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Hybrid spectrum sensing Technique based on energy and Cyclostationary techniques in cognitive radio: A Review

Roohi [*] ***and Naseeb Singh Dhillon*** [**]

[*] *M. Tech. Student, Department of CSE, AIET, Faridkot, (PB), INDIA.*
[**] *Assistant Professor, Department of CSE, AIET, Faridkot, (PB), INDIA.*

(Corresponding author: Roohi)
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ABSTRACT: Cognitive Radio is a radio for wireless communications in which either a network or a wireless node changes its transmission or reception parameters based on the interaction with the environment to communicate effectively without interfering with the licensed users. Spectrum sensing is an important process in cognitive communication and must be performed accurately. In this work we are going to implement a low complexity detector based on a combination of two well-known and complementary spectrum sensing methods: energy and cyclostationary detection. The cyclostationary detector is used to estimate the noise level N0, which is then used to fix the threshold of the energy detector. Simulation results show promising performances of the proposed detector in low Signal to Noise Ratio (SNR).

Keywords: Cognitive Radio, Spectrum Sensing, cyclostationary

I. INTRODUCTION

The need for a flexible and robust wireless communication is becoming more important in recent times. The future of wireless networks is thought of as a union of mobile communication systems and internet technologies to offer a wide variety of services to the users. Conventionally, the policy of spectrum licensing leads to spectrum scarcity and unbalanced utilization of frequency spectrum. It has become essential to introduce new licensing policies and co-ordination infrastructure to enable dynamic and open way of utilizing the available spectrum efficiently.

One promising solution to such problems is the **Cognitive Radio**. It has an intelligent layer that performs the learning of environment parameters in order to achieve optimal performance under dynamic and unknown situations. Spectrum Sensing i.e. checking the frequency spectrum for empty bands forms the foremost part of the cognitive radio. It enables a smooth and interactive way of using the spectrum and communication resources in more efficient manner. Cognitive Radio is a paradigm that has been proposed so that the frequency spectrum can be better utilized. The formal definition for Cognitive Radio is given as [1]. If we carefully examine the given Fig. 1 , then the frequency range can be classified into 3 sub-categories

-Empty bands most of the time
-Partially occupied bands, and
-Congested Bands.

The main category of interest for the cognitive radio users is the first category in which the hardly used or empty bands are classified [4]. In layman terms cognitive radio is nothing but a methodology where the first category of the frequency range is brought to the use for unlicensed users in such a way that interference to the licensed users is minimized.

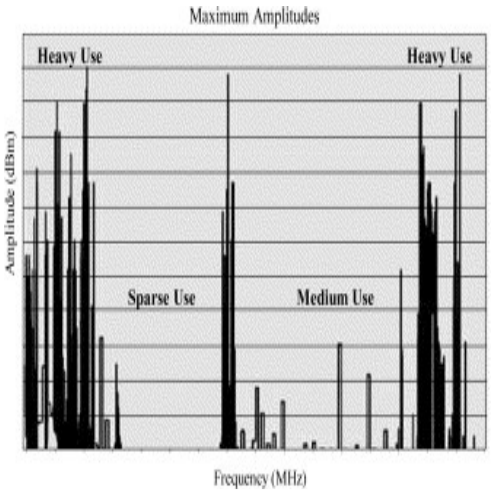

Fig. 1. Spectrum Utilization.

In order for the unlicensed or secondary users to use the licensed spectrum there are many things that should be taken care of in advance like
-Scanning the frequency spectrum for the discovery of different empty bands.
-Selecting the best available band. The selection can be done on the basis of the secondary user's application frequency requirement.
-Before transmitting on the selected band the power level should be maintained such that it provides minimal interference to other users. Also the power level can be so adjusted as to have maximum number of secondary users in the frequency band of interest.
-Depending on the distance and the error performance requirement the modulation scheme used can be varied.
-Spectrum sharing should be allowed so that other secondary users can also access the empty bands.
-Even after the beginning of the transmission, the bands must be continuously checked for any primary user entering to transmit in this range. If so then the secondary users should vacate the bands as quickly as possible and go to some other empty frequency spectrum. Each of the above essential steps indicates unique features of the cognitive radio like Continuous Awareness, Dynamic Frequency Selection, Power Control, Adaptive Modulation, Frequency Negotiation and Frequency Agility. The steps are shown in the figure 2

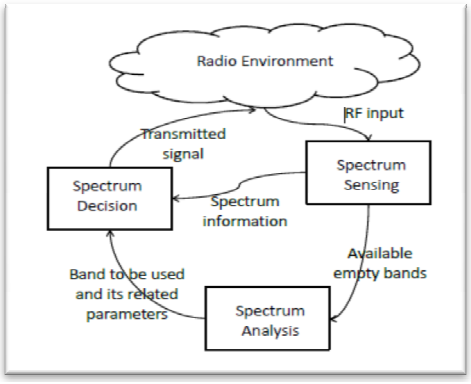

Fig. 2. Cognitive Cycle.

