

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 8, August 2017

## Survey Paper on Performance of Cooperative Spectrum Sensing based on Cognitive Radio Networks

Aparna Singh Kushwah<sup>1</sup>, Kartik Mehra<sup>2</sup>

Assistant Professor, Department of Electronics and Communication, UIT, RGPV, Bhopal, India<sup>1</sup>

M. Tech. Scholar, Department of Electronics and Communication, UIT, RGPV, Bhopal, India<sup>2</sup>

**ABSTRACT:** The functionality of Cognitive Radio is to detect the presence and absence of licensed user (i.e.) Primary User, in the spectrum, so that the secondary user can use it. Many works has been contributed on spectrum sensing of cognitive radio with single user, which has less complexity but offers inferior detection performance compared to cognitive radio with multiple users. Further there arises hidden user problem in single user system which degrades the system performance. Therefore, it is advisable to use multiple cognitive radio users to sense the spectrum individually and combine their result at the fusion center. This technique is known as co-operative spectrum sensing. Cooperative sensing is considered to be a boon to the problems that arise in spectrum sensing due to noise uncertainty, fading and shadowing. Further, co-operative sensing decreases the probabilities of miss detection and false alarm to a considerable extent. This paper presents various co-operative spectrum sensing techniques with exhaustive survey and comparison.

**KEYWORDS:** WiMAX, MIMO-OFDM, Cognitive Radio, MATLAB

### I. INTRODUCTION

The rapid growth in wireless communication has led to huge demand of frequency spectrum. The fixed spectrum assignment has resulted in poor spectrum utilization, where some frequency bands are overcrowded and other frequency bands are underutilized [1]. In this regard, spectrum sensing has emerged as a new technology to avoid this problem. It enables the access of unoccupied frequency bands (i.e.) spectrum holes and thus increases the spectral efficiency. This becomes possible with the help of Cognitive Radio, [2]. The Cognitive Radio paves way to allot the unused spectrum to the secondary unlicensed user without interrupting the primary user communication [2]. Radio Scene analysis is the most important unit in CR [4]. Now the main task is to identify these spectrum holes, so that the secondary user can use it. There are several spectrum sensing methods widely used in communication applications, particularly energy detection, matched filter and cyclo-stationary feature detection [3]. Energy detection is one of the simplest techniques in spectrum sensing. In CR, measuring of energy involves various parameters like

time, space, frequency and code. The main advantage of energy detection technique is that, it does not require any prior knowledge about the primary signal [4]. SNR wall is one drawback of energy detection technique, where detection fails at low SNR region. The author reported in shows that how energy of signal is useful in detecting the spectrum over fading channels. Further the authors in [5] has presented about the design of energy detection technique with noise uncertainty. The probability of detection is an illustrating measure to be studied against primary (licensed) user signal to noise ratio. There are few relay model cooperative spectrum sensing strategies, namely amplify and relay (AR) model and detect and relay (DR) model, which aims in increasing the detection performance [6]. Rather than a single CR user involving the process of spectrum sensing, multiple CR users in a network can cooperate each other to improve the detection probability. Multiple CR users sending their decisions to the fusion center for hard combination has been reported in. The algorithms used in hard combination include OR rule [7], AND rule, majority rule [51] and optimized K out of N users [25]. In hard combination, fusion centre combines the decision from CR users, whereas soft combination scheme combines metric itself from CR users, has been reported in [8]. A method of Sequential Cooperative Spectrum Sensing scheme has been reported in [9] in which fusion center collects local sensing data

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 8, August 2017

efficiently from cognitive radio users based on the reputation of individual Cognitive user. In addition, cooperative spectrum sensing mitigates hidden user problem and decreases sensing time, but challenges on security need to be taken care [7]. The works reported in comprise of linear combination of computed energies from each CR user. The author in [8] has optimized a non-convex problem to obtain those weights. The work in consists of obtaining optimized weight coefficients to maximize the detection probability. NP rule is used in deriving out the test metric for fusion centre in. The main contribution of this paper is to propose a survey on cooperative spectrum sensing techniques which is an emerging and powerful solution for many problems in wireless communication. In this regard, we would like to present and compare the detection performances for hard combining rules like OR, AND, M out of K rules. We would also like to compare the performances of soft combining rules like maximal ratio combining, equal gain combining and linear weighted combining of individual CR user results.

