Sindh Univ. Res. Jour. (Sci. Ser.) Vol.46 (1) 05-08 (2014)

SINDH UNIVERSITY RESEARCH JOURNAL (SCIENCE SERIES)

Performance of two Algorithms of Energy Detection in Cooperative-Cognitive Networks with Path Loss Effects over AWGN Channel

M. ADNAN, Z. U. ISLAM, K. BASHIR, S. ALI, I. KHAN++, I. A. SHAH, S. JAN, M. A. MAHMOOD

University of Engineering and Technology, Peshawar (Mardan Campus).

Received 1st January 2014 and Revised 3rd March 2014

Abstract: This paper presents the comparative performance analysis of two energy detection algorithms, single and double threshold energy detection, in the Cooperative-Cognitive Networks. Path loss effect has been considered in order to measure the efficiency of the system in terms of detection accuracy interference with Primary User (PU). The two algorithms are analysed using single and multiple relays at different positions from PU. The path loss exponent is considered as 3 in order to get degenerative environment. We have used Monte Carlo Simulation for our proposed double threshold technique by considering AWGN channel and Maximal Ratio Combining (MRC) at the receiver. The simulation results are presented for the Probability of Detection (P_d), Collision probability (P_c) and unavailable probability (P_{na}) by considering both the algorithms.

Keywords: Cognitive Radio, Single Threshold, Double Threshold, AWGN, Cognitive Centre, TDMA, MRC

1. INTRODUCTION

Radio Spectrum is of great importance in now a day's communication because it is limitedly provided by the regulatory authorities. Meanwhile, some part of radio spectrum is heavily occupied while most of it is underutilized (Zarin *et al.,* 2012). Cognitive Radio networks are the solution of this low usage of spectrum by allocating the vacant spectrum to the unlicensed Secondary User (SU) in the presence or absence of licensed Primary User (PU) in order to avoid the interference with the PU (Atapattu *et al.,* 2009). Decisive spectrum sensing is suggested in (Haq *et al.,* 2013), which lessens the interference between PU and SU.

Energy detection has gained popularity in spectrum sensing techniques due to its low complexity because other techniques such as matched filter, cyclostationary feature and fuzzy logic based detection are complex. This technique gives high detection probability and Signal-to-Noise Ratio (SNR) because it simply senses the energy of PU and compares the detected energy with the predefined threshold and makes decision whether the PU is present or absent. We have two algorithms of energy detection, *i.e*., single and double threshold; in single threshold, the detected energy is compared by single predefined threshold while in double threshold the detected energy is compared by two predefined thresholds (Srinu and Sabat, 2010), (Bhargavi and Murthy, 2010). The predefined threshold plays a very important role in probability of detection and probability of false alarm because improper value of predefined threshold gives less probability of detection and high probability of false alarm (Saleem and Shahzad, 2012). Single threshold is more sensitive to the noise power than the double threshold, while double threshold energy detection algorithm is considered to be improved in macro detection capability (Sun and Letaief, 2007). In (Wu and Yu, 2009), we see that double threshold energy detection gives more accurate results in terms of detection accuracy than the single threshold energy detection without considering path loss effect.

In cooperative-cognitive network, the detection performance of energy detector is improved by using spatially located cognitive relays. These relays can share their sensing information in order to improve decision by making individual decision into combine decision (Akyildiz *et al.*, 2010). We have three types of schemes which are used at relays, *i.e.*, Amplify-and-Forward (AF), Decode-and-Forward (DF) and Estimate-and-Forward (EF) (Zarin *et al.*, 2012). In AF scheme, the relay amplifies the noisy version of received signal and then retransmits it (Kwasinski and Liu, 2008). Thus, for improvement of sensing capabilities, AF relaying scheme is used which increases detection probability (Ganesan and Li, 2005). In (Bhowmick *et al.*,2012) Maximal Ratio Combining (MRC) is used for energy fusion where OR rule is suggested for decision fusion.

