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PERFORMANCE ANALYSIS OF ARTIFICIAL BEE COLONY ALGORITHM IN SPECTRUM SENSING FOR COGNITIVE RADIO IN DIFFERENT FADING CHANNELS

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Abstract

Recently, cognitive radio (CR) is viewed as a novel approach for improving the utilization of a radio spectrum. The cognitive radio is defined as an intelligent wireless communication system that is aware of its surrounding and uses the technique of understanding-by-learning from the environment and adapt to statistical variations in the input stimuli. Spectrum sensing is a fundamental component in a cognitive radio. This paper analyses the performance of the artificial bee colony algorithm (ABC), optimization in different fading environments.

Keywords:

Cognitive Radio, Spectrum Sensing, Artificial Bee Colony

1. INTRODUCTION

A cognitive radio senses the spectral region over a wide range of frequency bands and exploits the temporally unoccupied bands for opportunistic wireless transmissions [1] [2]. Since a cognitive radio operates as a secondary user, which does not have the rights to access any pre assigned frequency spectrum, it is essential for secondary user to optimally detect the presence of primary users dynamically.

As stated above, spectrum sensing is a paramount component in a cognitive radio based wireless communication systems. However, there are several factors, which make it hard to solve the sensing problem. First, the received signal-to-noise ratio (SNR) of the primary users detected at the secondary receivers may be very low, which make it hard to distinguish from the noise signal. In addition, fading of the transmitted signal and time dispersion of the wireless channel may complicate the problem of spectrum sensing [3] [5]. Because of the random nature of the noise and interference level, there exists a noise uncertainty, which include receiver device uncertainty due to thermal noise, and environment noise uncertainty caused by transmissions due to other users in the vicinity. There by, making it very difficult to obtain the accurate noise power.

Recently, authors proposed several spectrum-sensing algorithms, namely, the energy detection, the matched filtering technique, and cyclo-stationary spectrum sensing technique. Each has its own advantages and disadvantages. The energy detection does not need any information about the primary user signal to be detected and is robust to unknown dispersive channel. However, this method requires an exact information of the noise component power, thereby, inaccurate estimation of the noise power level results in SNR wall and high probability of false alarm [6] [7]. In addition, while it is optimal for sensing independent and identically distributed signal, it is not considered optimal for sensing correlated signal. The disadvantage of the matched filtering detection technique is that it requires the information about the waveforms and channels of the primary users. The cyclo stationary sensing technique requires the knowledge of the cyclic frequencies of the primary users.

To overcome the shortcomings of the above-mentioned techniques, in this work, a novel algorithm for spectrum sensing based on Eigen value detection method using the artificial bee colony (ABC) has been proposed. In this work, the ratio of maximum Eigen value to minimum Eigen value is obtained for received signal covariance matrix. This ratio is compared with a decision threshold to detect the primary user. Threshold is an important parameter for detection of primary user. If this threshold value is lower, then the probability of false alarm will increase and for higher threshold values Probability of missed detection will increased. That’s why an optimized threshold is required. In conventional Eigen value detection method, the threshold is pre calculated and depends on no. of samples and smoothening factor L. The value of L is assumed constant but in proposed method L is optimized by ABC optimization technique. Thus threshold is also get optimized. In practical wireless communication system, fading causes the received signal energy fluctuating dynamically, while time-varying channel cause coherent detection unreliable. Therefore, for the proof-of-principal, we test our proposed algorithm in different fading environment including the Nakagami, the Rayleigh and the Rician fading channel.

2. LITERATURE REVIEW

In last 15 years several researchers have been done work on cognitive radio.

Haykin [2] gave the concept of cognitive radio and its efficient utilization in radio spectrum.

Yucek et al. [9] introduced various spectrum sensing algorithms used for Cognitive Radio. Initially matched filter detection method was proposed but in this CR would need a dedicated receiver for every primary user. Then Cyclo stationary feature detection method is used and it requires large observation time and its algorithm is also complex.

Brkic et al. [10] worked on conventional energy detection method but exact knowledge of noise is required in this method, also this method performs only for lower SNR values.

Hasbullah [8] proposed a new sensing method named Singular Value Detection based signal detection which uses Eigen values of the received signal covariance matrix. Two sensing algorithms are suggested, first is based on ratio of maximum to minimum Eigen value detection and second is ratio of average Eigen value to minimum Eigen value method. The proposed work is based on first algorithm including ABC optimization technique.