## II. LITERATURE REVIEW

**Mohammad Hassan Adeli et al. [1]**, we study the probability of error optimization problem in collaborative spectrum sensing (CSS) with limited time resources in cognitive radio (CR) networks. The frame structures for sensing and data transmission, if the spectrum is identified as vacant, are both assumed fixed. This implies that the time resource dedicated for CSS is limited and shared between spectrum sensing time and results reporting time, which depends on the number of sensing users. We consider an optimization problem containing network constraints on time resources for secondary users (SUs) which cooperate with each other using a weighted fusion rule. It is assumed that the SUs are in energy-surplus regime and a predefined constraint on probability of collision is satisfied to protect the cooperative network performance. We analytically prove the convexity of the optimization problem to ensure obtainability of a global solution. Analytical results, in addition to simulation results, are provided to prove the claims.

**Prince SembaYawada et al. [2]**, the recent and rapid evolution of wireless technologies has led to a high demand in terms of resources. To solve the problem the idea of cognitive radio has been introduced to facilitate a good spectrum management and efficient use of the spectrum. In this article we present the spectrum sensing techniques which is a very important step in cognitive radio. The energy detection method used in this paper through the simulation result represented by the ROC curve (Receiver Operating Characteristic) shows that the performance of this method is simple and effective. In this paper, we conduct the performance evaluation of energy detection based on non-cooperative spectrum sensing. The simulation was made using the MATLAB based on the AWGN channel.

**P. Bachan et al. [3]**, in cognitive radio network spectrum sensing is a fundamental element to detect the presence of primary user. In this paper cooperative spectrum sensing scheme is employed to optimize the performance in fading channel environments. This paper will focus on A WGN, rayleigh and rician fading channels to compare the error rates for 'n' number of cognitive users. Neyman's hypothesis testing and data fusion rules are used to satisfy and compare the error bounds in a large network for different values of SNR. Finally error rates are compared by considering different threshold values and keeping the SNR as fixed. This comparative analysis can be extended further for double threshold energy detection scheme.

**Imtiyaz Khan et al. [4]**, from the last decade much more emphases were drawn to develop robust Cognitive Radio Networks (CRNs). For robust CRNs, Spectrum Sensing is one of the most important issue for its better existence in licensed spectrum. Spectrum sensing is used for finding unoccupied frequency bands, called white space or spectrum holes. However, spectrum sensing performance in practice is often compromised with multipath fading, shadowing and receiver uncertainty issues due to low signal to noise ratio (SNR). In this paper, we propose a robust double threshold feature detector (DTFD) that detect even very low SNR primary user. Here we have used DTFD in cooperative spectrum sensing scenario in cognitive radio networks (CRNs) on a additive white Gaussian noise (AWGN) channel. Here individual detectors employ double threshold method in feature based detection of Orthogonal Frequency Division Multiplexing (OFDM) signal, and sends their results to fusion center (FC) where final decision takes place. Detection is done by using popular autocorrelation property of cyclic prefix (CP) in OFDM signal. From proposed

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 8, August 2017

technique, our objective is to achieve a better sensing performance under very low SNR, such that the primary networks and the CRNs can coexist in better way.

Simulation results are done under theoretical perspective which illustrate that the proposed sensing technique can reliably detect OFDM signals at SNR as low as -20 dB.

**Srinivas Nallagonda et al. [5]**, Cognitive radio (CR) systems need to detect the presence of licensed primary user (PU) reliably. Cooperation among multiple CRs helps to enhance the reliability of detection of the PU in case of unreliable decision by a single CR due to channel uncertainties. In this paper, we consider cooperative spectrum sensing (CSS) based on energy detection in cognitive radio networks (CRN) which uses soft combination of the observed energy values from different CRs. More precisely, we study the performance of CSS with several soft data fusion schemes namely, (a) Square law selection (SLS) (b) Square law combining (SLC) (c) Maximal ratio combining (MRC) that can be implemented at fusion center (FC). The performance of CSS has been assessed under several cases of sensing (S) channels such as AWGN, log-normal shadowing, Rayleigh and Rician fading channels. Comparative performance of CSS for various soft data fusion schemes under different fading channels has been studied for various values of average S-channel SNRs, time bandwidth products, different number of CRs. The impact of shadowing and fading parameters on missed detection performance of CSS is indicated. Further, the performance comparison between soft data fusion schemes and hard decision fusion schemes is also highlighted.

