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REVIEW ARTICLE

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A NOVEL ADAPTIVE COOPERATIVE SPECTRUM SENSING – A REVIEW

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ABSTRACT

The rising demand of wireless applications has put a lot of constraint on the usage of available radio spectrum which is limited and precious resource. However, a fixed spectrum assignment has lead to under utilization of spectrum as a great portion of licensed spectrum is not effectively utilized. Cognitive radio is a promising technology which provides a novel way to improve utilization efficiency of available electromagnetic spectrum. A cognitive radio must be able to detect the presence of primary user to avoid interference. In this paper, a survey of spectrum sensing for cognitive radio is discussed. However spectrum sensing techniques are needed to detect the free spectrum. This paper also gives brief explanations of different categorization of spectrum sensing.

Keywords: Spectrum sensing, Cognitive radio, Primary users, Secondary users, Cooperative spectrum sensing, Non-cooperative detection.

INTRODUCTION

Now-a-days the demand of radio spectrum is increasing day by day due to the increase of wireless devices and applications. Also the allocated spectrum is underutilised due to the stationary allocation of the spectrum. In order to overcome these circumstances, we need an improved methodology for spectrum access and utilization. It can be achieved by using cognitive radio (CR) technology. Cognitive radio is a hopeful resolution to contest the dearth of electromagnetic radio spectrum resource. There are two main entities in cognitive radio, namely primary users (PUs) and secondary users (SUs) as shown in figure 1.

The primary users have the elite right to use the licensed band of spectrum. On the other hand these licensed bands are not essentially used by the primary users. Therefore the cognitive radio allows unauthorised users (SUs) to use the licensed bands whenever these bands are not occupied by the PUs. Thus, cognitive radio in actual fact can augment the spectrum efficiency.

1. SPECTRUM SENSING

One of the most prominent features of cognitive radio networks is that the secondary users must have the knack to detect the existence of primary users over a wide range of spectrum at a particular time and at a specific geographic location. The detection process should be done as quickly as possible and the secondary users are required to leave the band in a short range of time so as to avoid the interference with the primary users and to improve the licensed spectrum utilization efficiency.

Spectrum sensing techniques may be grouped into two categories, namely frequency domain approach and time domain approach [1]. The frequency domain approach is also known as direct method, where the estimation is carried out directly from signal. The time domain approach which is otherwise considered as indirect method, where the estimation is performed using autocorrelation of the signal. Another way of categorizing the spectrum sensing and estimation methods are by making group into model based parametric methods and periodogram base non parametric method. Another way of classification depends on the need of spectrum sensing as mentioned below [2]

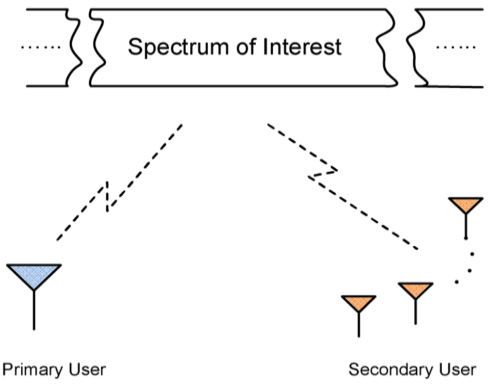

Figure 1: Primary user and secondary user

1.1 Spectrum sensing for spectrum opportunities

a. Primary transmitter detection: In this technique the primary user detection process is done based on the received signal at cognitive radio users. This technique is also stated as non cooperative detection. This approach includes, matched filter (MF) based detection, energy based detection, radio identification based detection, cyclostationary based detection and random Hough Transform based detection.

b. Cooperative and collaborative detection: In this case, the primary signals for spectrum opportunities are detected by co-operating the information from other multiple users, and the method can be implemented as either centralized access to spectrum coordinated by a spectrum server or distributed approach implied by the spectrum load smoothing algorithm or external detection.

1.2 Spectrum sensing for interference detection

a. Interference temperature detection: In this method, the cognitive radio network functions same as that of ultra wideband (UWB) technology, where the secondary users along with primary users and are allowed to transmit with low power and are restricted by the interference temperature level so as not to cause any harmful interference to the primary users.

b. Primary receiver detection: In this method, the interference and/or spectrum opportunities are detected based on the receiver's local oscillator leakage power.