In this paper, we propose optimization of Relay in cooperative-cognitive radio network by using two algorithms of energy detection technique with path loss effect. Every relay is using AF protocol and mutually orthogonal transmission of the received PU signals. The Time Division Multiple Access (TDMA) system is proposed for this orthogonal transmission where the

++Corresponding author: I. Khan, E-mail: imrankhan@nwfpuet.edu.pk Phone: +92(0)937-9230295

data transmission in cooperative TDMA relaying network occurs in two steps. In first step, the signal is sent from PU to relay and in second step signal is forwarded from relay to SU (Salma *et al.*, 2008). Additive White Gaussian Noise (AWGN) channel is assumed for data transmission.

The paper is structured as follows: In Section 2 Materials and Methods are explained. Section 3 comprises of Results and Discussion. Section 4 concludes our work.

2. MATERIALS AND METHODS

System Model

Consider a cooperative network with multiple relays as given in **(Fig. 1)**. The primary user, PU, acts as source and cognitive user, SU, as destination. The multiple relays are operating in AF mode, Ri, where $i \in \{1,2,3,\ldots,N\}$. Here, the Additive White Gaussian Noise Channel (AWGN) is considered. We suppose the normalize distance between PU and SU as 'd0' because path loss effect is considered. We suppose 2-Relay network (N=2) spectrum sensing scheme.

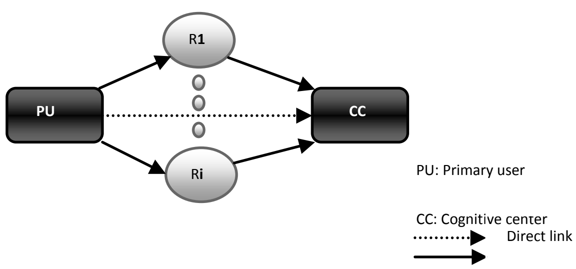

Fig. 1: Cooperative Network with Multiple Relays

A. *Cooperative network of single relay:*

While transmitting a signal, we deal with three nodes, *i.e.,* PU, Relay and SU. The transmitting signal of PU, '$x(t)$' and the signal received at relay, '$y_{pr}(t)$' and at SU, '$y_{rs}(t)$' are:

$$y_{pr}(t) = (d_{pr})^{-n}\, x(t) + n_{pr} \tag{1}$$

$$y_{rs}(t) = \beta_r\, (d_{rs})^{-n}\, x(t) + n_{rs} \tag{2}$$

Where 'd_{pr}' and 'd_{rs}' in the Equations (1) and (2) are the distances between source and relay, and relay to destination respectively, 'n' is the path loss exponent, while 'n_{pr}' and 'n_{rs}' are the AWGN's at the relay and destination respectively.

The amplification factor of relay is 'β_r' which is given as:

$$\beta_r = y_{pr}(t)/\sqrt{|y_{pr}(t)|^2} \tag{3}$$

B. *Cooperative spectrum sensing:*

In spectrum sensing, the most common and easy method is energy detection. In **(Fig. 2)**, there are two algorithms of energy detection, *i.e.,* signal threshold and double threshold energy detection. **(Fig. 2a)**, shows that when received signal, $y(t) > V_{th}$ means that PU is present, shown as H_1. But when received signal $y(t) < V_{th}$, it represents that PU is absent, shown as H_0. Here V_{th} is the predefined detection threshold. For Double threshold in **(Fig. 2b)**, when received signal $y'(t) > V_{th1}$ is showing that PU is present, shown as H_1. When received signal $y'(t) < V_{th0}$ tell us that PU is absent, shown as H_0. But when received signal $y'(t)$ is in between the two thresholds then it cannot make any decision and re-detection is needed. Here V_{th0} and V_{th1} are two predefined detection threshold. Detection probability, false alarm probability, Misdetection probability, Collision probability and Unavailable probability for both Algorithms can be calculated as: (Wu and Yue, 2009). For Single Threshold:

$$P_d = P\{y(t) > V_{th}|H_1\} = Qu\,(\sqrt{2Y}, \sqrt{V_{th}}) \tag{4}$$

$$P_f = P\{y(t) > V_{th}\,|H_0\} = \Gamma(u, V_{th}/2)\Gamma(u) \tag{5}$$

$$P_m = P\{y(t) < V_{th}\,|H_1\} = 1 - P_d \tag{6}$$

$$P_c = P_f \tag{7}$$

$$P_{na} = P_m \tag{8}$$

For Double Threshold:

