FACTA UNIVERSITATIS
Ser: **Elec. Energ.** Vol. 25, N^o 3, December 2012, pp. 235 - 243
DOI: 10.2298/FUEE1203235D

OPTIMIZATION OF SPECTRUM SENSING IN COGNITIVE RADIO USING GENETIC ALGORITHM

Rashmi Deka, Soma Chakraborty, Jibendu Sekhar Roy

School of Electronics Engineering, KIIT University, Bhubaneswar-751024, Odisha, India

Abstract. *Spectrum availability is becoming scarce due to the rise of number of users and rapid development in wireless environment. Cognitive radio (CR) is an intelligent radio system which uses its in-built technology to use the vacant spectrum holes for the use of another service provider. In this paper, genetic algorithm (GA) is used for the best possible space allocation to cognitive radio in the spectrum available. For spectrum reuse, two criteria have to be fulfilled - 1) probability of detection has to be maximized, and 2) probability of false alarm should be minimized. It is found that with the help of genetic algorithm the optimized result is better than without using genetic algorithm. It is necessary that the secondary user should vacate the spectrum in use when licensed users are demanding and detecting the primary users accurately by the cognitive radio. Here, bit error rate (BER) is minimized for better spectrum sensing purpose using GA.*

Key words: *cognitive radio, genetic algorithm, probability of detection, probability of false alarm, bit error rate*

1. INTRODUCTION

It is observed that the spectrum is not utilized by the licensed users effectively and some of the holes remain vacant. So, it is indeed necessary that the spectrum should be utilized effectively. Cognitive radio is secondary users who use the spectrum when the primary users are not using it [Fig. 1]. It is necessary due to the fast development of technology [1]. FCC has allowed cognitive users to use the unlicensed spectrum in 2004. Cognitive radio has the capability of sensing the spectrum in the real time environment and the dynamic wireless environment. It can acquire information from the environment and gets adapted to the environment accordingly by changing its various parameter like frequency, power, etc. Using these changes, a cognitive radio senses the spectrum in a better way. The main purpose of the cognitive radio is to sense the spectrum, learn from the environment, adapt to the environment. Primary users, who have the highest priority, exploit the spectrum and secondary users have to vacant the spectrum accordingly not to interfere in the operation of the primary users.

Received December 07, 2012
Corresponding author: Rashmi Deka
School of Electronics Engineering, KIIT University, Bhubaneswar-751024, Odisha, India
E-mail: drjsroy@rediffmail.com

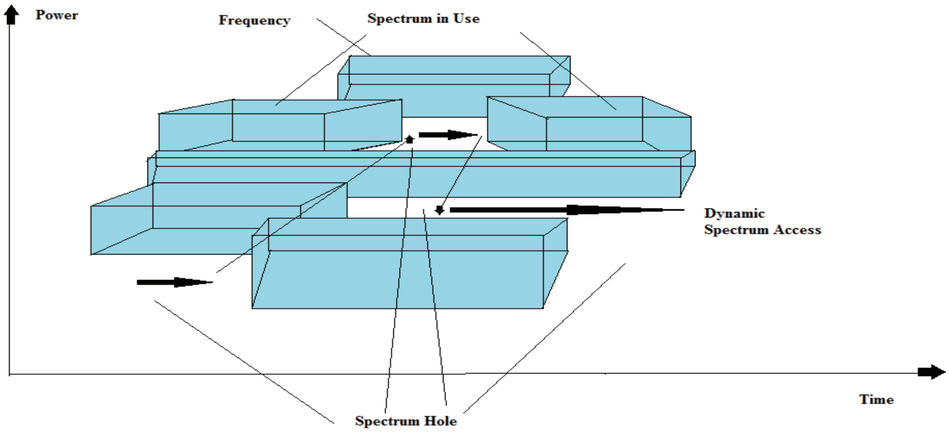

Fig. 1 Illustration of spectrum

2. SPECTRUM SENSING METHOD

Cooperative sensing methods are used here as they reduce the probability of false alarm and even reduce the hidden primary user problem [2]. Cooperative sensing can use different methodologies. Cooperation can be between the cognitive radios or between cognitive radio and external nodes.

