Performance Analysis for Cooperative and Non-Cooperative Spectrum Sensing under AWGN and Rayleigh Fading Channel

Sabrina Ferdous[1], Abdullah Al Zubaer[1*], Md. Shahabub Alam[2], Md. Manik Ahmed[3], Sujit Kumar Mondal[4]
[1]Lecturer, Department of Computer Science and Engineering, Rabindra Maitree University, Kushtia, Bangladesh
[2]Lecturer, Department of Computer Science and Engineering, German University Bangladesh, Gazipur, Dhaka, Bangladesh
[3]Lecturer, Department of Information and Communication Technology, Rabindra Maitree University, Kushtia, Bangladesh
[4]Professor, Department of Computer Science and Engineering, Islamic University, Kushtia, Bangladesh

*Corresponding Author: zubaerranacseiu@gmail.com

ABSTRACT
Among other applications, being an existing technology cognitive radio has the potentiality to unlock the spectrum which is needed to bring it into effective action for the next generation of high data rate systems. Infarct, in cognitive radio technology spectrum sensing is a basic component. However, if the users feel fading effect, in that matter detection can be compromised. The result of misdirection is that the user cannot be able to discern between an unused band and a deep fade. That is why, to optimize cooperative performance the proposed term is spectrum sensing. The performance of cooperative spectrum sensing is also analyzed by us. In this session the main focus of this paper is to simulate comparison of cooperative with the non-cooperative spectrum sensing about the Rayleigh fading channel based on OR and AND majority rule. It is noticeable that in the presence of cooperation the spectral sensing presence is better by comparing the noncooperation curve with the cooperative curves compared to the Rayleigh fading channel. Additionally, it is also noticeable that the performance of the AND and other majority rules is not as good as OR rule.

Keywords-- AND, channel, OR, rule, study

INTRODUCTION

In order to evaluate the performance of the discussed system, a detailed analysis of the sensing performance parameters including sensitivity, accuracy, efficiency, complexity and power is carried out for power identification on the AWGN channel and the Raleigh feeding channel. Both energy detection and cooperative spectrum sensing techniques are exploited and analyzed. A comparative study is then carried out on the energy detection and AWGN channels and the railing fading channels considering all the different parameters under the sensitive cooperative spectrum [1]. Thus, the performance of spectral sensing detection is evaluated by the following metrics:

Probability of Detection (): This implies the probability of the described CR user that a PU is present if the spectrum is indeed occupied by the PU. It should have a higher price for better performance.

Probability of False Alarm (): It defines the probability of a CR user that the CR detects that the spectrum has actually been occupied after being free. It should be of low value for improved performance.

Probability of Miss-detection (): It defines the probability of a CR user that the CR detects that the spectrum is free when the spectrum is actually used by the PU. This interferes with PU. It should be zero for better performance.

Detection Delay: This parameter agrees with the sample of the average number of detector adoption to decide whether PU is present or absent. Missed and false alarms in interference detection guides at PU will reduce spectrum efficiency. Concerns such as receiver uncertainty problems, multipath fading, and shading affect the effectiveness of detection. Also, spectral holes need to be detected at very low SNR (<20 dB). Further, the measurement setup to validate the simulation results has been presented for power identification on the AWGN channel and the Rayleigh fading channel, as well as the cooperative spectrum synthesis using both simulated spectrum and using rules and OR. In this chapter we have described all the plots with their plots in detail [2, 3]. The effectiveness of the power detector applied to a secondary user for spectral sensing is evaluated. All simulations of this work are implemented in Matlab (version R2010a). The Monte Carlo (MC) method, which forms the basis of these simulations of stochastic techniques (based on the use of random numbers).

To compare the performance of the detection values, the receiver operating feature (ROC) curves and the complementary ROC curves allow detecting the relationship between the false alarms of a sensing technology for different values of detection probability and false alarm probability. The effectiveness of energy detection is evaluated [4]. Various performance metrics (e.g., detection probability, false alarm probability, probability of missed detection, sensing time, receiver operating characteristics, and complementary receiver operating characteristics) are considered to evaluate the effectiveness of the energy detector algorithm [5].

