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Review Paper on Performance Analysis of Sensing Error Probability in Cognitive Radio Networks

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Abstract

The electromagnetic radio spectrum is a precious natural resource but with the fast development of wireless communication the increasing demand of limited spectrum ultimately cause spectrum scarcity therefore the use of this spectrum is licensed by the government. The government licensed the spectrum bands to some specific services, such as mobile communication, TV broadcast, and satellite communication, in order to protect the different networks from harmful interference. Most of the spectrum band is allocated to specific services but worldwide observations show that only a few per cent of the spectrum band are efficiently utilized. A possible solution to these problems has been provided if licensed spectrum is made available to unlicensed users provided there is no interference with licensed users. This can solve almost all spectrum scarcity problems, and this solution can be achieved via intelligent radio system called CR. Cognitive radios, with cognition and reconfigurable capabilities are seen as a promising technology. One of the most prominent tasks in the implementation of cognitive radios in communication networks is the spectrum sensing. However, its performance is adversely affected due to noise uncertainty particularly in low SNR conditions. Therefore Cognitive Radio technology, Spectrum Sensing procedure, Spectrum sensing classifications is explained. Finally, Cooperative Spectrum Sensing is discussed along with its advantages and disadvantages.

Keywords: *Cognitive Radio, Spectrum Sensing, Cooperative Sensing.*

1. Introduction

Studies have shown that most of the licensed radio-wave spectral bands are under-utilized in time and space domain [1, 2], resulting in unused “white spaces” in the time-frequency grid at any particular location. The spectrum utilization is mainly around certain parts of the spectrum whereas a considerable amount of the spectrum is unutilized as depicted in Figure 1.1. As can be observed, spectrum utilization is more intense and competitive at frequencies below 3 GHz whereas the spectrum is under-utilized in the 3-6 GHz bands [1]. The Federal Communications Commission (FCC) has also reported the temporal and geographic variations in spectrum utilization to range from 15% to 85% [2]. On the other hand, fixed spectrum allocation policies do not allow for reusing of the rarely used spectrum allocated to licensed users by unlicensed users. This problem coupled with the rapidly increasing demand for wireless services and radio spectrum has led to spectrum scarcity for wireless applications.

This has necessitated a new communication standard that allows unlicensed (secondary) users to utilize the vacant bands which are allocated to licensed (primary) users. However, this opportunistic access should be in a manner that does not interrupt any primary process in the band. Therefore, the secondary users must be aware of the activity of the primary user in the target band. They should spot the spectrum holes and the idle state of the primary users in order to exploit the free bands and also promptly vacate the band as soon as the primary user becomes active. Cognitive radio encompasses this awareness by dynamically interacting with the environment and altering the operating parameters with the mission of exploiting the unused spectrum without interfering with the primary users. Showing support for the cognitive radio idea, the FCC allowed for usage of the unused television spectrum by unlicensed users wherever the spectrum is free. IEEE has also supported the cognitive radio paradigm by developing the IEEE 802.22 standard [3]. This standard is for Wireless Regional Area Network (WRAN) which works in unused TV channels.

