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Spectrum Sensing Techniques in Cr Networks: Comparative Study

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Abstract: In this paper we have discuss about overview of all existing spectrum sensing techniques and comparison is evaluated on the basis of their capacity of detecting the presence of primary users. In present day wireless communication has become the most popular communication. Cognitive radio is widely expected another field in wireless communications. Spectrum sensing allows cognitive radios to be aware of the surroundings by determining which frequencies are in use. The spectrum sensing is the focal point of CRs allowing them to detect vacant spectrum holes and use them without harmful interference to other CRs or licensed users.

Keywords: Cognitive Radio, Spectrum Sensing Techniques, Sensing Performance, Non-cooperative System.

I. INTRODUCTION

The electromagnetic spectrum is a range of all type of EM radiation. Radiation is energy that travels and spread out as it goes that radio wave that come from a radio station. It is natural scarce resource [2]. The available electromagnetic radio spectrum is a limited natural resource and getting crowded day by day due to increase in wireless devices and applications. It has been also found that the allocated spectrum is underutilised because of the static allocation of the spectrum.

The radio frequency spectrum involves electromagnetic radiation with frequencies between 3000 Hz and 300 GHz. The use of electromagnetic spectrum is licensed by Governments for wireless and communication technologies .The issue is spectrum utilization in wireless communication but it can be resolved by cognitive radio technology (CR). Cognitive radio, that can be provide high reliable communication for all user in the network. Cognitive radio: It is a radio that can change its transmitter parameters based on interaction with environment in which it operates. Cognitive radio includes spectrum sensing, spectrum management, and spectrum sharing and spectrum mobility [1].

•Spectrum sensing: Detecting unused spectrum and sharing the spectrum without harmful interference with other users.
•Spectrum management: Capturing the best available spectrum to meet user communication requirements.
•Spectrum mobility: Maintaining seamless communication requirements during the transition to better spectrum.
•Spectrum sharing: Providing the fair spectrum scheduling [5].

Spectrum sensing:
Spectrum sensing is the process to measure, sense and be aware of the parameters related to the radio channel characteristics, availability of spectrum and transmit power, interference and noise, radio's operating environment, user requirements and applications, available networks (infrastructures) and nodes, local policies and other operating restrictions. It is done across Time, Geographical Space, frequency, Code and Phase. In practice, the unlicensed users, also called secondary users (SUs), need to continuously monitor the activities of the licensed users, also called Primary Users (PUs), to find the spectrum holes (SHs), which is defined as the spectrum bands that can be used by the SUs without interfering with the PUs. This procedure is called spectrum sensing.

Principle of spectrum sensing:
In the fig. the PU transmitter is sending data to the PU receiver in a licensed spectrum band while a pair of SUs intends to access the spectrum. To protect the PU transmission, the SU transmitter needs to perform spectrum sensing to detect whether there is a PU receiver in the coverage of the SU transmitter.

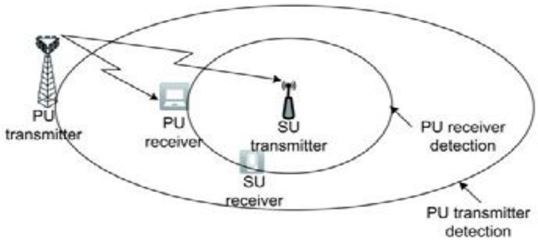

Fig. 1 Spectrum Sensing

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II. CLASSIFICATION OF SPECTRUM SENSING TECHNIQUES

Spectrum sensing technique can be categorized:
A. Non Cooperative detection:
Based on the received signal at CR users the detection of primary users is performed. This approach includes energy based detection, Matched filter (MF) based detection, cyclostationary based detection, Waveform based detection, Radio-Identification Based detection [3].

B. Cooperative and collaborative detection:
The primary signals for spectrum opportunities are detected reliably by interacting or cooperating with other users, and the method can be implemented as either centralized access to spectrum coordinated by a spectrum server or distributed approach implied by the spectrum load smoothing algorithm or external detection [3].

C. Interference Based Detection:
In this technique, CR user would be operated draw on spectrum underlay.

III. METHODS OF SPECTRUM SENSING TECHNIQUES

A. Cooperative Spectrum Sensing Techniques:
1. Energy Detection:
In this method primary signal depend on the sensed energy and sensed energy is detected by primary signal. This non-coherent detection method .This is very easy method because there are no required any knowledge related to primary signal [2]. Introducing most important sensing technique in cooperative sensing called energy detection.

