Methodology for implementation of cognitive radios using MATLAB

Nitika Sharma[1], Kamal Kumar Sharma[2], Sharad Chauhan[3]

[1]Student, M. Tech, ESEAR, Ambala
[2]Professor, Dept. of ECE, E-Max group of Institutions, Ambala
[3]Assistant Professor, Dept. of CSE, E-Max group of Institutions, Ambala

Abstract— Cognitive radio is the emerging technology for supporting dynamic spectrum access. To detect the presence of the primary users in a licensed spectrum is a fundamental problem for cognitive radio. In cognitive radio networks, the performance of the spectrum sensing depends on the sensing time and the fusion scheme. These schemes are used when cooperative sensing is applied. In this paper, spectrum sensing techniques such as energy detection, matched filtering detection, cyclostationary detection and waveform based sensing methods are discussed. Energy detection is most commonly used in local spectrum sensing. This paper gives the overview about comparison between different methods. It helps to find the better method of spectrum sensing.

Keywords - Cognitive radio, spectrum sensing, dynamic spectrum access

I. INTRODUCTION

In wireless communication systems, the right to access the spectrum is generally defined by frequency, transmission power, spectrum owner (i.e., licensee), type of use, and the duration of license. Usually, a license is assigned to one licensee, and the use of spectrum by this licensee must be conformed to the specification in the license. In the older spectrum licensing schemes, the license cannot change the type of use or transfer the right to other licensees. Moreover, the radio spectrum is licensed for larger regions and generally in larger chunks. All these factors in the current model for spectrum allocation and assignment limit the use and result in low utilization of the frequency spectrum. Because the existing and new wireless applications and services are demanding for more transmission capacity and more data transmission hence, the utilization of the radio spectrum needs to be improved. [4]

To improve the efficiency and utilization of the radio spectrum, the above mentioned limitations should be amended by modifying the spectrum licensing scheme and adopting a dynamic spectrum management model. The basic idea is to make spectrum access more fl exible by allowing the unlicensed users to access the radio spectrum under certain conditions and restrictions. Because the traditional wireless systems were designed to operate on a dedicated frequency band, they are not able to utilize the improved flexibility provided by this spectrum licensing scheme. Therefore, the concept of cognitive radio (CR) emerged, the main goal of which is to provide adaptability to wireless transmission through dynamic spectrum access (DSA) so that the utilization of the frequency spectrum can be enhanced without losing the benefits associated with static spectrum allocation. The CR is a “smarter radio” in the sense that it can sense channels that contain signals from a large class of heterogeneous devices, networks, and services. On the basis of this sensing, the radio will implement sophisticated algorithms to share the limited-bandwidth channel with other users in order to achieve efficient wireless communication. In this way, the CR concept generalizes the idea of multiple access involving devices in a single homogeneous system to multiple access among devices in different radio spectrums using different radio transmission techniques and hence different systems (i.e., inter-system multiple access as opposed to the more traditional intra-system multiple access), which have different priorities in accessing the spectrum. [4][5].

II. COGNITIVE RADIOS

The term "Cognitive Radio" (CR) was coined by Joe Mitola in 1999-2000, in a number of publications and in his PhD thesis. The term was intended to describe intelligent radios that can autonomously make decisions using gathered information about the RF environment through model-based reasoning, and can also learn and plan according to their past experience. Clearly, such a level of intelligence requires the radio to be self-aware, as well as content and context-aware. [28] [29]

Moreover, Haykin defines CR as a radio capable of being aware of its surroundings, learning, and adaptively changing its operating parameters in real-time with the objective of providing reliable anytime, anywhere, and spectrally efficient communication [28] [29].

The term CR is defined in as follows: “Cognitive radio is an intelligent wireless communication system that is aware of its ambient environment. A cognitive radio transmitter will learn from the environment and adapt its internal states to statistical variations in the existing RF stimuli by adjusting the transmission parameters (e.g., frequency band, modulation mode, and transmission power) in real- time and on-line manner.”

