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COOPERATIVE SPECTRUM SENSING FOR OFDM BASED COGNITIVE RADIO NETWORKS

MONA.SHOKAIR*, SAHAR.SAID, RANA. GHALLAB ***, M.I.DESSOUKY*, S.EL-ARABIE****
*Faculty of Electronic Engineering, El-Menoufia University
**Atomic Energy Authority

****Faculty of Engineering, Kafr El-Sheikh University*

Email: i_shokair@yahoo.com, r_sahar10@yahoo.com, eng_rna2000@yahoo.com

ABSTRACT

Due to the increase in the usage of wireless devices and the consequent spectrum allocation radio spectrum is becoming scarce. However, studies have shown that most of the allotted spectrum is not used for large periods of time. Cognitive radio (CR) has been proposed to exploit the presence of the spectrum holes. To use the unused spectrum, spectrum sensing is need to know if the primary user (licensed user) exist or not where the spectrum sensing problem has gained new aspects with cognitive radio and opportunistic spectrum access concepts. It is one of the most important operations of cognitive radio, determines the efficiency with which the secondary users or cognitive users (CU) can use the primary spectrum, without causing appreciable interference to the primary users. Severals factors like fading and shadowing affects the ability of the cognitive radio to detect the primary user. In this paper, the performance of cooperation based spectrum sensing scheme will be studied for OFDM (orthogonal frequency division multiplexing) based cognitive users using the energy detector method .The effect of variable channel gain on the cooperation between secondary users will be investigated which is not clarified until now. Moreover, the effect of fusion rules will be made. AWGN will be assumed. Simulation results show that improvement using OR rule with cooperative scheme is better than using AND rule .This is because OR rule is very conservative for CRs to access licensed band.
Keywords: *Wireless, Cognitive Radio, Cognitive Users, OFDM, AWGN*

1. INTRODUCTION

The need for high data rates is increasing as a result of the transition from voice-only communications to multimedia type applications. Given the limitations of the natural frequency spectrum, it becomes obvious that the current static frequency allocation schemes cannot accommodate the requirements of an increasing number of high data rate devices. As a result, innovative techniques that can offer new ways of exploiting the available spectrum are needed. Cognitive radio arises to be tempting solution to the spectral congestion problem by introducing opportunistic usage of the frequency bands that are not heavily occupied by licensed users [1], [2]. While there is no agreement on the formal definition of cognitive radio as of now, the concept has evolved recently to include various meanings in several contexts [3]. In this paper, the definition adopted by Federal Communication 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 system operation, such as maximize throughput, mitigate interference, facilitate interoperability, access secondary markets."[4]. Hence, one main aspects of cognitive radio is related to autonomously exploiting locally unused spectrum to provide new paths to spectrum access. One of the most important components of the cognitive radio concept is the ability to measure, sense, learn, and beware of the parameters related to the radio channel characteristics, availability of spectrum and power , radio's operating environment, user requirement and applications, available networks (infrastructures) and nodes, local policies and other operating restrictions. In cognitive radio terminology, primary users (PU) can be defined as the users who have higher priority or legacy rights on the usage of a specific part of the spectrum. On the other hand, secondary users (SU), which have lower priority, exploit this spectrum in such a way that they do not cause interference to primary users. Therefore, secondary users need to have cognitive radio capabilities, such as sensing the spectrum reliably to check whether it is being

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used by a primary user and to change the radio parameters to exploit the unused part of the spectrum. Being the focus of the this paper, spectrum sensing [5] is the most important task among others for the establishment of CRs because they need to sense the spectrum band decide to use the spectrum band If a spectrum hole, which is described in detail in[5-9], detected or not. In addition, they need to sense the spectrum periodically to sense the primary user reappearance. A number of different techniques have been proposed for identifying the presence of the signal transmission. In some approaches, characteristics of the identified transmission are detected for deciding the signal transmission as well as identifying the signal type. Matched filter [6, 7], energy detection [8, 9] and cyclostationary detection [10] are widely used techniques as detection techniques.

In this paper, we assume the secondary user deployed detection based on energy detector which is used due to its simplicity of implementation and complexities. In addition, it does not need any prior information about the primary users' signals. Therefore, it has been thoroughly studied both in local spectrum sensing [8-12] and cooperative spectrum sensing [13-16]. Because of its attractive features, OFDM has been considered to be of great importance, ever since its conception. The basic advantage of OFDM lies in achieving higher bandwidth and thus higher data rates, without being drastically affected by the channel conditions like attenuation, narrowband interference and frequency-selective fading and maintaining slow modulation rather than requiring a rapid modulation which is often required for wide-band modulation technique utilizing the same amount of bandwidth OFDM has been accepted as the future of wireless networks .The IEEE working groups have accepted OFDM as the modulation scheme for 4G networks. In this paper, study the performance of cooperative spectrum sensing scheme will be investigated under the effect of some parameters such as channel gain and fusion rules which is not clarified until now. AWGN will be assumed. The rest of this paper is organized as follows. spectrum sensing is provided in Section 2. Energy detection scheme for OFDM signal is explained in Section 3 .Cooperative spectrum sensing based on decision fusion is introduced in Section 4 .Effect channel gain on sensing channel are presented in section 5. Simulation results will be made in Section 6. Finally, Conclusions will be done in Section 7.