Distributed sensing uses many cognitive radios to collect information from the environment. They use this information for using a spectrum and is decided by them. Distributed spectrum sensing has got many added advantages since it has got reduced cost and if one node fails the whole system does not. A far away cognitive user is informed by the nearby cognitive user weather a primary user is present or not [2-14]. The information is broadcast among the cognitive nodes and the decision is taken which part of the spectrum is to be used by which cognitive node. In multi-slot spectrum sensing, the sensing time is divided into multi mini discontinuous time slots, as shown in Fig. 2.

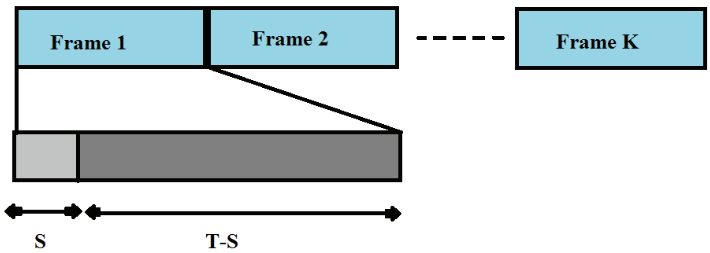

Fig. 2 Multi-slot spectrum sensing

Multi-slot spectrum sensing uses the information provided by various slots for sensing the spectrum. It uses two methods to detect the spectrum available:

1. Data fusion: All data from the slots are fused together to make one single decision.
2. Decision fusion: Separate decisions are taken and then one decision is made on the basis of the decisions taken.

3. Genetic Algorithm

There are various optimization techniques available. The most reliable one is the genetic algorithm which is adaptable to the radio environment. GA uses Darwin's theory of survival of the fittest. GA is quite flexible to the wireless environment and can be implemented in multi-objective optimization [15-16]. A chromosome is defined where the variables are stored and a population is initialized by using array in a matrix. An objective function is taken and is tested for its best solution. In the process, two parents are chosen where crossover takes place. After mating, the offspring is a mixture of the two parents involved. In this way iteration process is carried out until a best solution is reached.

4. Sensing Through Distributed and Multi-slot Spectrum Sensing

During sensing, each secondary user senses the spectrum within its location area and takes a decision after sensing the primary user. When primary user is active, the sampled received signal $Y(n)$ at the secondary user is represented as [3]:

$$Y(n) = u(n) \tag{1}$$

Otherwise it is represented as:

$$Y(n) = s(n) + u(n) \tag{2}$$

Here, $s(n)$ is the primary user's signal. $T_i(y)$ is the test statistic for the i-th mini-slot:

$$T_i(y) = \frac{1}{N_1} \sum_{n=1}^{N_1} | y_i(n) |^2 \tag{3}$$

$$T(y) = \frac{1}{N_1} \sum_{i=1}^{M} g_i T_i(y) \tag{4}$$

Where, $g_i \geq 0$ is the weighting factor with the ith mini-slot. For probability of false alarm P_d, the minimum achievable probability of false alarm is given by [3]:

$$g_i = \frac{| h_i |^2}{\sqrt{\sum_{i=1}^{M} | h_i |^4}} \tag{5}$$

For maximum probability of detection:

$$Max \sum_{i=1}^{M} g_i \, | h_i |^2 \tag{6}$$

Probability of false alarm and probability of detection is represented as:

$$P_f = Q_f(B_1 Q_f^{-1}(P_d^{-1}) + \gamma \sqrt{\frac{N}{M}} \sum_{i=1}^{M} | h_i |^2) \tag{7}$$

$$P_d = Q_d\left(\frac{1}{B_1} Q_d^{-1}(P_f^{'}) - \sqrt{\frac{N}{M}}\gamma \sum_{i=1}^{M} |h_i|^2\right) \tag{8}$$

$$B_2 = \sqrt{1 + \frac{2\gamma}{M}\sum_{i=1}^{M} |h_i|^2} \tag{9}$$

In distributed spectrum sensing, many cooperative nodes are taken for consideration

$$H_1 : y_i(n) = h_i s(n) + u_i(n) \tag{10}$$

$$H_0 : y_i(n) = u_i(n) \tag{11}$$

$$y(n) = \sum_{i=1}^{M} \frac{hi^*}{\sum_{i=1}^{M} |hi|^2} y_i(n) \tag{12}$$

Hypothesis is equivalent to:

