COMPARATIVE STUDY OF VARIOUS SPECTRUM SENSING TECHNIQUE

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Abstract— Nowadays wireless applications has become the most popular applications . Growing appeal on wireless applications has put a lot of constraints on available radio spectrum which is limited. In fixed spectrum assignments many unused frequencies are not properly used so cognitive radio helps us to use these unused frequency bands. This improves utilization of electromagnetic spectrum by using cognitive radio. Cognitive radio includes four functional blocks that are spectrum sensing, spectrum management, spectrum administration and spectrum mobility. Among all functions spectrum sensing is believed as most crucial task for cognitive radio networks. In this paper we are going to discuss and compare spectrum sensing technique in detail.

Index Terms— Cognitive Radio (CR), Primary User (PU), Secondary User (SU).

I. INTRODUCTION

The available electromagnetic radio spectrum is getting crowded day by day. It has been also found that allocated licensed spectrum is underutilized because of its static allocation. Since a lot of useful radio spectrum already allocated, it is difficult to find vacant bands either to set up new casework or to enhance the absolute one. Best solution for this situation is that improve utilization of spectrum creating opportunities which is known as dynamic spectrum management. Thus issues of spectrum underutilization in wireless communication can be solved in better way by cognitive radio (CR) Technology. Cognitive radio provides highly reliable communications for all users of network. Thus in cognitive radio (CR) secondary users are allowed to use the unused spectrum of licensed users(primary users).

Cognitive radio will vary its transmission parameters according to changes in environmental conditions. Cognitive radio has four major functions. They are spectrum sensing, spectrum management, spectrum sharing, and spectrum mobility. [1]-[3]

- Spectrum sensing: Detecting the presence of licensed users and unused frequency bands i.e. white spaces in licensed bands. Spectrum management: Capturing the best available spectrum to fulfill user's communication requirements.
- Spectrum mobility: Maintaining seamless communication requirements during transition to better spectrum.
- Spectrum sharing : Distribute spectrum holes fairly among secondary users.

II. PRINCIPLE OF SPECTRUM SENSING

Spectrum sensing is the ability to measure, sense and be aware of parameters related to radio channel characteristics, availability of spectrum and transmit power, interference, noise, radios operating environment,users requirements and applications, available networks, nodes, local policies and other operating restrictions.Before utilizing the unused band in spectrum by secondary user ,first it will make sure that primary user is absent in licensed spectrum and quit the frequency band as early as possible if the corresponding primary radio emerges in order to avoid interference to primary users. Spectrum sensing and estimation is important step in cognitive radio system.

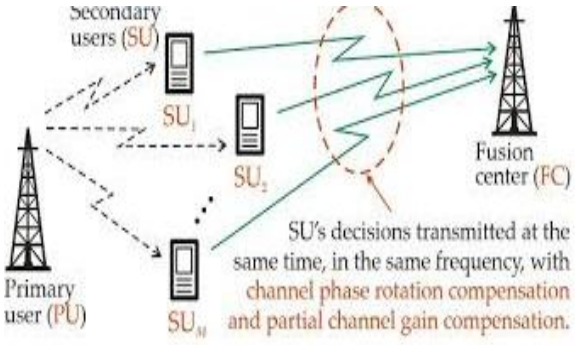

Figure 1: Principle of Spectrum Sensing

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III. CLASSIFICATION OF SPECTRUM SENSING TECHNIQUES

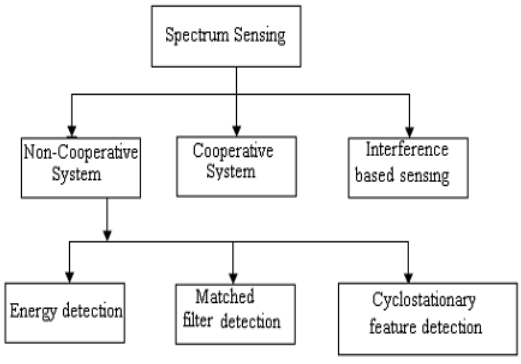

Figure 2: Classification of Spectrum Sensing Techniques

A. Primary Transmitter Detection Techniques

(i)Energy Detection Method

It is non-coherent detection methodsimple to implement. It is mostly used sensing technique in cooperative sensing. For this detection technique user not require previous knowledge of primary signal.Figure 3 shows block diagram of energy detection technique. In this method signal is passed through band pass filter of bandwidth 'w' and is integrated over time interval. To find out the existence of absence of primary users output from integrator is compared with predefine threshold,threshold may be fixed or variable depends on conditions of channel. Energy detector is also called as blind signal detector because it ignores the structures of signal.It estimates the presence of signal by comparing the energy received with a known threshold 'v' derived from the statistics of the noise. Signal detection by simple hypothesis test.[8]-[10]

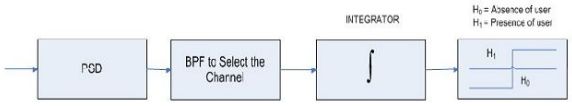

Figure 3: Block Diagram of Energy Detection Technique

y(k)=n(k)----------H0
y(k)=h *s(k)+n(k)----------H1
where y(k) is the sample to be analyzed at each instant k and n(k) is the noise of varianceσ^2 .Let y(k) be the sequence of received sample.
K E{1,2----N} at the signal detector then a decision rule can be stated as.
H0---------if ϵ<v
H1---------if ϵ>v
Where,
$\epsilon = E|y(k)|^2$ the estimated energy of the received signal and 'v' is chosen to be the noise variance σ^2 .