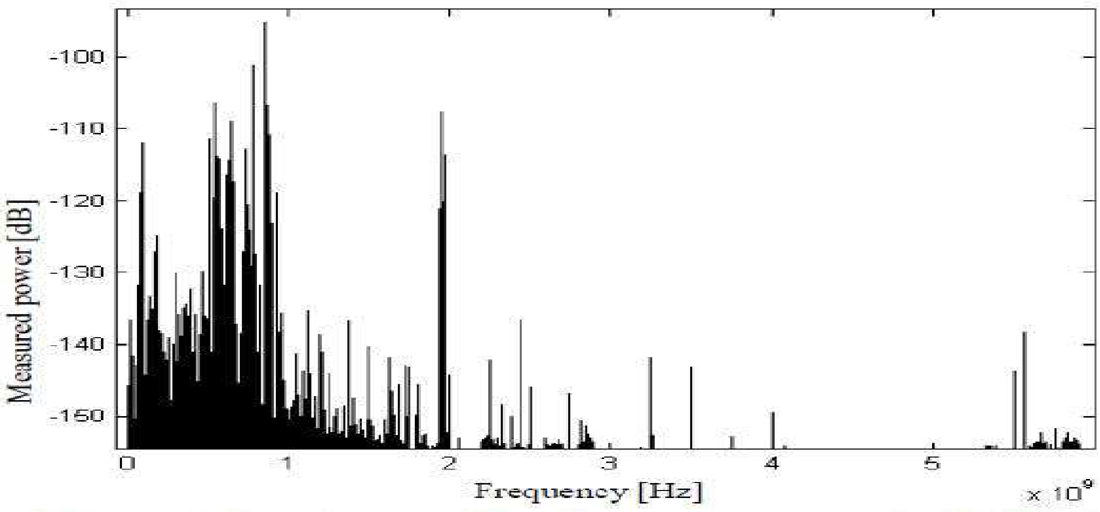

Figure 1.1: Spectrum Utilization Measurements [1]

2. Cognitive Radio

Cognitive radio (CR) is an intelligent wireless communication system that is aware of its surrounding environment, learns from the environment and adapts its internal states to statistical variations in the incoming RF stimuli by making corresponding changes in certain operating parameters in real time. The key issues in the cognitive radio are awareness, intelligence, learning, adaptively, reliability, and efficiency. A comprehensive description of the term cognitive radio was first discussed in a paper written by J.Mitola III et. al in 1999 . In 2000, J. Mitola III wrote his PhD dissertation on cognitive radio as a natural extension of the SDR concept [4-7]. When addressing the broad issue of wireless personal digital assistants in his dissertation, Mitola mentioned that the term cognitive radio identifies the point at which wireless PDAs and the related networks are sufficiently smart & computationally intelligent regarding radio resources and related computer-to-computer communications to

(a) Detect user communications needs as a function of use context, and
(b) To provide radio resources and wireless services most appropriate to those needs.

Different Scenarios in Cognitive Radio

There are two different types of spectrum sharing scenarios i.e. the way in which primary and secondary users share frequency spectrum. They are

• Cooperative scenario
• Non-cooperative scenario.

In cooperative scenario, a primary user provides secondary users with all information regarding the occupancy of the spectrum and about the unused spectrum so that the secondary users make use of that unused spectrum and keep away from the occupied spectrum. In the non-cooperative scenario, a secondary user needs to sense the spectrum for the unused spectrum and use that spectrum band without causing any interference to the primary user [6]. In the cooperative scenario, a malicious user can masquerade as the primary user and provide false information to the secondary user regarding the occupancy of the spectrum, such as the spectrum is unoccupied and the secondary user can use though the primary user occupies the spectrum. With the information provided, the secondary user tries to occupy the spectrum and as a result, interference takes place between the primary user and secondary user.

Advantages of Cognitive Radio

The main purpose of using a cognitive radio over a primitive radio is because of the following advantages [8]:
1. Senses the radio frequency environment for the presence of white spaces
2. Manages the unused spectrum
3. Increases the efficiency of the spectrum utilization significantly
4. Improves the spectrum utilization by neglecting the over occupied spectrum channels and filling the unused spectrum channels [9].
5. Improves the performance of the overall spectrum by increasing the data rate on good channels and moving away from the bad channels [10].

3. Cooperative Spectrum Sensing In Cognitive Radio

Typically, spectrum sensing is classified into three main detection approaches. In a non- cooperative primary transmitter detection approach, CR makes a decision about the presence or absence of PU on its local observations of primary transmitter signal. In comparison, Cooperative detection refers to transmitter detection based SS methods where multiple CRs cooperate in a centralized or decentralized manner to decide about the spectrum hole.

