IJCAT International Journal of Computing and Technology, Volume 1, Issue 5, June 2014
ISSN : 2348 - 6090
www.IJCAT.org

Analysis of Energy Detector Based Spectrum Sensing in Fading Cooperative Cognitive Network

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Abstract - Ever increasing wireless services and networks results in spectrum scarcity. But already allocated spectrum is in under utilization in the current static fixed spectrum allocation method .So dynamic spectrum access is only solution for this issue .Spectrum sensing is one of the key technique in cognitive radio for dynamic spectrum access. There are many algorithm proposed for the spectrum sensing. Among all the algorithm energy detector is the only one that is less computationally complex so it is adapted as one of the candidate in 802.22 standard of TV white space based RAN network. Many research work proposed on energy detector based spectrum sensing but all focus on AWN channel of non-fading environment. But real channel is not always non fading one .In case of the cooperative spectrum sensing with different cognitive radio different channel will be experienced, some will be fading .So here in this paper an analysis of energy detector performance on Rayleigh fading environment is going to analyze under cooperative spectrum sensing .Under this analysis the amplify and forward network and indoor cases also considered and performance is studied.

Keywords **- Cognitive radio, Spectrum Sensing, Energy Detector, Amplify and Forward Network**

1. Introduction

The Spectrum sensing has become increasingly important because of the high demand on spectrum and under utilization of the spectrum. As Cognitive Radio technology is being used to provide a method of using the spectrum more efficiently, spectrum sensing is the main application of cognitive radio. One of the main thing in spectrum sensing is that Cognitive Radio systems has to access empty sections of the radio spectrum, and to keep monitoring the spectrum to ensure that the Cognitive Radio system does not cause any undue interference relies totally on the spectrum sensing elements of the system. For the overall system to operate effectively and to provide the required improvement in spectrum efficiency, the Cognitive Radio spectrum sensing system must be able to effectively detect any other transmissions, identify what they are and inform the central processing unit within the Cognitive Radio so that the required action can be taken.

Cognitive radio systems coexist with other radio systems, using the same spectrum but without causing interference. The spectrum sensing algorithm should be continuously sense the spectrum occupancy and will utilize the spectrum on a non-interference basis to the primary user. There are two major methods in which cognitive radio spectrum sensing can be performed. They are Non-cooperative spectrum sensing and Cooperative spectrum sensing. In Non-cooperative spectrum sensing a cognitive radio acts on its own. But in Cooperative spectrum sensing will be undertaken by a number of different radios within a cognitive radio network. Typically a central station will receive reports of signals from a variety of radios in the network and adjust the overall cognitive radio network to suit.

It reduces problems of interference where a single cognitive radio cannot hear a primary user because of issues such as shading from the primary user. All the sensing algorithm assumes that the channel will be flat and the performance is studied with the flat fading .But in the cooperative sensing scenario some cognitive radio undergo fading, some may be flat. So in this paper we analysis cooperative spectrum sensing using energy detector on Rayleigh fading.

This paper is organized as bellow that section II discuss about the system model of the energy detector based spectrum detection algorithm on Rayleigh fading. Section

III presents the results of the simulation study, section IV concludes the paper

2. System Model

The energy detector system consists of a wireless receiver which gives the digital version of the received signal, then the energy of the received signal is calculated. The calculated energy is fed to the decision device which perform the decision of spectrum sensing and gives the output of whether the sensing spectral frequency is free or occupied by some primary user .The entire operation is given in the fig.1

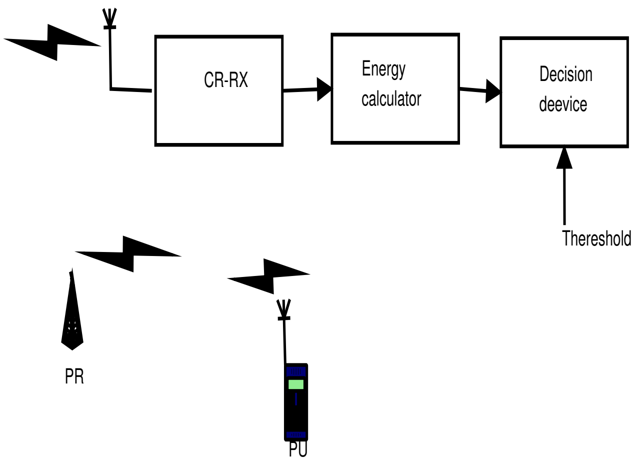

Fig.1 CR ENERGY DETECTOR SYSTEM BLOCK DIAGRAM

The received signal under AWGN is

Y(n)=s(n)+n(n) (1)

S(n) is the transmitted signal ;n(n) is the additive Gaussian noise The output that comes out of the energy calculator is energy of the received signal over the time interval T and this output is considered as the test statistic to test the two hypotheses H_0 and H_1 [1]. H_0: corresponds to the absence of the signal and presence of only noise. H_1: corresponds to the presence of both signal and noise.

