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Literature Review of Spectrum Sensing in Cognitive Radio Networks

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Abstract – **The enduring growth of wireless digital communications and incredible addition of users has raised spectrum shortage and security issues in the last decade. In particular, the fixed spectrum allocation and non-availability of new bands in the spectrum is the main obstacle for the growth of wireless digital communications. The fixed spectrum allocation schemes makes spectrum inflexible for sharing. Recent studies on radio spectrum usage have shown that pre-allocation of spectrum bands to specific applications lead to inefficient utilization of those allocated bands. Therefore, the real problem is not the spectrum scarcity but inefficient spectrum allocation and its usage. Spectrum sensing is a key enabler for cognitive radios and cognitive radio is believed to be the key enabling technology for network implementation. Spectrum sensing identifies idle spectrum and provides attentiveness about the sensing radio environment. Recent spectrum sensing techniques are reviewed in this paper.**

Keywords –**Cognitive Radio, FCC, SDR, Spectrum Sensing.**

I. Introduction

There are likely to be a variety of different views of what exactly would be a cognitive radio may be. Accordingly a definition of a cognitive radio may be of use in a number of instances.

"A cognitive radio may be defined as a radio that is aware of its environment and the internal state and with knowledge of these elements and any stored pre-defined objectives can make and implement decisions about its behaviour" [1].

"In general the cognitive radio may be expected to look at parameters such as channel occupancy, free channels, the type of data to be transmitted and the modulation types that may be used. It must also look at the regulatory requirements. In some instances knowledge of geography and this may alter what it may be allowed to do" [2].

According to Federal Communications Commission (FCC): "Cognitive radio: A radio or system that senses its operational electromagnetic environment and can dynamically and autonomously adjust its radio operating parameters to modify the system operation, such as maximize throughput, mitigate interference, facilitate interoperability, access secondary markets [3].

Cognitive radio is an intelligent wireless communication system that is aware of its surrounding environment (i.e., outside world), and uses the methodology of understanding-by-building to learn from the environment and adapt its internal states to statistical variations in the incoming RF stimuli by making corresponding changes in certain operating parameters (e.g., transmit-power, carrier-frequency, and modulation strategy) in real-time, with two primary objectives in mind:

- Highly reliable communications whenever and wherever needed;
- Efficient utilization of the radio spectrum.

Six key words stand out in this definition: awareness, intelligence, learning, adaptivity, reliability, and efficiency. Implementation of this far-reaching combination of capabilities is indeed feasible today, thanks to the spectacular advances in digital signal processing, networking, machine learning, computer software, and computer hardware.

The sophistication possible in a software-defined radio (SDR) has now reached the level where each radio can conceivably perform beneficial tasks that help the user, help the network, and help minimize spectral congestion. Radios are already demonstrating one or more of these capabilities in limited ways. A simple example is the adaptive digital European cordless telephone (DECT) wireless phone, which finds and uses a frequency within its allowed plan with the least noise and interference on that channel and time slot. Of these capabilities, conservation of spectrum is already a national priority in international regulatory planning.

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Major applications that raise an SDR's capabilities and make it a cognitive radio:

1. Spectrum management and optimizations.
2. Interface with a wide variety of networks and optimization of network resources.
3. Interface with a human and providing electromagnetic resources to aid the human in his or her activities.

Two main characteristics of cognitive radio can be defined:

Cognitive Capability: Through real-time interaction with the radio environment, the portions of the spectrum that is unused at a specific time or location can be identified. CR enables the usage of temporally unused spectrum, referred to as spectrum hole or white space. Consequently, the best spectrum can be selected, shared with other users, and exploited without interference with the licensed user.

Reconfigurability: A CR can be programmed to transmit and receive on a variety of frequencies, and use different access technologies supported by its hardware design. Through this capability, the best spectrum band and the most appropriate operating parameters can be selected and reconfigured.

II. Literature Review

Jiao et al. (2016) focused on energy consumption because of spectrum sensing. This paper present an adaptive spectrum sensing time interval strategy, in which SUs can adjust the next spectrum sensing time interval according to the current spectrum sensing results (namely, channel status). In order to find an optimal spectrum sensing time interval, this paper introduce the Markov model. Then establish a Markov model-based mathematical modeling for analyzing the relationship between spectrum sensing time interval and prior spectrum sensing results. Finally, numerical results demonstrate that the proposed strategy with dynamic adaptive spectrum sensing time interval exceeded listen before talk (LBT) strategy which is widely used for traditional wireless sensor networks [4].

Kumar et al. (2015) introduced a framework and an innovative approach to eliminate the malicious behaviors of secondary users. It is found that spectrum sensing alone cannot prevent the malicious behaviour without any information on users' reputation. Based on the evaluation of malicious behaviour resistance methods, joint spectrum sensing and malicious nodes detection approach for optimal prevention from sensing falsification is being proposed [5].

