# A Diversity-based Multi-antenna Cooperative Detection Model in Cognitive Radio Network

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***ABSTRACT:*** *Spectrum sensing is a key technology in the study of cognitive radios, but its attributes are easily influenced by the channel fading. Compared with single-user spectrum sensing, multiple-user spectrum sensing can overcome the impacts caused by the fading environment of cognitive radio. Since diversity technology has been proved to provide the system high transmission rate and high link reliability, we propose a diversity-based multi-antenna cooperative detection model based on the original cooperative detecting model. By introducing the antenna technology, sensing users are equipped with a multi-antenna system. Simulations show that the performance of our proposal is better than that of detection based on single-antenna in cognitive radio network. What's more, performance of cooperative detection based on multi-antenna is even better than that of cooperative detection based on single-antenna cognitive radio network.*

**Categories and Subject Descriptors**
C.2.1 **[Network Architecture and Design]**: Wireless Communication; J.2 **[C.2.1 Network Architecture and Design PHYSICAL SCIENCES AND ENGINEERING]**; Electronics

**General Terms:** Wireless Communication, Cognitive Radio, Frequency Spectrum

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## 1. Introduction

Currently, a variety of wireless communication services are emerged. The development of wireless communication technology has brought tremendous changes to our lives. With the rapid growth of wireless communication services and demands, the problem caused by the shortage of spectrum resources is becoming increasingly serious [1]. Meanwhile, the research reports of the Federal Communications Commission (FCC) indicate that the major factor causing the low utilization rate of spectrum resources is the traditional fixed spectrum allocation scheme. A report of a project made by American National Radio Network Research Test bed (NRNRT) also drew the same conclusion. The report pointed out that the average utilization rate of spectrum resources in six areas of American was merely 5.2%.

In 1999, Dr. J.Mitola proposed Cognitive Radio [2], which opened a new door for solving the problem of low utilization rate of spectrum resources. He proposed a conceptual model which was used as the software radio intelligent expansion. The model mainly includes two big modules, software module and hardware module. Specifically, the hardware module contains intelligent module and software module. The most basic unit of hardware module includes antenna, modem, baseband processor, RF modules and user interface. The hardware module is the most basic structure of software radio.

The conception of Cognitive Radio networks was proposed by Virginia Polytechnic Institute. At first, the definition of the concept was that the communication network is able to sense the existing network environment, real-timely adjust the configuration of the communication network by the understanding of the environment, and intelligently adapt to changes in the environment. At the same time, by the previous training, it can also make a judgment on the new changes in the networks through constantly learning. The end-to-end goals must be considered in all judgments. Through this model, we can clearly know that the functions of Cognitive Radio networks include wireless transmitter, wireless receiver, the channel estimation, engine analysis and so on. The first three modules pass their own relating operating parameters to the engine analysis module, and the engine analysis module derives the optimal value of all the result sets through the comparison of the analysis of aggregated data and the previously accumulated parameters. Then the optimal value selected by the last step, in turn, is passed upwards to the wireless transmitter, wireless receiver, and the channel estimation. Thus, the first two can complete the function of automatically changing the configuration parameters according to environmental changes.

The rest of the paper is organized as follows: Section 2 describes the related wok. Section 3 provides the design details of a diversity-based multi-antenna cooperative detection model and the simulations and results are shown in section 4. In the last section, we present conclusions and directions for future work.

## 2. Related Work

An important prerequisite for Cognitive Radio networks can be achieved is the ability of spectrum sensing. It is not only reflected in the self-learning and change, but reflected in accurately and efficiently finding idle spectrum through detecting. Also in order to avoid interference to authorized users, the cognitive users, in the process of communicating by using the detected idle spectrum, need to quickly detect the emergence of authorized users, and promptly switch communication bands and give up the previous channel for authorized users, or continue using the original frequency band by adjusting transmit power and other methods in the preconditions of not affecting the authorized users.

We find that cooperative spectrum sensing can effectively remedy the deficiencies existed in single-user spectrum sensing. On one hand, the cooperative way uses data detected by multi sensing users who transport in different locations. In other words, the cooperative way can make full use of diversity gain algorithm, effectively suppress spectrum on the multi-path fading problems and reduce the impacts caused by the shadow effect. Thus, the cooperative way can reduce the uncertainty of the single-user spectrum sensing and improve the sensing accuracy. On the other hand, this cooperative spectrum sensing can satisfy the sensitivity of reduction requirement of single sensing user. It reduces the hardware complexity and costs, and increases practicability.