2. SPECTRUM SENSING

Suppose that the frequency bandwidth carrier frequency f_c and bandwidth W are introduced and the received signal is sampled at sampling frequency f_s. The essence of spectrum sensing is a binary hypothesis-testing problem

H_0 : Primary user is absent.

H_1 : Primary user is in operation

The key metrics of the spectrum sensing are the probabilities of correct detection given by prob (Decision = H_1 / H_1) and prop(Decision = H_0 / H_0). The false alarm probability is given by
prop (Decision=H_1 / H_0),and the missed detection probability given by prob (Decision= H_0 / H_1) . From the primary user's perspective , if the probability of detection is high , the received protection will be better .From the secondary user's perspective, however, if the probability of false alarm is low, there are more chances from which the secondary users can use the frequency bands when they are available . Obviously, for a good detection algorithm, the probability of detection should be as high as possible while the probability of false alarm should be as low as possible.

3. ENERGY DETECTOR BASED SENSING

We consider a CR network composed of K CRs (secondary users) and a common receiver. The common receiver manages the CR networks and all associated K CRs. We assume that each CR performs local spectrum sensing independently. In order to see how the energy detector works; we only consider the ith CR in the following. The local spectrum sensing problem is to decide between the following two hypotheses.

$$X_i(t) = \begin{cases} n_i(t) & H_0 \\ h_i\, s(t) + n_i(t) & H_1 \end{cases} \quad (1)$$

Where $X_i(t)$ is the observed signal at the ith CR, s(t) is the signal coming from the primary transmitter , $n_i(t)$ is the additive white Gaussian noise, and h_i is the complex channel gain of the sensing channel between the primary user and the ith CR. The energy detection is performed

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by measuring the energy of the received signal $X_i(t)$ in a fixed bandwidth W over an observation time window T. The energy collected in the frequency domain is denoted by E_i, which serves as a decision statistic with following distribution.

$$E_i \sim \begin{cases} \chi^2_{2u} & H_0 \\ \chi^2_{2u} & H_1 \end{cases} \quad (2)$$

Where χ^2_{2u} denotes a central chi-square distribution with 2u degrees of freedom and $\chi^2_{2u}(2\gamma_i)$ denotes anon central chi-square distribution with u degrees of freedom and anon centrality parameter $2\gamma_i$ respectively the instantaneous SNR of the received signal at the ith CR is γ_i and u=TW is the time -bandwidth product. By comparison the energy E_i with threshold ζ_i, the detection of primary user is made. Therefore the average probability of false alarm, the average probability of detection, and the average probability of missed detection are given by [9], respectively:

$$p_f^{(i)} = \frac{\Gamma(u, \zeta_i/2)}{\Gamma(u)} \quad (3)$$

$$p_d^{(i)} = e^{-\zeta_i}\sum_{p=0}^{u-2}\frac{1}{p}(\zeta_i/2)^p + \left(\frac{1+\bar{\gamma}_i}{\bar{\gamma}_i}\right)^{u-1} \times \left[e^{\frac{-\zeta_i}{2(1+\bar{\gamma}_i)}} - e^{(-\zeta/2)_i}\sum_{p=0}^{u-2}\frac{1}{p}\left(\frac{\zeta_i\bar{\gamma}_i}{2u+\bar{\gamma}_i}\right)^p\right] \quad (4)$$

$$p_m^{(i)} = 1 - p_d^{(i)} \quad (5)$$

Where γ_i denotes the average SNR at the ith CR, Γ (a, x) is the incomplete gamma function, and Γ(a) is the gamma function.

4. COOPERATIVE SPECTRUM SENSING BASED ON DECISION FUSION

Figure 1, shows the cognitive radio network composed of N cognitive radios (secondary users) and common receiver. In cooperative spectrum sensing, all CRs identify the availability of the licensed spectrum independently Each cooperative partner makes a binary decision based on its local observation and then forwards one bit of the decision to the common receiver .let $D_i \in \{0,1\}$ denote the local spectrum sensing result of the ith CR . Specifically, {0} indicates that the CR infers the absence of the PU (Primary User) in the observed band. In contrast, {1} infers the operating of the PU . At the common receiver; all 1-bit decisions are fused together according to the following logic rule:

$$z = \sum_{i=1}^{k} D_i \begin{cases} \geq n & H_1 \\ < n & H_0 \end{cases} \quad (6)$$

