

Spectrum Sensing Techniques for Cognitive Radio

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Abstract: Optimized spectrum sensing using techniques for secondary user spectrum access is becoming important in Cognitive Radio (CR) systems, which have been proposed to utilize the available frequency spectrum more efficiently. For achieving best performance and ensuring minimal acceptable interference to spectrum owners, it is important to accurately sense and detect the presence or absence of primary licensed users. In this paper, we review spectrum sensing challenges.

Keywords: Spectrum sensing, spectrum sensing challenges, spectrum sensing classification, hybrid spectrum sensing.

I. INTRODUCTION

In this paper we focus attention on the particular task on which the very essence of cognitive radio rests: spectrum sensing, defined as the task of finding spectrum holes by sensing the radio spectrum in the local neighborhood of the cognitive radio receiver in an unsupervised manner. The term “spectrum holes” stands for those sub bands of the radio spectrum that are underutilized (in part or in full part) at a particular instant of time and specific geographic location. To be specific, 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.

II. SPECTRUM SENSING CHALLENGES

Several sources such as hidden node problem, limited sensing abilities and wideband sensing etc are challenges in spectrum sensing.

A. HIDDEN NODE PROBLEM

The fading effects of the wireless channel plays an especially negative role in the well known ‘hidden node’ problem [1] which also refers to hidden primary user. In this problem, the spectrum sensing terminal is deeply faded with respect to the transmitting node while having a good channel to the receiving node. The spectrum sensing node then senses a free medium and initiates its transmission, which produces interference on the primary transmission. Thus, fading here introduces uncertainty regarding the estimation problem. To solve this issue, cooperative sensing has been proposed [2].

B. LIMITED SENSING ABILITIES

Cognitive radio has only a basic ‘sense of hearing’ to detect the spectrum holes that’s why its ability is limited. That indicates, a cognitive radio has to detect its multidimensional environment with only a single sense. Advanced techniques are needed to overcome this problem and sense very wide bandwidths reliably and rapidly.

C. WIDEBAND SENSING

One of the main concerns in spectrum sensing is how to set the boundaries of spectrum to sense. Instead of very wide band detection, limited spectrum can be used for spectrum sensing. Working in limited spectrum; received signal can be sampled at or above Nyquist rate with current technology.

III. CLASSIFICATION OF SPECTRUM SENSING TECHNIQUES

Figure 1.1 shows the detailed classification of spectrum Sensing techniques. They are broadly classified into three main types, transmitter detection or non cooperative sensing, cooperative sensing and interference based sensing. Transmitter detection technique is further classified into energy detection, matched filter detection and cyclostationary feature detection [3].

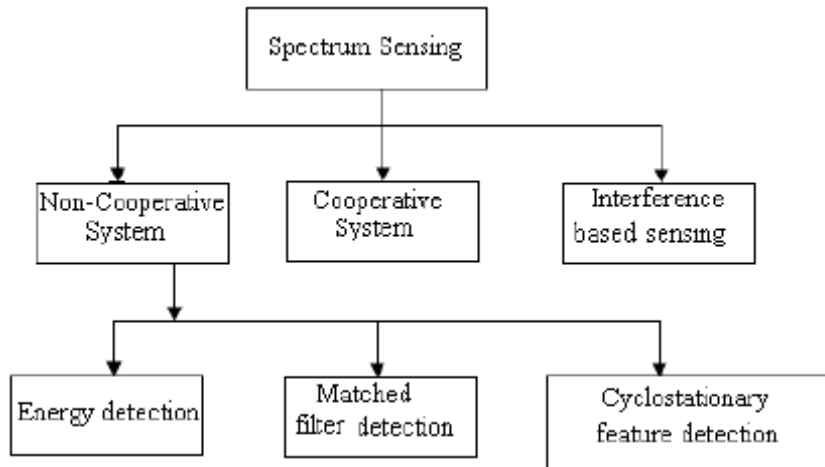


Fig 1.1 Classification of spectrum sensing techniques

A. TRANSMITTER DETECTION (NON-COOPERATIVE DETECTION)

The cognitive radio should distinguish between used and unused spectrum bands. Thus, the cognitive radio should have capability to determine if a signal from primary transmitter is locally present in a certain spectrum. Transmitter detection approach is based on the detection of the weak signal from a primary transmitter through the local observations of users.

a. MATCHED FILTER DETECTION

When the information of the primary user signal is known to the xG user, the optimal detector in stationary Gaussian noise is the matched filter since it maximizes the received signal-to-noise ratio (SNR) [4]. While the main advantage of the matched filter is that it requires less time to achieve high processing gain due to coherency, it requires a priori knowledge of the primary user signal such as the modulation type and order, the pulse shape, and the packet format.

b. ENERGY DETECTION

If the receiver cannot gather sufficient information about the primary user signal, for example, if the power of the random Gaussian noise is only known to the receiver, the optimal detector is an energy detector [4]. In order to measure the energy of the received signal, the output signal of band pass filter with bandwidth W is squared and integrated over the observation interval T . Finally, the output of the integrator, Y , is compared with a threshold, k , to decide whether a licensed user is present or not [5].

c. CYCLOSTATIONARY FEATURE DETECTION

An alternative detection method is the cyclostationary feature detection [6],[7],[8]. Modulated signals are in general coupled with sine wave carriers, pulse trains, repeating spreading, hopping sequences, or cyclic prefixes, which result in built-in periodicity. These modulated signals are characterized as cyclostationarity since their mean and autocorrelation exhibit periodicity. These features are detected by analyzing a spectral correlation function. The main advantage of the spectral correlation function is that it differentiates the noise energy from modulated signal energy, which is a result of the fact that the noise is a wide-sense stationary signal with no correlation, while modulated signals are cyclostationary with spectral correlation due to the embedded redundancy of signal periodicity. Therefore, a cyclostationary feature detector can

perform better than the energy detector in discriminating against noise due to its robustness to the uncertainty in noise power [8]. However, it is computationally complex and requires significantly long observation time.