**Vidyardhar Reddy G et al. [6]**, This paper deals with cooperative spectrum sensing (CSS) under AWGN and Rayleigh channels with energy detection as sensing technique for cognitive radio network (CRN). The performance of m-out-of-N voting rule, OR fusion logic and AND fusion logic rules under varying threshold is studied, appropriate range of thresholds over which particular fusion rule can be applied has been investigated. An optimum voting rule has been used for AWGN and Rayleigh channels with an aim to improve the performance for real time implementation. A generalized optimal voting rule is derived to minimize the number of cognitive radios (CRs) required to meet target error bound. Simulations are performed for both the channels and the results are found to be comparable with the analytical results. It is observed that 2CRs for Rayleigh channel and 5 CRs for AWGN channel give minimum error in a CRN of 10 CRs.

### III. SPECTRUM SENSING

We considered a cognitive radio network composed of N cognitive radios (secondary users), we deploy the fusion rules like AND Logic, OR Logic, and m-OUT-N Logic and a common receiver, We are performing centralized cooperative spectrum sensing in which each cognitive radio will sense the spectrum separately and then their distinct decisions are posted to the common receiver which can amalgamate all independent decisions and arrive at the absence or presence of primary user.

The essence of spectrum sensing is a binary hypothesis testing problem.

$H_0$ : Primary user is not present

$H_1$ : Primary user is present

By considering spectrum sensing only at  $j^{\text{th}}$  cognitive radio, analytically, signal decision for hypothesis test is done for following cases [9]

$$y_j(t) = \begin{cases} w_j(t), & H_0 \\ h_j(t)x_j(t) + w_j(t), & H_1 \end{cases} \quad (1)$$

Where  $y_j(t)$  is received signal at  $j^{\text{th}}$  CR,  $x_j(t)$  is the primary user signal,  $w_j(t)$  is additive white Gaussian noise (AWGN) and  $h_j(t)$  denotes the complex channel gain between the PU and the  $j^{\text{th}}$  CR. We consider some realistic assumptions, as shown in Figure 1 [8] that local sensing time smaller than total sensing period or coherence time of the channel we

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 8, August 2017

consider that channel is time invariant during local sensing period so  $h_j(t)$  can be replaced by  $h_j$  without losing any information, under the assumption that PU is not changed in sensing period.

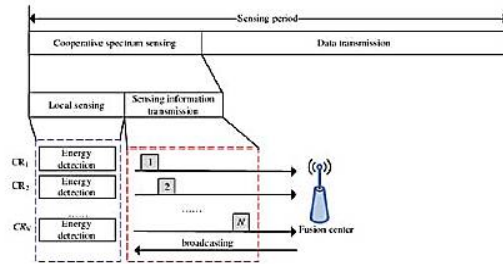


Figure 1: Complete cooperative Spectrum sensing model

## A. AWGN Channel

It is well known that the energy detection is the optimal signal detector considering no prior information on the zero mean constellation signals. For the  $j$ th cognitive radio with energy detection, average probability of detection, average probability of false alarm, average probability of missed detection over AWGN channel us given by

$$P_{f,i} = \frac{\Gamma(u, \lambda/2)}{\Gamma(u)} \quad (2)$$

$$P_{d,i} = Q_u(\sqrt{2\gamma_i}/2, \sqrt{\gamma_j}) \quad (3)$$

$$P_{m,j} = 1 - P_{d,j} \quad (4)$$

Where  $\lambda_j$  is threshold,  $\gamma_j$  is SNR,  $u$  is time-bandwidth product of energy detector for a  $j$ th CR,  $\Gamma(a)$  is the gamma function.

## IV. COOPERATIVE SPECTRUM SENSING(CSS)

In cooperative spectrum sensing, binary hypothesis decision from each CR i.e. one bit decision (1 standing for the presence of licensed user, 0 stands for absence of licensed user) is forwarded to fusion centre. At the fusion centre, all 1-bit decisions are combined according to any one of the logic rule (AND Logic, OR Logic, and M-OUT-N Logic), a global decision will be taken; this final decision can be in favour of  $H_1$  or  $H_0$ .

$$Y = \sum_{j=1}^N D_j \begin{cases} \geq m, & H_1 \\ < m, & H_0 \end{cases} \quad (5)$$

Where  $H_1$  and  $H_0$  are decisions taken by fusion Centre that the primary user is transmitted or not transmitted respectively. Threshold  $m$  is an integer representing  $m$ -out-of- $N$  logic. From above the inference it can be seen that the AND logic corresponds to  $m=N$  and OR logic corresponds to  $m=1$ .