Thus for the two state hypotheses numbers of important cases are

R1)H1 turns out to be TRUE in case of presence of Primary user i.e. P (H1 / H1) is known as Probability of Detection (P_d).

R2)H0 turns out to be TRUE in case of presence of primary user i.e. P (H0 / H1) is known as Probability of Missed-Detection (P_m).

R3)H1 turns out to be TRUE in case of absence of primary user i.e. P (H1 / H0) is known as Probability of False Alarm (P_f). Under AWGN channel case the Probability of detection is [2],

$p_d = P(Y > \frac{TH}{H1})$ (2)

The probability of false alarm P_f can be evaluated $P_f = P(Y > \frac{TH}{HO})$ (3)

analytically we can derive the P_d for the AWGN channel as below
$P_d = Q_d(\sqrt{2\alpha}\sqrt{TH})$ (4)

Where
$\alpha = E_s/N = \beta/2$ (5)

Where β is the effective SNR in terms of non-centrality parameter
Where, $Q_d(.,.)$ is the generalized Marcum-Q function For the case of the Rayleigh Channel *The received signal is*

Y(n)=s(n)h(n)+n(n) (6)

Probability density function for Rayleigh channel is

$f(h) = 1/h e^{-(h/h^{\alpha})}, h \geq 0$ (7)

Probability of detection for Rayleigh Channel is obtained by averaging their probability density function over Probability of detection for AWGN Channel [2] that is

$P_{d,ray} = \int_0^{\infty} P_d \, f(h)\, dh$ (8)

By analytically, we can derive the probability of the detection for the Rayleigh Channel

$P_{d,ray} =$
$e^{-\frac{TH}{2}} \sum_{n=0}^{d-2} \frac{\left(\frac{th}{2}\right)^n \frac{1}{}}{n!} + (1 + \frac{h^{\alpha}}{h^{\alpha}})[e^{-\frac{th}{2(1+h^{\alpha})}} - e^{-\frac{th}{2}} \sum_{n=0}^{d-2} \frac{1}{n!} (\frac{th h^{\alpha}}{2(1+h^{\alpha})})^n$
] (9)

3. Result and Discussion

The energy detector algorithm is simulated with 100 cooperative node and the AND rule based final decision is made to find out the spectral occupancy .the Rayleigh fading channel is simulated and the out of the channel is taken as received signal .fig.2 shows the distant between the node kept for the simulation in the cooperative network

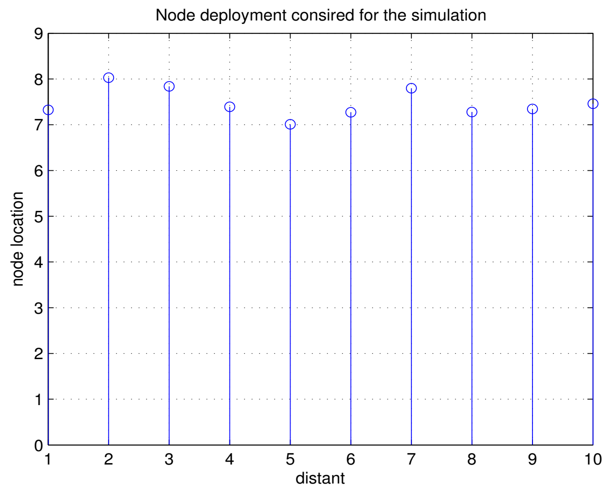

Fig.2 node deployment scenario with some distant between them Fig.3 shows the Rayleigh channel coefficient that are used for realization of the Rayleigh channel.

The threshold values for the local detection is calculated by using inverse incomplete gamma function .the computed threshold values are plotted in the fig.4.the plot shows that based on the distant of the node location the threshold values are selected ,more the distant less the threshold value.

The performance of the algorithm in Rayleigh fading is compared with AWGN channel and plotted in the fig.5. Fig.5 shows that the performance of the energy detector is actually improved in Rayleigh fading.

