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Performance Analysis of Cooperative Sensing in Fading Channels for Wireless Communication

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Abstract: Cognitive radio (CR) is a new era of wireless communication system in which the use for efficient spectrum utilization of radio frequency (RF) band or RF channel for future wireless communication. Cooperative spectrum sensing is the very important key component of cognitive radio technology in which the sensing information from CR users combines at the Fusion center (common receiver) by soft combination or conventional hard combination techniques. Soft combination has excellent performance but, it requires a lot of overhead for feedback observation. In contrast, the conventional hard combination scheme requires only one bit of overhead, but it has worst performance because of loss of sensing information. Softened hard (quantized)decision fusion based cooperative spectrum sensing is optimum choice between overhead and detection performance. In this paper we mainly concentrate on the quantized (softened) cooperative spectrum sensing in environment of different fading channel like Rayleigh, Rice an and Nakagami. Centralized detection approaches are considered for the analysis of different data fusion rules of quantized cooperative sensing. The simulation result indicates the various types of analysis and comparison which can be very useful for analysis of fading in quantized cooperative spectrum sensing research and development.

Keywords: Cognitive radio, cooperative spectrum sensing, energy detection, fading channel.

I. INTRODUCTION

The Federal Communications Commission (FCC) report says that almost 80% of allotted spectrum are idle at most of the time so current frequency assignment policy cannot meet the real time requirement so they recommend to change/redesign the fixed frequency assignment policy and suggest the opportunistic access of licensed spectrum by SUs conditioned that there is no any interference on the PUs or user who pay charges for communication[1]. Cognitive radio is intellegency device which is capable to sense the spectrum and avoid the interference on the licensed users, It is capable of identifying the presence or absence of the primary user (PU) signal. The PU signal is always suffered by deep fading because of propagation loss and secondary-user (SU) interference. To compensate the fading effects, we can use from the diversity techniques that can be used by employing several SUs to cooperatively detect the spectrum Spectrum sensing is a difficult task because of shadowing, fading, and time-varying nature of wireless communication channels [2]. Because of severe multipath fading effect in wireless communication, a cognitive radio cannot identify the presence of the licenses user (PU) and then will access the licensed frequency band for communication and create interference with primary user. In order to cope with this problem in cognitive radio networks, multiple cognitive users can cooperatively work for spectrum sensing. In some paper [3], [4] cooperative spectrum sensing can improve the probability of detection and probability of false alarm parameter of spectrum sensing. However, the most of the work only examined the performance of cooperative sensing in AWGN channel

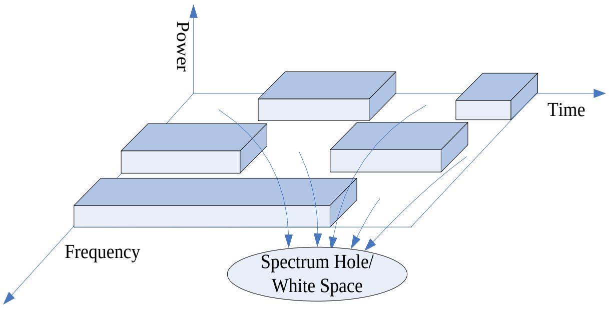

Fig 1 Utilization of Spectrum Holes

But not for examined quantized cooperative spectrum for different fading channel

In this paper, we analyze the various types of the performance of quantized cooperative spectrum sensing in the various fading environment like Rayleigh, Nakagamias well as Ricean. More specifically, we compare our detection performances of quantized cooperative spectrum sensing in these channels. The energy detection technique of spectrum sensing in various types of fading channels was investigated in [6]. Here, we mainly concentrate on quantized cooperative spectrum sensing.

This paper is arranged by brief introduction of spectrum sensing in Section II. We proposed the system model, Quantized Cooperative spectrum sensing over various

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fading environment and its performance metrics are derived in Section III, In Section IV, simulation results are given for the analysis and comparison purpose. Finally, we draw our conclusions in Section V.