This definition essentially captures the fundamental concept behind CR. A cognitive radio network (CRN) enables us to establish communications among CR nodes/users. The communication parameters can be adjusted according to the change in the radio environment, topology, operating conditions, or user requirements. Two main objectives of the CR are to improve the utilization of the frequency spectrum and to achieve the highly reliable and highly efficient wireless communications. [5][6].

III. SPECTRUM SENSING

In this paper, our attention is on the particular task on which the very essence of cognitive radio depends is spectrum sensing. It is defined as the task of finding spectrum holes or spectrum white space by sensing the radio spectrum in the local neighborhood of the cognitive radio receiver.

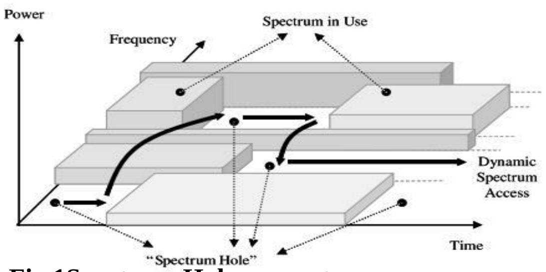


Fig.1Spectrum Hole concept

The term, spectrum holes stands for those sub-bands of the radio spectrum that are underutilized at a particular instant of time and specific geographic location. The task of spectrum sensing involves the following subtasks: 1) detection of spectrum holes; 2) spectral resolution of each spectrum hole; 3) estimation of the spatial directions of incoming interferes; 4) signal classification[2]. In this paper many spectrum sensing methods are viewed including the energy detection (ED) , matched filtering (MF) detection , cyclostationary detection (CSD) , and some newly emerging methods such as radio identification based sensing, waveform based sensing. These methods have different requirements for implementation. For example, matched filtering and cyclostationary detection require both source signal and noise power information; ED and waveform based sensing methods require only noise power information; Eigen value-based sensing method does not require any information about source signal and noise.

IV. CLASSIFICATION

Depending on transmission and reception parameters, there are two main types of cognitive radio:

Full Cognitive Radio (or Mitola radio): In which every possible parameter observable by a wireless node (or network) is considered. [23]

Spectrum-Sensing Cognitive Radio: In which only the radio-frequency spectrum is considered.[23]

Other types are dependent on parts of the spectrum available for cognitive radio:

Licensed-Band Cognitive Radio: It is capable of using bands assigned to licensed users such as the U-NII band or the ISM band. The IEEE 802.22working group is developing a standard for wireless regional area network (WRAN), which will operate on unused television channels.[23]

Unlicensed-Band Cognitive Radio: Which can only utilize unlicensed parts of the radio frequency (RF) spectrum. One such system is described in the IEEE 802.15 Task Group 2 specifications, which focus on the coexistence of IEEE 802.11 and Bluetooth. [23]

V. SPECTRUM SENSING TECHNIQUES:

Some of the most common spectrum sensing techniques in the cognitive radio is:

1. Energy Detector Based Sensing:

   Energy detector based approach which is also known as radiometry or periodogram, is the most common way of spectrum sensing because of its low computational and implementation complexities. It is more generic method as receivers do not need any knowledge on the primary users' signal. The signal is detected by comparing the output of the energy detector with a threshold which depends on the noise floor. [3]

2. Waveform-Based Sensing:

   Patterns known are usually utilized in wireless systems to assist synchronization or for other purposes. 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. [3][8]

3. Cyclostationarity-Based Sensing:

   Cyclostationarity feature detection is a method for detecting primary user transmissions by exploiting the cyclostationarity features of the received signals. Cyclostationary features are caused by the periodicity in the signal or in its statistics like mean and autocorrelation or they can be intentionally induced to assist spectrum sensing. [3] [9]-[11]