$$P'_d = P\{y'(t) > V_{th1}|H_1\} = Qu\,(\sqrt{2Y'}, \sqrt{V_{th1}}) \tag{9}$$

$$P'_f = P\{y'(t) > V_{th1}|H_0\} = \Gamma(u', V_{th1}/2)\Gamma(u') \tag{10}$$

$$P'_m = P\{y'(t) < V_{th1}|H_1\} = 1 - P'_d \tag{11}$$

$$P'_c = P\{y'(t) < V_{th0}|H_1\} = 1 - P\{y'(t) > V_{th0}|H_1\} = 1 - Qu\,(\sqrt{2Y'}, \sqrt{V_{th0}}) \tag{12}$$

$$P'_{na} = P\{y'(t) > V_{th0}|H_0\} = \Gamma(u', V_{th1}/2)/\Gamma(u') \tag{13}$$

'*H0*' and '*H1*' shows the status of primary user, PU is absent, PU is present respectively. Qu(…) shows generalized Marcum Q-Function, u is the Time bandwidth factor, while $\Gamma(.,.)$ and $\Gamma(.)$ are incomplete and complete Gama function respectively.

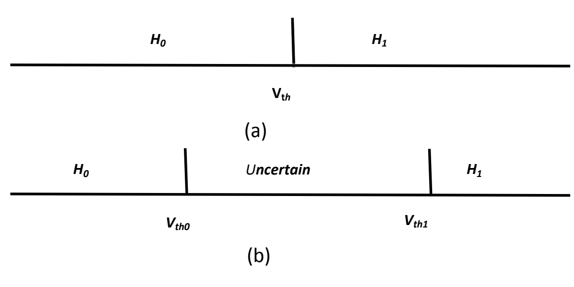

Fig. 1: (a) single threshold energy detection algorithm

(b) double threshold energy detection algorithm

It is also given that:

$$P'_d < P_d,\; P'_c < P_c,\; P'_{na} > P_{na} \tag{14}$$

C. *Optimization of Relay:*

In order to improve the detection probability in energy detection, Optimization of Relay plays an important role. In (**Fig. 3**) we show a system model for Relay optimization as given in (Tanoli *et al.*, 2012).

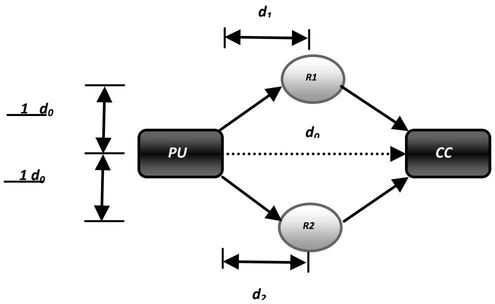

Fig. 3: Optimization of Relay

We consider here the normalized distance between source and destination as 'd_0'. Both Relays are separated from each other by ½ d_0. Relay-1 and Relay-2 are at d_1 and d_2 distances from source, respectively.
The signals received at R1 and R2 are given from (2) as:

$$Y_{r1s}(t) = \beta_{r1} (d_{r1s})^{-n} x(t) + n_{r1s} \qquad (15)$$

$$Y_{r2s}(t) = \beta_{r2} (d_{r2s})^{-n} x(t) + n_{r2s} \qquad (16)$$

3. RESULTS AND DISCUSSION

In this section, we have shown our numerical and simulation results for AWGN channel. We considered four different scenarios as same model in (**Fig. 4**). In first scenario, there is only one Relay at a distance of *'½ d_0'* from source. In second scenario, there are two Relays at a same distance of *'½ d_0'* from source, then in third scenario same Relays are at a distance of *'¾ d_0'* from source. While in last scenario, one relay is at the distance of *'¾ d_0'* from source while the second relay at *'½ d_0'* from source.Here we introduce our simulation results verifying that which algorithm is efficient in terms of detection accuracy considering path loss effect. The different parameters used in our simulations are Signal to Noise ratio (SNR) = 1dB, Time Bandwidth factor = u = 1, V_{th0} = 0.8V_{th} and V_{th1} =1.2V_{th} where V_{th} has the range from 0 to 100.