II. SPECTRUM SENSING

Spectrum sensing is a key element in cognitive radio networks as it should be firstly performed before allowing CR users to access a vacant licensed channel. The goal of the spectrum sensing is to decide between the two hypotheses, H_0:no signal transmitted, and H_1: signal transmitted. In this regard, there are two probabilities that are most commonly associated with spectrum sensing: probability of false alarm P_f which is the probability that a presence of a signal is detected even if it does not exist and probability of detection P_d which is the probability for a correctly detected signal. The local spectrum sensing is to decide between the following two hypotheses

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

In AWGN channel environment the average probability of false alarm, the average probability of detection, and the average probability of missed detection are given, respectively, by [7]

$$P_d = P\{Y > \lambda | H_1\} = Q(\gamma, \lambda) \quad (2)$$

$$P_f = P\{Y > \lambda | H_0\} = \frac{\Gamma(TW, \lambda/2)}{\Gamma(TW)} \quad (3)$$

$$P_m = 1 - P_f \quad (4)$$

Where, $\lambda$is the energy detection threshold, $\gamma$is the instantaneous signal to noise ratio (SNR) of CR, TWis thetime-bandwidth product of the energy detector, $\Gamma(.)$ is the gamma function,$\Gamma(.,..)$is the incomplete gamma and $Q(.,..)$is generalised Marcum Q-function defined as follow

$$Q_u(a,b) = \int_b^{\alpha} \frac{x^u}{a^{u-1}} e^{-\frac{x^2+a^2}{2}} I_{u-1}(ax)dx \quad (5)$$

The threshold of i^{th} CR according to Neyman-Pearson criteria is determined as

$$\lambda^* = 2\Gamma^{-1}(P_f, TW) \ (6)$$

Replace the above threshold in probability of detection equation gives receiver operating charactertics(ROC) for given probability of false alarm which is given by following.

$$P_d = P\{Y > \lambda | H_1\} = Q(\gamma, \lambda^*) \quad (7)$$

In cooperative spectrum sensing common receiver calculates detection probability with the help of average probability of each CR which is given by

$$Q_d = \sum_{k=n}^{N} \binom{N}{k} {P_d}^k (1 - p_d)^{N-k} = prob\{H_0/H_1\} \quad (8)$$

III.QUANTIZED COOPERATIVE SPECTRUM SENSING OVER VARIOUS FADING CHANNELS

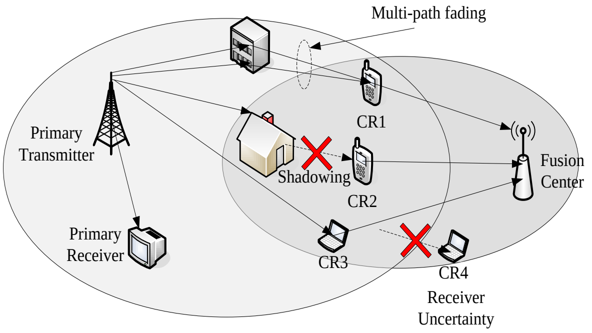

Fig 2 Cooperative spectrum sensing model of cognitive radio

In real communication, the hidden station problem, deep fading and shadowing, etc., would slow down spectrum sensing performance of cognitive users. To address this issue, multiple cognitive users can be cooperated to perform spectrum sensing. It has been shown in [3], [4] shown that cooperative spectrum sensing can greatly increase the probability of detection in fading channels. Figure 2 shows the system model of cooperative spectrum sensing Here the SUs send their spectrum sensing information to fusion centre (FC), which makes a global decision whether any PU is present or absent according to some rule. If SUs send all information received to FC without making any decision, it is called soft decision rule [8]. On the other hand, if SUs send their decision information to FC (general one-bit decision), it is called hard decision rule [9]. There is trade-off between detection performance and overhead. The way the local decision is reported to the fusion centre plays a main role for performance in cooperative schemes in general and in spectrum sensing. In quantized cooperative spectrum sensing Each cooperating secondary user senses the spectrum and sends its'quantized' local measurement as the index of the quantization level to the fusion center at the cognitive base station. The fusion center makes a decision according to index.