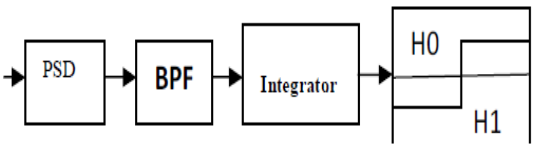

Fig. 2 Block Diagram of Energy Detection

In this method signal is given to the band pass filter with bandwidth W and signal is integrated over the time interval. Predefined threshold values are compared to the output of the band pass filter. To find a primary user is existence and absence depend on the comparison of input signal and threshold signal. Values of threshold signal can be fixed and variable based on channel condition.
Where H0 = Absence of User.
H1 = Presence of User.
Analytically, signal detection can be reduced to a simple identification problem, as a hypothesis test

$$y(k) = n(k) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. H_0$$

$$y(k) = h * s(k) + n(k) \ldots\ldots\ldots\ldots\ldots\ldots. H_1$$

Where y (k) is the sample to be analyzed at each instant k and n (k) is the noise of variance
Let y (k) be a sequence of received samples k _ {1, 2….N} at the signal detector, then a decision rule can be stated as

$$H_0 \ldots.. \text{if } \varepsilon < v$$
$$H_1 \ldots.. \text{if } \varepsilon > v$$

The simplified signal that the CR receives is model as

$$y(i) = s(i) + n(i)$$

where y(i) is the received signal, s(i) is the primary user's transmitted signal, and n(i) is the noise, which is assumed to be additive white Gaussian noise (AWGN). The index i denotes the sample. In order to make a decision about the availability of a frequency band, the receiver for the traditional energy detector (TED) compares the threshold to a decision metric [12]

$$M = \sum_{i=0}^{N} |y(i)|^2$$

Where, N is the total number of received samples. Therefore, if the energy of the received is greater than a threshold (λ), then this particular frequency band is detected as being in use [3][7].

2. Matched-Filtering Sensing:
A linear filter that can be maximized the output signal to noise ratio for a given input signal, it is called matched–filter sensing. Matched-filter is applied when secondary user has a sufficient knowledge of primary user signal.

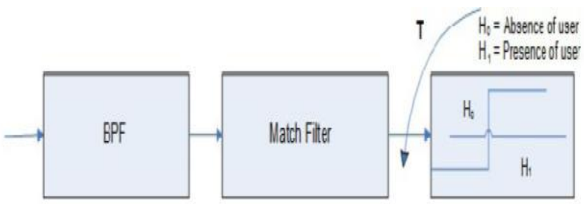

Fig. 3 Block Diagram of matched filter

Matched filter operation is equivalent to correlation in which the unknown signal is convolved with the filter whose impulse response is the mirror and time shifted version of a reference signal. The operation of matched filter detection is expressed as

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

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.

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Detection by using matched filter is useful only in cases where the information from the primary users is known to the cognitive users [2][3].

3. Cyclostationary Feature Detection:
In this method to identify present or absence of primary user to exploits the periodicity in the received primary signal [5]. The term periodicity is to be defined as sinusoidal carrier pulse train, spreading code, hopping sequence of the primary signal.

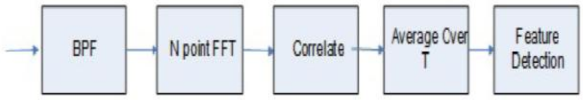

Fig. 4 Block Diagram of Cyclostationary detection

The cyclic spectral density function as defined as [10]

$$s(f,\alpha) = \sum_{\tau=-\inf}^{\inf} R_y^{\alpha}(\tau) e^{-j2\pi f\tau}$$

Where $R_y^{\alpha}(\tau)$ is the autocorrelation function and α is the cyclic frequency. The function output peak values when the cyclic frequency is equal to the transmitted signal's fundamental frequency.

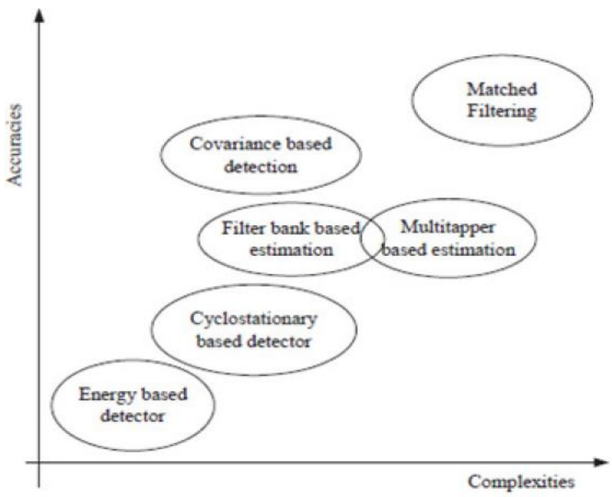

Fig. 5 Accuracy and Complexity of Various Sensing Methods [8]