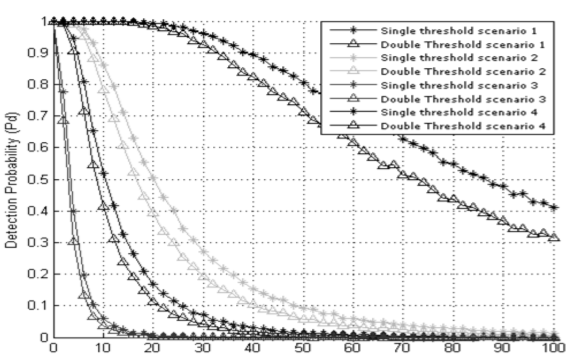

Fig. 2: Probability of Detection (P_d) of two algorithm of energy detection vs Threshold (V_{th})

(**Fig. 5**) shows the probability of detection (P_d) vs. detection threshold (V_{th}) for both algorithms considering path loss effect in different scenarios. It explains that, as distance between source and relay decreases the detection probability increases. It is also shown that probability of detection decreases (P_d) as the detection threshold (V_{th}) is increased. We notice that the probability of detection for scenario 4 is higher than other scenarios. As we see in scenario 2, at V_{th} = 50 , P_d = 0.1 and P'_d = 0.06 which means that probability of detection of double threshold is 4% lesser than probability of detection of single threshold.

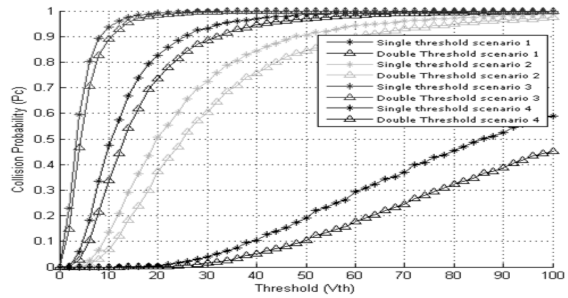

Fig. 3: Probability of collision (P_c) vs threshold (V_{th})

In (**Fig. 6**) probability of collision (P_c) between SU and PU vs threshold (V_{th}) is plotted. The probability of collision (P_c) between SU and PU is decreased using double threshold energy detection algorithm as compared with single threshold energy detection. In scenario , at V_{th} = 50, P_c = 0.9 and P'_c = 0.84, it means when using double threshold energy detection algorithm it decreases the collision probability between SU and PU upto 6%. It is also noticed that as the distance between source and relay decreases the collision probability (P_c) between SU and PU decreases and when threshold (V_{th}) increases the collision probability increases. (**Fig.6**) describes the unavailable probability (P_{na}) of spectrum vs threshold (V_{th}) shows that by increasing threshold (V_{th}), unavailable probability (P_{na}) decreases, and when distance between source and relay increases, the unavailable probability (P_{na}) also increases. In scenario 2, at V_{th} = 50, P_{na} = 0.8 and P'_{na} = 0.87, means by using double threshold energy detection algorithm the efficiency of channel drops up to 7%.

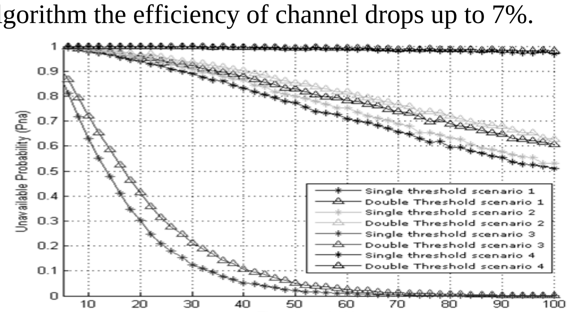

Fig. 4: Probability of spectrum unavailable (P_{na}) vs threshold (V_{th})

4. CONCLUSION

In this paper we have analyzed the two algorithms of Energy detection i.e single and double threshold energy detection algorithm in Cooperative-Cognitive radio network with path loss effect. We examined the Probability of detection (Pd), Probability of collision (Pc) and Probability of unavailability (Pua) for different positions of Relays between primary user and Cognitive Center. It is observed that collision probability in licensed user and unlicensed user is decreased when we use double threshold energy detection technique and the interference decreases between licensed user and unlicensed user with slightly reduction in spectrum efficiency. Our future work is to analyze the same these two algorithms for different channels.