SPECTRUM SENSING

To gain the best available spectrum through cognitive capability and re-configurability is the core objective of the cognitive radio. Having shortage of spectrum, the most prominent challenge is to share the licensed spectrum without any interference which is illustrated in Fig. 1. However, the temporal unused spectrum which is mentioned as spectrum hole or white space is used by the cognitive radio. The cognitive radio will move to another spectrum hole or stays in the same band if this band is further used by a licensed user. Additionally, to avoid interference it will alter its transmission power level or modulation scheme [6]. Another feature of the cognitive radio is that it has the cognitive capability for real time interaction with its environment.

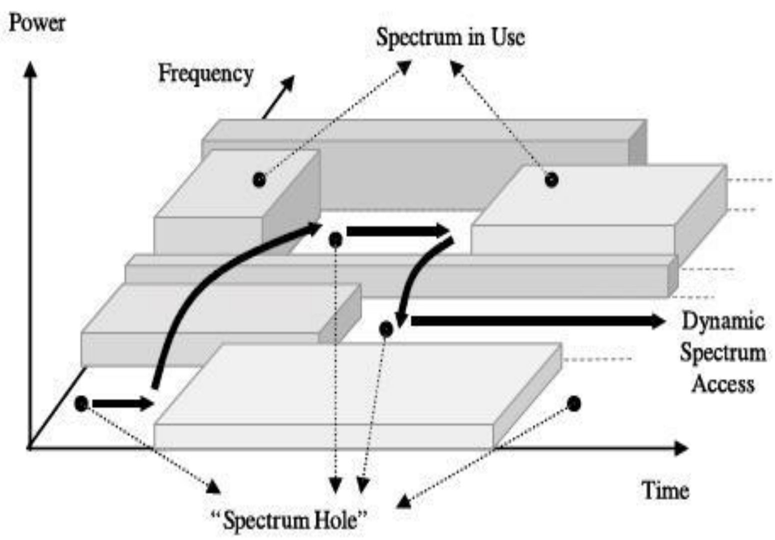

Figure 1: *Spectrum hole concept.*

This feature is used to determine appropriate communication parameters and cope with the environment which is dynamic radio environment. The tasks which are required for adaptive operation in open spectrum is shown in Fig. 1. It is also referred to as the cognitive cycle [7]. The three main steps of the cognitive cycle shown in Fig. 2 are as follows:

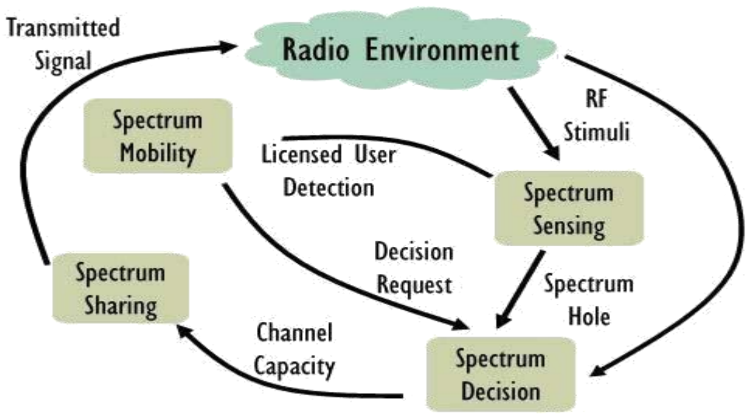

Figure 2: *Cognitive cycle.*

Spectrum Sensing
The radio environment is sensed by a cognitive radio. The main work of it is to find available spectrum band and to detect spectrum holes.

Spectrum Analysis
Spectrum analysis: In this sector, the spectrum holes are analyzed and their characteristics are evaluated.

Spectrum Decision
The data rate, the transmission mode, and the bandwidth of the transmission are used by cognitive radio for determining its own capabilities. After that the expected spectrum band selection is done from the spectrum holes determined in spectrum sensing. After determining the operating spectrum band, the communication can be continued over this spectrum band. The cognitive radio should also be aware of the changes of radio environment. The spectrum mobility function is called to provide a seamless transmission for the communication which is already in the use of cognitive radio. Any adjustment can be activated by any environmental change during the transmission such as primary user appearance, user mobility or traffic variation [8].

SYSTEM MODEL

Throughout this project, it is assumed that at each CR user the energy detection Fig. 3 is applied. A square law device which is consisted of the energy detector based on a finite time integrator, the output of the integrator at any time is the energy of the input to the squaring device over the interval T. For limiting the noise bandwidth the pre-filter is served. However, the noise input has some criteria such as band flat spectral density [9, 10].