4. Matched-Filtering Technique:

   Matched-filtering is known as the optimum method for detection of primary users when the transmitted signal is known. The main advantage of matched filtering is the short time to achieve a certain probability of false alarm or probability of missdetection as compared to other methods. Matched-filtering requires cognitive radio to demodulate received signals. Hence, it requires perfect knowledge of the primary users signaling features such as bandwidth, operating frequency, modulation type and order, pulse shaping, and frame format. [13][3][14]

VI. COMPARISON OF VARIOUS SENSING METHODS

A basic comparison of the sensing methods given in this section is presented in Fig. Waveform-based sensing is more robust than energy detector and cyclostationarity based methods because of the coherent processing that comes from using deterministic signal component. However, there should be a priori information about the primary user's characteristics and primary users should transmit known patterns or pilots.

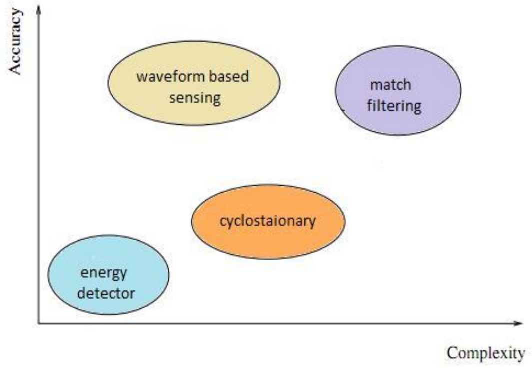


Fig. 2: Main sensing methods in terms of their sensing accuracies and complexities

The performance of energy detector based sensing is limited when two common assumptions do not hold. The noise may not be stationary and its variance may not be known. Other problems with the include baseband filter effects and spur stated in literature that cyclostationary-based methods perform worse than energy detector based sensing methods when the noise is stationary .However, in the presence of co-channel or adjacent channel interferers, noise becomes non-stationary. Hence, energy detector based schemes fail while cyclosta algorithms are not affected. On the other hand, cyclostationary features may be completely lost due to channel fading. It is shown in that model uncertainties cause an SNR wall for cyclostationary based feature detectors similar to energy detectors. Furthermore, cyclostationarity based sensing is known to be vulnerable to sampling clock offsets. [15][16][17][3]

VII. METHODOLOGY FOR IMPLEMENTATION OF COGNITIVE RADIOS USING MATLAB:

Digital implementations offer more flexibility by using FFT-based spectral estimates. Fig. 3 shows the architecture for digital implementation of an energy detector [4].

Energy detector based approach is the most common waymof spectrum sensing because of its low computational and implementation complexities. When the primary user signal is unknown or the reciever cannot gather sufficient information about the primary user signal, the energy detection method is used.

