Analysis of Spectrum Sensing Techniques in Cognitive Radio

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***Abstract*: The growing demand of wireless applications leads to development of spectrum sensing techniques for the efficient usage of available bandwidth. The available frequency is limited and hence efficient utilization of frequency is an important constraint. A high proportion of the licensed spectrum is not utilized properly. In order to improve the effective usage of the limited available spectrum, cognitive radio technology is used. Spectrum sensing is the important aspect in the cognitive radio technology. Spectrum sensing helps to find the spectrum holes and provides high spectral resolution capability. The most challenging issue in cognitive radio systems is the detection of white spaces(holes) in the spectrum and allotting the unused spectrum to the secondary users. This paper focus on comparison of different spectrum sensing techniques used in cognitive radio technology.**

***Keywords*: cognitive radio, spectrum sensing, spectrum mobility, PU users, unliscened users, spectrum holes.**

I. INTRODUCTION

The present system uses the radio spectrum allocation policy that is the licensed user is allocated with the specified channel which is used for their services. Only the licensed users can transmit and receive the data in the allocated channel. Others are not allowed to use this channel even if the channel is idle. According to the fixed spectrum allocation (FSA) policy, it is reported that the spectrum utilization varies from 15% to 85% in the US [4].

The authorized/liscensed users are better-known as primary users. When the frequency band allotted to the licensed user is not used at a particular instant then it creates a hole and this is known as white space. The secondary users cannot use the frequency band even though the particular frequency band remains unused by the primary user [8][9]. This traditional method is a static system and it is inefficient. The effectiveness can be improved by managing the spectrum dynamically. The system is said to be dynamic when the secondary or unlicensed users can use the licensed channel when it is not in use. One such method to improve the efficiency is by using the cognitive radio technology.

The spectrum under-utilization in wireless world can be resolved by using a higher approach called cognitive radio technology. For the reliable communication for all the users of the network, CR measure is designed.

This observation has forced the regulative bodies to look method wherever secondary (unlicensed) systems [1] square measure allowed to opportunistically utilize the unused primary (licensed) bands normally spoken as white areas. Cognitive radio can change its transmitter parameters supported interaction with surroundings during which it operates.

II. COGNITIVE RADIO TECHNOLOGY

Cognitive radio is an intelligent radio frequency transmitter/receiver designed to detect the available channels and adjust its transmission parameters enabling more communications and improving radio operating behaviour [14]. Cognitive radio ensures the effective utilisation of the radio spectrum. This technology helps the secondary

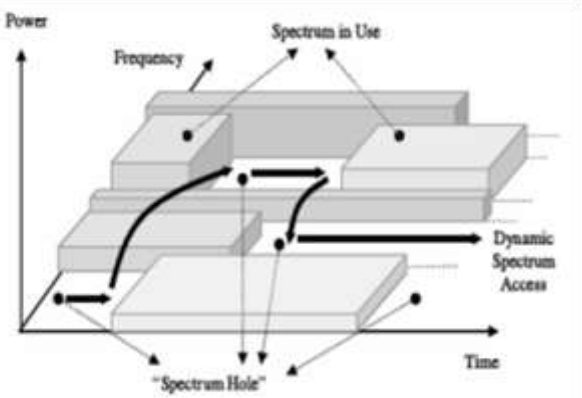


Fig. 1. Illustartion of spectrum white space

users to temporarily use the unutilised radio spectrum of the primary users. Depending upon the environment the transmitter parameters can be changed by the cognitive radio. It is capable of taking decisions [2] depending upon the environment. It makes efficient decision by learning and adapting to its environment.

The following blocks are the four main functional blocks of cognitive radio technology:

- spectrum sensing
- spectrum management
- spectrum sharing
- spectrum mobility [p2].

1) The objective of spectrum sensing technique is to detect the available spectrum of the licensed users. It also helps in avoiding the interference of the secondary users with the primary users.

2) Spectrum management [3] is the process of managing the available spectrum that is by obtaining the best available spectrum for the secondary users.