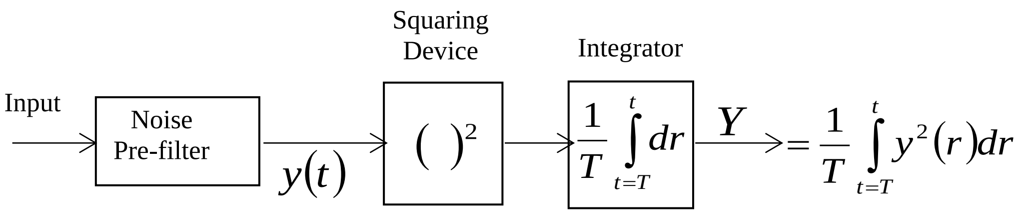

Figure 3: *Energy detection.*

The detection is a test of the following two hypotheses:

H_0: The input $y(t)$ is noise alone:

$$y(t) = n(t)$$

$$E[n(t)] = 0$$

Noise spectral density = N_{02}, (two-sided)

Noise bandwidth = W cycles per second.

H_1: The input $y(t)$ is signal plus noise:

$$y(t) = n(t) + s(t)$$

$$E[n(t) + s(t)] = s(t)$$

The local spectrum sensing is to decide between the following two hypotheses,

$$y(t) = \begin{cases} n(t) & H_0 \\ hs(t) + n(t) & H_1 \end{cases} \quad \text{-----------------(1)}$$

Secondary user receives a signal which is x (t) and primary user transmit a signal which is s (t). There is also additive white Gaussian noise which is n (t) and the amplitude gain of the channel is h. The SNR is y. An ideal band pass filter pre-filters the received signal first with the transfer function [11, 12].

$$H(f) = \begin{cases} \dfrac{2}{\sqrt{N_{01}}}, & |f - f_c| \le W, \\ 0 & |f - f_c| > W, \end{cases} \quad \text{-----------(2)}$$

The output of this filter is then squared and integrated over a time interval T to limit the average noise power and normalize the noise variance. There will be two hypotheses H_o and H_1. These two hypotheses will be tested by the output of the integrator denoted by Y. According to the sampling theorem, the noise process can be expressed as [13]:

$$n(t) = \sum_{i=-\infty}^{\infty} n_i \sin c(2Wt - i) \quad \text{---------(3)}$$

Where $\sin c(x) = \dfrac{\sin(\pi x)}{\pi x}$ and

$$n_i = n\left(\frac{i}{2W}\right)$$

One can easily check that $n_i \approx N(0, N_{01}W)$, for all i. Using the fact that [13]

$$\int_{-\infty}^{\infty} \sin c(2Wt-i)\sin c(2Wt-k)\,dt = 1/2W,\ i=k$$
$$= 0, \qquad i \neq k \quad \text{----(4)}$$

We may write:

$$\int_{-\infty}^{\infty} n^2(t)\,dt = \frac{1}{2W}\sum_{i=-\infty}^{\infty} n_i^{\,2} \quad \text{--------------------(5)}$$

Over the time interval $(0,T)$, $n(t)$ the noise energy can be approximated by a finite sum of $2TW$ terms as:

$$n(t) = \sum_{i=1}^{2TW} n_i \sin c(2Wt-i), \quad 0<t<T \quad \text{--------(6)}$$

Similarly, the energy in a sample of duration T is approximated by 2TW terms of the right-hand side:

$$\int_{0}^{T} n^2(t)\,dt = \frac{1}{2W}\sum_{i=1}^{2u} n_i^{\,2} \quad \text{-------------------- (7)}$$

Where $u=TW$. We assume that T and W are chosen to restrict u to integer values. If we define:

$$n_i^{'} = \frac{n_i}{\sqrt{N_{01}W}} \quad \text{---------------------------------(8)}$$

Where N_{01} =one-sided noise power spectral density. Then, the test or decision statistic Y can be written as:

$$Y = \sum_{i=1}^{2u} n_i^{'2} \quad \text{-------------------------------------(9)}$$

Y can be represented as the total summation of the squares of 2u standard Gaussian variants with zero mean and unit variance. However, a central chi-square x^2 distribution is followed by Y with 2u degrees of freedom. The same approach is also preferred when the signal s (t) is present with the replacement of each n_i by $n_i + s_i$ where $s_i = s\left(\frac{i}{2W}\right)$. Which is decision static in this case will have a non-central x^2 distribution with 2u degrees of freedom and a non-centrality parameter 2λ. Following the short hand notations, which is mentioned here? In the beginning of this section, we can describe the decision static as:

$$Y \approx \begin{cases} \chi_{2u}^{\ 2} & H_0 \\ \chi_{2u}^{\ 2}(2\gamma), & H_1 \end{cases} \quad \text{--------------(10)}$$