A basic cognitive cycle [2] comprises of following three basic tasks:
-Spectrum Sensing
-Spectrum Analysis
-Spectrum Decision Making

II. COGNITIVE RADIO'S CAPABILITIES

A. Spectrum Sensing

Spectrum sensing is the ability 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 Frequency, Time, Geographical Space, Code and Phase.

B. Spectrum Analysis

Spectrum Analysis is based on spectrum sensing which is analyzing the situation of several factors in the external and internal radio environment (such as radio frequency spectrum use by neighboring devices, user behavior and network state) and finding the optimal communication protocol and changing frequency or channel accordingly. It is also known as channel estimation.

C. Spectrum Decision Making

Spectrum Decision Making calls for reconfiguration for the channel and protocol required for constantly adapting to mobile changing environments and adjustment of output power or even alteration of transmission parameters (such as modulation formats (e.g. low to high order QAM), variable symbol rates, different channel coding schemes) and characteristics by the Cognitive radio devices.

III. CHARACTERISTICS OF COGNITIVE RADIO

The two main characteristics of the cognitive radio are:-
Cognitive Capability-It refers to the ability of the cognitive radio to sense the environment or channels used for transmission and derive the information about the state of the channel. It encompasses all the basic functions of the cognitive radio like spectrum sensing, spectrum analysis and spectrum decision. Finding the vacant bands and selecting the most efficient of all available options is main character of cognitive [3].
Reconfigurability- It refers to programming the radio dynamically without making any changes to its hardware section. Cognitive radio is a software based radio and not hardware based so it has the capability to switch between different wireless protocols and also supports a number of applications. This software based approach gives the re-configurability characteristics to the cognitive radio.

With this it can easily switch between frequencies, change modulation schemes and monitor power levels without affecting any of the hardware provided [4], [5].

IV. TECHNIQUES OF SPECTRUM SENSING IN COGNITIVE RADIO

Energy Based Detector : It is a simple detector which detects the total energy of the received signal over specified time duration. A threshold value is required for comparison of the energy found by the detector. Energy greater than the threshold values indicates the presence of the primary user.

Pros:

-No prior knowledge of the primary user's signal is required.

-Computational and implementation complexity is low.

Cons:

-Poor performance under low SNR conditions.

-No proper distinction between primary users and noise.

-Issues related to selecting a proper threshold for comparison purposes.

Matched Filter: The Matched Filter Technique is very important in communication as it is an optimum filtering technique which maximizes the signal to noise ratio (SNR). It is a linear filter and prior knowledge of the primary user signal is very essential for its operation. The operation performed is equivalent to a correlation.

Pros:

-Optimal detector as it maximizes the SNR

-The sensing time is low as compared to other detectors but more than waveform based detector.

Cons:

-Requires prior knowledge of the primary user signal.

-Computational complexity is high as compared to other detectors.

-Since the requirement is for large number of receivers so different algorithms need to be evaluated and thus power consumptions is large.

Cyclostationary Based Spectrum Sensing: Cyclostationary based sensing use the periodicity property of signals. The signals which are used in several applications are generally coupled with sinusoid carriers, cyclic prefix, spreading codes, pulse trains etc. which result in periodicity of their statistics like mean and auto-correlation. Such periodicities can be easily highlighted when cyclic spectral density (CSD) for such signals is found out. Primary user signals which have these periodicities can be easily detected by taking their correlation. Fourier transform of the correlated signal results in peaks at frequencies which are specific to a signal and searching for these peaks helps in determining the presence of the primary user. Noise is random in nature and as such there are no such periodicities in it and thus it doesn't get highlighted on taking the correlation.

Pros:

-Works well for low SNR conditions.

-It has the capability to distinguish between primary user and noise.

-It can differentiate between different types of signals

Cons:

-Since all the cycle frequencies are calculated so the computational complexity is higher than energy detector.

V. LITERATURE REVIEW

This section gives a brief review of the work carried out by various researchers in this field. Various aspects of the problem were studied.

Mohapatra S.G., Mohapatra A.G., and Lenka S.K [6] This paper explores various sensing methods, their performance, applicability and effectiveness under different transmission conditions and advantages and disadvantages incorporated with each sensing method. In this paper authors evaluated the performance of cognitive radio with energy detection based spectrum sensing (ED-SS) in AWGN, and cyclo-stationary feature is used for Spectrum sensing .In this paper the results of different windowing techniques are implemented along with their contour plots and a comparative study based on the simulation results is also proposed successfully. This technique based on window functions will be helpful to detect the primary user under low SNR conditions. Shiyu X., Zhijin Z., and Junna S. [7]. In this paper Cyclostationary feature is used for spectrum sensing. Usually, Cyclostationary feature detection requires high computation complexity but in this paper author analyze the performance of some frequencies and cycle frequencies for detection according to the licensed users' signal features, which reduce the complexity significantly. The best detection point is determined through simulation analysis on different detection points, and then author propose combined detection method using multiple detection points to obtain better performance. Results validate the effectiveness of the proposed method. Wenjing Y., Baoyu Z., [8] In this paper, author suggest a possible two-stage spectrum sensing approach. More specifically, a fast spectrum sensing algorithm based on the energy detection is introduced focusing on the coarse detection. A complementary fine spectrum sensing algorithm adopts one order Cyclostationary properties of primary user's signals in time domain.