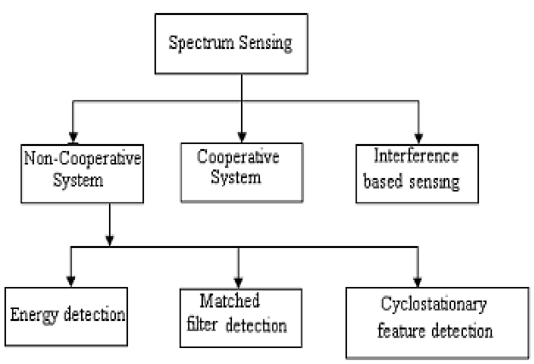

Figure 1.2: Broader Classification of spectrum Sensing Techniques

Depending on the application at hand, CR can opt for either narrowband or wideband sensing. Thus, the focus of CR will be on identifying narrowband hole or free wide band spectrum. To find spectrum opportunity, CR may adopt either a proactive (periodic) or reactive (on-demand) sensing strategy. Figure 1.2 and Figure 1.3 shows the Broader Classification of spectrum sensing techniques and General Classification of spectrum sensing techniques respectively.
Different transmitter detection based sensing techniques are categorized as non-blind, semi-blind or total blind. Non-blind schemes require primary signal signatures as well as noise power estimation to reliably detect PU. Fundamental to all these classifications is to detect presence or absence of PU signal [11]. Here, we focus on transmitter detection sensing based on a non-cooperative and cooperative approach.

The most serious limitation of transmitter detection approach is its degraded performance in the presence of multi-path fading and shadowing. This problem can be solved by exploiting the inherent spatial diversity in a multi-user environment resulting from the fact that if some SUs are in deep fade or observe severe shadowing, as shown in Fig. 1.3, there might be other SUs, in the network, with relatively strong signal from primary transmitter [12-15]. Consequently, combining the sensing information from different CRs gives a more reliable spectrum awareness. This leads to the concept of cooperative spectrum sensing [16] (CSS) wherein CRs employing different technologies, exchange information about the time and frequency usage of spectrum to avail more efficiently any vacant spectrum opportunity [17-19].

High sensitivity requirements on the cognitive user can be alleviated if multiple
CR users cooperate in sensing the channel. Various topologies are currently used and are broadly classifiable into three regimes according to their level of cooperation [20-21][25].

Decentralized Uncoordinated Techniques: The cognitive users in the network don't have any kind of cooperation which means that each CR user will independently detect the channel, and if a CR user detects the primary user it would vacate the channel without informing the other users. Uncoordinated techniques are fallible in comparison with coordinated techniques. Therefore, CR users that experience bad channel realizations detect the channel incorrectly thereby causing interference at the primary receiver.

Centralized Coordinated Techniques: In such networks, an infrastructure deployment is assumed for the CR users. One CR that detects the presence of a primary transmitter or receiver, informs a CR controller which can be a wired immobile device or another CR user. The CR controller notifies all the CR users in its range by means of a bro adcast control message. Centralized schemes [22] can be further classified according to their level of cooperation as: Partially cooperative where network nodes cooperate only in sensing the channel. CR users independently detect the channel and inform the CR controller which then notifies all the CR users; and totally cooperative Schemes where nodes cooperate in relaying each other's information in addition to cooperatively sensing the channel [26], shown in Figure 1.5.

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 themselves [27]. 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.

