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Algorithms for Spectrum Sensing on Cognitive Radio: Survey

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ABSTRACT:As the use of Cognitive Radio is increasing day by day, the problems related to spectrum sensing is also increasing. This paper presents a survey on different spectrum sensing methodologies. Furthermore, various sensing features like multi-dimensional spectrum sensing, cooperative sensing, dynamic spectrum access, external sensing algorithms and other alternative sensing methods are reviewed.

KEYWORDS: Cognitive Radio, Multi-layer sensing, Spectrum sensing, Comparison of sensing techniques.

I. INTRODUCTION

As the number of wireless equipment such as mobile phones, laptops, etc are increasing day by day; the need of communication channel is also increasing. There is a limited allocation of the spectrum given to us by the government for different applications like defense purpose, media purpose, communication purpose, etc. Therefore, we need smart techniques to enhance the communication efficiency. Cognitive Radio is the key to solve this problem. Cognitive Radio is a smart radio which has the ability to sense the available spectrum and can change the transmitting parameters accordingly to switch from one spectrum to the other spectrum.

Users having higher priority or rights to use particular part of the spectrum is called **primary users**. Users having lesser priority to access a particular part of spectrum are called **secondary users**. With the help of Cognitive Radio, we can use the spectrum allocated to the primary users while it is not in use. Secondary users can utilize the available spectrum without causing any interference to the primary users. Therefore, secondary users need the concept of Cognitive Radio to sense that the available spectrum is in use by the primary users or not and changes the radio parameters to access available spectrum.

Spectrum Sensing is one of the major task in Cognitive Radio communication. This paper will focus on different spectrum sensing techniques and its communication aspects. Section [II] explains multi-layersensing, Section [III] explains challenges in spectrum sensing, Section [IV] explains different sensing techniques, Section[V] compares different sensing techniques.

II. MULTI-LAYER SENSING

Generally secondary user detects vacant spectrum of primary users, it considers three dimensions- time, space and frequency. Basic sensing methods are related to these three dimensions. But we need a large spectrum opportunity which is defined as ***"a range of frequencies in a band assigned to a primary user and this user is not using that frequency at a particular time"[1]***. Other dimensions of spectrum sensing such as code dimension, angle dimension are not in use for the spectrum opportunity. Therefore, we face problem in signals which deals in Time and Frequency Hopping coding. Generally, we assume transmission in all direction but there is a need of angle dimension sensing.

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Invention of Multi-Antenna also introduced different dimensions for sensing for example time division, frequency division and formation of various beams. With the help of these dimensions, sensing of only frequency spectrum is not sufficient. So the radio space can be defined as ***"a space which is occupied by various radio signals, including various dimensions of angle of arrival, time, frequency, location." [2][3].*** This space can be called by various names such as hyperspace, electro space, transmission hyperspace, radio spectrum space. Its main use is to present the way the radio environment is shared among multiple systems.

III.OBSTACLES IN SENSING

First we will discuss major obstacles in spectrum sensing and further different sensing techniques used in cognitive radio.

- Obstacle in Hardware.
- Security of primary user obstacle.
- Sensing of primary user's spectrum.
- Time period and Frequency of detection.

IV.SPECTRUM SENSING METHODS

Spectrum sensing is the backbone for the cognition process. There are large number of methods which are used for spectrum sensing. Here, some of the most popular spectrum sensing techniques are explained.

1.Detection based on energy:

This sensing is more generic as knowledge on the primary user's signal is not needed by the receiver. To detect the signal, the comparison of the output of the energy detector and threshold which depends on the noise floor is done [64]. This technique faced some common problem such as level of noise floor, threshold level for primary users, ability to detect interference for noise and primary users. In addition, if we consider low signal to noise ratio, then performance of this technique is poor.

Let's assume this as a simple form of received signals

$$Z(n)=X(n) + W(n) \qquad -(i)$$

Where, X(n) is actual signal going to detect and W(n) is AWGN.

If X(n)=0, it means primary user is not using a particular spectrum which will be utilized by the secondary user.

Energy of the received signal

$$Z= \sum_{n=0}^{N} |(n)|^2 \qquad -(ii)$$

This equation is also called decision matrix.So, the energy level Z will be compared with the noise threshold γ_n. This noise is fix.

So, they use two cases:-

$H_o : Z(n) = W(n) \qquad -(A)$

$H_1 : Z(n) + W(n) \qquad -(B)$

In case A where the primary user is not present while in case B primary user is present.For detection of availability of a signal there are two probability P_d and Pf, which are probability of detection of a signal when it is actually present, is separated by P_d and probability of detection of signal when it is not present is called false alarm, is separated by P_F.It can be expressed as

$$P_D = P_R(Z > \gamma_N / H_1) \qquad -(iii)$$

$$P_F = P_R(Z > \gamma_N / H_0) \qquad -(iv)$$

So factor P_F play an important role in energy detection technique. Therefore, underutilization of the available spectrum can be prevented by maintaining the value of P_F as small as possible.

