Performance Analysis of Cooperative Spectrum Sensing in CR under Rayleigh and Rician Fading Channel

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Abstract: ***To increase RF spectrum utilization is the main goal of Cognitive radio technology design concept. Spectrum sensing is the most appropriate method performed by cognitive radio for the efficient utilization of RF spectrum without any harmful interference to the primary users. Energy detector based spectrum sensing method concept has been used. Cooperative sensing is done to overcome the problem of miss detection and false alarm over various spectrum sensing technique which occur in the case of single node. Cooperative spectrum sensing gives admirable performance. In CSS, multiple cognitive radio users sense the free spectrum and send their decision to fusion center and then final decision are made by the fusion center. This paper studies the cooperative spectrum sensing scheme by considering faded environment. In this paper, Performance is done under Rayleigh and Rician fading channel. Probability of detection vs. probability of false alarm for all different channel factor has been calculated. In previous paper, using same concept, probability of detection under different value of SNR for three different values of false alarm was calculated. All the performance has been evaluated using MATLAB environment and giving satisfactory results.***

Keywords: CR, QoS, PU, CSS, nakagami, rayleigh, rician.

1. Introduction

Because of the rapid advancement in a wireless communication system, the demand for the new wireless services for both the used and unused spectrum also increases. However, because of limitation of the radio resources this increasing demand faces a great problem. This issue in wireless communication in a better way can be solved by cognitive radio (CR). Cognitive radio provide reliable communication where it is needed and for efficient radio frequency utilization. Cognitive radio is unlicensed user that has to utilize the licensed band of primary user when the channel is sensed to be free. Thus, CR technology is recommended for searching the unlicensed use of vacant bands. Thus, the most important function of CR is to detect the free bands through the process of spectrum sensing. Spectrum sensing performs the functions that detect the Presence of primary user (PU) signals in the concerned bands and also identify the available channel that can be used. In identifying the vacant and employed bands, the signals is analyzed by unlicensed systems that can be received from the licensed system [1-6]. During spectrum sensing, when the licensed user (LU) wish the frequency band back which is allocated for LU itself, the cognitive user start searching for another vacant licensed. Energy detection, matched filtering, and cyclostationary feature detection are the different ways through which spectrum sensing performance can be execute. The factor such as reliability and probability of detection are used to determine the improved sensing performance. If the frequency band are sensed by using single user than it is known as single node sensing or non-cooperative sensing and if multiple CR users are used to sense the signal it is termed as multi node or cooperative sensing. Due to fading and shadowing in the channel single node is unreliable and probability of detection also reduces. This problem of unreliability and detection are overcome using cooperative spectrum sensing and improves the sensing performance by aggregating their sensed decision to the fusion center [7]. Fusion center than perform two function either soft or hard decision to allot the empty channel to CR user[8]. In this paper, the cooperative spectrum sensing using energy detection was studied. It is used for the purpose of minimizing the total error rate in cognitive radio networks (CRNs) [16][18]. Another investigation of the cooperative spectrum sensing are done by using an improved energy detector along with Rayleigh and Rician fading channel and imperfect reporting channels for enhancing the reliability in detecting a spectrum hole was also carried out.

Thus, this paper is further organized as: Section II cooperative spectrum sensing concept. Section III shows performance metrics under different fading channel. Section

IV represents simulation results and conclusion is given in section V.

2. Cooperative Spectrum Sensing Concept

In this section same as previous paper, the spectrum sensing concept is introduced. It also provides a survey of the energy detection scheme to analyze how the probability of detection and probability of false alarm are related.

2.1 System model

Fig.1 displays the system model of, and it is noticed that some of the CR make detection of the primary signal without any problem, whereas some other CR users cannot detect the presence of the primary signal due to the impact of deep fading and shadowing.

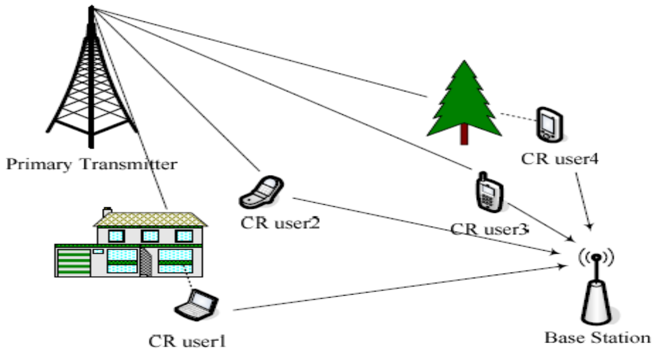

Figure 1: Cooperative Spectrum Sensing

In the cooperative spectrum sensing scheme, each cognitive radio user sense the spectrum by performing local sensing and then binary local decision is send to the fusion center[3][4]. The fusion center then fuses the local decision and make the final decision in order to make primary user is present or not.