3. SYSTEM MODEL

To test the presence of a primary user at the receiver, transmitter signal detection technique is used. For the signal detection, there are two kinds of hypothesis: H_0, which indicates the absence of a primary user, H_1, which indicates the presence of a primary user's signal. The two hypothesis can effectively be represented as:

$$H_0 : x(n) = \eta(n) \tag{1}$$

$$H_1 : x(n) = \bar{s}(n) + \eta(n) \tag{2}$$

where, $\bar{s}(n)$ represents the sample of the received signal at n^{th} time instant. The wireless channel impairment effects including attenuation, path loss, multipath fading, shadowing effect, and time dispersion is assumed to be included in the $\bar{s}(n)$. $\eta(n)$ represents identically distributed additive white Gaussian noise (AWGN) with mean zero and variance σ_η^2.

The received noisy signal at the receiver can then be represented as:

$$x(n) = \sum_{j=1}^{P} \sum_{k=0}^{N_{ij}} h_j(k) s_j(n-k) + \eta(n) \tag{3}$$

where, P represents the total number of transmitter (number of source signals), $h_j(k)$ represents the wireless channel impulse response and N_{ij} is equal to the order of the wireless channel.

The detection techniques performance can be determined through two probabilities:

- Probability of false alarm (P_f): which represents the probability of detecting the primary user incorrectly in the given frequency band. It is depicted by the hypothesis is H_0.
- Probability of detection (P_d): It is equal to the probability of detecting the primary user correctly in the given frequency spectrum. This case is equivalent to the hypothesis H_1.

4. ARTIFICIAL BEE COLONY BASED EIGEN VALUE DETECTION

Random matrix theory based Eigen values detection provides two parameters namely decision threshold and probability of false alarm. Eq.(4) shows ratio of maximum to minimum eigenvalues of the signal received for covariance matrix [8]:

$$T_Y = \lambda_{max}/\lambda_{min} \tag{4}$$

The Eq.(4) provides the essential statistics to attain the required probability of false alarm using the estimation of detection threshold (g). It is accomplished using the density of the test statistic (T_Y) [8]. The detection threshold in terms of anticipated probability of false alarm is considered by:

$$\gamma_{mme} = \left(\frac{\left(\sqrt{N_S} + \sqrt{L}\right)^2}{\left(\sqrt{N_S} - \sqrt{L}\right)^2} \right) \times \left(1 + \frac{\left(\sqrt{N_S} + \sqrt{L}\right)^{\frac{2}{3}}}{\left(N_S L\right)^2} F_1^{-1}\left(1 - P_{fa}\right) \right) \tag{5}$$

where F_1^{-1} represents the inverse of cumulative distribution function (CDF) of the Tracy-Windom distribution of order 1.

The threshold definition is formulated based on deterministic asymptotic values of the minimum and maximum eigenvalues of the covariance matrix R, when the number of samples, N_s is very large. As shown in the Eq.(5), it is defined only in terms of number of samples, N_s, level of covariance matrix, L and the desired probability of false alarm, P_{fa} [8].

Threshold optimization is performed using Artificial Bee Colony (ABC) algorithm which is explained as follows.

The search cycle of ABC consists of three rules:

1. Sending the employed bees to a food source and evaluating the nectar quality.
2. Onlookers choosing the food sources after obtaining information from employing bees and calculating the nectar quality.
3. Determining the scout bees and sending them on to possible food sources.