B. COOPERATIVE DETECTION

Cooperative detection refers to spectrum sensing methods where information from multiple users are incorporated for primary user detection. Cooperative detection can be implemented either in a centralized or in a distributed manner [9],[10]. In the centralized method, the base-station plays a role to gather all sensing information from the users and detect the spectrum holes. On the other hand, distributed solutions require exchange of observations among users. Cooperative detection among unlicensed users is theoretically more accurate since the uncertainty in a single user's detection can be minimized [11]. Moreover, the multi-path fading and shadowing effect are the main factors that degrade the performance of primary user detection methods [12]. However, cooperative detection schemes allow to mitigate the multi-path fading and shadowing effects, which improves the detection probability in a heavily shadowed environment [11].

C. INTERFERENCE-BASED DETECTION

Interference is typically regulated in a transmitter-centric way, which means interference can be controlled at the transmitter through the radiated power, the out-of-band emissions and location of individual transmitters. However, interference actually takes place at the receivers. Therefore recently, a new model for measuring interference, referred to as interference temperature shown in Fig 1.2 has been introduced by the FCC [13]. The model shows the signal of a radio station designed to operate in a range at which the received power approaches the level of the noise floor. As additional interfering signals appear, the noise floor increases at various points within the service area, as indicated by the peaks above the original noise floor. Unlike the traditional transmitter-centric approach, the interference temperature model manages interference at the receiver through the interference temperature limit, which is represented by the amount of new interference that the receiver could tolerate.

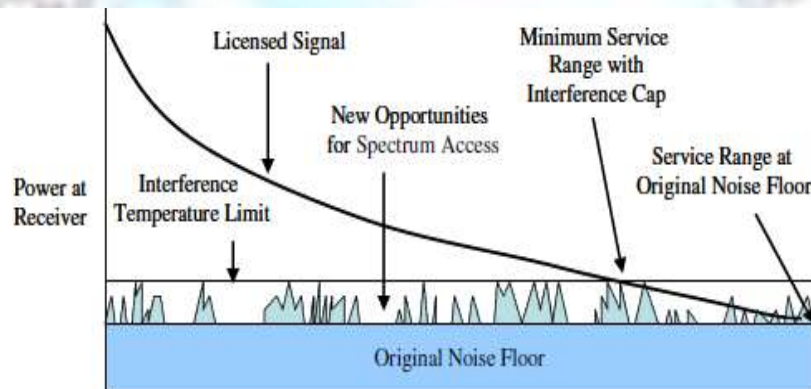


Fig 1.2 Interference Temperature Model

IV. HYBRID SPECTRUM SENSING

A possible way to obtain spectrum information with minimum sensing duration and low computational complexity is to use hybrid sensing techniques, which is a balanced combination of the sensing approaches above. For example, energy detection may be used on a broader band to have an idea about which portions of the spectrum may be available [14]. Based on this information, more accurate sensing methods can be performed over selected potential channels. Therefore, hybrid sensing techniques addressing the tradeoff between sensing accuracy and complexity must be investigated.

A. ENERGY DETECTION-CYCLO STATIONARY DETECTION

This algorithm basically divides the tasks between Energy based detector and Cycle stationary feature detection. Actually the energy based detection is used as detector and Cycle stationary feature detection is used as feature extractor when primary user is present. This feature of algorithm provides flexibility to switch to the tasks on need basis.

B. ENERGY DETECTION- EIGEN VALUE BASED DETECTION

A new hybrid spectrum sensing scheme which involves simple energy detector and Eigen value based detector is proposed to enhance the performance of CRSN without any previous knowledge about the primary users and their properties [15]. All cognitive sensor nodes are equipped with a modified simple energy detection scheme with two appropriate energy threshold value T_1 and T_2 where T_1 is lower threshold value and T_2 is upper threshold value. When a cognitive radio sensor node detects a signal to be in the range T_1 and T_2 cluster head transfer this information to detection center. Detection centers employing Eigen value based detector which does not demand any prior information about the signal or its characteristics is responsible for making a final decision on signal detection.

V. CONCLUSION

Spectrum sensing is one of the major functionalities distinguishing CRSN from traditional WSN. Spectrum sensing can be done in three ways Non-cooperative sensing, Cooperative sensing, Interference based sensing. Co-operative spectrum sensing techniques can improve the cognitive radio network performance by enhancing spectrum efficiency and spectrum reliability by effectively combating the destructive effects present in the CRSN environment at the cost of comprises in overhead traffic, power consumption, and complexity and control channels. The identification of an appropriate spectrum sensing scheme for CRSN is a challenge within the constraints of wireless sensor nodes. Efforts have been concentrated to develop energy efficient and a cost effective co-operative spectrum sensing techniques which performs well in fading and shadowing environment. To obtain spectrum information with minimum sensing duration and low computational complexity is to use hybrid sensing technique.

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