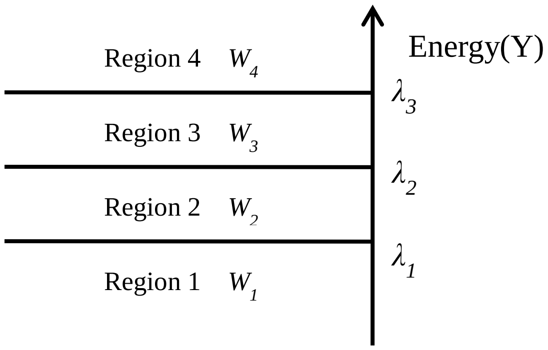

Fig 3 Principle of two-bit hard combination scheme

Figure 3 show the principle of the softened two-bit hard combination (Quantized) based data fusion scheme.In

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conventional one-bit scheme with only one threshold, Here we have a three thresholds in the two-bit scheme, λ1, λ1 and λ3, divide the whole range of the observed energy into 4 regions. Each cooperating secondary user senses the spectrum and sends its two bit information “quantized data ” to indicate which region its observed energy falls in to the fusion centre at the cognitive base station. The fusion centre makes a global decision according to its 2-bit value measurement

The probability of having observation in respective region under hypothesis $H_0$and H_1 and AWGN channel are following.

$$P_{di} = \begin{cases} 1 - P_d(\lambda_k) & if\ k = 1 \\ P_d(\lambda_{k-1}) & if\ k = n \\ P_d(\lambda_{k-1}) - P_d(\lambda_k) & otherwise \end{cases} \quad (9)$$

The decision function is evaluated with the help of the weights and the number of users in the each energy level.

$$f(\overrightarrow{w}) = \begin{cases} 1 & if\ \vec{N}.\overrightarrow{W} > 0 \\ 0 & otherwise \end{cases} \quad (10)$$

Here the weighted summation is given by

$$N_c = \textstyle\sum_{i=0}^{3} w_i . N_i \quad (11)$$

Where N_i = Number of observed energies falling in region i.

In Quantized cooperative spectrum sensing the probabilities of cooperative detection derived using [10] which is given by following

$$P_d = \sum_{i=1}^{4}\sum_{j=1}^{4} P_r(N_1 = n_1, N_2 = n_2, N_3 = n_3, N_4 = n_4 | H_1) (12)$$

$$P_d = \sum f(\overrightarrow{w}) \sum_{i=1}^{4} \binom{N - \sum_{j=1}^{i-1} N_j}{N_i} \ldots\ldots$$
$$(1 - P_{d1})^{n_1}(P_{d1} - P_{d2})^{n_2}(P_{d2} - P_{d3})^{n_3}(P_{d4})^{n_4} \quad (13)$$

$$P_d = \sum f(\overrightarrow{w}) \binom{N}{n_1}\binom{N-n_1}{n_2}\binom{N-n_1-n_2}{n_3}\binom{N-n_1-n_2-n_3}{n_4} \ldots.$$
$$(1 - P_{d1})^{n_1}(P_{d1} - P_{d2})^{n_2}(P_{d2} - P_{d3})^{n_3}(P_{d4})^{n_4} \quad (14)$$

The average probability of detection may be derived by averaging the conditional P_d in the AWGN case over the SNR fading distribution by following

$$P_d = \int Q_u(\gamma, \lambda) f_\gamma(x) dx \quad (15)$$

Where $f_\gamma(x)$is the probability distribution function (PDF) of SNR under fading. In the followingsection, we give the average detection probability over Rayleigh, Nakagami, and Ricean fading channels and in closed form [6].

