculating the performance are:

1) Probability of Detection (Pd).
2) Probability of Miss Detection (Pm).
3) Probability of false alarm (Pf).

The probability of detection is defined as a metric in which secondary user declares the existence of a primary user when the spectrum is occupied by the primary user whereas the probability of false alarm is defined as a metric in which secondary user declares the existence of the primary user when the spectrum is idle. The probability of miss detection is a metric in which secondary user declares the non-existence of a primary user when the spectrum is occupied. The probability of miss detection is basically, $Pm = 1 - Pd$. False alarms tends to reduce performance of radio spectrum and probability of miss detection causes hindrances in the work of licensed primary user , So in order to have better performance we should achieve maximum probability of detection with minimum probability of false alarm . Energy Detection method of spectrum sensing requires various components like band-pass filter, an analog to digital converter, square law device and an integrator. First the input signal is passed through a band-pass filter of bandwidth W. Then the filtered signal is squared and integrated over an observation interval *T*. Finally the output of the integrator is compared with a threshold value to decide whether primary signal is present or not.

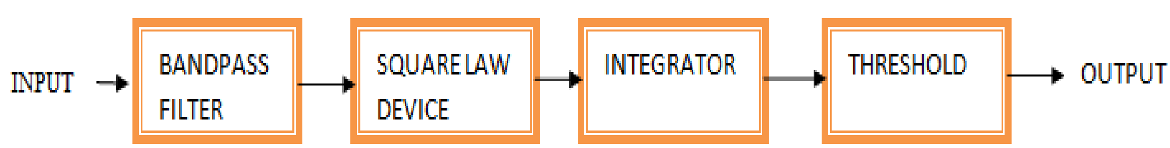

Figure.2. Energy Detector Block Diagram

The energy detection technique can be defined by following two equations:

X (t) = {n (t)} H0 (White Space)

X (t) = {h * s (t) + n (t)} H1 (Occupied)

Where X (t) is the signal received by secondary user, s (t) is the signal transmitted by primary user ,n(t) is the additive white Gaussian noise(AWGN) and h is the amplitude gain of the channel.

The advantages of Energy detection Technique is as follows:

1) Knowledge of the primary user's signal is not required in prior.

2) Easy to implement.

The disadvantages of Energy detection Technique is as follows:

1) Energy detection technique does not perform well in low SNR conditions.

2) This technique of spectrum sensing cannot distinguish between the primary user signal and noise signal.

3) It is difficult to select a suitable threshold value for comparing it with the value of the energy signal.

B. Matched filter detection

The most optimal method for spectrum sensing in cognitive radio is a matched filter detection technique because it maximizes received signal to noise ratio and it takes least time .but it requires the *prior* knowledge of primary users. So every time it requires different signal receivers for each signal type that leads to the implementation complexity. The operation of matched filter detection is expressed as [7]:

$$Y[n] = \sum_{K=-\infty} [n-K]\, x[K]$$

Where 'x' is the unknown signal (vector) and is convolved with the 'h', the impulse response of matched filter that is matched to the reference signal for maximizing the SNR.

Figure.3. Matched Filter Block Diagram

The advantages of matched filter detection are as follows:

1) It maximizes the SNR which makes it an optimal detector among all other sensing techniques.

2) Matched filter technique is faster as compared to other techniques.

The disadvantages of matched filter detection are as follows:

1) This technique also require the prior knowledge of the primary user signal.

2) Computational complexity is high as compared to other sensing techniques.

3) Power consumption is high.

C. Cyclo-stationary Feature Detection

Noise rejection capability makes Cyclo-stationary a better detection technique as compared to other spectrum sensing techniques. The presence of primary user is detected by using Cyclo-stationary property of user signal. For checking primary user presence, cyclic correlation function is used instead of power spectral density function. Cyclo-stationary feature detection is able to discriminate between primary signal and noise as spectral correlation is applied to the modulated signal. This algorithm gives optimal results for low SNR value. This method basically detects the presence of primary users by using the periodicity in received primary signal. Because of periodicity, periodic statistics and spectral correlation features are exhibited by the Cyclo-stationary feature detection method.

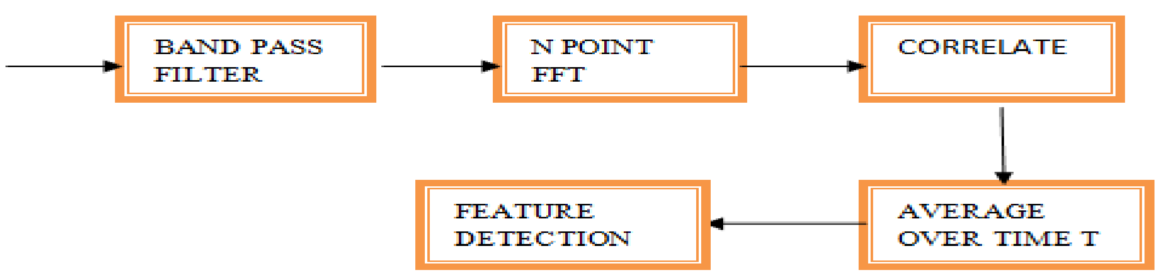

Figure.4. Cyclo-stationary Detector Block Diagram

The Advantages of Cyclo-stationary Method is as follows:

1) It gives better performance than energy detection technique and also gives satisfactory results in low SNR regions.

2) Prior knowledge of signal characteristics is not required in the case of Cyclo-stationary.

The disadvantages of Cyclo-stationary Method are as follows:

1) It has more computational complexity as compared to other methods for sensing.

2) It requires more sensing time as compared to the other techniques used for sensing.

VI CONCLUSION

Efficient utilization of radio spectrum is provided by the cognitive radio which uses the method of spectrum sensing to utilize the spectrum holes present in the spectrum. Spectrum sensing is one of the most important task of cognitive radio. In order to sense the spectrum various spectrum sensing techniques are proposed which have their own advantages and disadvantages. And in this paper we have reviewed three main spectrum sensing techniques which are Energy Detection, Matched Filter Detection and Cyclo-stationary feature Detection. The main advantage of Energy detection is that it is simple to implement and it does not require information about the primary user signal but it does not perform well in low SNR values. On the other hand Matched filter detection is better than energy detection as it starts working at low SNR of even -30 dB s. Cyclo-stationary feature detection is better than both the previous detection techniques since it produces better results at lowest SNR values. The Cyclo-stationary feature detection spectrum sensing outclasses the other two sensing techniques, but the processing time of Cyclo-stationary feature detection is greater than the energy detection and matched filter detection techniques and it is more complex as well. As all the techniques are proposed only with limited number of parameters like probability of detection, probability of missed detection, probability of false alarm but in real time various other parameters are to be used with respect to the signal vicinity. This paper can prove a useful means to understand the concept of spectrum sensing in cognitive radio.

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