There are still a lot of researches on the spectrum sensing.

The main research ways are listed as follows.

C.W. Wang [3] proposed an adaptive credibility-based cooperative spectrum sensing technique, which evaluates the sensing reliability of SUs based on previous sensing performance, and adjusts the probability of false alarm of each SU individually.

J.Lisa [4] proposed a realistic cooperative spectrum sensing network where the reporting channels from the cognitive radios to the CBS are affected by Additive White Gaussian Noise (AWGN) and Rayleigh fading. To minimize the effects caused by these channel uncertainties an optimal Minimum Mean Square Error (MMSE) detector is used to improve the detection performance under realistic spectrum sensing environment.

X.B.Li [5] proposed a population adaptive Gbest-guided Artificial Bee Colony (PA-GABC) algorithm and it is applied to cooperative spectrum sensing for cognitive radios field. Simulations are performed to compare the performance of the PA-GABC algorithm and traditional Artificial Bee Colony (ABC) algorithm.

O.A. Alghamdi [6] proposed a new method to optimize the overall performance in hard cooperative spectrum sensing in cognitive radio networks. Two optimization strategies are proposed in order to optimize the overall performance by controlling the number of locally sensed samples at each CR. The proposed strategies contribute to the methods in the literature by taking their performances to the optimist point. Additionally, the effects of spectrum sensing technique type that used locally at each CR, the number of locally sensed samples, the local SNR, and the total number of cooperated CRs on the optimal fusion rule are investigated.

## 3. Systerm Model

### 3.1 System Model

Let us think about the cognitive model with two cooperative users, the situation of channel MIMO [7]. Firstly, we assume that user SU1 is the direct relay of sensing user SU2, then authorized receiver will receive those users' data and signals in a relative fixed rate under TDMA mode. It is described in Figure.1. We first illustrate several assumptions before explicating the experimental data, we first illustrate several assumptions. 1) We suppose that both SU1 and SU2 have $G$ antennas and the authorized receiver has the same configuration with the transmitter. What is more, it is necessary to make the assumption that different users can work independently and do not interfere with each other. At the same time, each of them will have the fading phenomena. 2) We make a further assumption that each user can capture the available channel and the information of the channel utilization, which is supported by sending the frequency setting symbol got in the last step through the transmitting port. Here we default that there are receivers and transmitters to achieve the above functions in the network and the transmitters can be detected by each sensing user in the overall situation.

We divide the sending time into two stages when SU1 and SU2 transporting data: the first stage is the traditional sense of SU1 broadcasting and SU2 receiving; the second stage is forwarding the broadcast content received by SU2 in the last time segment. Further illustrated, that is if, in the initial stage, authorized users use the channel detected by the sensing users mentioned in the last stage, then SU1 and SU2 must stop detecting and give the right back to the authorized users since they have lower priority than the authorized users. Naturally thinking, detecting time plays an important role during this process. But if the detecting time is too long which is caused by transporting distance or users themselves, then the fading will be a horrible phenomenon. Conversely, if we make use of the multi-user cooperative model, this way will be able to greatly improve the detection ability of the entire cognitive radio network, enhance the accuracy and sensitivity and other related performance.

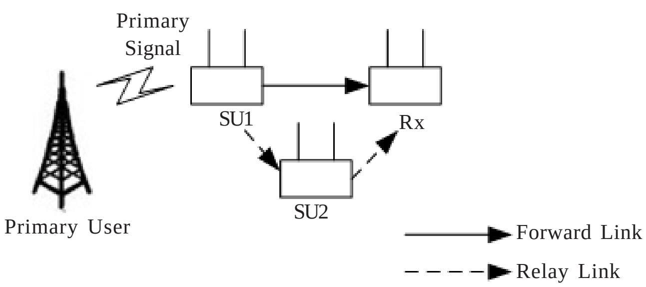


Figure 1. The Two user multi-antenna-aware wireless networks process

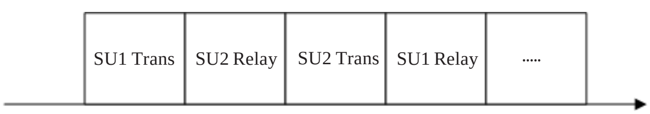


Figure 2. The Figure DMA transfer slot

Figure 2 gives the time quantum of transporting under the cooperative way, in the first part, content broadcasted by SU1 is $x_1$, and SU2 will receive $x_1$ as well. The third part is SU1Trans.