$$H_1 : y(n) = \sqrt{\sum_{i=1}^{M} |h_i|^2} s(n) + u(n) \tag{13}$$

$$H_0 : y(n) = u(n) \tag{14}$$

$$P_f = Q_f(B_1^{'} Q_f^{-1}(P_d^{'}) + \sqrt{N}\gamma \sum_{i=1}^{M} |h_i|^2) \tag{15}$$

$$B_1^{'} = \sqrt{2\gamma \sum_{i=1}^{M} |h_i|^2 + 1} \tag{16}$$

With the probability of false alarm given P_f, the probability of detection is given by:

$$P_d = Q_d\left(\frac{1}{B_2^{'}} Q_d^{-1}(P_f^{'}) - \sqrt{N}\gamma \sum_{i=1}^{M} |h_i|^2\right) \tag{17}$$

$$Q_d = \sum_{i=1}^{N} P_{di}(1 - P_d)^{N-1} \tag{18}$$

$$Q_f = \sum_{i=1}^{N} P_{fi}(1 - P_f)^{N-1} \tag{19}$$

Where Q_d is the interference level and Q_f is the throughput of the cognitive radio network.

5. BER PERFORMANCE

Fig. 3 shows three-node cognitive relay system. CR1 and CR2 are the cognitive users which are in the range of each other. CR1 is in the range of primary user PU while CR2 is not. Here, rc is the transmission range. It uses the principle of time division multiplexing.

In the first slot, the message is sent and if the message is sent correctly then in the next slot the second message is sent.hsd is the power received by CR1, hrd is the power received by CR2 which is forwarded by CR1[14].

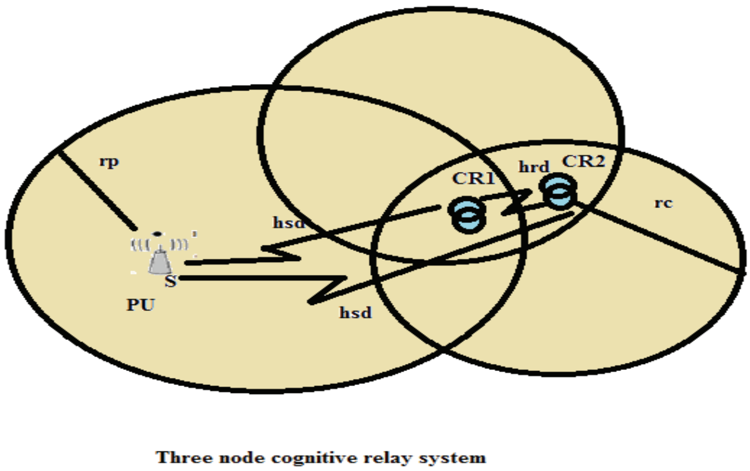

Fig. 3 Relay System in Cognitive Radio Environment

BER of CR2's can be expressed as [3]:

$$P_e = P_{dec} P_{e-co} + (1 - P_{dec}) P_{e-dir} \tag{20}$$

The simplified form of BER, where P_1/σ^2 and P_2/σ^2 tends to infinity, then:

$$P_e = \frac{\sigma^2}{b_2 P_1 \delta^2 s_d} \left(\frac{A^2}{P_1 \delta^2 s_d} + \frac{B^2}{P_2 \delta^2 s_r} \right) \tag{21}$$

$$A = \frac{M-1}{2M} + \frac{\sin \frac{2\Pi}{M}}{4\Pi} \tag{22}$$

$$B = \frac{3(M-1)}{8M} + \frac{\sin \frac{2\Pi}{M}}{4\Pi} - \frac{\sin \frac{2\Pi}{M}}{32\Pi} \tag{23}$$

6. GA Optimized Results

Genetic algorithm using MATLAB is used to optimize the BER performance in cognitive radio. The cognitive relay system of Fig. 3 is used in optimization. Fig. 4 shows the BER performance of a cognitive radio which is reduced with the help of GA.