The probability density function (PDF) [15] of Y can then be written as:

$$f_Y(y) = \begin{cases} \dfrac{1}{2^u \Gamma(u)} y^{u-1} e^{-\frac{y}{2}} & H_0 \\ \dfrac{1}{2}\left(\dfrac{y}{2\gamma}\right)^{\frac{u-1}{2}} e^{-\frac{2\gamma+y}{2}} I_{u-1}\left(\sqrt{2\gamma y}\right), & H_1 \end{cases} \quad \text{--------------(11)}$$

Γ(.) which the gamma function. In testing H_0 versus H_1 there will be observed two types of errors that can be made: H_o can be falsely rejected or H_1 can be falsely rejected. However, the first error is mentioned as a False Alarm and the second one is mentioned as a misdetection [11]. The presentation of energy detector can be estimated by the probability of occurrence of both types of errors., i.e., the probability of false alarm which clarifies the probability of erroneously fixes that the band is occupied, when is actually not, and the probability of misdetection (P_{md}), which is probability of erroneously indicates that the primary user not present, which is really present. However, the complement of the probability of misdetection, i.e., the probability of detection (P_d) is another form which is used to explain the performance. The probability of detection and false alarm can be generally computed by:

$$P_d = \Pr(Y > \lambda \mid H_1) \quad \text{----------------------(12)}$$

$$P_f = \Pr(Y > \lambda \mid H_0) \quad \text{------------------------(13)}$$

Where λ is the final threshold of the local detector to decide whether there is a primary user present. Using (3.12) to evaluate (3.14) yields

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$$P_f = \frac{\Gamma\left(u, \frac{\lambda}{2}\right)}{\Gamma(u)} \quad , \qquad \text{--------------------------(14)}$$

Hence,

$$P_d = Q_u\left(\sqrt{2\gamma}, \sqrt{\lambda}\right) \qquad \text{-------------------------(15)}$$

Where $\gamma = \frac{\sigma_x^{\ 2}}{2\sigma_n^{\ 2}} = \frac{\sigma_x^{\ 2}}{2}$ denotes the signal to noise ratio (SNR),Q_u is the generalized Marcum's Q function [14].

SIMULATION RESULTS AND DISCUSSIONS

The following figures show the performance of spectral sensing between cooperation and non-cooperation in cognitive radio. OR rules involve a minimum single user result outside of power identification nodes to declare the presence or presence of a PU. However, the AND fusion rule indicates a slightly better performance at lower P_{fa}. Since, the OR adjustment rule reduces the overhead of communication, this fusion rule will be adopted for the rest of the analysis of cooperative users considering the fading channel model.