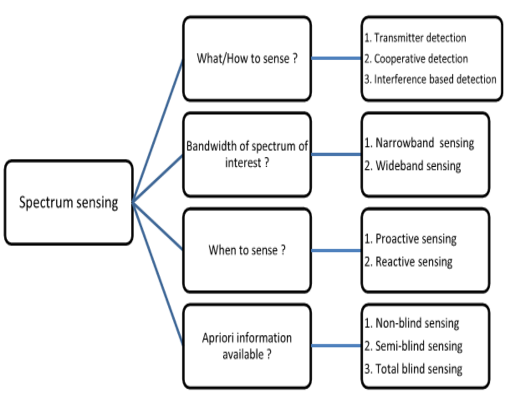

Figure 1.3: General Classification of Spectrum Sensing Techniques

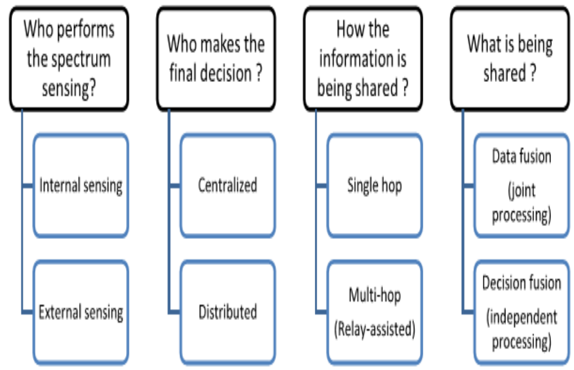

Figure 1.4: Classification of Cooperative Sensing

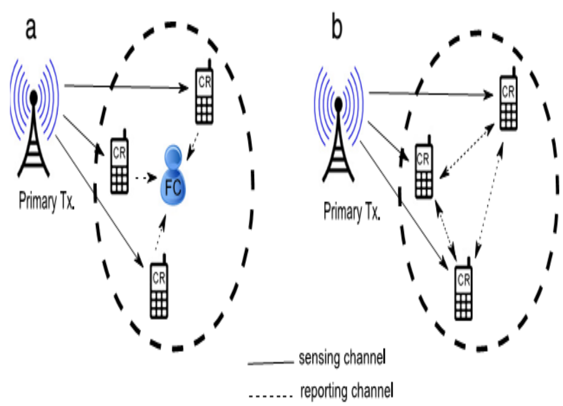

Figure 1.5: Cooperative Spectrum Sensing (a) Centralized Approach (b) Distributed Approach

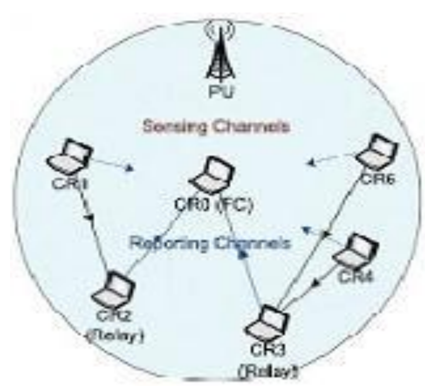

Figure 1.6: Decentralized Coordinated Techniques

Benefits of Cooperation: Cognitive users selflessly cooperating to sense the channel have lot of benefits among which the plummeting sensitivity requirements :channel impairments like multipath fading, shadowing and building penetration losses, impose high sensitivity requirements inherently limited by cost and power requirements. Employing cooperation between nodes can drastically reduce the sensitivity requirements up to -25 dBm, also reduction in sensitivity threshold can be obtained by using this scheme; agility improvement: all topologies of cooperative networks reduce detection time compared to uncoordinated networks[21].

DisadvantagesofCooperation: The CR users need to perform sensing at periodic intervals as sensed information become obsolete fast due to factors like mobility, channel impairments etc. This considerably increases the data overhead; large sensory data: since the cognitive radio can potentially use any spectrum hole, it will have to scan a wide range of spectrum, resulting in large amounts of data, being inefficient in terms of data throughput, delay sensitivity requirements and energy consumption. Even though cooperatively sensing data poses lot of challenges, it could be carried out without incurring much overhead because only approximate sensing information is required, eliminating the need for complex signal processing schemes at the receiver and reducing the data load. Also, even though a wide channel has to be scanned, only a portion of it changes at a time requiring updating only the changed information and not all the details of the entire scanned spectrum [9-12].

4. Conclusion and Future Scope

We studied about CR technology, Spectrum Sensing Techniques along with their classifications and nature. Finally we complete our work with advantages and disadvantages of cooperation. We can calculate probability of detection of PU, probability of false alarming and probability of wrong detection of PU from this paper and its references.

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