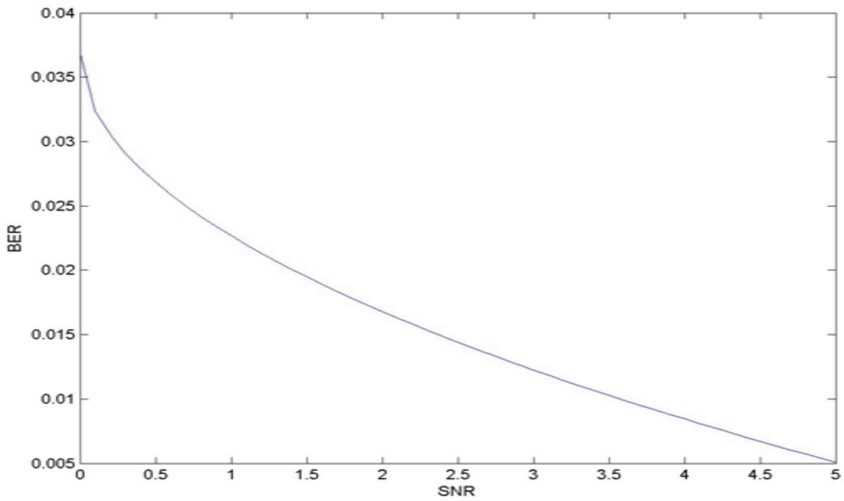

Fig. 4 BER performance

Fig. 5 and Fig. 6 show the probability of false alarm and probability of detection for multi-slot spectrum sensing. Probability of false alarm has to be reduced for efficient utilization of the spectrum. On the other hand, probability of detection is maximized for protection of the primary users. The various data shown is for different values of M, mini-slots.

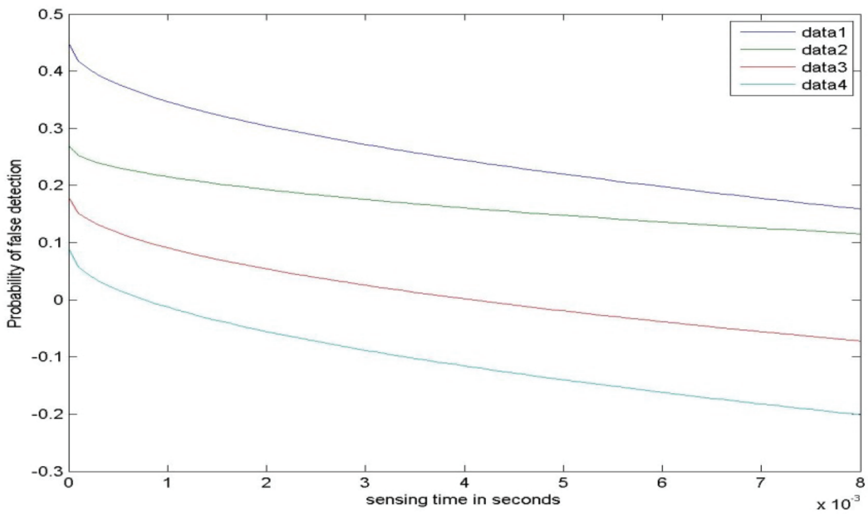

Fig. 5 The average probability of false alarm for multi-slot spectrum sensing, when channels are unknown.