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 8, August 2017

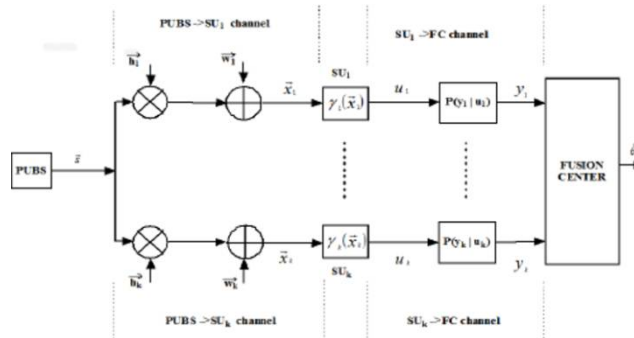


Figure 2: Block diagram for system model of Cooperative Spectrum Sensing (CSS) technique with K SUs (sensors), one FC and one PU. Final decision is made at the FC.

## V. PROPOSED METHODOLOGY

Particle swarm optimization (PSO) is a population based random search algorithm developed by Kennedy and Eberhart based on swarm behavior of bird flocking and fish schooling. In PSO, a population, also known as swarm, is initially created based on the search space of a given optimization problem. Each member in the swarm, also referred to as particle, is distributed randomly within the predefined search space. This population will randomly ‘fly’ through the search space to look for the global optimum. The trajectory of each particle is influenced by the best position personally found so far, which is called personal best (pbest), and the best position found by the entire swarm, named as global best (gbest).

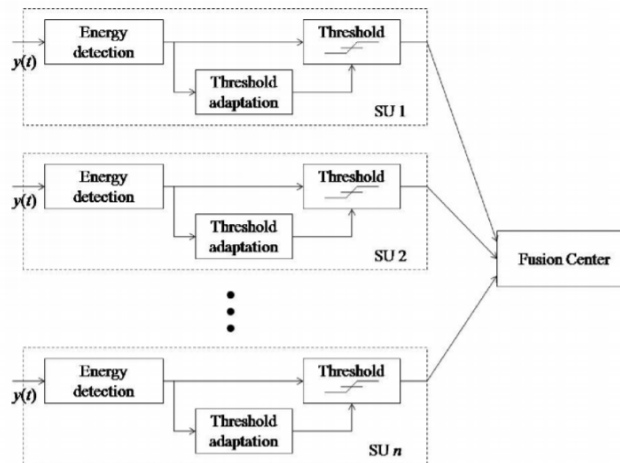


Figure 3: Block diagram for cooperative spectrum sensing with PSO-based threshold adaptation.

$$V_{ij}(t+1) = V_{ij}(t) + c_1 r_1 (y_{ij}(t) - x_{ij}(t)) + c_2 r_2 (\hat{y}_j(t) - x_{ij}(t)) \quad (6)$$

$$x_{ij}(t+1) = x_{ij} + V_{ij}(t+1) \quad (7)$$

Where  $v_{ij}(t)$  denotes the velocity of  $i^{\text{th}}$  particle in  $j^{\text{th}}$  dimension at  $t$ -th iteration,  $c_1$  and  $c_2$  are referred as acceleration constants,  $r_1$  and  $r_2$  are uniformly distributed random values ranging in  $[0, 1]$ .  $y_{ij}(t)$  is referred as pbest, which is the best

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 8, August 2017

position found by the  $i^{\text{th}}$  particle in  $j^{\text{th}}$  dimension so far by the  $t^{\text{th}}$  iteration whereas  $\hat{y}^j(t)$  is referred as  $g_{\text{best}}$ , which is the best position found by the entire swarm in  $j$ -th dimension so far at the  $t^{\text{th}}$  iteration.  $x_{ij}(t)$  denotes the position of  $i^{\text{th}}$  particle in  $j^{\text{th}}$  dimension at  $t^{\text{th}}$  iteration. Another parameter, so-called maximum velocity,  $V_{\text{max}}$  is imposed to limit the velocity of each particle to ensure exploration within the search space. A pseudocode of PSO is shown in Figure 3 for a given minimization problem.