2. DIFFERENT CATEGORIZATION OF SPECTRUM SENSING

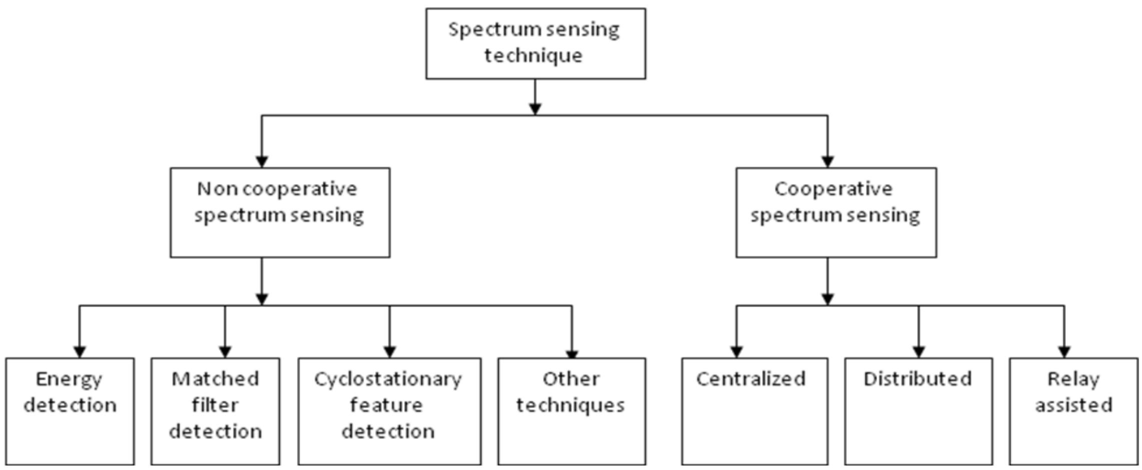

Figure 2: Different categorization of spectrum sensing

Figure 2 shows a brief description about the different categorization of spectrum sensing. They are mainly divided into two types, which include Non cooperative spectrum sensing and cooperative sensing. Non cooperative spectrum sensing is subdivided into energy detection, matched filter detection, cyclostationary feature detection and other techniques [3]. Whereas the cooperative sensing is subdivided into centralized spectrum sensing, distributed spectrum sensing and Relay assisted spectrum sensing [4].

3.1 Non cooperative spectrum sensing

In this detection technique individual cognitive users acts in the vicinity and unconventionally to carry out their own spectrum tenancy measurement and scrutiny [5]. They are broadly three approaches for non cooperative spectrum sensing.

3.1.1 Energy detection

Energy detector based approach, also known as radiometry or periodogram, is the most ordinary way of spectrum sensing because of its low computational and implementation complexities [6] [7]. In addition, it is more generic as receivers do not need any knowledge on the primary user's signal. The signal is detected by comparing the output of the energy detector with a threshold which depends on the noise floor [8]. Some of the challenges with energy detector based sensing include selection of threshold for detecting primary users, inability to differentiate interference from primary users and noise, and poor performance under low signal-to-noise ratio (SNR) values [9]. Moreover, energy detectors do not work efficiently for detecting spread spectrum signals [10] [11].

3.1.2 Matched filter detection

Matched filtering is known as the optimum method for detection of primary users when the transmitted signal is known [12]. The main advantage of matched filtering is the short time to achieve a certain probability of false alarm or probability of miss detection [13] as compared to other methods. In fact, the required number of samples grow as O(1/SNR) for a target probability of false alarm at low SNRs for matched filtering [13]. However, matched filtering requires cognitive radios to demodulate received signal. Hence, it requires perfect knowledge of the primary users signalling features such as bandwidth, operating frequency, modulation type and order, pulse shaping, and frame format. Moreover, since the cognitive radio needs receivers of all signal types, the implementation complexity of sensing unit is impractically large [10]. Another disadvantage of matched filtering is large power consumption as various receiver algorithm need to be executed for detection.

3.1.3 Cyclostationary feature detection

Cyclostationary feature detection is a method for detecting primary user transmissions by exploiting the cyclostationarity features of received signal [6] [10]. Cyclostationary features are caused by the periodicity in the signal or the statistics like mean and autocorrelation [14] or they can be intentionally induced to assist spectrum sensing. Instead of power spectral density (PSD), cyclic correlation function is used for detecting signals present in a given spectrum. The cyclostationarity based detection algorithms can differentiate noise from primary user's signals. This is a result of fact that noise is wide sense stationary (WSS) with no correlation while modulated signals are cyclostationary with spectral correlation due to redundancy of signal periodicities [15]. Furthermore, cyclostationarity can be used for distinguishing among different types of transmissions and primary users [16].