$$y_2 = H_{12}\, x_1 + n_2 \tag{1}$$

In function (1), we use $H_{12}$ to express the correlation matrix of the instant broadband gain ratio between SU1 and SU2, meanwhile in the first stage vector $x_1$ broadcasted by SU1 is highly tally with Gauss distribution, expression $E[x_1 x_1^H] = I, E[\bullet]$ means the expectation during the process, while $n_2$ represents the vector value of noise interference of SU2 (SNR is set as 0, variance is 1 in this paper), so the Gauss model can be simplified as highly symmetrical Gauss model, corresponding variables are treated as stochastic values. In the second stage, SU2 will use AF relay mode to transfer the information from SU1 to the receiver [8] according to the data materials. The signal $x_2$ here is expressed as:

$$x_2 = \beta\, y_2 \tag{2}$$

Where, $\beta$ is the factor symbol which taking the responsibility of magnifying signal. Then, what SU1 get from SU2 is listed as below:

$$y_1 = H_{21}\, \beta y_2 + n_1 \tag{3}$$

Here, $H_{21}$ represents the distance and brand gaining rate between SU2 and SU1.

### 3.2 The analysis of detection under single-antenna condition

In the single-antenna cognitive radio network environment, formula (1) can be rewritten as follows:

$$y_2 = \rho h_{p2} + x_1 h_{12} + n_2 \tag{4}$$

Where, $h_{pi}$ represents the distance and the brand gaining rate between SU2 and SU1. $h_{p2}$, $h_{12}$ and $n_2$are the independent variables mentioned above in the model of Gauss, $x_1$ is the message sent by SU1 after detecting, $\rho$ means the state of authorized users at this stage; when $\rho = 1$ there are users waiting for that channel, while $\rho = 0$ means the channel is available. Now, if we assume that P is broadcasting rate of SU1, and that of SU2 is PMAX, then we have proved that $E\{|x_1 h_{12}|^2\} = PG_{12}$, $G_{12} = E\{|h_{12}|^2\}$ is tone-up rate of brand between SU1 and SU2 , in which $h_{p2}$, $h_{12}$ and $n_2$ work independently without interference, We can draw $E\{|y_2|^2\} = \rho^2 P_2 + PG_{12} + 1$ from formula (4), where $Pi = E\{|h_{pi}|^2\}$ represents the value of channel power that sensing user SUi got from authorized users. Firstly, compared with spectrum sensing under the multi-antenna environment, in the time section T2, SU2 will do the same thing and transit to the central receiver. And in the process of the forward, SU1 will to receive other sensing information about channels as well and the information can be expressed as:

$$\begin{aligned} y_1 &= \sqrt{\beta_1}\, y_2 h_{12} + \rho h_{p1} + n_1 \\ &= \sqrt{\beta_1}\, h_{12}(\rho h_{p2} + x_1 h_{12} + n_2) + \rho h_{p1} + n_1 \end{aligned} \tag{5}$$

Where, $h_{p1}$ represents the distance and the brand gaining rate between SU2 and SU1, $n_1$represents gaussian noise, $\beta_1$ represents the developed factor during the model forwarding process. It was expressed as follows [9] [10]:

$$\beta_1 = \frac{P_{MAX}}{E\{|y_2|^2\}} = \frac{P_{MAX}}{\rho^2 P_2 + PG_{12} + 1} \tag{6}$$

If we further remove the corresponding ingredients from SU1, the remaining elements are:

$$Y = \rho H + W \tag{7}$$

In which $H = h_{p1} + \sqrt{\beta_1}\, h_{12} h_{p2}$, $W = n_1 + \sqrt{\beta_1}\, h_{12} h_{n2}$.