A. Rayleigh Channel

When the composite received signal consists of a large number of plane waves, the received signal can be approximated a Rayleigh distribution [11]. Under Rayleigh fading, γ would have an exponential distribution which is given by following equation

$$f(\gamma) = \frac{\gamma}{\bar{\gamma}} exp\left(\frac{\gamma}{\bar{\gamma}}\right), \gamma \geq 0 \quad (16)$$

In this case, a closed-form formula for probability of detection P_d may be obtained after some manipulation by substituting $f_\gamma(x)$ in the above equation

$$P_{dRay} = e^{-\frac{\lambda}{2}} \sum_{k=0}^{u-2} \frac{1}{k!}\left(\frac{\lambda}{2}\right)^k + \left(\frac{1+\bar{\gamma}}{\bar{\gamma}}\right)^{u-1} \ldots\ldots\ldots$$
$$\left(e^{\frac{\lambda}{2(1+\gamma)}} - e^{-\frac{\lambda}{2}} \textstyle\sum_{k=0}^{u-2} \frac{1}{k!}\left(\frac{\lambda\bar{\gamma}}{2(1+\bar{\gamma})}\right)^k\right) \quad (17)$$

B. Ricean Channel

Some types of scattering environments have a specular or Line of Sight component. In this case, the amplitude of received signals has a Ricean distribution. The PDF of will be given by

$$f(\gamma) = \frac{K+1}{\bar{\gamma}} exp\left(-k - \frac{(K+1)\gamma}{\bar{\gamma}}\right) I_0\left(2\sqrt{\frac{K(K+1)\gamma}{\bar{\gamma}}}\right) \gamma \geq 0 (18)$$

where$K$ is the Rice factor. P_dIn the case of a Ricean channel can be given by

$$P_{dRic} = Q\left(\sqrt{\frac{2K\bar{\gamma}}{K+1+\bar{\gamma}}}, \sqrt{\frac{\gamma(K+1)}{K+1+\bar{\gamma}}}\right) \quad (19)$$

C. Nakagami Channel

The Nakagami distribution has been found and was introduced by Nakagami in the era of 1940 to implement the rapid fast fading in long distance communication and high frequency channels. The Nakagami distribution was selected to fit empirical data, and is known to provide a closer match to some experimental data than the Rayleigh or Ricean distributions [11]. If the signal amplitude follows a Nakagami distribution, then the probability distribution function(PDF) of follows a gamma PDF is given by following

$$f(\gamma) = \frac{1}{\Gamma(m)}\left(\frac{m}{\bar{\gamma}}\right)^m \gamma^{m-1} exp\left(-\frac{m}{\bar{\gamma}}\gamma\right) \gamma \geq 0 (20)$$

where$m$is the Nakagami parameter. In this case, a closed-form formula of Nakagami channels can be given by following

$$P_{dNak} = \alpha\left[G_1 + \beta \sum_{n=1}^{u-1} \frac{(\lambda/2)^n}{2(n!)} F_1\left(m;\ n+1;\ \frac{\lambda}{2}\frac{\bar{\gamma}}{m+\bar{\gamma}}\right)\right]$$

where$F_1(.;.;.)$is the confluent hyper geometric function[12],

IV. SIMULATION RESULT

A simulation has been done to assess the performance analysis of softened hard decision (Quantized) fusion based cooperative spectrum sensing in various fading channel. We plot below the receiver operating characteristic (ROC) of conventional soft decision fusion technique i.e. EGC, hard design fusion technique i.e. AND, OR, MAJORITY rules and softened hard decision (Quantized) fusion technique under the AWGN, Rayleigh, Ricean and Nakagami channel. We have considered the parameter time-bandwidth product $TW = 5$, the number of received signal samples $M = 2u$. SNR of channel is 5dB and total number of cooperative users is 10.