3) Spectrum sharing is to share the available spectrum equally to the secondary users.

4) Spectrum mobility [4] is to maintain fair communication among the secondary users.

III. SPECTRUM SENSING MODEL:

Spectrum sensing has the pivotal role in the cognitive radio technology. The secondary users gather the knowledge about the radio environment by discovering the presence of the licensed user signal using various spectrum sensing techniques. It can be mathematically represented as: Let y(n) be the secondary user received signal

s(n) be the primary user signal

w(n) represents the additive white Gaussian noise

if

$$y(n)= w(n) \quad H0 : PU \text{ absent} \quad (1)$$

where n represents the number of samples,

eq (1) represents the absence of the licensed user signal.

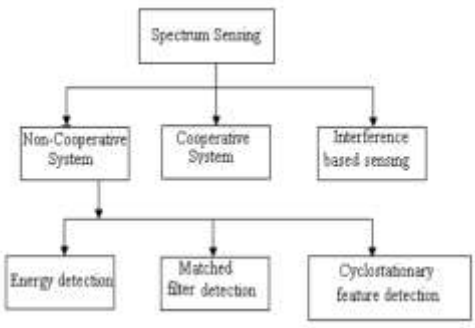
if

$$y(n) = h*s(n) +w(n) \quad H1 : PU \text{ present} \quad (2)$$

where n represents the number of samples, Eq (2) represents the presence of the licensed user signal. The output obtained by using any spectrum sensing technique is compared with a threshold value. After comparing the output with the threshold value the secondary users can utilise the channel if the primary user is absent otherwise they cannot use that particular channel at that instant of time.

IV. SPECTRUM SENSING TECHNIQUES

These are the techniques used to identify presence of PU signals in order to allocate spectrum for Secondary Users. They are of three types [5]



A. Transmitter Detection or Non-Cooperative Sensing

i. Energy Detection

ii. Matched Filter

Iii. Cyclostationary Feature

B. Cooperative Sensing

i.Centralized Coordinated

ii.Decentralized Coordinated

iii. Decentralized

C.Interference Based

i.Primary Receiver Detection:

ii.Interference Temperature Management:

A. NON COOPERATIVE SENSING:

a) Energy Detection:

It is a non coherent method. It functions without any prior knowledge about Primary User Signal. A threshold value is set in advance, to which is the received signal is compared. This threshold value depends on noise power. [6]

Operation:

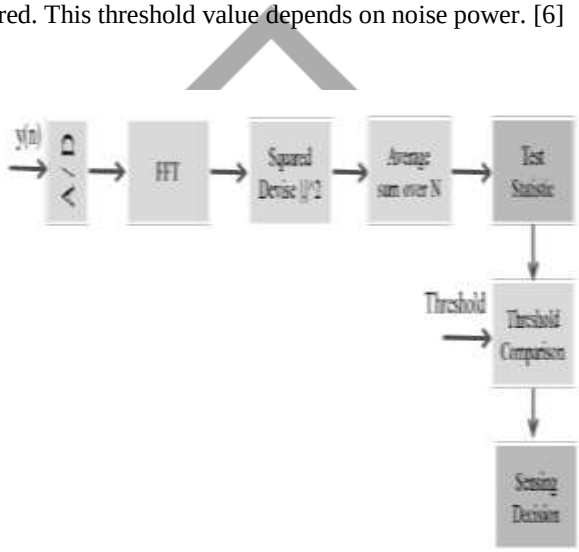


Fig.2. Energy Detection Technique

The received signal is sent through an analog to digital converter. The output digital signal is converted from its original domain to frequency domain using FFT. The decision value (Test Statistic) is found by taking the average over n samples of the squared FFT. Where n=1 to N, and N denotes the number of samples. Y(n) is the received Secondary User Signal. TED is the Decision value. The Decision value is compared to the threshold value based on which the presence or absence of the Primary User is determined.
If,
TED >= Threshold value, Primary User is present, denoted by H1.
TED < Threshold value, Primary User is absent, denoted by H0.

