Adaptive Spectrum Sensing Algorithm for Cognitive Radio System

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Abstract. Spectrum sensing is a critical functionality of Cognitive Radio(CR) systems. There are number of spectrum sensing techniques. One of techniques is energy detection. Energy detection is the simplest detection method and is the most commonly used. But, energy detection has a hidden terminal problem in real wireless communication, because of SU can be affected by frequency fading and shadowing. Cooperative spectrum sensing can solve this problem using spatial diversity of SUs. But it has a problem of increasing data by processing multiple secondary. So, we propose the system model using adaptive spectrum sensing algorithm and system model is simulated. This algorithm chooses sensing method between single energy sensing and cooperative energy according to the received signal's Signal to Noise Ratio (SNR) from Primary User (PU). The simulation result shows that adaptive spectrum sensing has an efficiency and improvement in CR systems.

Keywords: Cognitive Radio (CR), Adaptive Spectrum Sensing, Energy Detection, Cooperative Sensing

1 Introduction

Traditional spectrum allocation policies are facing scarce radio frequency resources due to the proliferation of wireless service. Development of wireless communication needs more spectrum resources to provide services with huge of quantity data and high data rate. And then demand of more spectrum resources leads to the scarcity of the public radio spectrum being a serious problem and it is especially important to manage spectrum resource efficiently. Frequency spectrum is licensed to primary user by government agencies in a fixed manner where the license has exclusive right to access the allocated band. CR technology is considered as the solution to low usage of licensed spectrum [1]. It is able to improve the efficiency of spectrum allocations by adopting dynamic spectrum resource management. Moreover, CR system is an intelligent wireless communication system that is aware of its surrounding environment. Federal Communications Commission (FCC) is developing policies for unlicensed wireless devices to opportunistically use vacant frequency bands especially vacant TV broadcast bands [2]. CR implementations face many technical challenges, including spectrum sensing, dynamic frequency selection, adaptive modulation, and wideband frequency-agile RF front-end circuitry [4]. That means CR users need to detect the licensed user's presence or absence because CR users need to use the unlicensed band without interference. This technique is known as spectrum sensing that is the most important technique of CR. In order to enhance spectrum sensing performance, cooperative sensing with among CR users has been proposed already. In cooperative sensing, CR users share sensing information. As a result, CR users have a better chance of detecting the primary user and reducing an effect of frequency selective fading and shadowing. Based on these backgrounds, we propose adaptive sensing between single sensing and cooperative sensing. We apply energy detection techniques to reduce system complexity. This paper is organized as follow. In Section 2, we introduce system model of adaptive spectrum sensing scheme based on energy detection. In this paper considered performance of the system are described and simulation results are presented in Section 3. Finally, concluding remarks are drawn in Section 4.

2 System Model

Cognitive radio system must be secured maximal white space through spectrum sensing quickly and accurately. These are spectrum sensing method to detect white space. One of these is energy detection. Energy detection has the simplest structure by detecting without primary user information and so it is the most widely used. But single energy sensing has hidden terminal problem. Secondary user can be affected by frequency deep fading and shadowing in real communication environments. The cooperative sensing is proposed to solve this problem. Cooperative sensing has good performance the more cooperating secondary users. But it has additional problems of the more overhead traffic. So we propose adaptive spectrum sensing method according to Secondary user's SNR status by selecting single sensing and cooperative sensing adaptively. If the secondary user has sufficient SNR to detect reliably, we proceed with a single sensing. Otherwise if the secondary user has not sufficient SNR to detect reliably, we proceed with a cooperative sensing. In the Fig.1 is the proposed system of adaptive sensing.

3 Detection probability and EGC Combining

We illustrate the system model for simulation about the performance comparison between proposed sensing scheme and cooperative spectrum sensing. The following two schemes have the two hypotheses in common for spectrum sensing at the k^{th} time instant as follows

$$\begin{aligned} H_0 &: y(k) = v(k), \\ H_1 &: y(k) = hs(k) + v(k), \end{aligned} \tag{1}$$

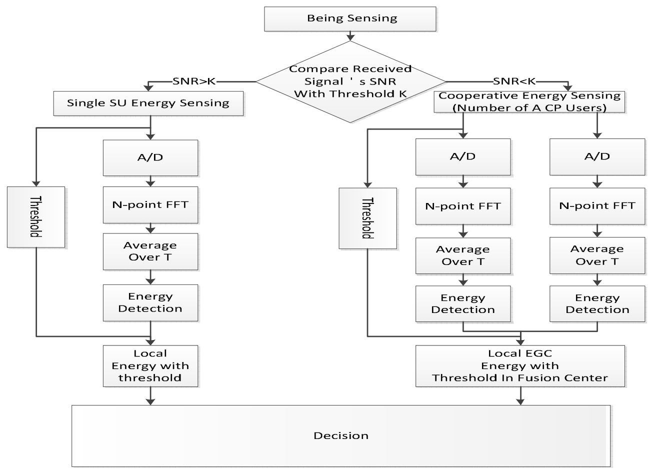

Fig. 1. Proposed Adaptive Sensing Model.