Where H_1 and H_0 denote the inferences drawn by the common receiver that the PU signal is transmitted or not transmitted, respectively. Equation (6) demonstrates that the common receiver infers the PU signal being transmitted, i.e H_1, when there exists at least n out of K CRs inferring. Otherwise, the common receiver decides the PU signal not being transmitted, i.e H_0, it can be seen that the OR rule corresponds to the case of n=1 and the AND rule corresponds to the case of n = K. For the OR rule, the common receiver infers the presence of the PU signal when there exists at least one CR that has local decision. The false alarm probability of cooperative spectrum sensing based on the OR rule given by

$$Q_f = 1 - \prod_{i-1}^{K}(1 - p^{(i)}{}_f) \quad (7)$$

Where $p_f^{(i)}$ denotes the false alarm probability of the ith CR in its local spectrum sensing the missed detection probability of cooperative spectrum sensing is given by

$$Q_m = \prod_{i-1}^{K} p^{(i)}{}_m \quad (8)$$

Where $p_m^{(i)}$ denotes the missed detection probability of the ith CR in its local spectrum sensing. Assume that every CR achieves identical p_f and p_m in the local spectrum sensing which is denoted by ,

$$p_f = p_f^{(i)} \text{ and } p_m = p_m^{(i)} \; \forall i = (1,2,\ldots\ldots K)$$
(9)

The false alarm probability and the missed detection probability of cooperative spectrum sensing are then given by,

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$$Q_f = 1-(1-p_f)^K \qquad (10)$$

$$Q_m = (p_m)^K \qquad (11)$$

Note that the detection probability of the cooperative spectrum sensing is

$$Q_d = 1 - Q_m \qquad (12)$$

5. EFFECT ON CHANNEL GAIN ON SENSING CHANNEL

We then investigate the effect of the presence of channel gain between the cognitive users and primary user will be investigated. A channel gain serves to distort the signal that is transmitted through the channel. Suppose that h_i is the channel gain between primary user and secondary user. So if a signal s (t) is transmitted by primary user then the signal received by cognitive users $X_i(t)$ is given by.

$$X_i(t) = h_i s(t) + n_i(t) \qquad (13)$$

Where $n_i(t)$ is channel noise affecting this transmission.

6. SIMULATION RESULTS

A. Simulation Condition

In this section, computer simulation results are presented to evaluate cooperative spectrum sensing over AWGN channel in which OFDM modulation with N=512 sub carriers using 64 QAM.

B. Simulation Results

Figure 2 shows the cooperative spectrum sensing with different fusions rules .We conclude that the improvement using OR rule with cooperative scheme is better than the case using AND rule. Because the OR rule is very conservative for the CRs to access the licensed band.

Figure 3 demonstrates simulation results of cooperative spectrum sensing for different numbers of CRs over AWGN channels with an SNR =15dB. It is seen that the probability of missed detection is greatly reduced when the number of cooperative CRs increases for a given probability of false alarm

Figure 4 shows performance results of cooperative spectrum sensing for different average SNR in sensing channels. It is seen that energy detector works efficiently at high SNR where the performance of energy detector is susceptible to uncertainly in noise power. To solve this problem, pilot tone from primary transmitter will be sent .another drawback in using energy detector is that it cannot differentiate signal types but can only determine the presence of the signal .Thus energy detector is prone to the false detection triggered by the un intended signals .

Figure 5 demonstrates the effect of channel gain on sensing scheme between the primary user and the secondary user .It's further seen that the channel gain is low, the probability of missed detection is decreased.

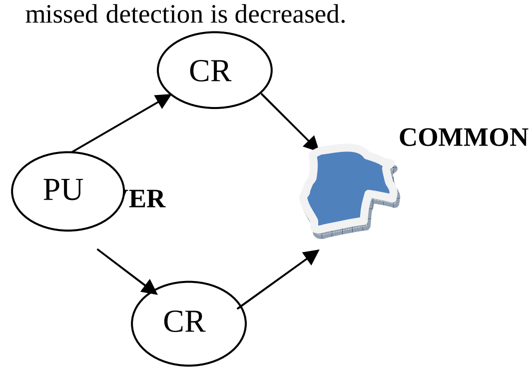

Fig .1. System model of cooperative spectrum sensing

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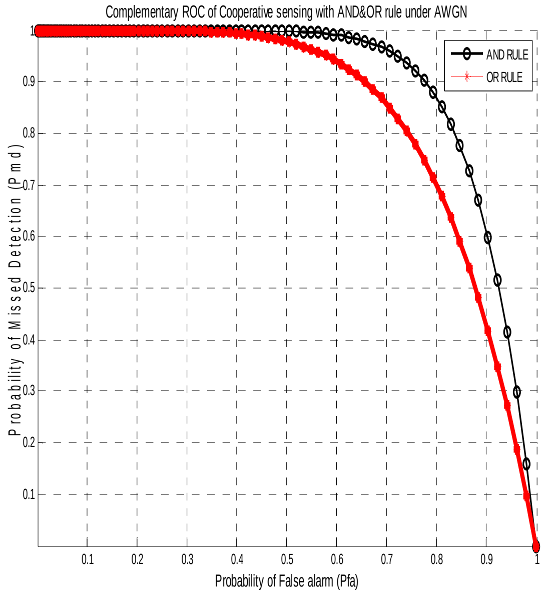