Disadvantages associated to energy detector

- Sensing time taken to achieve a given probability of detection may be high
- Detector performance is subject to the uncertainty of noise power.
- Energy detector cannot be differentiating between primary signals and CR user signals.
  Cognitive Radio users need to be tightly Synchronized and refrained from the transmission during an interval called quiet period in cooperative sensing.[7]

(ii)Matched Filter Detection

Matched filter is a linear filter designed to maximize ratio of output signal to noise for given input signal. Matched filter detection requires previous knowledge of primary user signal applied. Matched filter perform the detection operation by taking convolution of unknown signal with the filter whose impulse response is the mirror and time shifted version of a reference signal. The output equation of matched filter detection is expressed as

$$Y[n]=\sum_{-\infty}^{\infty} h[n-k]x[k]$$

Where 'x' is unknown signal (vector).
'h' is impulse response of matched filter that is matched to the reference signal. Increasing the SNR Detection by using matched filter is applicable only when cognitive radio users known the information of primary user.

Figure 4: Block diagram of Matched Filter Detection

Advantages

- Matched filter detection needs less detection time because it requires only 0(1/SNR) samples to meet a given probability of detection constraint. This detection technique is suitable only when cognitive radio users known the information about primary users signal, It is optimal detection in stationary Gaussian noise.

Disadvantages

- Matched filter detection is useful only when previous knowledge of every primary signal is known
- In this detection CR requires dedicated receiver for every type of primary user.[7]

(iii) CyclostationaryFeatures Detection

Cyclostationary features Detection exploits the periodicity in the received primary signal to identify the presence of Primary users. The periodicity is commonly embedded in sinusoidal carriers, pulse trains, spreading code, hopping sequence or cyclic prefixes of primary signals. Due to periodicity there cyclostationary signals displaythe features of periodic statics and spectral correlation which is not appearin stationary noise and interference[11].

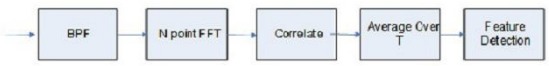

Figure 5: Block diagram of Cyclostationary Features Detection

Advantages

- Perform better for low SNR regions than energy detection and Robust to noise uncertainties.
- Cyclostatinary features detection differentiate betweenCR and various PU signals. This Detection requires previous knowledge of signal characteristics.
- No need of synchronization in cooperative sensing. Thus improving overall CR throughput.

Disadvantages

- Highly complex.
- Sensing time requires is more.
- This is rarely used method in cooperative sensing.[12]

B. Cooperative Techniques

We need topologies with high sensitivity when multiple cognitive radio users cooperate in sensing the channel.According to their level of cooperation cooperative. [7]

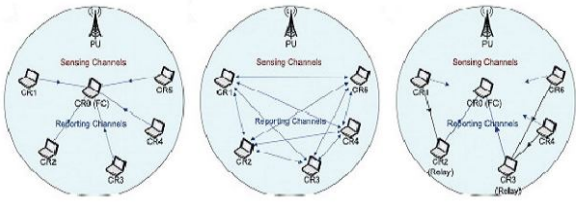

Figure 6: Different Cooperative Techniques

Techniques are divided as

- Centralised Coordinated
- Decentralised Coordinated
- Decentralised Uncoordinated[7],[13]

Benefits of Cooperation

- Cognitive plummeting sensitivity requirements : channel impairments like multipath fading ,shadowing and building penetration losses, impose high sensitivity requirements inherently bound by amount and power requirements. Implementation of cooperationamong nodes can drastically reduce the sensitivity requirements upto -25dBm.sensitivity can be reduced by application of cooperation scheme.[7]

Disadvantages of Cooperation

- In CR sensing should be periodic because sensed information is very fast due to factors like mobility, channel impairments etc. This large sensory data increasesdata overhead. In cognitive radio any spectrum hole can be potentially use, so it will have to scan a wide range of spectrum, resulting in large amounts of data ,being inefficient in terms of data throughput, delay sensitivity requirements and energy consumption. Wide channel has to be scanned; only a portion of it changes at a time requiring updating only the changed information and not all the details of the entire scanned spectrum[7-14].