Where the fading coefficient h, $s(k)$ is transmitted signal by primary user and the additive white Gaussian noise (AWGN) $v(k)$ are modeled as independent Gaussian random variables. Unless otherwise mentioned the $v(k)$ assumed as normal distribution $N(0,\sigma_v^2)$. H_0 is that the primary user is absent and H_1 is that the primary user is present and is located closed to secondary user. If a H_1 cell is being tested, the probability density function (PDF) of the received signal $y_C^i(k)$ at the i^{th} CR user can be expressed as

$$f_{Y_C^i}\left(y|H_1\right)=\frac{1}{\sqrt{2\pi\sigma_Y^2}}e^{-\frac{\left(y-\overline{S_C}\right)^2}{2}}, \tag{8}$$

where $\overline{S_C}$ is the mean magnitude value of the transmitted signal at the primary user. And if a H_0 cell is being tested, then the PDF of $y_C^i(k)$ can be expressed a

$$f_{Y_C^i}\left(y|H_0\right)=\frac{1}{\sqrt{2\pi\sigma_Y^2}}e^{-\frac{y^2}{2}}. \tag{9}$$

After each CR user determines whether there is the primary user or not, the results are retransmitted to the fusion center over wireless channel. Then, the fusion center makes the final decision by combining the received signals from M CR users. When the H_1 and H_0 cells are being tested, the PDFs of the combined result $y_F(k)$ at the fusion center are expressed as

$$f_{Y_F}\left(y|H_1\right)=\frac{1}{\sqrt{2\pi M\sigma_F^2}}e^{-\frac{\left(y-\overline{s_F}\right)^2}{2}}, \tag{10}$$

$$f_{Y_F}\left(y|H_0\right)=\frac{1}{\sqrt{2\pi M\sigma_F^2}}e^{-\frac{y^2}{2}}, \tag{11}$$

where $\overline{s_F}=\sum_{i=1}^{M}\overline{s_F^i}$ and $\overline{s_F^i}$ is the mean value of the transmitted signal from the i^{th} CR user. The detection probability for a given value of the decision threshold is defined as the probability of the event that the output decision variable corresponding to the H_1 cell exceeds the decision threshold, which can be obtained by

$$\begin{aligned} P_D &= \int_{\gamma}^{\infty} f_{Y_F}\left(y|H_1\right)dy \\ &= \int_{\gamma}^{\infty}\frac{1}{\sqrt{2\pi M\sigma_F^2}}e^{-\frac{\left(y-\overline{s_F}\right)^2}{2}}dy, \end{aligned} \tag{12}$$

where P_D represents the detection probability of the H_1 cell. Let $z=\frac{y-\overline{s_F}}{M\sigma_F^2}$, then the detection probability can be expressed as

$$\begin{aligned} P_D &= \int_{\frac{\gamma-\overline{s_F}}{M\sigma_F^2}}^{\infty}\frac{1}{\sqrt{2\pi}}e^{-\frac{z^2}{2}}dz \\ &= Q\left(\frac{\gamma-\overline{s_F}}{M\sigma_F^2}\right), \end{aligned} \tag{13}$$

where $Q(\cdot)$ is the Q function.

We present EGC and decision combining scheme for spectrum sensing decision. Since the transmitted signal of primary user is random signal, we use energy detector as spectrum sensing rule. Various techniques are known to combine the signal from multiple antennas. In Equal Gain Combining (EGC), each signal branch weighted the same factor, irrespective of the signal amplitude. EGC is simpler to implement than Maximum Ratio Combining (MRC) and channel amplitude estimation is unnecessary. Each local sensing result is combining employing EGC.