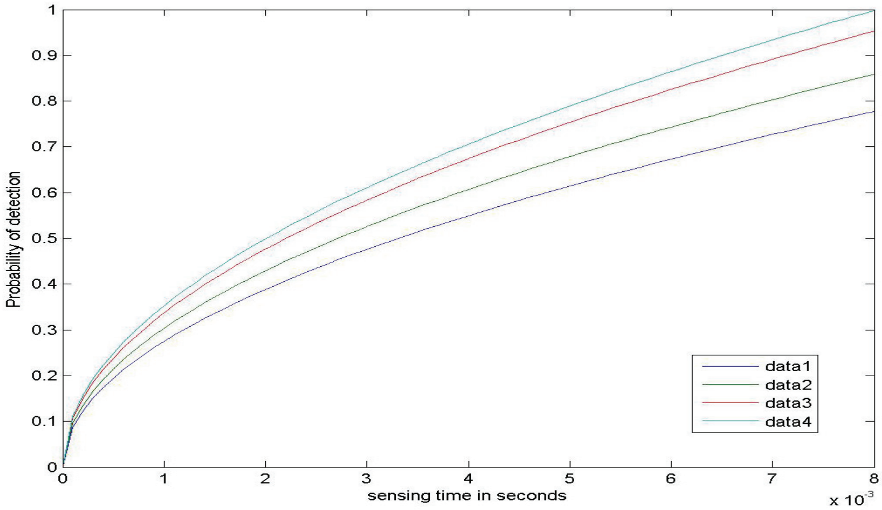

Fig. 6 Probability of detection versus sensing time

In Fig. 7 and Fig. 8 the advantages, obtained with the use of GA are shown. Probability of false alarm is further reduced which is necessary for better operation of the cognitive radio. Similarly, probability of detection is maximized further as shown. In the optimized results, various parameters are varied and multi-objective optimization is done. Sensing time is varied from 0 to 5 ms and h_i is varied from 0.2 to 0.4. Number of frames simulated is 100000.When the fading coefficients are unknown, the weighting factors are chosen to be the same for all the mini slots, i.e., $g_i = 1/\sqrt{m}$.