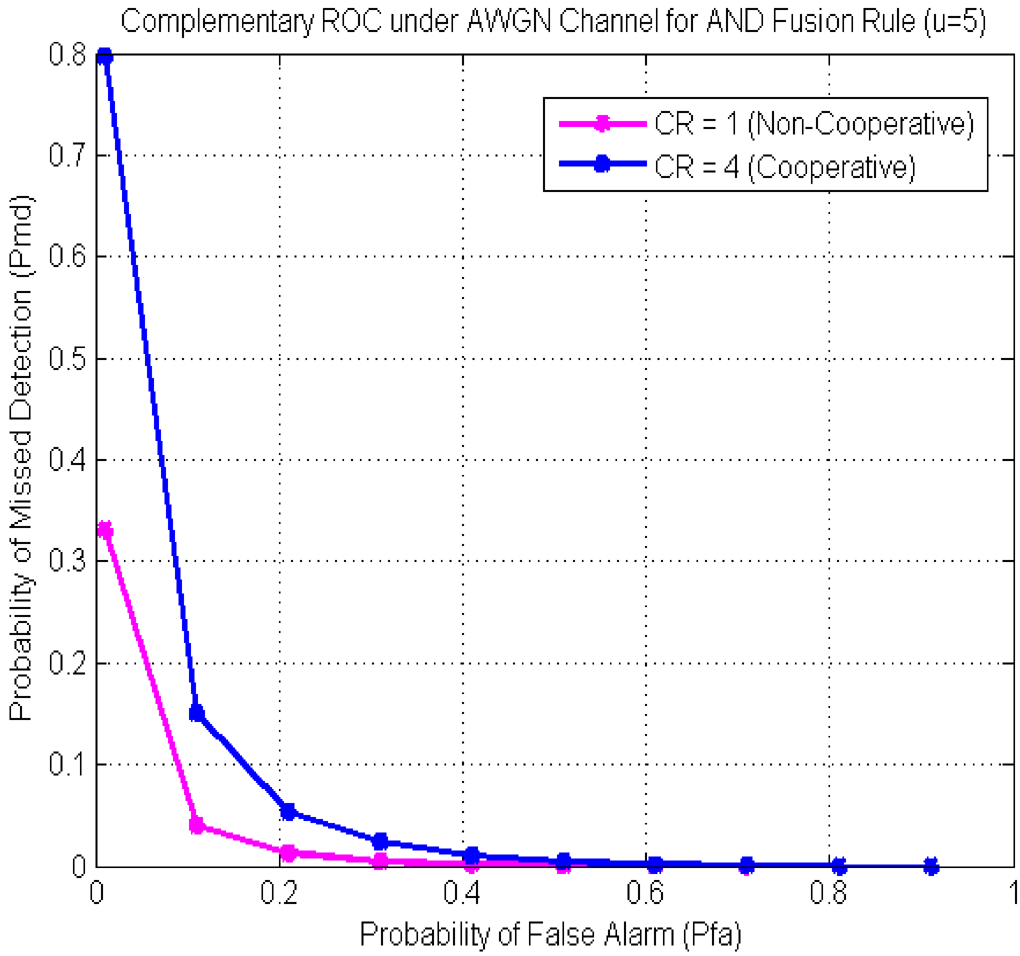

Figure 4: *Complementary ROC under AWGN channel for AND fusion rule (u=5).*

Fig. 4 shows the Complementary ROC under the AWGN channel with a different number of cognitive radio users for the AND Fusion Rule (U=5). CR =1 When called non-cooperative spectrum sensing, CR = 4 is called cooperative. We noticed that CR = 4 when the probability of better detection than CR = 1 for the condition.

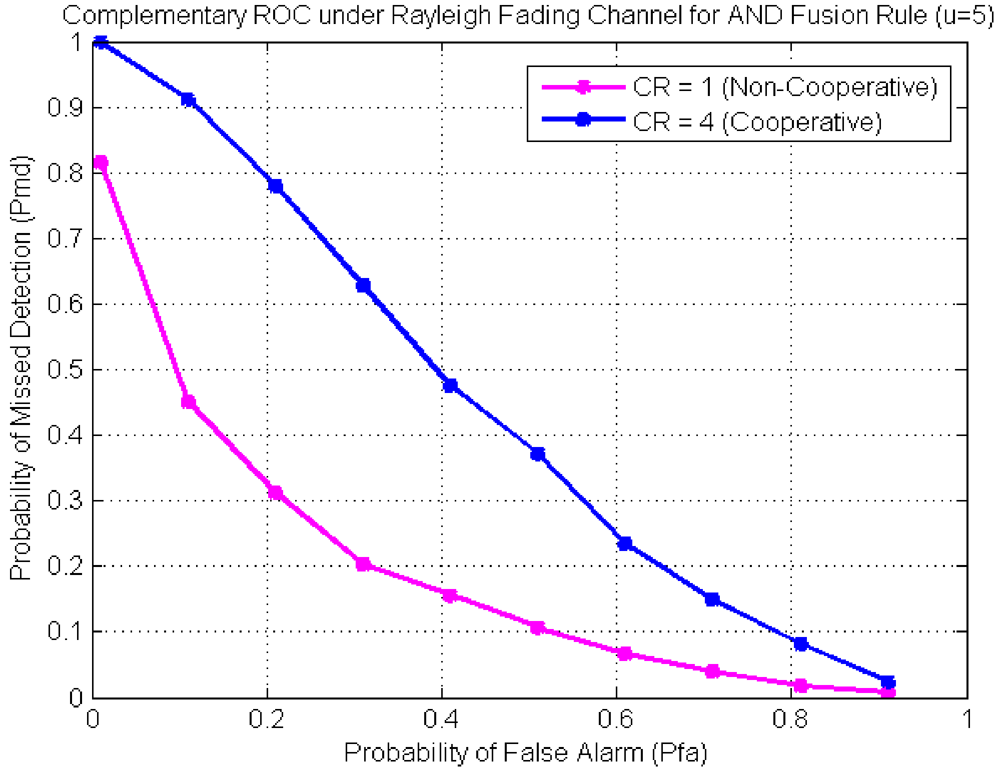

Figure 5: *Complementary ROC under rayleigh fading channel for AND fusion rule(u=5).*

Fig. 5 shows the complementary ROC with a different number of cognitive radio users under the Raleigh fading channel of the AND Fusion Rule (U = 5).