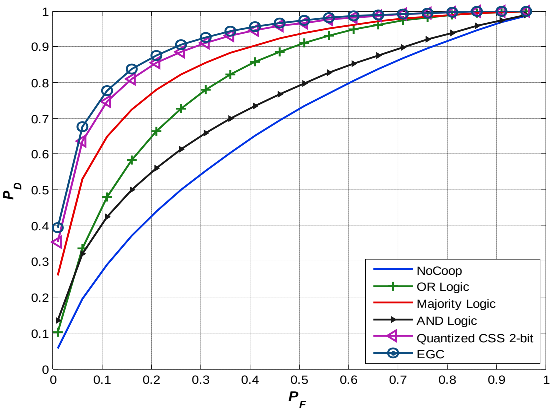

Fig 4 ROC curve of different decision logic under AWGN channel

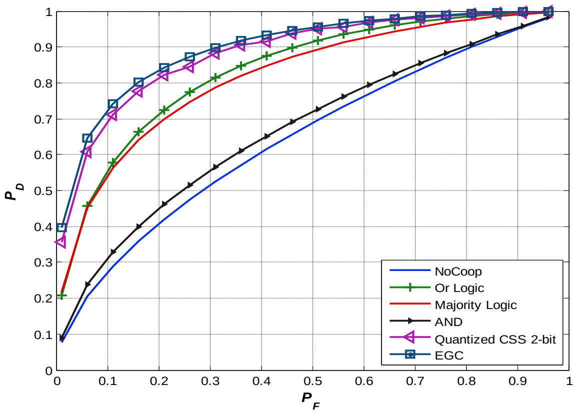

Fig 5 ROC curve of different decision logicUnder Rayleigh channel

weanalyzed the performance of different global decision logic on probability of detection under AWGN and Rayleigh channels which are plotted in Fig. 4 and Fig. 5, respectively for given probability of false alarm.

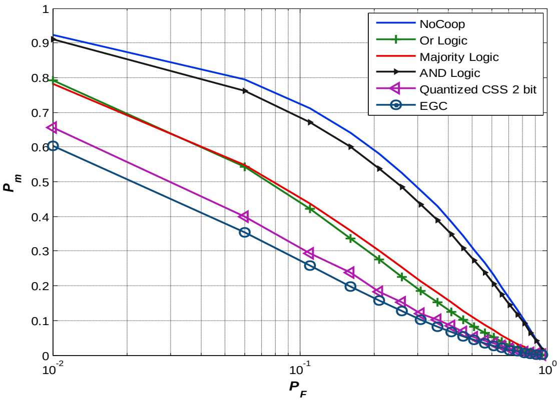

Fig 6 C-ROC curve of different decision logic under Ricean channel

In Rayleigh channel, OR logic performance is better than majority logic because total number of nodes with high SNR are fewer so improving OR logic

The complementary receiver operating characterise(C-ROC) under the Ricean channel are shown in the figure 6. Comparing the AWGN curve with other fading in channel, we observe that spectrum sensing performance is poor in presence of Rayleigh and Nakagami fading. In Ricean channel, because of the Line of sight, the sensing performance is better than in other channels. We observe that the OR rule has the better performance than AND and MAJORITY rule in various channels