The received signal contains two binary hypothesis-testing dilemmas[12]:

H0: Primary user is absent.

H1: Primary user in operation.

The probability of correct detection Pd, probability of false alarm Pf and probability of miss Pm are the key metric in spectrum sensing, given respectively as:

Pd = Prob.{Decision = H1/H1} (1)

Pf = Prob.{Decision = H0/H0} (2)

Pm = Prob.{Decision = H0/H1} (3)

There are many signal detection techniques, in order to enhance detection probability, which can be used in spectrum sensing [14]. CR users should efficiently identify and exploit the spectrum holes for required throughput and Quality-of Service (QoS) [11]. The cooperative sensing is applied in the energy detection

2.2 Energy Detection

Energy detection represent the most popular spectrum sensing schemes, its objective is to determine whether H0 or H1 is true; this is achieved by sensing the energy of signal [5][13].

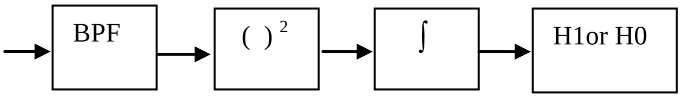

Figure 2: Energy Detector block diagram

Fig. 2 illustrates the traditional energy detector in time domain, the band-pass filter to the objective signal is made first and this is followed by squaring the received signal and integrating it in the integrator so that the test statistic can be obtained. Hypothesis test can be performed as [2][5]

$$\left.\begin{array}{l} y(k) = n(k)\ldots\ldots\ldots\ldots\ldots\ldots H0 \\ y(k) = h*s(k) + n(k)\ldots\ldots\ldots H1 \end{array}\right\} \quad (4)$$

Final output is obtained as

$$Z = \frac{1}{N}\sum_{j=1}^{N} |y_j(t)|^2 \quad (5)$$

Thus, based on the central limit theorem, when N is large enough, the value of Z approximates Gaussian distribution.

3. Performance Metrics under Different Fading Channels

In this section average detection probability for different channel factor under Rayleigh and Rician fading channel are given.

3.1 Rayleigh Channel

The received signal has a Rayleigh distribution when the composite received signal for some types of scattering environments consists of a large number of plane waves [10]. Under Rayleigh fading γ have an exponential distribution given by

$$f(\gamma) = \frac{1}{\gamma}\exp\left(-\frac{\gamma}{\gamma}\right), \gamma \geq 0 \quad (6)$$

Probability of detection is obtained in this case as,

$$P_{dj}=P(Z_i\mu_i|H_1)=\int Q_m\left(\sqrt{2\delta_i},\sqrt{\mu_i}\right)f_\gamma(x)d(x) \quad (7)$$

False alarm value can be calculated using

$$P_{fa}=1-Q(z) \quad (8)$$

Where,

$$z = {}^{1}/_{\sqrt{2}} \times norminv(1 - P_{fa}) \qquad (9)$$

$$P_d=[1\text{-normcdf}(z\text{-}d), k] \qquad (10)$$

Here, K is the Rayleigh channel factor

Using these mathematical term probability of detection and false alarm curve for rayleigh channel has generated at different channel factor.

3.2 Rician Channel

When one of the paths, typically a line of sight signal is much stronger than the others Rician fading occurs. Two parameters are used to describe rician channel: 1) The ratio between the power in the direct path and the power in other scattered paths is given by k, and 2) $\bar{\gamma}$ is the direct path power, it acts as a scaling factor to its distribution. The Rician fading reduces to Rayleigh fading when there is no line of sight signal present, for case (k = 0). In Rician fading channels, chi-square distribution with two degree of freedom given by

$$f(\gamma_n) = \frac{k_{n+1}}{\bar{\gamma}_n} exp\left\{-k_n - \frac{(k_n+1)\gamma_n}{\bar{\gamma}_n}\right\} \times I_0\left(2\sqrt{\frac{k_n(k_n+1)\gamma_n}{\bar{\gamma}_n}}\right), \ \gamma_n > 0 \qquad (11)$$

Where, k_n is the Rician factor for the n-th channel. With distinct $\bar{\gamma}_n$, SNRis given as

$$\gamma = \sum_{n=1}^{N} \gamma_n \qquad (12)$$

We get the average detection probability as

$$\bar{P}_{d\_Ric} = Q\left(\sqrt{\frac{2k\bar{\gamma}}{k+1+\bar{\gamma}}}, \sqrt{\frac{\lambda(k+1)}{k+1+\bar{\gamma}}}\right) \qquad (13)$$

False alarm can be calculated as

$$P_{fa}=1\text{-}Q(z) \qquad (14)$$

Where,

$$z = 0.5 + \sqrt{1 \times \text{norminv}(1-\text{pfa}))\text{^}2} \qquad (15)$$

Detection probability can be calculated as

$$P_d=[1\text{-normcdf}(z\text{-}d), K] \qquad (16)$$

Using these mathematical term probability of detection and false alarm curve for Rician channel has generated at different channel factor K.