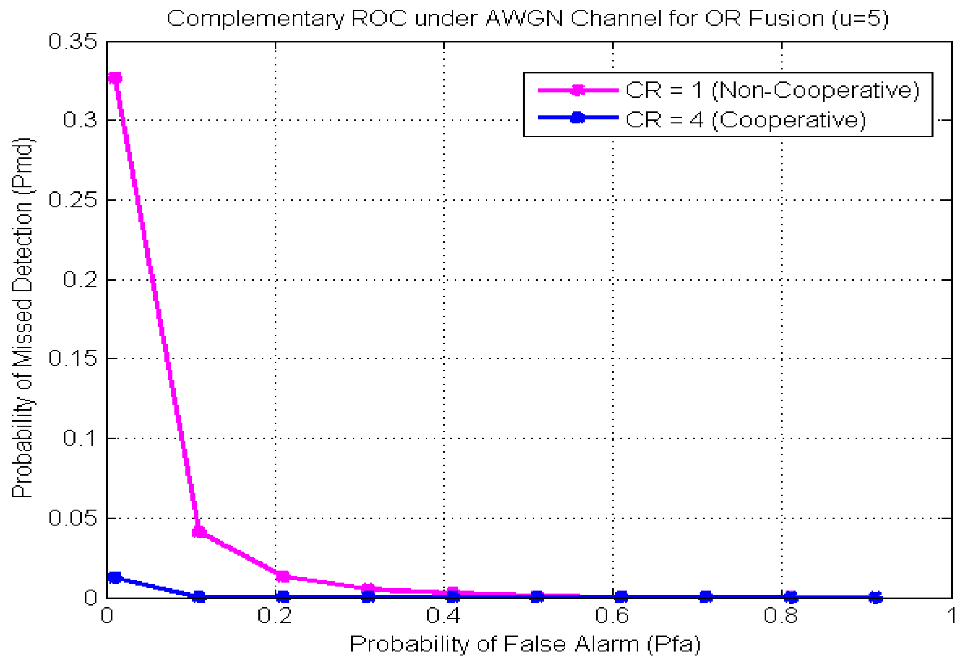

Figure 6: *Complementary ROC under AWGN channel for OR fusion (CR=4, u=5).*

Fig. 6 shows Complementary ROC under AWGN channel for OR Fusion Rule (u=5) with different number of cognitive radio user.

