Research Of Spectrum Sensing Based On Decode and Forward Retransmission

Yuebin Chen

college of information engineering
Yunnan university of Nationalities
Kunming, China
cybuestc@sina.com

Qian Wang

College of Information Engineering
Yunnan University of Nationalities
Kunmin, China
Xing-sheng Pang
t1001530@163.com

College of information engineering
Yunnan university of Nationalities
Kunming, China
pangxingsheng@163.com

Tuanwei Tian

College of Information Engineering
Yunnan University of Nationalities
Kunming , China
1007054704@163.com

Abstract—**In spectrum sensing, single point detection due to their own limitations is facing some problems such as hidden terminal, perceived sensitivity of the end, etc. Two nodes cooperative spectrum sensing schemes based on DF (Decode and Forward) protocols were proposed to achieve spatial diversity gains in cognitive radio networks, which were referred to DF-CSS(DF-based Cooperative Spectrum Sensing), respectively. This paper is based on DF retransmission spectrum sensing, and analysis the detection of Rayleigh fading environment program for the theoretical. At last, the advantages of collaborative by comparison the cooperative detection with the single point performance is showed.**

Keywords-Cognitive radio; Cooperation detection; Decode and Forward; Probability of detection

I. INTRODUCTION

Spectrum sensing is a key part in the cognitive radio technology, meanwhile, it is also a challenging task. Generally speaking, the spectrum sensing technology is divided into two parts: a single point detection scheme and cooperative detection scheme. Single point detection is easy to realize, but its performance will reduced with the multipath and shadow fading, and itself has some limitations too[1]. Cooperative detection suffers widespread concern because this detection can overcome the limitations of single point detection. A. Ghasemi and other people propose cooperative detection scheme，which can improve overall system probability of detection. But these schemes do not contain the protocol of retransmission[2]. Cooperative spectrum sensing is proposed by G. Ganesan and Li. firstly which based on AF (Amplify and Forward) retransmission[2][3]. But cooperative spectrum sensing which based on DF(Decode and Froward) retransmission few studies. Cooperative diversity based on diversity techniques, that based on the principles of wireless communication environment, and the different transmission will experience different fading. One same signal is able to generate multiple independent 'copy' signal conduct transmission, namely the formation of a "sub-set", which can be effective against fading[6]. Cooperative diversity is divided into two steps. Firstly, the source node sends a broadcast signal, then the destination node and relay nodes receive the signal, which the relay node accept the signal processing; Secondly, the relay node sends a signal to the destination node, and the destination node to merge signals which receive from two steps through some kind of merger.

The cooperative diversity can be divided into three types: the AF-CSS (AF-based Cooperative Spectrum Sensing), the DF-CSS, and the CC-CSS (CC-based Cooperative Spectrum Sensing) according to the relay node processing the received signal. AF-CSS: the relay node receive the signals then amplify and forward retransmission, that G. Ganesan and Li. A detailed study on this method[2][3]; DF-CSS: the relay node receive signals and carry out the judgment, and then forward out, this paper stresses a detailed discussion of this approach; CC-CSS is relay users try its partners to transmit redundant information.

In this paper, the probability of the detection of cooperative spectrum sensing based on DF retransmission is discussed. We analysis the probability of the detection in two situation: cooperation with the DF protocol and noncooperation, that is, signal point performance. It is shown that the cooperation scheme has a better performance than the signal detection. All the results are supported by mathematical analysis and simulations.

II. SPECTRUM SENSING BASED ON DECODE AND FORWARD

A. System Model

Assuming that the wireless network only has two cognitive users U_1 and U_2, shown in Figure 1, P denotes the authorized primary user, and the AP is the access point. Cognitive users U_1 and U_2 are going to communicate with the access point AP when the primary user P is to start using

band. The cognitive user should be detected as soon as possible and quit the band. In this model, U_1 is far away from the primary user P, and barely receive the signal of the primary user P, so set U_2 as the cooperative partner of U_1 that two cognitive users will collaborate. All of the channel in the model is independent, and the receiver attaches to a zero mean and double-sideband power spectral density for the complex Gaussian white noise of N_0. Figure 2 is a diagram of time slot assignment.

If a signal X is sent, the received signal Y is given by

$$Y = hX + w \qquad (1)$$

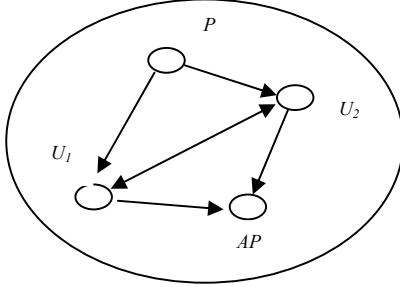where, h is the fading coefficient, w is the additive Gaussian noise.

Figure 1. SYSTEM MODEL

TABLE I. COOPERATION IN TWO COGNITIVE USERS

U_1TX	U_2 Relay	U_2TX	U_1Relay

Figure 2. RELAY PROTOCOL USED

B. Analysis DF-CSS

According to DF strategy, cooperative user should estimate whether the primary user on the basis of received signal or not, and retransmit the result to its partner.