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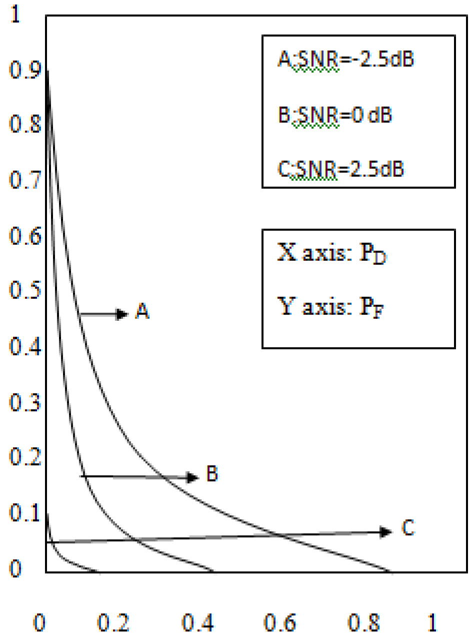


SNR also affect the performance of the energy detection technique. Figure shows the energy based spectrum sensing under different signal to noise ratio.

2.Waveform based sensing:

To assist synchronization the known patterns are usually utilized by wireless devices. Midambles, preambles, spreading sequences etc are some examples of these patterns. A midamble is transmitted in the middle of a burst or a slot while a preamble is transmitted before a burst or a slot. By correlation of the received signal with a known copy of itself, sensing can be done in the presence of a known pattern. This method is used by the systems with known patterns of signal which is called coherent sensing. In reliability and convergence time, coherent sensing performs extraordinary compared to energy detector based sensing. The known signals pattern's length increases with the increase in performance of sensing of algorithm.

3.R-I based sensing:

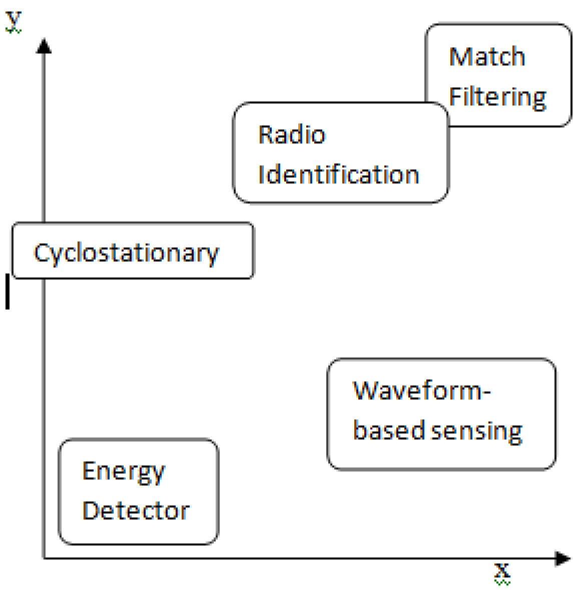
A full knowledge of characteristics of spectrum can be found by the identification of transmission technologies used by primary users. This enables cognitive radio with more accuracy as well as more knowledge of dimensions [59]. For example, the Bluetooth signal was identified as a primary user's technology. As Bluetooth's range is 10 meters, extraction of some useful information in space dimension can be done by Cognitive Radio. Also in some applications, cognitive radio wants to communicate with the identified communication systems. Classification and extraction techniques are mainly used which is based on European transparent ubiquitous terminal (TRUST) project for Radio-Identification [86]. The two tasks which are mainly used: Initial mode identification (IMI) and Alternative mode monitoring (AMM). In IMI, a possible transmission mode is searched by cognitive radio. In AMM, the main task is to monitor other modes while the cognitive radio is busy with communicating to other mode.

4.Match-Filter sensing:
It is known for the ultimate method for detecting primary users when the transmitted signal is known [91]. Its advantage is that it achieves a certain level of probability of false alarm in a very short span of time [92]. As growth O(1/SNR) of required number of samples is critically low for the target probability of false alarm [92]. For demodulation of received signals cognitive radio is needed by the matched-filtering sensing. Hence, the requirement of perfect knowledge of the signaling features of the primary users is must. These features consists of frame format, operating frequency, bandwidth and modulation type. As the requirement of receivers for all the signal types is needed by the cognitive radio, the complexity for implementation of sensing unit is large [26]. Its main disadvantage is its large power consumption.

5.Cyclostationary:
Detection of primary user transmissions by exploiting the cyclostationarity features of the received signals is called cyclostationary detection or sensing. It is caused by the periodicity in signals as well as in its statistics like mean or autocorrelation. Cyclic correlation function is used for detection of signals instead of power spectral density. Algorithms based on cyclostationary detection can differentiate noise from primary user's signals. Also cyclostationary can be used to distinguish primary users and different types of transmissions.

V.COMPARISON OF SENSING TECHNIQUES

Comparison of different spectrum sensing methods is shown in the figure.
Preface of all the methods are limited according to their algorithm and application.



x axis: Accuracy

y axis: Complexity.

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Accuracy of energy detection method is less but if we talk about other functions then it is most reliable technique. Complexity in energy detection technique is very less.
On other hand selection of any method have considered many trade off. Characteristics of primary user also plays an important role.

VI. CONCLUSION

In a wireless communication system, spectrum is a very important feature. Spectrum of channel is very important and focal point of research and development effort.
Sensing of available spectrum is an important element. In this paper we have re-evaluated different sensing algorithms. New interpretation of spectrum space will provide different opportunities in this area. Therefore, in the next paper we will evaluate the energy based spectrum sensing techniques to detect the available spectrum.

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