REFERENCES:

Akyildiz, I.F., F. L. Brandon, and R. Balakrishnan (2010) Cooperative Spectrum Sensing In Cognitive Radio Networks: A Survey Jour. Of Physical Communication Vol. **(4)** No 1: 40-62.

Atapattu, S., C. Tellambura, and H. Jiang (2009) Relay Based Cooperative Spectrum Sensing In Cognitive Radio Networks IEEE Global Commun. Conf. (Globecom):1-5. Honolulu, Hawaii, United States.

Bhargavi, D., & C. R. Murthy (2010, June). Performance comparison of energy, matched-filter and cyclostationarity-based spectrum sensing. In Signal Processing Advances in Wireless Communications (SPAWC), 2010 IEEE Eleventh International Workshop on (pp. 1-5). Marakech.

Bhowmick A., S. D. Roy And S. Kundu (2012) Performance Of Spectrum Sensing Scheme Using Double Threshold Energy Detection In The Presence Of Sensor Noise International Journal Of Energy, Information And Communications Vol (3) No 2:75-84.

Ganesan, Ghurumuruhan, and Ye Li (2005) Cooperative spectrum sensing in cognitive radio networks in New Frontiers in Dynamic Spectrum Access Networks, 2005. DySPAN 2005. 2005 First IEEE International Symposium on. IEEE, Maryland, USA.

Haq A. U., M.B. Ayub, J. Iqbal, N. Zarin, S. Ali And I. Khan (2013) Performance Of Double Threshold Energy Detection In Cooperative-Cognitive Networks Over Nakagami Fading Channels 8th IEEE Int. Conference On Digital Information Management (ICDIM): 166-169, Islamabad, Pakistan.

Kwasinski, A. and K. Liu (2008) Source-Channel Cooperation Trade-Offs For Adaptive Coded Communications Ieee Trans. Wireless Comm. Vol. **(7)** No 9:3347–3358.

Saleem, S. and K. Shahzad (2012) Performance Evaluation Of Energy Detection Based Spectrum Sensing Technique For Wireless Channel Int. Journ. Of Multidisciplinary Science. and Engg. Vol. **(3)** No 5:31-34.

Fares, S. A., F. Adachi and E. Kudoh (2009) A novel cooperative relaying network scheme with inter-relay data exchange. IEICE transactions on communications, Vol. (92) No. 5:1786-1795.

Srinu, S. and S. L. Sabat (2010) Fpga Implementation Of Spectrum Sensing Based On Energy Detection For Cognitive Radio Ieee International Conference Communication Control And Computing Technologies (Icccct):126-131.

Sun C., W. Zhang and K. B. Letaief (2007) Cooperative Spectrum Sensing For Cognitive Radios Under Bandwidth Constraints Proc. of IEEE Wireless Communication and Networking Conference (WCNC):1-5, Los Vegas, USA.

Wu, J., T. Lu, J. Li, and G. Yue (2009) A cooperative double-threshold energy detection algorithm in cognitive radio systems. In Proceedings of the 5th International Conference on Wireless communications, networking and mobile computing: 1451-1454. IEEE Press, Beijing, China.

Tanoli U. R., R. Abbasi, Q. J. Utmani, I. Khan, and S. Jan (2012) Performance Analysis Of Cooperative Networks With Inter-Relay Communication Over Nakagami-M And Rician Fading Channel International Journal Of Multi-Disciplinary Sciences And Engineering Vol. **(3)** No 4:24-29.

Zarin, N., I. Khan and S. Jan (2012) Relay Based Cooperative Spectrum Sensing In Cognitive Radio Networks Over Nakagami Fading Channel International Journal Of Multi-Disciplinary Sciences And Engineering Vol. (3) No 4:54-58.

Zarin N., S. A. Mahmud, and I. Khan (2012) RelayBased Cooperative Spectrum Sensing In Cognitive RadioNetworks Over Rayleigh Fading Channels With PathLoss Effects 15th IEEE Int. Multitopic Conference (INMIC):291-296, Islamabad, Pakistan.