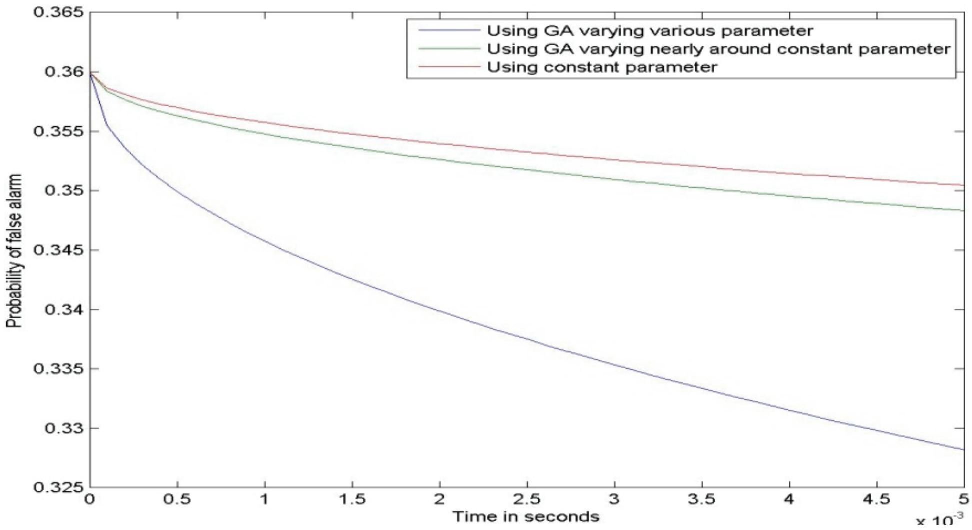

Fig. 7 Advantages of using GA for average probability of false alarm

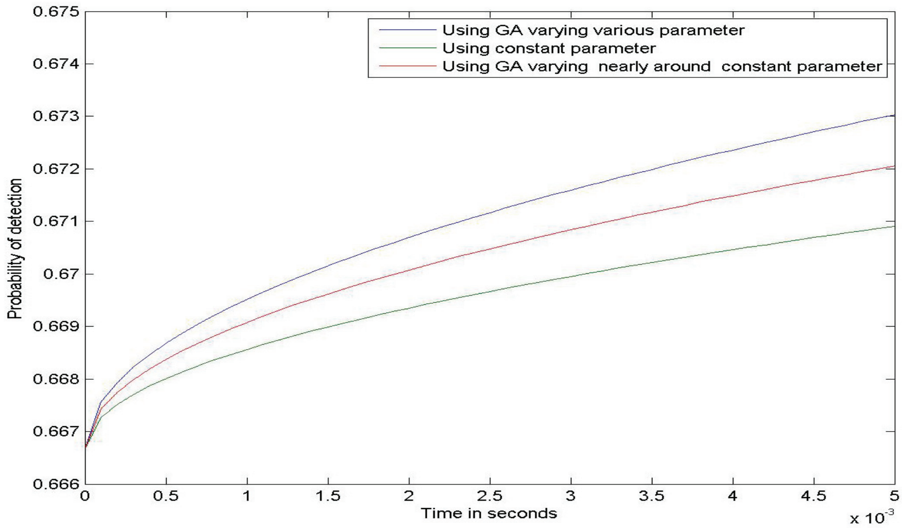

Fig. 8 Advantages of using GA for probability of detection

7. CONCLUSION

It is seen that probability of false alarm is minimized by varying the parameter with the help of GA. On the other hand, probability of detection is maximized by using GA in distributed spectrum sensing and multi-slot spectrum sensing. In distributed spectrum sensing, multiple secondary users are detecting the spectrum. The received SNR of each user are same, which is -15dB. BER is studied in cognitive relay system and also minimized by using GA.

REFERENCES

[1] J. Mitola and G. Q. Maguire, "Cognitive radios: making software radios more personal", *IEEE Pers. Commun*., vol. 6, no. 4, pp. 13-18, Aug. 1999.
[2] T. Yucek and H. Arslan, "A survey of spectrum sensing algorithms for cognitive radio applications", *IEEE Communications Survey & Tutorial,* vol. 11, no. 1, pp. 116-127, 2009.
[3] Y.C. Liang, Y.Z ,Edward, C.Y. Peh, and A.T Hoang, "Sensing throughput tradeoff for cognitive radio networks", *IEEE Transaction On Wireless Communications,* vol. 7, no. 4, pp. 1326-1337, 2008.
[4] S. Haykin, D.J Thompson, and J. H. Reed, "Spectrum sensing for cognitive radio", *Proc. IEEE*, vol. 97, pp.849-877, 2009.
[5] E.C.Y. Peh, Y. C. Liang, Y. L. Guan and Y. Zeng, "Optimization of cooperative sensing in cognitive radio networks: A sensing-throughput tradeoff view", *IEEE Trans. Vehicular Tech.*, vol.58, no.9, pp 5294-5299, Nov. 2009.
[6] S. Chen, N. T. R. Evans, and J. B. Wynglyski, "Genetic algorithm based optimization for cognitive radio network", *IEEE Sarnoff Symposium* , pp 1-6, 2010.
[7] M.R. Moghal, M.A. Khan, H.A Bhatti, "Spectrum optimization in cognitive radios using elitism in genetic algorithms", *6th International Conference on Emerging Technologies (ICET),* pp 49-54 ,2010.
[8] P. Guo, X. Wang, Y. Han, "The enhanced genetic algorithms for the optimization design", *3rd International Conference on Biomedical Engineering and Informatics (BMEI)*, pp 2990-2994, 2010.

[9] M. J. Kaur, M. Uddin and H.K. Verma, "Performance evaluation of qos parameters in cognitive radio using genetic algorithm", *World Academy of Science, Engineering and Technology ,* no. 46, 2010.
[10] S. J. Kim, G. Li, and G. B. Giannakis, "Multi-band cognitive radio spectrum sensing for quality-of-service traffic", *IEEE Transactions On Wireless Communications,* vol. 10, no. 10, pp. 3506-3515, 2011.
[11] V. Sood, M. Singh, "Capacity optimization using cognitive radios networks", *International Journal of Advanced Engineering Sciences And Technologies*, vol.7, no.1, pp. 70-76, 2011.
[12] M. J. Kaur, M. Uddin and H. K Verma "Optimization of QoS parameters in cognitive radio using adaptive genetic algorithm", *International Journal of Next-Generation Networks (IJNGN)*, vol.4, no.2, 2012.
[13] L. Luo and S. Roy, "Efficient spectrum sensing for cognitive radio networks via joint optimization of sensing threshold and duration", *IEEE Transactions on Communications,* vol. 60, no. 10, pp. 2851-2860, 2012.
[14] L. Zhang, X. Jian, J. Yang, H .Zhou, "Optimization of Relay-Based Cooperative Spectrum Sensing in Cognitive Radio Networks", 7th International Conference on *Wireless Communication, Networking and Mobile Computing,* 2011.
[15] R.L. Haupt, S.E. Haupt, *Practical genetic algorithms*, 2nd edition, John Wiley and Sons Inc, Aug.2005.
[16] D.E. Goldberg, *Genetic algorithms in search, optimization and machine learning*, Fourth Edition, Pearson Education, 2009.