Y(n)= x(n) ---------- H0
Y(n)= h*s(n)+x(n)-----H1

Where n= 1 to N samples, x(n) is the noise of variance.

Advantages:

- Does not need any prior Knowledge about the Primary User.
- Computational Cost is Low.
- Simple and Easy to implement.

Disadvantages:

- Sensitive to noise.
- When the signal power is low, it cannot distinguish between noise and the signal.
- The performance is less efficient if the threshold value not set properly.
- Sensing time may be high
- Detection of spread spectrum signal is not possible.

b) Matched Filter Sensing Technique:

Matched Filter is a linear filter in which the Secondary User has prior knowledge of the Primary User parameters [7] such as modulation type, bandwidth, order and pulse shape.

Operation:
In Matched filter, convolution of the filter signal (whose impulse response is the mirror and time shifted version of a reference signal) and the unknown signal is performed. It is done so to maximize the SNR (Signal to Noise Ratio).

Advantages:
- It requires less sensing time since it is coherent.
- Low Computational Cost.

Disadvantages:
- It requires prior Knowledge of the Primary User.
- Uncertainty arises if the prior information is not proper.

c) Cyclostationary Feature Sensing Technique:

This technique uses Cyclostationary features [8] to detect Primary Users. If the mean and autocorrelation of a signal exhibits periodicity, then it is characterized as Cyclostationary. Due to the periodicity exhibited by the cyclostationary signals, it can easily be distinguished from noise and interference. It can be used even if the SNR is very low.

Operation:

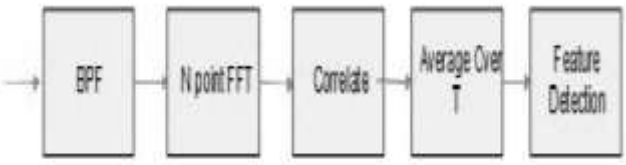


Fig.3. Cyclostationary sensing technique

Advantages:
- It can distinguish Cognitive Radio signals from Primary User signal.
- Does not require synchronization like Energy Detection.
- Highest Accuracy.

Disadvantages:
- Complexity of calculation.
- Requires all the frequencies to deal with spectral coorealtion.
- Long Sensing time.

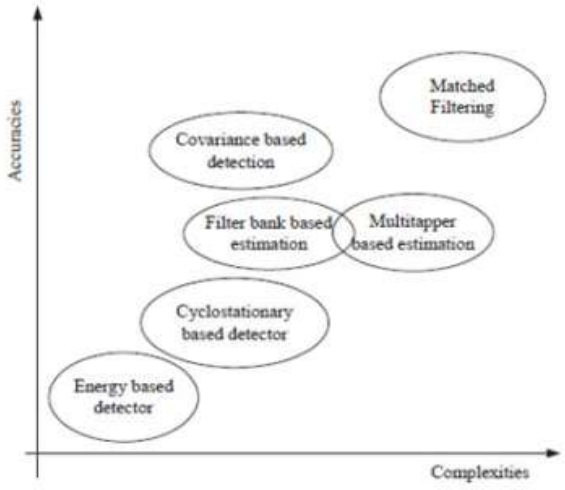


Fig.4. Sensing accuracy and complexity of various sensing methods

B. COOPERATIVE SENSING:

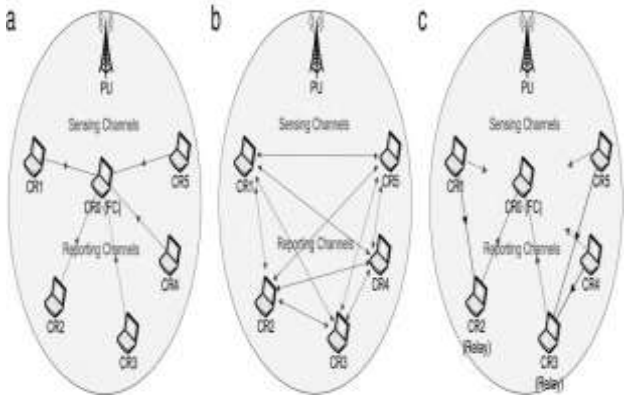


Fig.5. a) Centralized Coordinated b) Decentralized Coordinated c) Decentralized Uncoordinated

a) Centralized Coordinated Technique:

In this technique, a sequence of operations are assumed for the Cognitive Radio (CR). When a CR identifies a Primary User, it notifies the CR controller [9] which in turn sends notification to all the other CR users in its range, using a broadcast control message. Centralized Coordinated

Techniques are of two types.

- Partially Cooperative: Responsible only for sensing the channel.
- Totally Cooperative: Responsible for sensing as well as relaying information of the channels.

b) Decentralized Uncoordinated Techniques:

In this technique there is no coordination between any of the CR users. So, if an independent CR user detects a Primary User, it will vacate the channel without notifying other CR users. There is a higher possibility of error this technique when compared coordinated technique.

c) Decentralized Coordinated Techniques:

Unlike Centralized Coordinated Techniques, this method does not require any Controller. It performsSimple and Easy to implement.

Disadvantages:

- Sensitive to noise.
- When the signal power is low, it cannot distinguish between noise and the signal.
- The performance is less efficient if the threshold value not set properly.
- Sensing time may be high
- Detection of spread spectrum signal is not possible.

C. INTERFERENCE BASED DETECTION:

Primary Receiver Detection:

Usually, the Primary User receiver radiates Local Oscillator Leakage power from its RF front end. In order to determine the spectrum occupancy from the above mentioned Local Oscillator Leakage Power, a low cost sensor node [10] is installed to the Primary User's receiver which is within the communication range of cognitive radio (CR) user.

Interference Temperature Management:

This method is used for measuring interference at the receiver. For a particular geographic location, in a given frequency band an upper interference limit is set. This inference limit is set such that no harmful interference is caused by the CR users which attempt to use the frequency band. Harmful interference is controlled by the CR user transmission power regulation.

The operation is similar to UWB technology in which CR users using low transmit power coexist and transmit simultaneously with primary users which is restricted so as not to cause harmful interference to primary users [11].

To limit the interference at the Primary User, the CR users are not allowed to transmit at a higher rate than the preset value even if the Licensed System is completely idle. The CR user is also required to know the geographical location and the upper interference preset value before transmission.