(i)Centralized Coordinated Techniques

In this one CR that detects the attendance of a primary transmitter or receiver, informs a CR Controller or additional CR user. The CR controller communicate with all the CR users in its range through broadcast control message. According to their level of cooperation it is classified as Partially and fully[15].

(ii)Decentralized Coordinated Techniques

In this networks of cognitive radio without having controller. Different algorithm are used in decentralized Techniques such as gossiping algorithm or clustering scheme[23].The cooperative spectrum sensing raises the need for control channel, which can be implemented as a dedicated frequency channel or as an underlay UWB channel.[16]

(iii)Decentralized Uncoordinated Techniques

In this technique each CR users independently try to access channel. CR users don't have any kind of cooperation for detection of channel. In this if CR user detects the primary use, it make a channel free, without informing the other user. Therefore uncoordinated technique are not as much as efficient the coordinate techniques. So CR users experiences bad channel realization detects the channel incorrectly which create interference at primary receiver.

C. Interference Based Detection

In this CR users would operate in spectrum underlay (UWB like) approach.

(i) Primary Receiver Detection

Generally RF front end of primary receiver emits power leakage from local oscillator, when receiving data from primary transmitter. So to detect this leakage power emitted by RF front end of primary user, Sensor should be mount nearer to primary user's receiver. This sensor then reports the sensed data to CR users. So that it can identify status of the spectrum occupancy.

(ii)Interference Temperature Management

In this detection method upper interference limit is set for given frequency band in specific geographic location such that CR users are not allowed to cause harmful interference while using specific band in specific area.CR Transmitter control their interference by regulating their transmission power based on their locations with respect to primary users. This use to measure interference present at receiver [17].

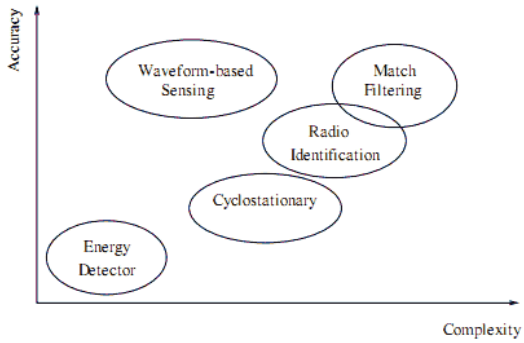

Figure 7: Diagram showing Accuracy of Different Techniques

IV. OTHER APPROACHES

(i) Multi-Taper Spectrum Sensing and Estimation
Multi Taper spectrum estimationhas proposed by Thomson (1982) before the CR concept was introduced. The last 'N' number of samples are collected from received samples in the form of vector which is represented as a set of base vector.

(ii) Filter Bank Based Spectrum Sensing
Filter Bank Based Spectrum Sensing is simplified version of Multi taper spectrum estimation which uses only one prototype filter for each band and has been proposed for multi carrier modulation based CR systems by using a pair of matched Nyquist filter .This uses the same concept of maximal energy concentration in the bandwidth fc-W to fc+W. By exploiting this information[18].

(iii)Wavelet Based Detection
It is used in image processing for edge detection applications. Tian and Giannakos have proposed this approach in spectrum sensing where wavelets are used for detecting edges in power spectral density of a wideband channel. The edges in power spectral density are the boundary between spectrum holes and occupied bands and hence it helps to find vacant bands. Based on this information CR can identify the spectrum opportunities.

(iv) Random Hough Transform Based Detection
It is also widely used for pattern such as lines, circles detection in image processing applications.Challapali et al.(2004) have proposed to perform Random Hough transform of received signal r(n) to identify the presence of radar pulse in the channels of IEEE802.11 wireless systems.

(v)Radio Identification Based Detection
These techniques are used in the context of European Transparent Ubiquitous Terminal(TRUST) project(Farnham et al.,2000)which is based on several extracted features such as transmission frequency ,transmission range, modulation technique etc. Once the features are extracted from the received signal,CR users exploit those features and can select suitable transmission parameters for them.

CONCLUSION

Spectrum is a very valuable resources in wireless communication systems and it has been a major research topic from last several decades. Cognitive radio is a promising technology which provided different spectrum sensing methods for optimistically uses spectrum hole. By considering issues related to cognitive radios, spectrum sensing methods play vital role to achieve satisfactory result in terms of efficient use of available spectrum and limited interference with the licensed primary users. This paper also describe many advanced techniques, including distributed spectrum sensing ,interference management ,cognitive radio reconfiguration management and cooperative communications whose involvement is required by cognitive radio for development of network.Furthermore ,in order to fully realize the CR system in wireless communications for efficient utilization of scarce RF spectrum, the method used in identifying the interference and/or spectrum sensing should be reliable and prompt so that the primary user will not suffer from CR system to utilize their licensed spectrum..We have presented the advantages and disadvantages of different spectrum sensing methods and compare in terms of operation, accuracies, complexities and implementations. The Energy detection technique is preferred the most because of it is less computational and implementation complexity.

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