4. Waveform-Based Sensing:
In waveform-Based sensing, known model are usually used in wireless system to help for synchronization. In this method to construct some data's to done the detection. Such type pattern consisting preamble, midamble, regularly transmitted pilot patterns, spreading sequence. A preamble is a known sequence transmitted before each burst and a midamble is transmitted in the middle of a burst or slot. In the presence of a known pattern, sensing can be performed by correlating the received signal with a known copy of itself. This method is only applicable to systems with known signal patterns, and it is termed as waveform-based sensing or coherent sensing [6]. The waveform-based sensing metric can be obtained as

$$M = R_e\left[\sum_{n=1}^{N} w(n)s^*(n)\right]$$

Where, * represents the conjugation operation. In the absence of the primary user, the metric value becomes

$$M = R_e\left[\sum_{n=1}^{N} y(n)s^*(n)\right]$$

Similarly, in the presence of a primary user's signal, the sensing metric becomes

$$M = \sum_{n=1}^{N} |s(n)|^2 R_e\left[\sum_{n=1}^{N} w(n)s^*(n)\right]$$

The decision on the presence of a primary user signal can be made by comparing the decision metric M against a stable threshold λ_W [11].

5. Radio-Identification Based Detection:
These technique are used in the surround of European Transparent Ubiquitour Terminal project and it's based on transmission frequency, modulation technique etc. Detected energy, channel bandwidth and shape, cyclic frequencies, spectral correlation density, etc. features may be used for identification.

B. Cooperative Spectrum Sensing Techniques:
In case, there are multiple CR users cooperate in sensing the channel at the same time are required high sensitivity. Spectrum sensing is less reliable the reason behind that multipath fading.

Multi-path fading is important factor in spectrum sensing. There are many methods are classified according to their cooperative level [4].

1. Centralized Coordinated Techniques:
Here in this technique we have Cognitive Radio controller. When one Cognitive Radio detects the presence of primary users then it indicates the Cognitive Radio controller about it. Then that controller informs all the Cognitive radio users by broadcast method.

This is further more classified into two types as partially cooperative in which network nodes cooperate only in sensing the channel. The other technique is totally cooperative in which nodes cooperate in relaying each other's information in addition to cooperatively sensing the channel.

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2. Decentralized Coordinated Techniques:
This type of coordination implies building up a network of cognitive radios without having the need of a controller. Various algorithms have been proposed for the decentralized techniques among which are the gossiping algorithms or clustering schemes, where cognitive users gather to clusters, auto coordinating them. The cooperative spectrum sensing raises the need for a control channel, which can be implemented as a dedicated frequency channel or as an underlay UWB channel.

3. Decentralized Uncoordinated Techniques:
In uncoordinated techniques Cognitive Radio will independently detects the channel and will vacate the channel when it finds a primary user without informing the other users. So Cognitive Radio users will experience bad channel realizations detect the channel incorrectly thereby causing interference at the primary receiver. So these are not advantageous when compared to coordinated techniques [9].

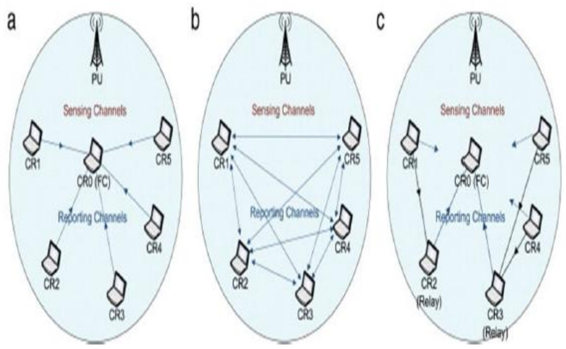

Fig. 6 a-Centralized Coordinated, b-Decentralized Coordinated, c-Decentralized Uncoordinated

C. Interference Based Detection:
There are two methods for detection:
1. Primary Receiver Detection:
In general, primary receiver emits the local oscillator (LO) leakage power from its RF front end while receiving the data from primary transmitter. It has been suggested as a method to detect primary user by mounting a low cost sensor node close to a primary user's receiver in order to detect the local oscillator (LO) leakage power emitted by the RF front end within the communication range of CR system users. The local sensor then reports the sensed information to the CR users so that they can identify the spectrum occupancy status. We note that this method can also be used to identify the spectrum opportunities to operate CR users in spectrum overlay.