3.1.4 Other techniques

Other alternative spectrum sensing methods include multitaper spectral estimation, wavelet transform based estimation, Hough transform, and time-frequency analysis. Multitaper spectrum estimation is proposed in [17]. The proposed algorithm is shown to be an approximation to maximum likelihood PSD estimator, and for wideband signals, it is nearly optimal. Although the complexity of this method is smaller than the maximum likelihood estimator, it is still computationally demanding. Random Hough transform of received signal is used in [18] for identifying the presence of radar pulse in the operating channels of IEEE 801.11 systems. This method can be used to detect any signal with a periodic pattern as well. Statistical covariance of noise and signal are known to be different. This fact is used in [19] to develop algorithms for identifying the existence of a communication signal. Proposed methods are shown to be effective to detect digital television (DTV) signals.

In [20], wavelets are used for detecting edges in the PSD of a wideband channel. Once the edges, which correspond to transitions from an occupied band to an empty band or vice versa, are detected, the powers within bands between two edges are estimated. Using this information and edge positions, the frequency spectrum can be characterized as occupied or empty in a binary fashion. The assumption made in [20], however, need to be relaxed for building a practical sensing algorithm. The method proposed in [20] is extended in [21] by using sub-Nyquist sampling. Assuming that the signal spectrum is sparse, sub-Nyquist sampling is used to obtain coarse spectrum knowledge in an efficient way. Analog implementation of wavelet-transform based sensing is proposed in [22], [23], [24] for coarse sensing. Analog implementation yields low power consumption and enables real time operation. Multi-resolution spectrum sensing is achieved by changing the basis functions without any modification to sensing circuitry in [22]. Basis function is changed by adjusting the wavelet's pulse width and carrier frequency. Hence, fast sensing is possible by focusing on the frequencies with active transmission after an initial rough scanning. A test-bed implementation of this algorithm is explained in [24].

3.2 Cooperative spectrum sensing

In this method group of CR's share sensing information so as to get a more efficient result. In this process group of secondary users (SU) collect the information regarding channel occupancy and maintain this information into spectrum map represented by bit-vector. SU periodically transmit it to the Central Coordinator as part of control message. Central Coordinator takes bitwise-OR of spectrum maps, to determine the set of UHF channels available at all of the nodes. After that Coordinator select the best available channel and broadcast it back to SU. The technique exploits the spatial diversity intrinsic to a multi-user network. It can be accomplished in a centralized or distributed fashion [25]. There are broadly three approaches for cooperative spectrum sensing:

3.2.1 Centralized approach

In this approach to cognitive radio cooperative spectrum sensing, there is a node called fusion centre (FC) or central processor controls within the network that collects the sensing information from all the sense nodes or radios within the network. It then analyses the information and determines the frequencies which can be used [26].

3.2.2 Distributed approach

In this approach distributed approach for cognitive radio cooperative spectrum sensing, no one node act as fusion centre (FC) or central processor controls. Instead communication exists between the different nodes and they are able to share sense information. However this approach need individual radios to have a much higher level of autonomy, and possibly setting themselves up as an adhoc network [27].

3.3.3 Relay-assisted cooperative

Cooperative sensing techniques have been studied to remove the wireless fading and also when the multiple cognitive users sense independently the licensed primary channel using a detector algorithm and reports to fusion centre (FC).

3. PROPOSED SYSTEM

Here we propose a novel adaptive cooperative spectrum sensing scheme based on the recently proposed single-reception spectrum sensing technique [28]. We adopt a temporal discount factor [29], which is crucial to the probability estimators. New theoretical analysis to justify the advantage of our proposed new estimators over the conventional sample-average estimators and to determine the optimal numerical value of the discount factor is presented. The Monte Carlo simulation results are also provided to demonstrate the superiority of our proposed adaptive cooperative spectrum-sensing method in both stationary and time varying environments.

CONCLUSION

Spectrum is a very valuable resource in wireless communication systems, and it has been a focal point for research and development efforts over the last decades. Cognitive radio, which is one of the efforts to utilize the available spectrum more efficiently through opportunistic spectrum usage, has become an exciting and promising concept. One of the important elements of cognitive radio is sensing the available spectrum opportunities. In this paper, the spectrum sensing concepts are re-evaluated and also several categories of spectrum sensing techniques are discussed briefly.

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