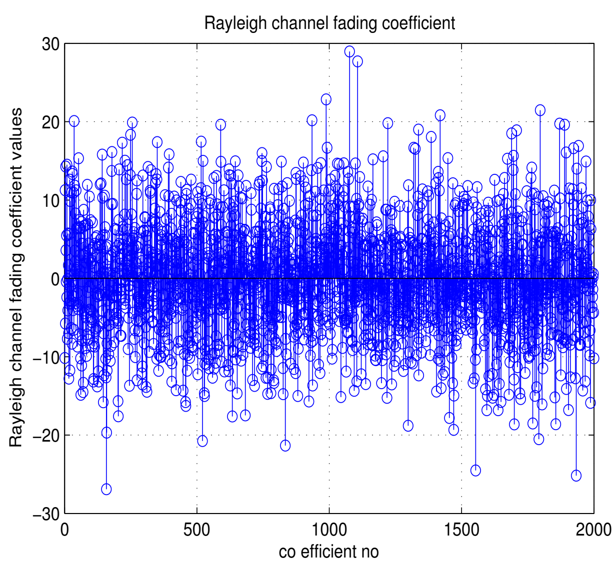

Fig.3 Rayleigh fading channel coefficients

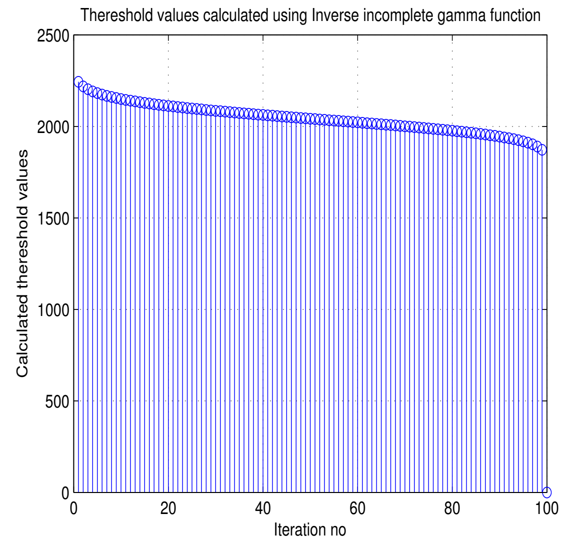

Fig.4 computed threshold values for 100 nodes

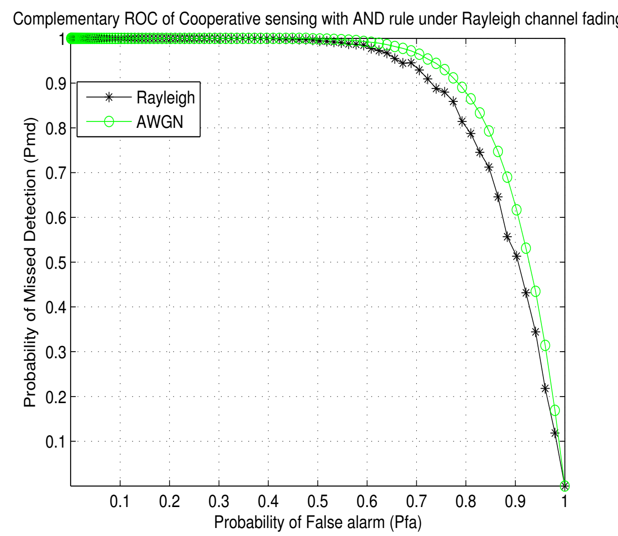

Fig.5 ROC curve for AWGN and Rayleigh fading channels

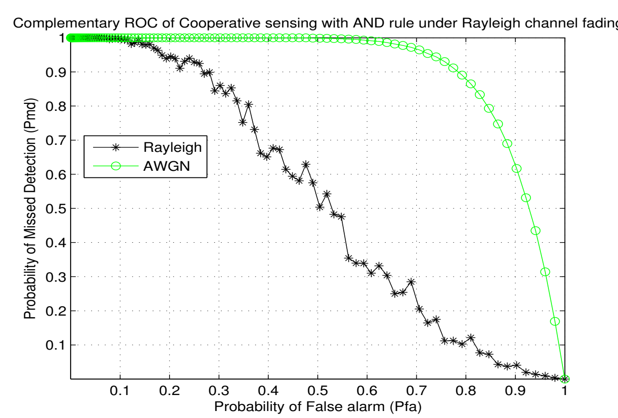

Fig.6 ROC curve for Amplify and forward cooperative network

In the cooperative case the amplify and forward relay network case is simulated and the performance is plotted in the ROC curve. Since the signal loss is avoided and the fading effect is reduced by the amplification process there is a drastic improvement in the energy detector under this case.fig.6 shows the improved performance of the energy detector .But there is some up and down the curve because of the incomplete inverse gamma function based there holding which assume some path loss in the calculation of the threshold. The performance of the algorithm is evaluated by using indoor path loss model where we absorb from the fig.7 that the performance is more or less same for both AWGN and Rayleigh channel.