4. Simulation Results

MATLAB simulation is done under different fading channel and the interesting point is receiver performance. Using complementary receiver operating characteristic (ROC) curve assessment of the performance of cooperative spectrum sensing is usually performed.

4.1 Rayleigh Fading Channel

The aim of using the complementary ROC curves of one SU sensing over Rayleigh fading detecting channel is to evaluate the fading impact of detecting channel on the execution of local spectrum sensing at a one SU, and this is provided by the curves with *K* equal to (1, 2, 3).

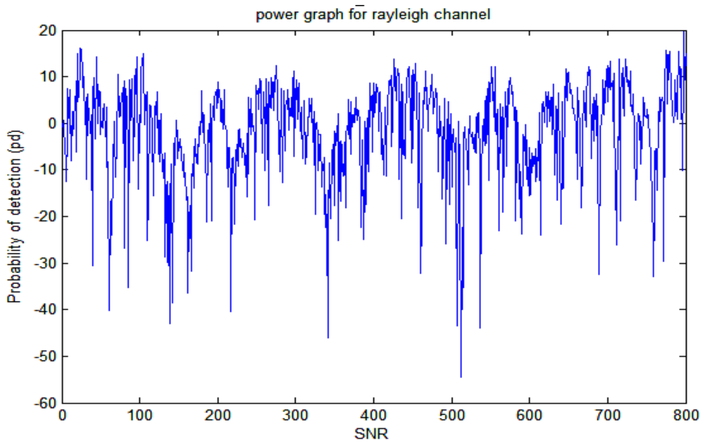

Figure 3: Signal variation in Rayleigh channel

Probability of detection at different SNR for different value of false alarm is shown in Fig.4.

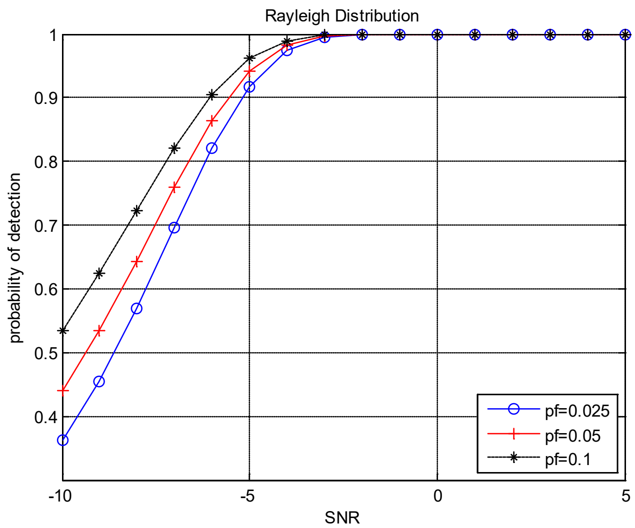

Figure 4: P_d Vs. SNR Curve under Rayleigh fading channel

From fig. 5 it is obvious that as increase in the probability of false alarm, the detection probability curve will increase, and probability of detection is highly improved. For the value of P_f =0.1 maximum throughput occur as comparison to the value of P_f =0.025 and 0.05.

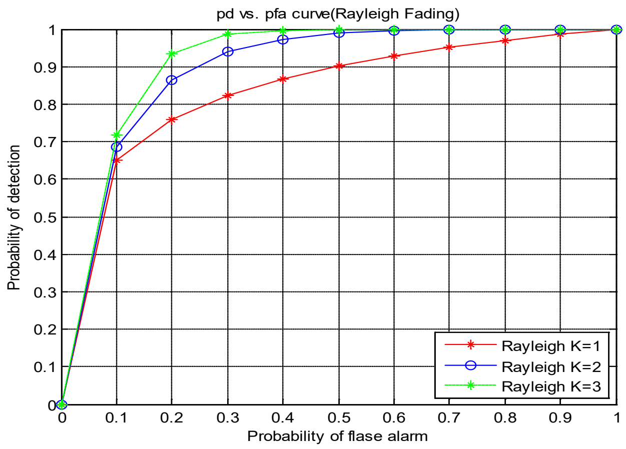

Figure 5: Probability of Detection (P_d) vs. Probability of False Alarm (P_f) in Rayleigh Fading channel at (K=1, 2, 3)

With the variation in Doppler shift probability of detection also varies at different values of false alarm. From fig.5 it can observe that the probability of detection increases with increase in Rayleigh factor 'K'.