Determine the presence of signal can be modeled as the following formula:

$$\begin{aligned} \psi_1 &: \rho = 1 \\ \psi_1 &: \rho = 0 \end{aligned} \tag{8}$$

We assume that $h_{12} = h_{21}$ that is to say, channels are symmetrical to each other and not interfere with each other, which further proved that $H$ and $W$ are in line with Gaussian random variables in Gaussian model, that is, 0 is the mean, and variance is the following expression:

$$\sigma_H^2 = P_1 + \beta P_2 h \tag{9}$$

$$\sigma_W^2 = 1 + \beta h \tag{10}$$

$h$ and $\beta$ can be split into the following expressions respectively:

$$h = \frac{|h_{12}|^2}{E\{|h_{12}|^2\}} = \frac{|h_{12}|^2}{G_{12}} \tag{11}$$

$$\beta = \frac{P_{MAX} G_{12}}{\rho^2 P_2 + PG_{12} + 1} \tag{12}$$

According to the nature of Gaussian random variables, the probability density expression of h can be expressed as:

$$f(h) = \begin{cases} e^{-h} & h > 0 \\ 0 & h \leq 0 \end{cases} \tag{13}$$

$T(Y) = |Y|^2$ is the statistic formula of energy detection, comparing its value with the extreme value $V_T$. Here, the extreme value is determined by the false alarm probability $\alpha$ in the network.

Let the probability function expression as:

$$\varphi(t, a, b) = \int_0^\infty e^{-h - \frac{t}{n + bh}} dh \; (t, a, b > 0) \tag{14}$$

Variables $a$, $b$, $t$ are integers. Given $h$, $Y$ are the Gaussian random variable values in line with the Gaussian model, random function $T(Y)$ is exponentially distributed, thus shows that when signal is null ,the average representative value of can be expressed as:

$$E\{T(Y) \mid \psi_0, h\} = E\{|W|^2 \mid h, \rho = 0\} = 1 + \frac{P_{MAX} G_{12}}{PG_{12} + 1} h \tag{15}$$

Expression shows that even if the user mentioned above does not exist, $T(Y)$ subject to the random variable distribution, we set the limit is still lower than the value:

$$P(T(Y) > t \mid \psi_0) = \int_0^\infty P(T(Y) > t \mid \psi_0, h) f(h)\, dh = \varphi\left(t, 1, \frac{P_{MAX} G_{12}}{PG_{12} + 1}\right) \tag{16}$$

When probability $\alpha$ in the formula is given, the above formula can still be used as the value of energy detection and confirmation, extreme value $V_T$ is expressed as the following formula:

$$\varphi\left(t, 1, \frac{P_{MAX} G_{12}}{PG_{12} + 1}\right) = \alpha \tag{17}$$

We note that the function $\varphi$ is strictly decreasing, while the factor that causes changes is $t$ (cause variation factor is $t$). Thus, we can determine the value of $V_T$ solely.

Meanwhile, if the authorized user is exiting, then the probability of that the mean value of Gaussian random variable in the Gaussian model will be much higher than extreme value, can be expressed in $\varphi(t, P + 1, \beta(P_2 + 1))$. Finally, with help of SU1detecting, SU2 will form its own detection probability:

$$P_c^{(1)} = \varphi(V_T, P + 1, \beta(P_2 + 1)) \tag{18}$$

But if there is no communication and collaboration between SU1 and SU2, then the $\rho$ in formula (5) is assigned 0. If this phenomenon occurs, we will take the following measures, first assume that $P_n^{(1)}$, $P_n^{(2)}$ are spectrum broadband detection rates of SU1 and SU2. Then we will apply multi-model fusion systems proposed in this article. Therefore, we can calculate each user's own calculated value:

$$P_n^{(1)} = \alpha^{\frac{1}{P_2 + 1}} \tag{19}$$

$$P_n^{(2)} = \alpha^{\frac{1}{P_2 + 1}} \tag{20}$$

### 3.3 Analysis of detection under multi-antenna conditions

We have talked about the performance of spectrum detecting under the two-user cognitive networks. In the following parts, we will have a deeper study of the conducts mentioned in the last chapter about what changes the performance of spectrum detecting will have when all the users in the network change the equipment to multi-antenna. First of all, we will pay more attention to the connection problem between user SU1 and user SU2. By using SVD, the matrix channel can get instantaneous decomposition of gain from H12. Therefore, two mutually parallel, non-interfering independent sub signal channels are carved out from MIMO channel which between user SU1 and SU2. While the corresponding gain rates of channel could be expressed by $\sqrt{\lambda_i}$, $i = 1 \ldots G$, where, $\sqrt{\lambda_i}$ means the gain rate of $H_{12}$, shown in the figure. Firstly, let us make the sub-channel i as the analysis point of the first round. In the first segment, in the channel of user SU2, the signal rate could be achieved by the antenna of $i$ is expressed as function (21):

$$y_{2,i} = \theta h_{p,2} + \sqrt{\lambda_i} x_{1,i} + n_2, \; i = 1 \ldots G \tag{21}$$

In the formula, $h_{p,2}$ means the distance between user SU2 and the authorized user; as well as the gain value $P_2 = E\{|h_{p,2}|^2\}$ $n_2$ represents the composite value of Gaussian noise.