Fig.2. Cooperative spectrum sensing performance with various fusion rules

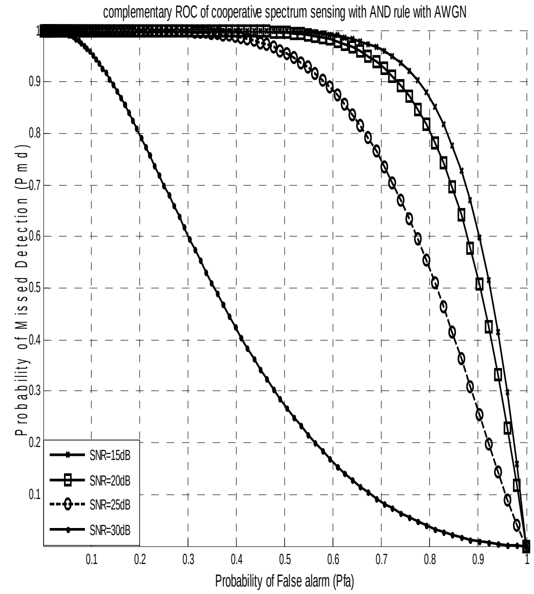

Fig.4.Performance results of cooperative spectrum sensing for different average SNR in sensing channels

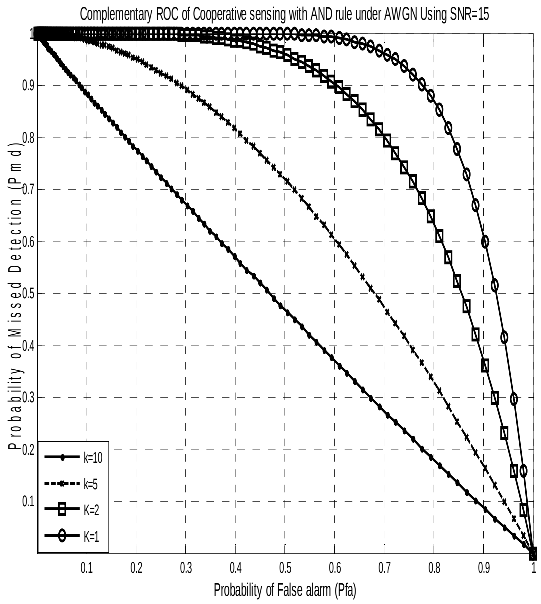

Fig.3. Cooperative spectrum sensing performance for different numbers of secondary users (CRs)

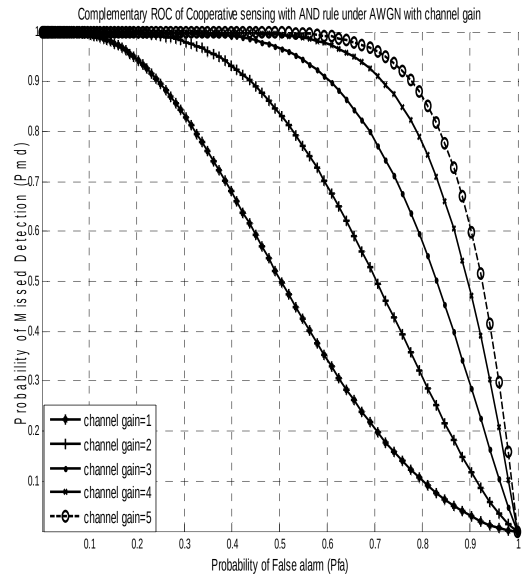

Fig.5. Effect channel gain on channel between secondary user and primary user

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7. CONCLUSIONS

Cognitive radio is a novel technology that can potentially improve the utilization efficiency of the radio spectrum. Cooperative communications can play a key role in the development of CR networks. In this paper, the performance of cooperative spectrum sensing with different fusion rules has been studied which is not clarified until now . By using this technique, it can seen that OR rule is the best among the fusion rules and gives better performance than AND rule. We have also shown that the value of probability of miss detection for a given value of probability of false alarm decreases significantly as the numbers of users increases. If the channel gain is varied between the secondary users and primary user this affects the performance of the sensing scheme negatively. It is further seen that lower the channel gain, greater the decrease in probability of missed detection

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