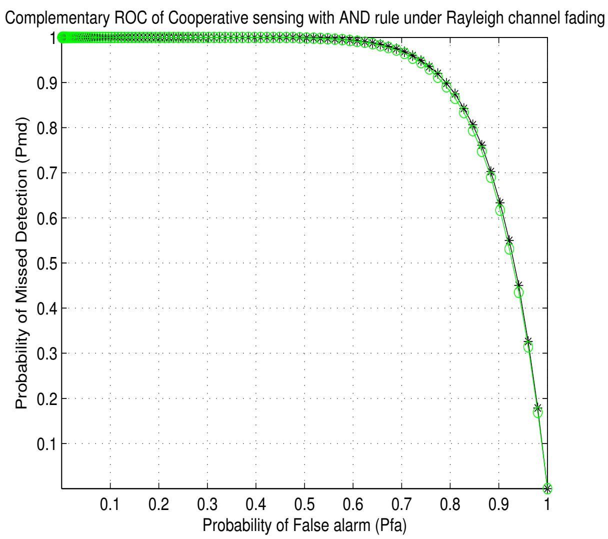

Fig.7 indoor scenario the AWGN channel and Rayleigh channel performance

4. Conclusions

This paper analyzed the performance of the energy detector spectrum sensing algorithm in Rayleigh fading environment and the result is compared with AWGN channel .The cooperative sensing based on the AND rule based decision is simulated and the performance in evaluated for the cases of indoor and amplify and forward cooperative networks. From the result we can conclude that Rayleigh fading supports the energy detection based algorithm comparing AWGN case but in the indoor scenario the performance is same for both AWGN and Rayleigh case. The energy detection algorithm performance is very good in the amplify and forward based relay cooperative networks. But we observe some kind of small oscillation because of the incomplete inverse gamma function based thresholding

References

[1] H. Urkowitz, ―Energy detection of unknown deterministic signals,‖ Proc. IEEE, vol. 55, no. 4, pp. 523–531, Apr. 1967.

[2] F.F. Digham, M.S. Alouini and M.K. Simon, ―Energy Detection of unknown signals over fading channels‖, IEEE Transactions on Communications, Vol. 5, No.1, pp. 21- 24, 2007.

[3] EbtihalHaiderGismalla and EmadAlsusa, ―Performance Analysis of the Periodogram-Based Energy Detector in Fading Channels‖, IEEE Transaction on Signal Prpcessing, vol. 59, no.8, pp. 3712-3721, August 2011.

[4] S. Atapattu, C. Tellambura and H. Jiang, ―Analysis of Area under ROC curve of energy detection‖ IEEE Transactions On Wireless Communications, Vol. 9, No.3, pp. 1216-1225, 2010.

[5] N. C. Beaulieu and Y. Chen, "Improved energy detectors for cognitive radios with randomly arriving and departing primary users," *IEEE Signal Processing Letters*, vol. 17, no. 10, pp. 867-870, Oct. 2010.

[6] J. Y. Wu, C. H. Wang, and T. Y. Wang, "Performance analysis of energy detection based spectrum sensing with unknown primary signal arrival time," *IEEE Trans. on Commun.*, vol. 59, no. 7, pp. 1779-1784, July 2011.

[7] S. Haykin, "Cognitive radio: brain-empowered wireless communications," *IEEE J. Sel. Areas Commun.*, vol. 23, no. 2, pp. 201–220, Feb. 2005.

[8] G. Ganesan and Y. Li, "Cooperative spectrum sensing in cognitive radio, part I: two user networks," *IEEE Trans. Wireless Commun.*, vol. 6, no. 6, pp. 2204–2213, June 2007.

[9] G. Ganesan and Y. Li, "Cooperative spectrum sensing in cognitive radio, part II: multiuser networks," *IEEE Trans. Wireless Commun.*, vol. 6, no. 6, pp. 2214–2222, June 2007

[10] S. Atapattu, C. Tellambura, and H. Jiang, "Performance of an energy detector over channels with both multipath fading and shadowing," *IEEE Trans. Wireless Commun.*, vol. 9, no. 12, pp. 3662–3670, Dec. 2010.