During the second segment, among all antennas of sensing user SU1, the signal received by $i$ could be represented as:

$$\begin{aligned} y_{1,i} &= \rho h_{p1} + \sqrt{\beta_1}\sqrt{\lambda_i}\, y_{2,i} + n_1 \\ &= \rho h_{p1} + \sqrt{\beta_1}\sqrt{\lambda_i}\,(\rho h_{p,2} + \sqrt{\lambda_i}\, x_{1,i} + n_2) + n_1 \end{aligned} \tag{22}$$

In the formula, $h_{p,1}$ means the distance and the broadband gain value between SU1 and authorized users, $P_2 = E\{|h_{p,1}|^2\}$represents the detecting rate received by the antenna $i$ of user SU1 from corresponding authorized users; $n_1$ is still the SNR in Gaussian model. Thus, if we depart information carried by users themselves, the remaining value of user SU1 is:

$$Y = \rho H + W \tag{23}$$

In which, $H = h_{p,1} + \sqrt{\beta_1}\sqrt{\lambda_i}\, h_{p,2}$, $W = n_1 + \sqrt{\beta_1}\sqrt{\lambda_i}\; n_2$. So we can clearly find that its spectrum broadband detection has the same expression with single-user antenna detection. After concluding, we get: when formula $Y = \theta H + W$ has been known, the corresponding decision condition becomes:

$$\begin{aligned} \psi_1 &: \rho = 1 \\ \psi_0 &: \rho = 0 \end{aligned} \tag{24}$$

Assuming $h_{p,1}, h_{p,2}, n_1, n_2$ are values of the random variables in the 0-mean value composite Gaussian model, and none of the variables can be departed from each other, then H and W are Gaussian distributed, the average of them is 0, the corresponding variances are $\sigma_H^2 = P_1 + \beta\lambda_i P_2$ and $\sigma_W^2 = 1 + \beta\lambda_i$.

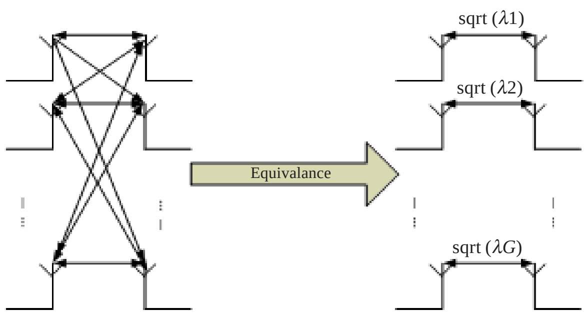


Figure 3. The Singular value decomposition schematic diagram of multi-antenna channel

Therefore, when $T(Y)$ does not have authorized users, the average value of channel could be expressed as follows:

$$E\{T(Y) \mid \psi_0\} = 1 + \beta\lambda_i \tag{25}$$

Similarly, when authorized users are existed, the average value is:

$$E\{T(Y) \mid \psi_1\} = P_1 + 1 + \beta\lambda_i (P_2 + 1) \tag{26}$$

When the signal of authorized users is not existed, the false alarm probability of antenna i of user SU1 could be written as:

$$P(T(Y) > V_T | \psi_0) = \exp\left(\frac{-V_T}{1 + \beta\lambda_i}\right) = \alpha \tag{27}$$

However, when the signal of licensed users is existed, the false alarm probability of antenna i of user SU1 could be written as:

$$P_{c,i}^{(1)} = P(T(Y) > V_T | \psi_1) = \exp\left(\frac{-V_T}{P_1 + 1 + \beta\lambda_i (P_2 + 1)}\right) = \alpha \tag{28}$$