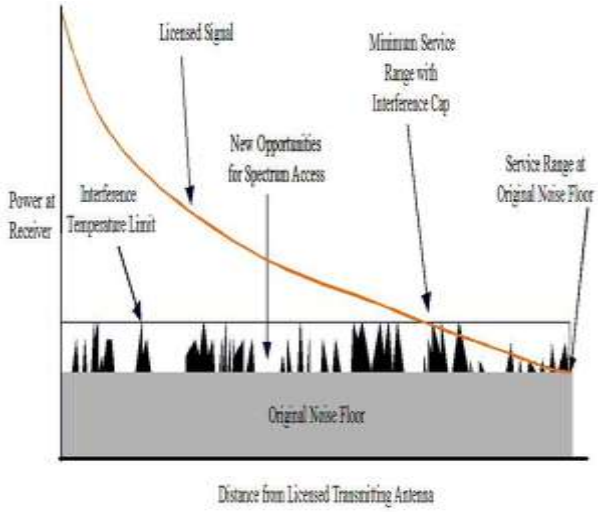


Fig.6. Inference Temperature Management

V.CONCLUSION

In this paper the importance about the cognitive radio technology was portrayed in order to avoid the spectrum scarcity and the various spectrum sensing techniques used in cognitive radio was discussed. Spectrum could be terribly valuable resource in wireless communication systems and it's been a serious research topic from last several decades. Cognitive radio is a promising technology which enables spectrum sensing for timeserving spectrum usage by providing a method for the utilization of white spaces. Considering the challenges raised by psychological feature radios, the use of spectrum sensing method appears as a vital got to attain satisfactory ends up in terms of economical use of accessible spectrum and restricted interference with the licenced primary users. As delineated during this paper, the development of the cognitive radio network requires the involvement and interaction of the many advanced techniques, including distributed spectrum sensing, interference management, cognitive radio reconfiguration management, and cooperative communications. Furthermore, in order to fully realize the CR system in wireless communications for economical utilization of scarce RF spectrum, the method used in identifying the interference and/or spectrum sensing ought to be reliable and prompt so the first user will not suffer from CR system to utilize their licenced spectrum.
We conferred the various signal process strategies by grouping them into three sand their details in turn. We have conjointly conferred the professionals and cons of various spectrum sensing methods, and performed the comparison in terms of operation, accuracies, complexities and implementations. There exist variety of problems to be addressed in terms of primary signal detection time, hardware requirements and computational complexities.

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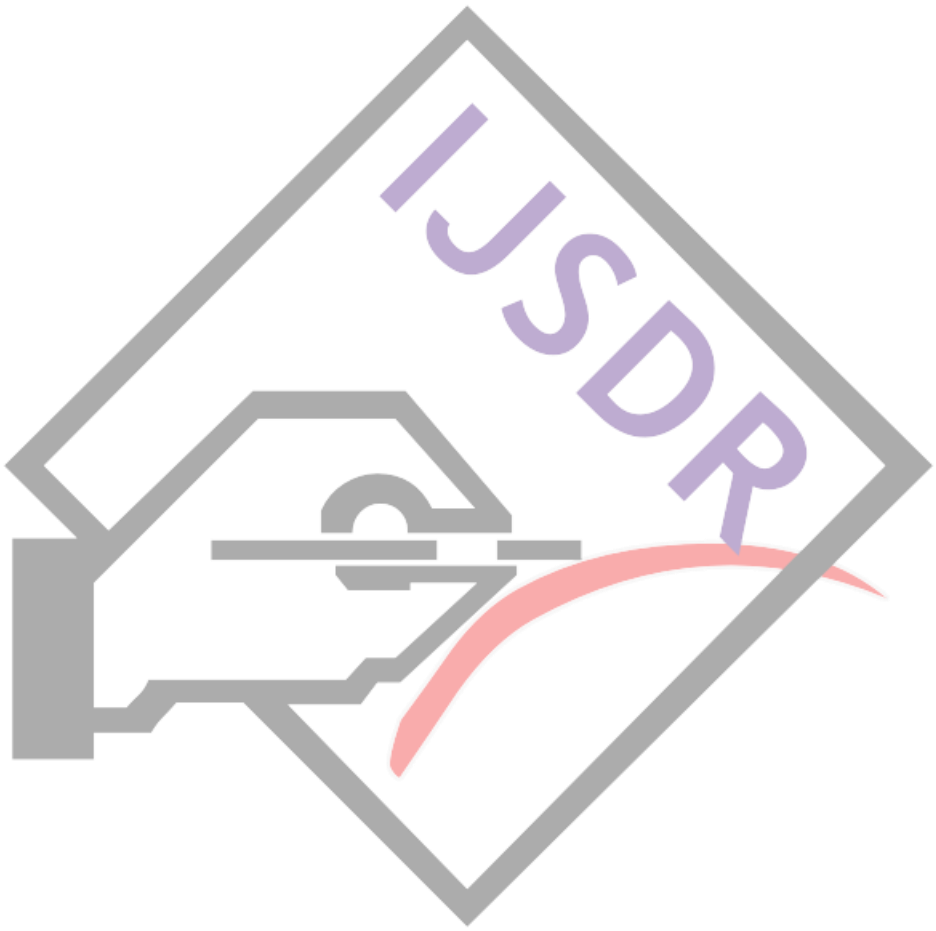
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