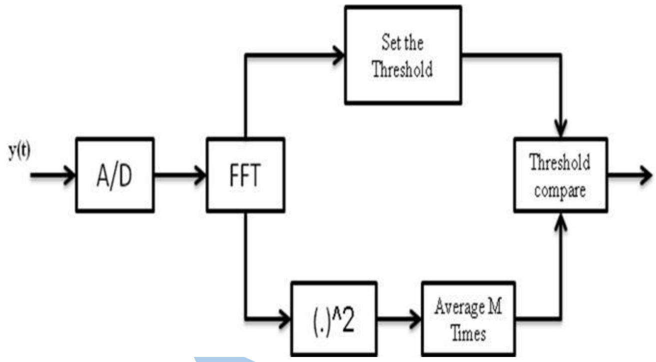
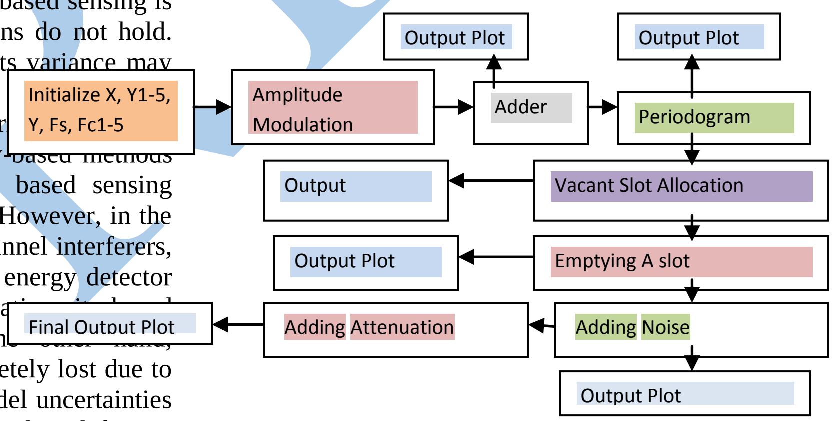
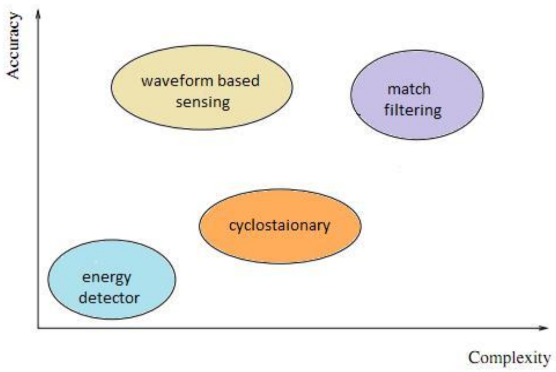


Fig. 3. Digital implementation of an energy detector

This method is optimal for detecting any unknown zero-mean constellation signals and can be applied to cognitive radios (CRs).The process flow of the energy detector is, the received signal is passed throug the ADC then calculate the FFT coefficient values then squared those values and average over the observation interval. Then the output of the detector is compared to a pre defined threshold value to decide whether the primary user is present or not.

VIII. SIMULATION SETUP USING MATLAB:





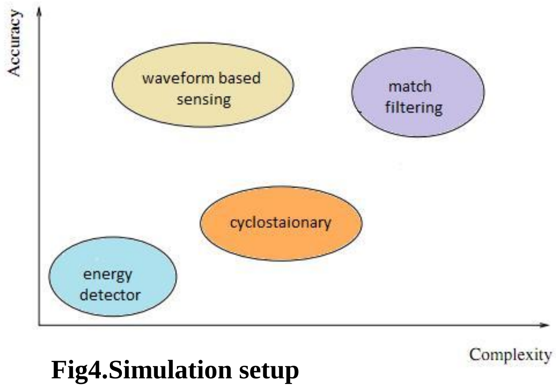


Fig4.Simulation setup

- **Initialization-** Carrier Frequency Bands for Users, Message Frequency and the Sampling Frequency are initialized.
- **Modulation-** Modulates user data over the respective frequency band by amplitude modulation
- **Adder-** Addition of all the modulated signals to produce a transmitting signal
- **Periodogram-** To estimate the power spectral density of received signal.

- **Vacant Slot Allocation-** New User isallotted to the first spectral hole when he arrives.
- **Emptying a slot-**Ask a user to empty a specific slot if all slots are engaged.
- **Addition of noise-**Amount of noise to be added.
- **Attenutation-**percentage of attenutation is introduced.

IX. CONCLUSION

Cognitive Radio is an innovative technology proposed to increase spectrum usage by allowing dynamic allocation of the unused spectrum in changing environment. Cognitive users monitor the spectrum and are allowed to use it as long as it does not interfere with primary users to whom it has been licensed. In this paper we have performed the energy detection spectrum sensing using FFT within the specified frequency band. The simulation result it has been shown that how the cognitive radio works with changing the frequency band from one to another and successfully demonstrated. In this simulation we are used the Additive White Gaussian noise with the Signal to noise ratio (SNR) values are taken as 5dB, 14dB and Attenuation percentages are 10 and 15.That is the Cognitive Radio demonstrated successfully without interfering with the other frequency bands which are used by the primary user and it is implemented in MAT LAB.

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