Thus, detection probability under the cooperation of SU1 and SU2 is:

$$p_c^{(1)} = \sum_{i=1}^{G} p_{c,i}^{(1)} - \sum_{1 \le i \le j \le G} p_{c,i}\; p_{c,j}^{(1)} + \sum_{1 \le i \le j \le G} p_{c,i}^{(1)} p_{c,j}^{(1)} p_{c,k}^{(1)} + \ldots + (-1)^{G-1} \prod_{i=1}^{G} p_{c,i}^{(1)} \tag{29}$$

If we set the number of antennas of user SU1 as $G = 2$, then detection probability under the cooperation of SU1 and SU2 is:

$$p_c^{(1)} = p_{c,1}^{(1)} + p_{c,2}^{(1)} - p_{c,1}^{(1)}\; p_{c,2}^{(1)} \tag{30}$$

However, when there is no cooperation between SU1 and SU2, $\rho = 0$.we can use similar methods when analysing the detecting rate, and the detecting rate of each is listed as follows:

$$p_n^{(1)} = \alpha^{\frac{1}{GP_1 + 1}} \tag{31}$$

$$p_n^{(2)} = \alpha^{\frac{1}{GP_2 + 1}} \tag{32}$$

As a result, we can get that, whether it is in single-antenna cognitive radio network or multi-antenna cognitive radio network, as long as ensuring the cooperative users could detect independently, then the total spectrum detection probability in the cognitive radio network can be expressed as:

$$p_n = p_n^{(1)} + p_n^{(2)} - p_n^{(1)} p_n^{(2)} \tag{33}$$

Likely, when user SU2 acting as a relay detects cooperatively with user SU1, the total detection probability is:

$$p_c = p_c^{(1)} + p_n^{(2)} - p_c^{(1)}\; p_n^{(2)} \tag{34}$$

After analysing the performance of the two-user model in multi-antenna cognitive ratio network, we will analyse detecting time in the following content. Using $T_n$ as the detecting time in mutual interference-free two-user model in multi-antenna cognitive ratio network while $T_c$ is the detecting time that no one is independent in two-user model in cognitive ratio network, that is, in cooperative way, the formula is:

$$T_n = \frac{2 - \dfrac{p_n^{(1)} + p_n^{(2)}}{2}}{p_n^{(1)} + p_n^{(2)} - p_n^{(1)} p_n^{(2)}} \tag{35}$$

$$T_n = \frac{2 - \dfrac{p_c^{(1)} + p_n^{(2)}}{2}}{p_c^{(1)} + p_n^{(2)} - p_c^{(1)} p_n^{(2)}} \tag{36}$$

### 4. Simulation Analysis

In the following, let's make the Monte Carlo simulation on the performance of the spectrum sensing in the situation of two-user cooperative networks. During the progress, we assume that SU1 is the key point and SU2 acts as intermediate successor who takes the responsibility of assisting checking and transited as a relative rate $P_1$ =0 dB to SU1 by authorized users. If the whole false alarm probability is 0.1 and the number of sensing equipment of each user is only 1 to 2 in the wireless environment. It shows that the performance of spectrum broadband sensing is enhanced supported by multi-antenna cognitive radio network.

As shown in Figure 4, there are curves describe the total detection probability in two-user cognitive radio network according to changes of power P2 of authorized users received by user SU2 . We can draw some useful conclusions from the figure: firstly, in any of the four conditions illustrated in figure, the spectrum broadband detection probability of the cognitive ratio network will change with the changing of power received by SU2, while all of the power is uploaded by authorized users to sensing users, in other words, the detection probability of sensing users is directly influenced by the receiving signal; Secondly, from the experiments and discussions we have done, we know that no matter in cognitive radio networks with single-user or multi-user or applying antenna, cooperative detecting way is always prior to traditional way. In other words, if we want the overall detection results of the spectrum broadband wireless networks have better enhancement and improvement, an effective measure is to deepen the mutual cooperation and communication among users; additionally, if we set the multi or single as the checking object both in the antenna environment and the cooperative or uncooperative manner as the factor, then the conclusion is that, multi-antenna model is much better than single-antenna model in whatever situation, further explanation can be done by using the channel powers as objects. Because the total signal power is fixed, if we enlarge receiving power of sensing users, then the rate of success detection could be improved.