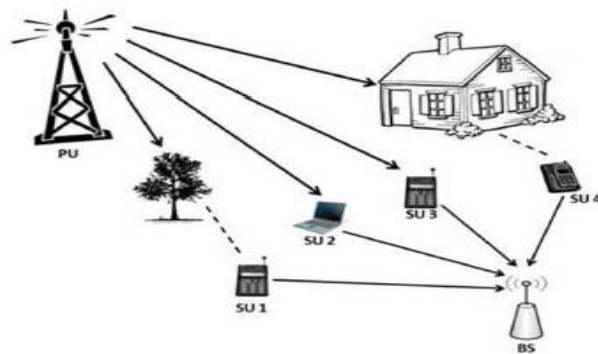


Figure 4: Cognitive radio network (CRN)

## VI. CONCLUSION

We examined the performance of cooperative spectrum sensing with energy detection technique under Rayleigh and AWGN channels in cognitive radio networks. Method of selecting thresholds for distinct fusion rules is presented. In this paper, the detection performance for local spectrum sensing and cooperative spectrum sensing using OR-rule under AWGN and Rayleigh fading channel are evaluated. It was demonstrated that the cooperative spectrum sensing can hardly improve the detection performance in low-SNR environment. Thus, cooperative spectrum sensing with PSO-based threshold adaptation has been proposed to address the aforementioned drawback. The PSO threshold adaptation algorithms are implemented at the receivers of CRN. The aim of improving the detection performance of CRN in low-SNR environment was realized by minimizing the overall sensing error; that is, by the joint minimization of probability of false alarm and probability of missed detection at the common fusion center of CRN.

## REFERENCES

- [1] Mohammad Hassan Adeli, Fariba Mohammadian, Abbas Taherpour and Tamer Khattab, "Optimization of Probability of Error in Collaborative Spectrum Sensing of Time-Limited Cognitive Radio Networks", 2016 IEEE Canadian Conference on Electrical and Computer Engineering (CCECE).
- [2] Prince SembaYawada, an Jian Wei, Mesmin Junior and Mbyamm Kiki, "Performance Evaluation of Energy Detection Based on Non-cooperative Spectrum Sensing in Cognitive Radio Network", 2015 4th International Conference on Computer Science and Network Technology (ICCSNT 2015).
- [3] P. Bachan and Samit Kumar Ghosh, "Comparative Error Rate Analysis of Cooperative Spectrum Sensing in Non-Fading and Fading Environments", 2015 International Conference on Communication, Control and Intelligent Systems (CCIS).
- [4] Imtiyaz Khan and Poonam Singh, "Double Threshold Feature Detector for Cooperative Spectrum Sensing in Cognitive Radio Networks", 2014 Annual IEEE India Conference (INDICON).
- [5] Srinivas Nallagonda and S. Kumar Bandari, "Performance of Cooperative Spectrum Sensing with Soft Data Fusion Schemes in Fading Channels", 2013 Annual IEEE India Conference (INDICON).
- [6] Vidyadhar Reddy G, N.S. Murthy, "Optimization of Cooperative Spectrum Sensing under AWGN and Rayleigh Channels in cognitive Radio Network", 2013 Third International Conference on Advances in Computing and Communications.
- [7] Shan Jin and Xi Zhang, "Compressive Spectrum Sensing for MIMO-OFDM Based Cognitive Radio Networks", 2015 IEEE Wireless Communications and Networking Conference (WCNC)-Track 4 - Services, Applications, and Business.
- [8] Kumar, "Introduction to Broadband Wireless Networks" in Mobile Broadcasting with WiMAX: Principles, Technology and Applications, New York, USA: Focal Press, 2008, pp. 24-50.
- [9] C. Eklund, R. B. Marks, K. L. Stanwood and S. Wang, "IEEE Standard 802.16: A Technical Overview of the WirelessMAN Air Interface for Broadband Wireless Access," *IEEE Commun. Mag.*, vol. 40, pp. 98-100, Jun 2002.
- [10] S. J. Vaughan-Nichols, "Mobile WiMAX: The Next Wireless Battleground," in *IEEE Comp. Soc. Mag.*
- [11] L. Koffman and V Roman, "Broadband wireless access solution based in IEEE 802.16," *IEEE communication Magazine*, vol. 40, pp 4, Apr. 2004 pp 96-103.