2. Interference Temperature Management:
The operating principle of this method is like an UWB technology where the CR users are allowed to coexist and transmit simultaneously with primary users using low transmit power that is restricted by the interference temperature level so as not to cause harmful interference to primary users. Here CR users do not perform spectrum sensing for spectrum opportunities and can transmit right way with specified preset power mask. However, the CR users can not transmit their data with higher power even if the licensed system is completely idle since they are not allowed to transmit with higher than the preset power to limit the interference at primary users. It is noted that the CR users in this method are required to know the location and corresponding upper level of allowed transmit power levels. Otherwise they will interfere with the primary user transmissions [9].

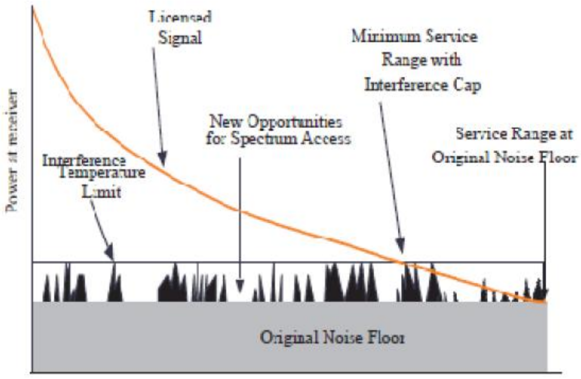

Fig. 6 Distance from Transmitting Antenna

TABLE1 COMPARISON BETWEEN LOCAL SENSING METHODS

Sensing Method	**Sensing Time**	**Robustness against SNR**	**Detection performance**	**Complexing**	**Perior Information required**
Energy detection	Low	Low	Low	Low	Low
Matched filter	High	High	High	High	High
Cyclostationarity Detection	High	High	Low	medium	High
Radio Identification Based	Medium	Medium	Medium	High	Medium

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TABLE.2 ADVANTAGES AND DISADVANTAGES OF SPECTRUM SENSING METHOD

SPECTRUM SENSING METHOD	ADVANTAGES	DISADVANTAGES
Energy detection (Non-Cooperative sensing)	• Implementation simplicity and low computational complexities. • Optimum detection if the primary user signal is not known.	•High sensing time taken to achieve a given probability. • Relies on the accurate knowledge of noise power. • Performance in shadowing and under fading degrades significantly. • Difficult to distinguish primary signals from the CR user signals. •ED not suitable to detect spread spectrum signals.
Matched filtering (Non-Cooperative sensing)	• Optimal detection. • Short sensing time.	• Complete knowledge of the transmitted signal necessary. • High power consumption (since various receiver algorithms need to be executed). • Perfect synchronization required.
Cyclostationary detection (Non-Cooperative sensing)	• No need for complete knowledge of the transmitted signal. • Applicable for the majority of transmitting signals in use. • Good performance at low SNR.	• Knowledge of specific transmitted signal parameters needed. • High computational complexity. • Long sensing time.
Waveform-based sensing (Non-Cooperative sensing)	• Short sensing time. • Good performance at low SNR.	• Knowledge of longer •Sequences of the transmitted signal for higher performance required.
Radio identification based sensing (Non-Cooperative sensing)	• Good knowledge for the spectrum utilization.	• Complex computations. • Combination of different techniques.
Cooperative sensing	• Can solve problems that arise due to noise uncertainty, fading and shadowing. • Decreases false alarm rate significantly. • Less costly. • Power consumption is reduced.	• CR users need to perform sensing at periodic time intervals as sensed information become fast due to factors like mobility, channel impairments. • Limited Bandwidth, Short Timescale, Scalability

IV. CONCLUSION

Spectrum is a very valuable resource in wireless communication system. As the usage of frequency spectrum is increasing. In this paper discussed about the most important technique that is Spectrum sensing and the issues involved in it to establish the communication using Cognitive radio. Advantage and Disadvantage of each spectrum sensing technique are also mentioned in the paper. One method proves to be efficient under some conditions and other method seems to be efficient under some other conditions, so there is still a lot of research work left to be done to get the desirable sensing method. Cooperative spectrum sensing is better than as compare to another spectrum sensing methods as it overcomes the hidden node problem, reduces false alarm and gives more accurate signal detection.

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