The specific process is as follows: In the first slot t_1, the cognitive user U_1 transmit own information to the access point AP, while U_2 receive this information too. In the second slot t_2, the received information is decoded and judged by U_2, then the judgment be retransmitted to U_1. Therefore, we can know that the signal received by the cognitive user U_2 in time slot t_1 can be expressed as:

$$y_2 = \theta h_{p2} + \alpha h_{12} + \omega \qquad (2)$$

The signal received by the cognitive user U_1 in the time slot t_2 can be expressed as:

$$y_1 = \theta h_{p1} + \hat{\theta} h_{12} + \omega \qquad (3)$$

In (2) and (3), θ denotes the primary user indicator; $\theta = 1$ implies presence of the primary user and $\theta = 0$ implies its absence. h_{pi} denotes the instantaneous channel gain between the primary and U_i , i=1,2. h_{12} denotes the instantaneous channel gain between U_1 and U_2. We assume that the channels are reciprocal, i.e., $h_{12}=h_2$, and h_{p1}, $h_{p2,}$ ω are zero-mean complex Gaussian random variables which are pairwise independent. The random variables h_{p1}, h_{p2} and h_{12} have the variances σ_{p1}^2 , σ_{p2}^2 and σ_{12}^2 respectively. $\hat{\theta}$

denotes the estimated indicator, and there is one of two results about the judgment: correct judgment $\hat{\theta} = \theta$ and incorrect judgment $\hat{\theta} \neq \theta$. The detection indicator of the cognitive user will judge the primary user though the two values of the variable θ. α denotes the signal sent form U_1.

$$H_1 : \theta = 1 \qquad (4)$$
$$H_0 : \theta = 0$$

In this paper, we utilize the energy detector to show advantage of the proposed cooperation scheme. The output of the energy detector is expressed as:

$$T(y) = |y|^2 \qquad (5)$$

compared with the threshold λ which is determined by a prespecified probability of false alarm γ, we determine that whether the primary user is presence or not.

III. THE PERFORMANCE ANALYSIS OF COOPERATIVE SPECTRUM SENSING

A. Detection Probability

In this section, we suppose that symbol A denotes U_2 can correctly detect the primary user P and symbol B denotes U_1 detect user P. According to the total probability formula, we can come to the detection probability of the primary user from U_1:

$$P(B) = P(A)P(B/A) + P(\overline{A})P(B/\overline{A}) \qquad (6)$$

$P(A)$ is the detection probability which the cognitive user correctly detect the primary. According to the received signal in the time slot t_1, U_2 judge the existence of primary user :

$$T(y_2) = |\theta h_{p2} + \alpha h_{12} + \omega|^2$$
$$= \theta^2 |h_{p2}|^2 + \alpha^2 |h_{12}|^2 + N_0 \qquad (7)$$

Since h_{p2} and h_{12} are complex Gaussian and pairwise independent, it is obvious that $|h_{p2}|^2$ and $|h_{12}|^2$ are exponential and pairwise independent. Hence, we can get

$$P(A) = P\{T(y_2) \geq \lambda \mid H_1\}$$
$$= P\{(\theta^2 |h_{p2}|^2 + \alpha^2 |h_{12}|^2) \geq \lambda - N_0 \mid H_1\}$$
$$= \frac{\sigma_{p2}^2}{\sigma_{p2}^2 - \sigma_{12}^2 \alpha^2} \exp\left(-\frac{\lambda - N_0}{\sigma_{p2}^2}\right)$$
$$+ \frac{\sigma_{12}^2 \alpha^2}{\sigma_{12}^2 \alpha^2 - \sigma_{p2}^2} \exp\left(-\frac{\lambda - N_0}{\sigma_{12}^2 \alpha^2}\right) \qquad (8)$$

We seek the appropriate detection threshold and assume the probability of false alarm γ :

$$\gamma = P\{T(y) \geq \lambda \mid H_0\}$$
$$= \exp\left(-\frac{\lambda - N_0}{\sigma_{12}^2 \alpha^2}\right) \qquad (9)$$

That is

$$\lambda = N_0 - \sigma_{12}^2 \alpha^2 \ln \gamma \qquad (10)$$

The error detection probability which U_2 detect P is:

$$P(\overline{A}) = 1 - P(A) \tag{11}$$

$P(B/A)$, the detection of the user U_1 while the U_2 made a correct judgment: $\theta = \hat{\theta}$.

$$y_1 = \theta h_{p1} + \hat{\theta} h_{12} + \omega = \theta h_{p1} + \theta h_{12} + \omega \tag{12}$$

$$\begin{aligned} P(B \mid A) &= P\{T(y_1) \geq \lambda \mid H_1\} \\ &= P\left\{\left(|h_{p1}|^2 + |h_{12}|^2\right) \geq \frac{\lambda - N_0}{\theta^2}\right\} \\ &= \frac{\sigma_{p1}^2}{\sigma_{p1}^2 - \sigma_{12}^2} \exp\left(-\frac{\lambda - N_0}{\sigma_{p1}^2}\right) \\ &\quad + \frac{\sigma_{12}^2}{\sigma_{12}^2 - \sigma_{p1}^2} \exp\left(-\frac{\lambda - N_0}{\sigma_{12}^2}\right) \end{aligned} \tag{13}$$