Nhan Nguyen-Thanh et al. (2013) proposed a cluster-based optimal selective CSS scheme for reducing reporting time and bandwidth while maintaining a certain level of sensing performance. Clusters are organized based on the identification of primary signal signal-to-noise ratio value, and the cluster head in each cluster is dynamically chosen according to the sensing data qualities of CR users. The cluster sensing decision is made based on an optimal threshold for selective CSS which minimizes the probability of sensing error. A parallel reporting mechanism based on frequency division is proposed to considerably reduce the time for reporting decision to fusion center of clusters. In the fusion center, the optimal Chair-Vashney rule is utilized to obtain a high sensing performance based on the available cluster's information [6].

Waleed Ejaz et al. (2013) proposed a spectrum sensing scheme which obtains reliable results with less mean detection time. First, the scheme determines a better matched filter, or a combination of energy and cyclostationary detectors based on the power and band of interest. In the combined energy and cyclostationary detector, an energy detector with a bi-threshold is used, and the cyclostationary detector is applied only if the energy of the signal lies between two thresholds. Second, sensing is performed by the selection choice resulting from the first step. To evaluate the scheme's performance, the results are compared with those where only an energy detector, matched filter, or cyclostationary detector are performed. The performance metrics are the probability of detection, probability of false alarm, and mean detection time [7].

S. Thamizharasan et al. (2013) developed a cyclostationary spectrum sensing method for identifying the presence of primary user is introduced which uses the concept of periodicity in OFDM signals. In existing method, the periodicity of pilot signals in the OFDM symbols is used to detect the signals. The proposed scheme is robust to the detection of primary user signal with guard interval insertion in the OFDM signals which use the concept of periodicity. The power spectral density of average and true method which defines the spectrum power is compared and the simulation results are given in this paper. It is observed from the results that true power spectral density method is well suitable for CR which enables perfect sensing over primary users [8].

Hongjian Sun et al. (2013) in this paper examine various wideband spectrum sensing algorithms, together with a discussion of the pros and cons of each algorithm and the challenging issues. Special attention is paid to the use of sub-Nyquist techniques, including compressive sensing and multichannel sub-Nyquist sampling techniques [9].

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Jitendra Kumar Saini et al. (2013) in this paper investigates what cognitive radio systems that require focusing on the spectrum sensing device. Taking two voice applications which running under different Orthogonal Frequency Division Multiplexing (OFDM) schemes. These devices are Wi-Fi and Wireless Microphone. Then, a Cyclo-stationary Spectrum Sensing technique is studied and applied to define a device capable of detecting OFDM signals in a noisy environment [10].

Farrukh Aziz Bhatti et al. (2012) used Software defined radios (SDRs) with the correlated signal reception capability to evaluate the sensing performance of the existing covariance based detection (CBD) techniques. The existing techniques considered in this work are; Covariance absolute value (CAV), Maximum-minimum eigenvalue (MME), Energy with minimum eigenvalue (EME) and Maximum eigenvalue detection (MED). Most importantly this paper presents a novel technique for blind signal detection that uses Principal Component (PC) Analysis. The PC based signal detection algorithm and the CBD algorithms are tested in a real scenario with SDRs and their sensing performance is compared. The PC algorithm outperforms the MED and EME algorithms under all conditions and it performs better than the MME and CAV algorithms under certain conditions [11].

Energy detection method is a basic method, which requires knowledge of noise power but suffers from the noise uncertainty problem. Covariance based detection exploits space-time signal correlations that does not require the knowledge of noise and signal power. The covariances of signal and noise are generally different which can be used in the detection of licensed users. However, there are not many studies that show the feasibility of the detectors and analyze their performance under fading channels. **Tanuja Satish Dhope et al. (2012)** analyzed the detector performance exploiting TV White Space under Rayleigh and Rician fading channel by setting probabilities of false alarm and measuring the probability of detection. They further analyze the effect of smoothing factor and the overall correlation coefficient on the performance of covariance based detector. Covariance based detector outperformed the energy detector with noise uncertainty even under the time-varying fading channels [12].

Mohd. Hasbullah Omar et al. (2011) proposed the Singular Value Decomposition (SVD) method to detect the presence of the wireless signal. The method is used to find the maximum and minimum eigenvalues. They simulated the algorithm using the common digital signal in wireless communication namely rectangular pulse shape, raised cosine and root-raised cosine to test the performance of the signal detector. They found that the SVD-based signal detection is a more efficient way of sensing signal without knowing the properties of the transmitted signal. The execution time is acceptable compared to the favourable energy detection. The computational complexity of SVD-based detector is medium compared to the energy detector. The algorithm is suitable for blind spectrum sensing where the properties of the signal to be detected are unknown. This is also the advantage of the algorithm since any signal would interfere and subsequently affect the quality of service (QoS) of the IEEE 802.22 connection. Furthermore, the algorithm performed better in the low signal-to-noise ratio (SNR) environment [13].

III. Conclusion

Sensing provides awareness regarding the radio environment so that the spectrum opportunities can be efficiently reused while limiting the interference to the primary user. In this paper, a review of the CRs technology is presented. Different papers of the spectrum sensing techniques are reviewed. CR technology will be applied to many real systems in the near future. Research can be possible for deriving a method for finding out how to minimize the energy consumption by the semiconductor chip while configuring the hardware into the CR.

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