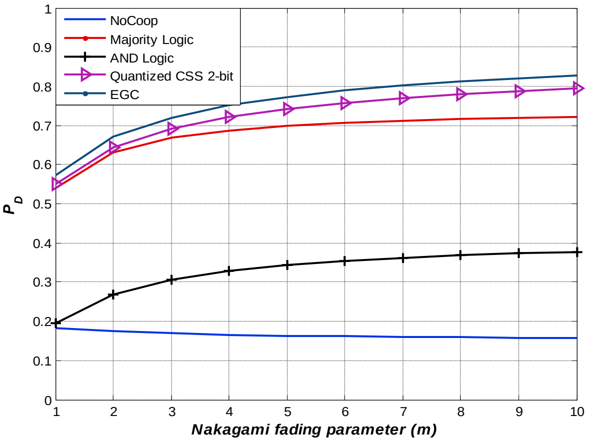

Fig 7 m versus P_d curves of different global decision logic

V. CONCLUSION

We have studied the performance of quantized cooperative spectrum sensing in cognitive radio networks in various fading channel. The energy detector based performances of spectrum sensing over different channel i.e Rayleigh, Ricean and Nakagami fading are presented and compared with each other. It has been concluded that the quantized cooperative signal detection enhance the detection performance by marginal increase the overhead bits.

Moreover, in many practical situations, the channel behaviour can be more closely modeled by using a composite distribution that consider for shadowing and multipath fading in wireless communication. In this situation, ROC curves for the Rayleigh, Ricean and Nakagami case provide a more realistic picture of the detection performance of the quantized cooperative spectrum sensing system. The analysis and comparison with this channel can be very used for future reference of quantized cooperative spectrum sensing in the field of cognitive radio.

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REFERENCES

[1] S.Haykin, “Cognitive radio: Brain-empowered wireless communications,” IEEE J. Sel. Areas Commun., vol. 23, no. 2, pp. 201–220, Feb. 2005
[2] D. Cabric, S. M. Mishra, and R. W. Brodersen, “Implementation issues in spectrum sensing for cognitive radios,” in Proc. Asilomar Conf. on Signals, Systems, and Computers, vol. 1, pp. 772–776,Nov. 7-10, 2004.
[3] A. Ghasemi and E. S. Sousa, “Collaborative spectrum sensing for opportunistic access in fading environments,” in Proc. 1st IEEE Symp. New Frontiers in Dynamic Spectrum Access Networks, Baltimore, USA, pp. 131-136,Nov. 8-11, 2005.
[4] G. Ganesan and Y. Li, “Cooperative spectrum sensing in cognitive radio networks,” in Proc. DySPAN, pp. 137-143,Nov. 2005.
[5] S. Kyperountas, N. Correal, Q. Shi and Z. Ye, “Performance analysis of cooperative spectrum sensing in Suzuki fading channels,” in Proc. CrownCom 2007. 2nd International Conference, 1-3. pp. 428 – 432.Aug. 2007.
[6] F. F. Digham, M.-S. Alouini and M. K. Simon, “On the energy detection of unknown signals over fading channels,” in Proc. of IEEE International Conference on Communications (ICC’03), pp. 3575–3579, May 2003.
[7] Wei Zhang, Member, IEEE, Ranjan K. Mallik, Senior Member, IEEE, and Khaled Ben Letaief, Fellow, IEEE “Optimization of Cooperative Spectrum Sensing with Energy Detection in Cognitive Radio Networks”, IEEE transactions on wireless communications, vol. 8, no. 12, December 2009.
[8] J. Ma, G. D. Zhao, and L. Ye, “Soft combination and detection for cooperative spectrum sensing in cognitive radio networks,” IEEE Transactions on Wireless Communications, vol. 7, no. 11, pp. 4502-4507, 2008.
[9] D. C. Oh, H. C. Lee, and Y. H. Lee, “Linear hard decision combing for cooperative spectrum sensing in cognitive radio systems,” IEEE 72nd Vehicular Technology Conference, Ottawa, Canada, pp. 1-5, Sep. 2010
[10] Jun Ma, Guodong Zhao, and Ye (Geoffrey) Li, " Soft Combination and Detection for Cooperative Spectrum Sensing in Cognitive Radio Networks" IEEE Transactions on Wireless Communications, vol. 7, no. 11, Nov. 2008.
[11] G. L. Stüber, Principles of Mobile Communications, second ed. Norwell, MA: Kluwer Academic Publishers, 2002.
[12] I. S. Gradshteyn and I. M. Ryzhik, Table of Integrals, Series, and Products, 7th ed. Academic Press, 2007

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