$P(B/\overline{A})$, the detection of the user U_1 while the U_2 made a incorrect judgment: $\theta \neq \hat{\theta}$.

$$y_1 = \theta h_{p1} + \hat{\theta} h_{12} + \omega$$

$$\begin{aligned} P(B \mid \overline{A}) &= P\{T(y_1) \geq \lambda \mid H_0\} \\ &= P\left\{|h_{p1}|^2 \geq \frac{\lambda - N_0}{\hat{\theta}^2}\right\} \\ &= \exp\left(-\frac{\lambda - N_0}{\sigma_{p1}^2 \hat{\theta}^2}\right) \end{aligned} \tag{14}$$

Detection threshold λ :

$$\lambda = N_0 - \sigma_{12}^2 \hat{\theta}^2 \ln \gamma \tag{15}$$

In summary, we get the detection probability of the U_1 for cooperative spectrum sensing as (6).

When there is no cooperation between U_1 and U_2, h_{12} in (1) is zero. In this case, let $P_n(B)$ and $P_n(A)$ denote the respective detection probabilities. Now we calculate the detection probability of the U_1 for no-cooperative:

$$y_1 = \theta h_{p1} + \omega \tag{16}$$

where, the symbols here have the same meaning as before. Since y_1 is complex Gaussian, it is obvious that $T(y_1)$ is exponential. Then, we can easily get that

$$\begin{aligned} P_n(B) &= P(T(y_1) > \lambda \mid H_1) \\ &= \exp\left(-\frac{\lambda}{\sigma_{p1}^2 + N_0}\right) \end{aligned} \tag{17}$$

and

$$\gamma = P(T(y_1) > \lambda \mid H_0) = \exp\left(-\frac{\lambda}{N_0}\right) \tag{18}$$

From (16) and (17), we can get

$$P_n(B) = \gamma^{\frac{1}{SNR_1 + 1}} \tag{19}$$

In the same way, we can calculate the detection probability of the U_2:

$$P_n(A) = \gamma^{\frac{1}{SNR_2 + 1}} \tag{20}$$

Where SNR_i refers to the received signal power to noise ratio at U_i from the primary user.

B. Overall Detection Probability of System

In the model of the system, the primary user is detected by the cognitive user U_1 or U_2, and we can decide presence of the primary user.

According to the rule of the "or", the overall detection probability of system is:

Cooperative detection:

$$P = 1 - [1 - P(A)][1 - P_n(B)] \tag{21}$$

No-cooperative detection:

$$P = 1 - [1 - P_n(A)][1 - P_n(B)] \tag{22}$$

IV. RESULT AND ANALYSIS

In this section, the result of the probability of the detection versus signal to noise and probability of false of alarm under Rayleigh environment is shown.

Fig.3 shows the detection probability is different between the cooperative detection and the no-cooperative detection under noise uncertainty:-1db and -1.5 db. Follow the signal power to noise ratio, we can know that detection probability of cooperation is higher than no-cooperation.
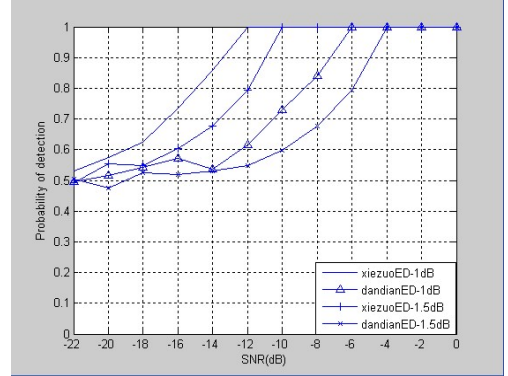

Figure 3. DIFFERENT SIGNAL POWER TO NOISE RATIO

Fig.4 shows the detection probability is different follow the change of the false alarmγ. Here the signal to noise is defined -22 and -18. we can figure out that cooperative detection is better than no-cooperative under the certain signal to noise.
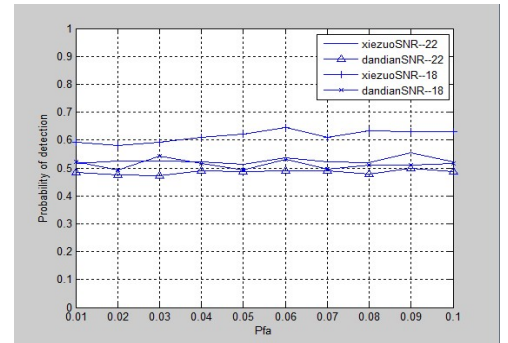

Figure 4. DIFFERENT PROBABILITY OF FALSE ALARM

V. Conclusion

In this section, the probability of detection of the cooperation and noncooperation scheme under Rayleigh environment is discussed. We can know that, DF-CSS can overcome some weakness of the single point detection, so DF-CSS can improve the performance of the cognitive radio. It is shown that, by using DF-CSS protocol, the probability of detection under Rayleigh environment significantly improves at very low SNR range.

Acknowledgment

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