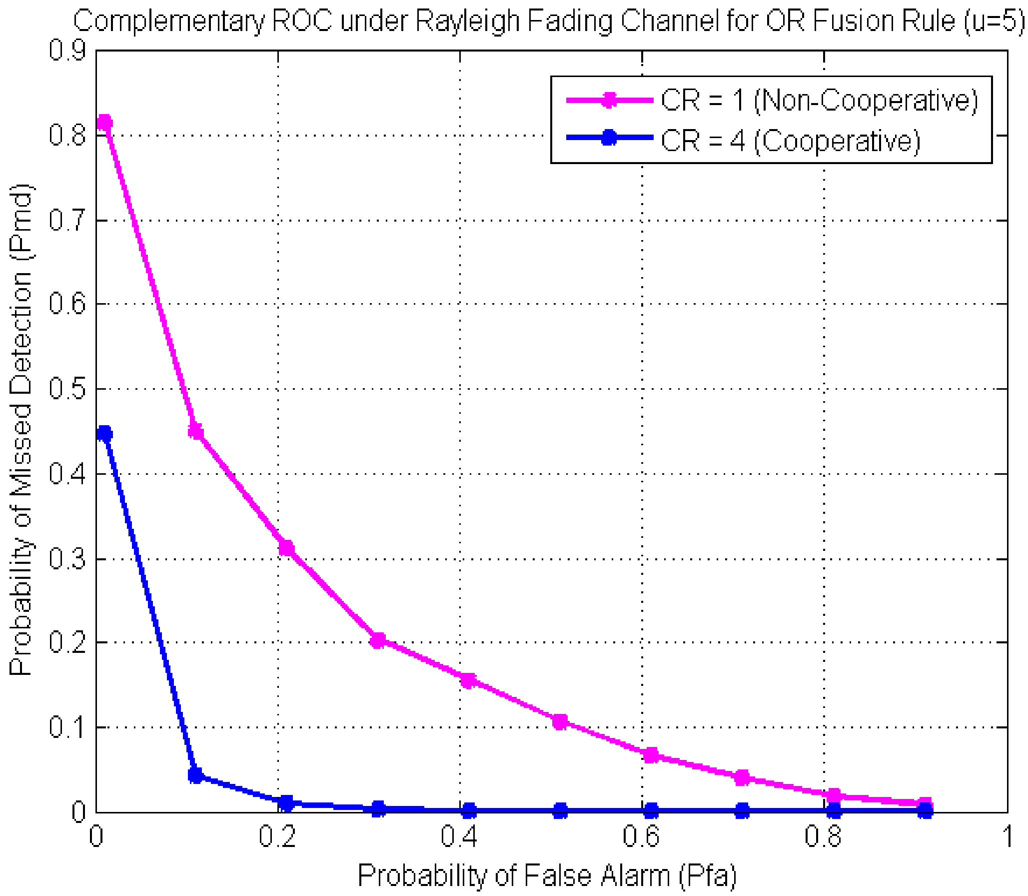

Figure 7: *Complementary ROC under rayleigh fading channel for OR fusion rule (u=5).*

Fig. 7 shows the complementary ROC under the Raleigh fading channel for the OR fusion rule (u=5) with a different number of cognitive radio users. How does cooperative reception improve the effectiveness of energy detection projects? This investigation is described above in Fig. 4-7. Fig. 4 and 6 show the AWGN channel and the complementary ROC performance curve of power detection with rules and regulations. Number of cooperative nodes with average SNR 10 dB and time bandwidth product, CR = 4, the same parameter applies to the probability of fig detection in Fig. 5 and the fading of the Rayleigh in Fig. 7 P_{md} when a network of associate nodes is applied to a network of collaboration nodes. Is applied using energy detection methods; Compared to the case of single user detection. From this curve, considering the same parameters, compared to the AWGN channel, the highest performance gain is obtained from a Raleigh Fading channel case. Therefore, it is clear that the collaborative sensation fights against the deadly fading and deterioration of the energy detector's performance in shady environments.

CONCLUSION

From the above discussion, the idea is clear that cognitive radio is a buzzword. This radio has many lucrative parameters such as it is sensitive about its operational environment and dynamic and automatically adjusts to its operating parameters. Since, this radio has unlicensed spectrum users, who are able to avoid interfering with licensed primary users which is a very common criterion of cognitive radio. On the other hand, effective data is to identify early users who are using the existing tradition theoretically assigned frequency spectrum. The existing presence of two types of users is the primary user and the cognitive user. The main goal of cognitive radio is to reduce interference between primary users and cognitive users. This performance of cognitive radio is measured by detector algorithms under both AWGN and Raleigh fade channels. Another important term called spectral detection performance is also discussed. Indeed, it has been the focus of research for the past few decades. In this term, cognitive radio is transformed into a fancy technology that has the potential to improve the usability of the radio spectrum. There are several spectral sensing techniques that are modified in this project and a comparison between them is also shown. However, energy detection among them received special attention due to the low calculation complexity. The main advantage is that it has the ability to improve the effectiveness of detection under severe discoloration and hidden terminal problems. However, some of the basic features such as overcoming hidden node problems, reducing false alarms and providing more accurate signal detection that make cooperative spectrum sensing more than classical spectrum sensing technology make cooperative-based co-operative spectrum sensitive. For performance analysis between power detection algorithms for ROC sensitive spectrum and the probability of detecting complementary ROC feature curves, SNR vs. detection probability, cognitive radio system error vs. threshold probability. Additionally, many project fading and hidden terminal problem challenges are also considered in this project. It can also be noted that and the evaluation of the end rule shows better results in different situation and cooperative energy spectrum sensing identification based on tough decisions. A simulation of the AND and OR cooperative decision fusion rules was compared and the results show that OR performs the rules and AND and the OR connected rules.

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