This feature detection technique in time domain realizes simple and low computational complexity compared to spectral feature detection methods. Also, it drastically reduces hardware burdens and power consumption as opposed to two-order feature detection. The sensing performance of the proposed method is studied and the analytical performance results are given. The results indicate that better performance can be achieved in proposed two-stage sensing detection compared to the conventional energy detector. Waleed *et al.,* In this paper, the authors proposed a a new local spectrum sensing scheme, namely I3S (Intelligent Spectrum Sensing Scheme) was proposed to improve the utilization efficiency of the radio spectrum by increasing detection reliability and decreasing sensing time. The proposed scheme chooses either the combined energy and Cyclostationary detector, or the matched filter detection based on the power and band of interest. The proposed I3S is compared with the existing transmitter detection techniques. It is concluded that I3S has reliable results with less mean detection time, depending on the prior knowledge of PU waveform. And it is observed that the I3S provides detection results nearly equal to Cyclostationary detection. On the other hand, the mean detection time of the I3S is quite lower than Cyclostationary detection in most cases. Hao F., Yanbo W., and Shiju L. [10] In this paper a novel method is proposed based on finding the optimum lag in cyclic autocorrelation of the primary user signals. This method exploits the cyclostationarity of modulated signals and aims at finding a single lag for computing the test statistic in order to reduce the amount of computation and improve the performance. Theoretical analysis demonstrates that the optimum lag is actually the one which maximizes the absolute value of the cyclic autocorrelation of primary user signals. Simulation demonstrates that this method has satisfying performance under low SNR conditions compared with energy detector, and the performance meliorates as data length increases.. Finally, simulation result also shows that the proposed method has a good anti-interference property compared with matched filter. Hence, the method based on finding optimum lag in cyclic autocorrelation provides an efficient approach for detecting free bands in cognitive radios.

VI. PROBLEM FORMULATION

A number of different methods are proposed for identifying the presence of signal transmission in different research papers.

From our Literature survey we conclude that out of the various techniques available for spectrum sensing in cognitive radio, the most important ones are Energy Based and Cyclostationary based methods. So in our work we are going to combine the advantages of above mentioned methods and implement a Hybrid spectrum sensing Technique based on energy and Cyclostationary techniques

a. Advantages of Energy Based Detection Spectrum Sensing

-Energy Detection is the most common way of spectrum sensing because of its low computational and implementation complexities.

-It is a more generic method as the receivers do not need any knowledge on the primary user's signal.

-PD (probability of detection) and PF (probability of false alarm) are the important factors for energy based detection which gives the information of the availability of the spectrum.

-The signals can be detected at low SNR's provided the detection interval is adequately long & noise power spectral density is known.

b. Advantages Of Cyclostationary Based Spectrum Sensing

-Robust to noise uncertainties and performs better in low SNR regions.

-In Cyclostationary though we need prior knowledge of the signal characteristics however it is capable of distinguishing the CR transmissions from various types of PU signals.

-Synchronization requirement of energy detection in cooperative sensing is eliminated using this technique.

-Improves the overall CR throughput.

VII. OBJECTIVES

Various objectives for Enhanced Hybrid Spectrum Sensing in Cognitive Radio are:

-To study Energy Detector Technique and Cyclostationary Technique for spectrum sensing in Cognitive Radio

-To purpose and implement a Hybrid spectrum sensing Technique based on energy and Cyclostationary techniques.

-To test and compare the results with existing techniques

VIII. METHODOLOGY & FACILITY REQUIRED

For implementation of our proposed work we need to develop firstly the Energy Detector, and Cyclostationary detector respectively and then we will combine these two detectors to form a hybrid system of spectrum sensing in cognitive radio.

The facilities required for the proposed work include the connection to the World Wide Web for study of the work done, being done and the scope for work in this field. Following software will be required for the simulation of the proposed work. To simulate the work NS2 (Network simulator version 2) is required. Ns-2 is a discrete event simulator targeted at networking research. It provides substantial support for simulation of TCP, routing and multicast protocols over wired and wireless networks. It consists of two simulation tools. The network simulator (NS) contains all commonly used IP protocols. The network animator (NAM) is use to visualize the simulations. Ns-2 fully simulates a layered network from the physical radio transmission channel to high-level applications.

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