Therefore, when the number of users is fixed, increasing the number of equipment which can receive channel frequency, since it has direct proportion with detection probability, when the total receiving probability is enhanced, the detection probability will be improved as well. Finally, we have a cross comparison of the two groups of variables. The conclusions can be drawn that the total band spectrum detection probability checked in the multi-antenna cognitive network is much better than that in the single-antenna cognitive network even if the former is in no cooperative way while the latter is using cooperative sensing way. The explanation is the same with last one, which can also use the signal power transported by authorized users. And in multi-user and multi-antenna cognitive radio network, users could receive more channel information about authorized users, then get more reliable detection results.

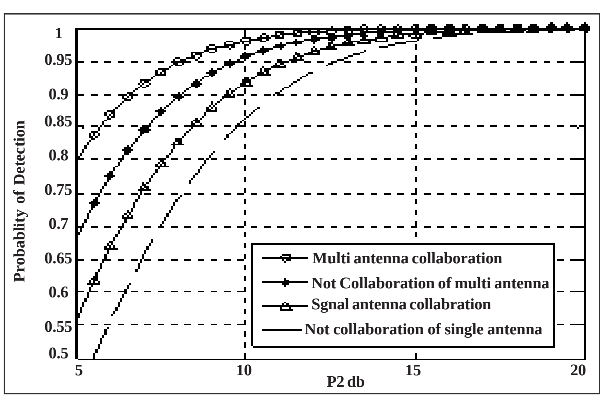


Figure 4. Perceived probability of detection of the wireless network under different conditions

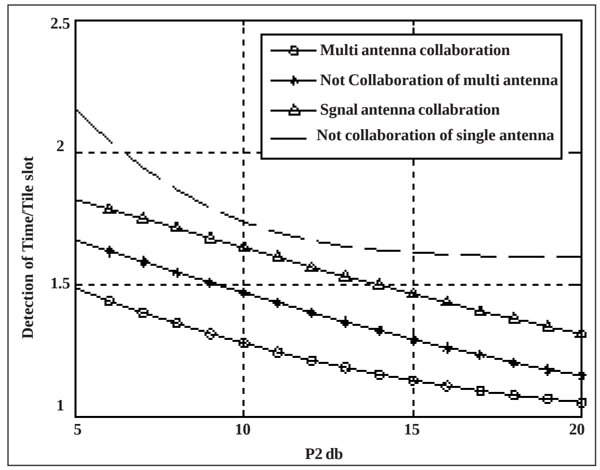


Figure 5. Perceived probability of detection of the wireless network under different conditions

Figure 5 shows the change of detection results with the changing of the environment detected by the detecting users in cognitive radio network, time charts; it takes the time slot of segment as the units to measure. The four cases are showed in the figure. We can draw the appropriate conclusions in each case. First, we can know, in cognitive radio network environment, each detection time will change with the changing of the value of uploading power P2 received by SU2, and this change will be inversely proportional to the uploading rate P2 of authorized users, namely the test value will decrease while the P2 increase. This conclusion is applicable to any kind of test mode, in other words, single or multiple users as well as cooperative and non-cooperative way can meet this conclusion by experiments, what's more, the cooperative mode is always superior to non-cooperative way; likely, no matter the detection mode is cooperative and non cooperative, multi-antenna user network is always prior to single-antenna user network, which the detection time of the former is far less than that of the latter ; the time needed by the cross-contrast multi-antenna user network is still better than the overall time of a collaborative network of single-antenna. The reason is consistent with the performance analysis. Namely if performance is improved better, the consuming time required testing is less.

## 5. Conclusion

In this paper, we analyze a cooperative mode in cognitive radio network. That is multi-antenna cooperative energy detection model in the two-user cognitive radio network. In this model, we can detect receiving or sending methods adopted by users through related algorithms, then we analog this process into a sensing mode. At the same time, we also compare the values of spectrum broadband detection probability in different cooperative modes, and we are able to draw the detection probabilities of multi-user cooperative mode and multi-user uncooperative mode, respectively. Through experiments, we can conclude that, if cooperative groups detecting in the whole sensing network is fulfilled in the multi-antenna sensing user groups, then the success rate of the overall spectrum broadband detection will be far greater than that in the non-cooperative way. Additionally, while analyzing performance of the network, as one of the analysis indicators, we also carry out further detection and discussion on the analysis time in the two detection models. Likewise, similar conclusion, that detecting time in cooperative model is much less than that in the non-cooperative model, can be drawn. So as can be seen in the above, multi-user cooperative detection model in cognitive ratio network can well improve the performance of transmission and the utilization rate of signal bandwidth.

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