4.2 Rician Fading Channel

Here, the probability of detection increases with increase in Rician factor (K). Fig.6 represents signal variation in Rician fading channel. Probability of detection vs. SNR is shown in fig.7 which shows that as the value of false alarm increases probability of detection also increases with increasing SNR. From fig.8, at K=2, and P_f = 0.01 the probability of detection is near about 0.56. At K=6 and same value of P_f detection probability reaches near 0.96 and with further increase in value of P_f it reaches completely to 1.

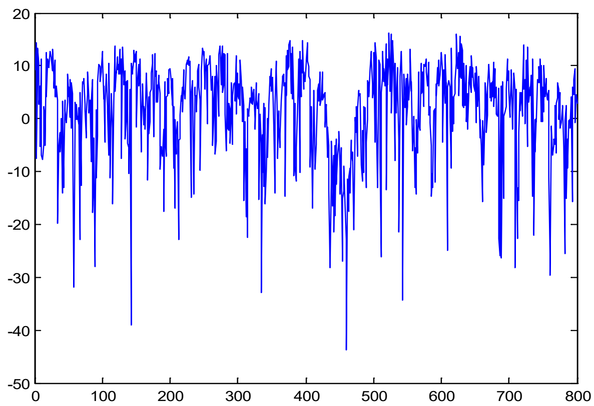

Figure 6: signal variation in Rician fading channel

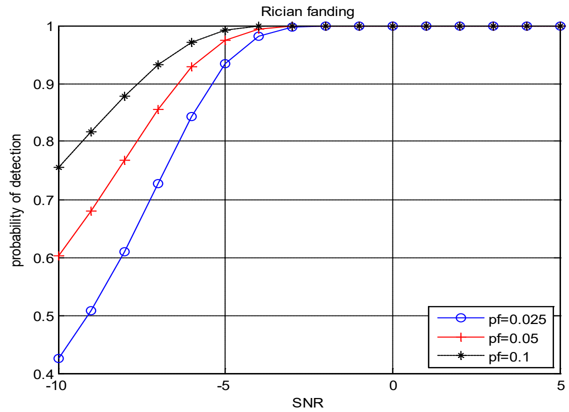

Figure 7: P_d Vs. SNR under Rician fading channel

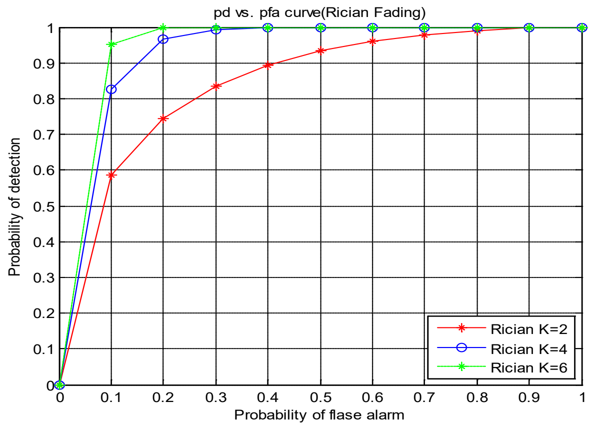

Figure 8: Probability of Detection (P_d) vs. Probability of False Alarm (P_f) in Rician Fading channel at (K=2, 4, 6)

Again from the ROC curve for P_d vs. P_f of both Rayleigh and Rician channel we can analyze that Rician channel perform better than Rayleigh channel. In Rician channel, at value of P_f = 0.01, P_d reaches near 1. But in case of Rayleigh channel when P_f = 0.02 then the detection probability (P_d) reaches to 1.

5. Conclusion

In this paper, the evaluation of detection performance for local spectrum sensing and cooperative spectrum sensing is provided under Rayleigh and Rician fading channel. With the perspective of CR, it is probable that the missed detection of PUs (licensees) by CR users cause severely interference while releasing false alarms by the CR users. The spectrum accessibility will definitely impact which in turn reduces the throughput of the CR network. The energy detector execution of spectrum sensing was also evaluated in this paper under Rayleigh, Rician fading environments. Also it has been found that the improvement of the detection execution is ensured by the cooperative signal detection by using data fusion rules using ROC curve. Moreover, by using a complex distribution the channel behavior can be more closely modeled and gives a description of multipath fading and shadowing. By comparing the two signals it shows that Rician channel is better than Rayleigh channel.

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