4 Simulation Result

In this section, we represent simulation result in order to confirm performance improvement of the proposed system model. Below table.1 is simulation parameter. Binary Phase Shift Keying (BPSK) signal is used for the primary user's signal. Detection method is used for energy detection scheme. Combining scheme is used EGC(Equal Gain Combining) for processing data of Cooperative sensing in fusion center. FA(False Alarm Probability) are applied for detection threshold each of 5% and 10% in order to get detection probability in fusion center. Channel model is used for two channel model each of AWGN and Rayleigh.

Table 1.Simulation Parameter.

Parameter	Single Sensing	Cooperative Sensing
Noise Model	AWGN / Rayleigh	AWGN/ Rayleigh
Detection method	Energy sensing	Energy Sensing
Modulation scheme	BPSK	BPSK
Combining method	-	EGC
FA	5%, 10%	5%,10%

As shown above graphs from Fig.2 to Fig. 4, these simulation results show the performance detection probability when false alarm threshold probability 5% in fusion center. As shown Fig.2, we can show result of threshold probability for detection probability between AWGN and Rayleigh channel. As shown Fig.3, we can show results of detection probability between single sensing and cooperative sensing. AWGN channel in Fig 3, when secondary user's SNR has less than 1dB, single sensing has Detection probability higher than cooperative sensing. On the contrary, when secondary user's SNR has higher than 1dB, cooperative sensing has Detection probability higher than single Sensing. Rayleigh channel in Fig 3, secondary user's SNR has 2.5dB, same as above. So, we propose adaptive spectrum sensing on the basis of the overlap in the values. In Fig.4, we can confirm that improvement of performance detection probability in adaptive sensing.

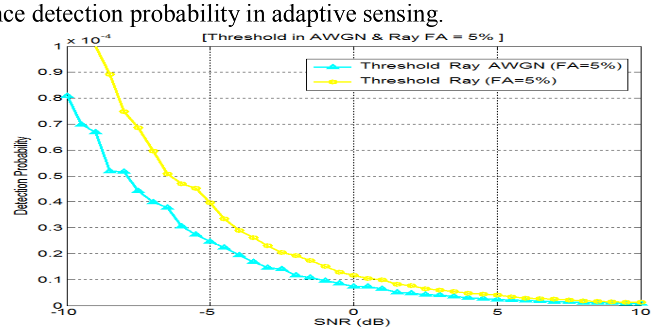

Fig. 2. Compare Detection Threshold Probability between AWGN and Ray in FA=5%

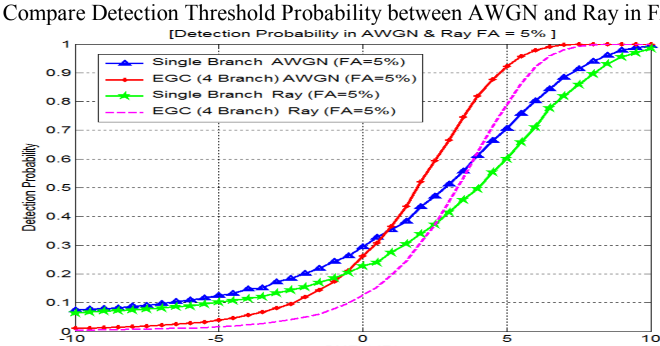

Fig. 3. Compare Detection Probability Single Sensing with 4 branch of Cooperative Sensing and AWGN with Ray in Threshold FA=5%.

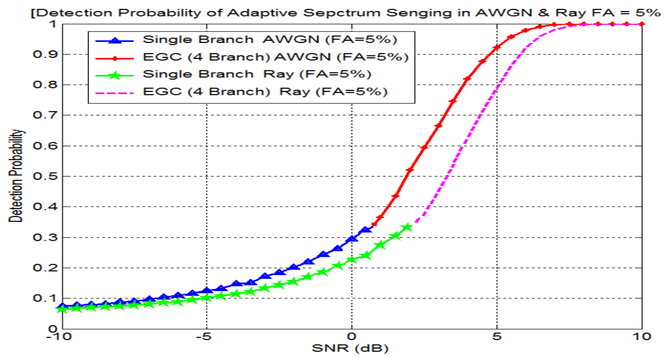

Fig. 4. Compare Detection Probability of Adaptive Spectrum Sensing between AWGN and Ray.

5 Conclusion

Cooperative sensing solves the hidden terminal problem by using Secondary user's advantageous diversity. But, cooperative sensing has problem of reporting delay to fusion center and this problem can reduce overall system performance. So we propose adaptive spectrum sensing method according to Secondary user's SNR state by selecting both single sensing and cooperative sensing and confirm performance improvement.

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