Pseudo code of the Artificial Bee Colony (ABC) Algorithm

```
Step 1:  Initialize the population of solutions $x_{ij}$
Step 2:  Evaluate the population
Step 3:  $cycle=1$
Step 4:  Repeat
Step 5:  Produce new solutions (food source positions) $v_{ij}$ in the
         neighbourhood of $x_{ij}$ for the employed bees and evaluate them.
Step 6:  Put on the greedy selection process between $x_i$ and $v_i$
Step 7:  Compute the probability values $p_i$ for the solutions $x_i$ by
         means of their fitness values. For calculating the fitness
         values of solutions
             $\begin{bmatrix} \frac{1}{1+f_i} & if\ f_i \geq 0 \\ 1+abs(f_i) & if\ f_i < 0 \end{bmatrix}$   (6)
Step 8:  Normalize $p_i$ values into [0, 1]
Step 9:  Produce the new solutions (new positions) $v_i$ for the
         onlookers from the solutions $x_i$, selected depending on $p_i$,
         and evaluate them
Step 10: Put on the greedy selection process for the onlookers
         between $x_i$ and $v_i$
Step 11: Determine the abandoned solution (source), if exists,
         and replace it with a new randomly produced solution $x_i$
         for the scout using the Eq.(7).
             $x_{ij} = \min_j + rand(0,1)*(\max_j - \min_j)$   (7)
Step 12: Memorize the best food source position (solution)
         achieved so far
Step 13: $cycle = cycle+1$
Step 14: Until cycle= Maximum Cycle Number (MCN)
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4.1 FLOWCHART OF PROPOSED METHOD

- A modified spectrum sensing technique in cognitive radio is proposed.

- In the proposed approach, firstly a received sample covariance matrix is obtained.
- Then Eigen values of the covariance matrix are calculated.
- Threshold value is optimized by using ABC Algorithm.
- The ratio of maximum to minimum Eigen values are compared with predetermined optimized threshold value obtained using ABC algorithm. Based on that, a decision on the spectrum availability is obtained.
- If this ratio is greater than the decision threshold, it implies PU is present and spectrum is not free and process should be repeated for another free band. If this ratio is less than the threshold, it means spectrum is available for SU and can be utilized by SU until PU is not available.
- The performance is evaluated by two metrics: Probability of false alarm and probability of detection.

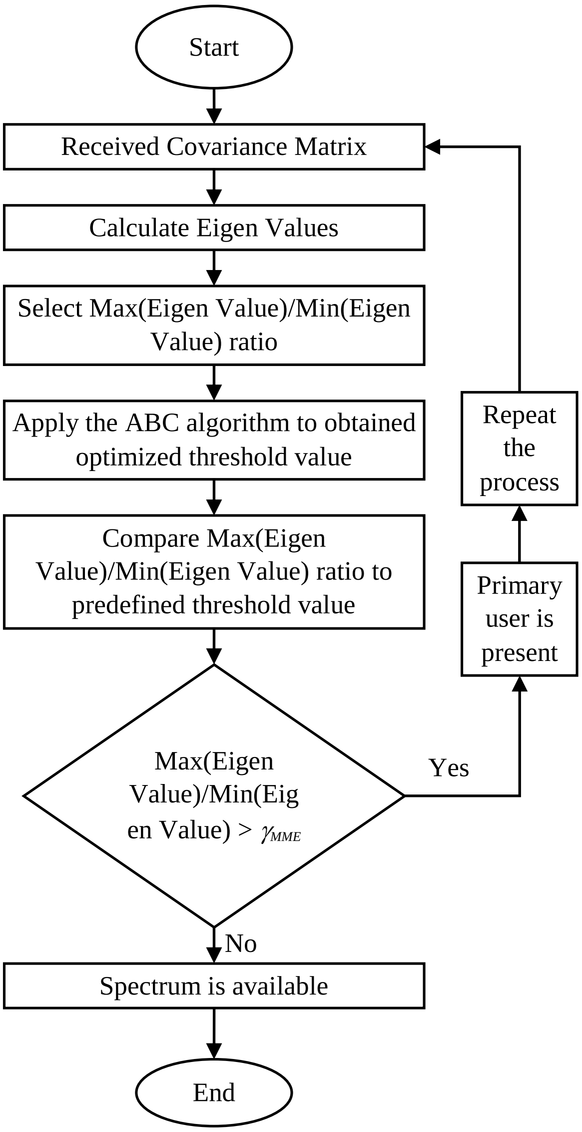

Fig.1. Flowchart describing the proposed algorithm

5. SIMULATION AND RESULTS

The simulation work has been done on Matlab and several results have been obtained.

The Fig.2 depicts P_f vs P_d curve of ABC optimized eigenvalue based detection method at different value of SNR (SNR = -10dB, SNR=-15dB, and SNR=-22dB) using Rayleigh fading channel. From the simulation result, it clear that the value of P_d is higher at -10dB SNR level when compare with different SNR level (-10dB, -15dB and -22dB) which proves the good performance of ABC-EVD detection method at higher SNR.

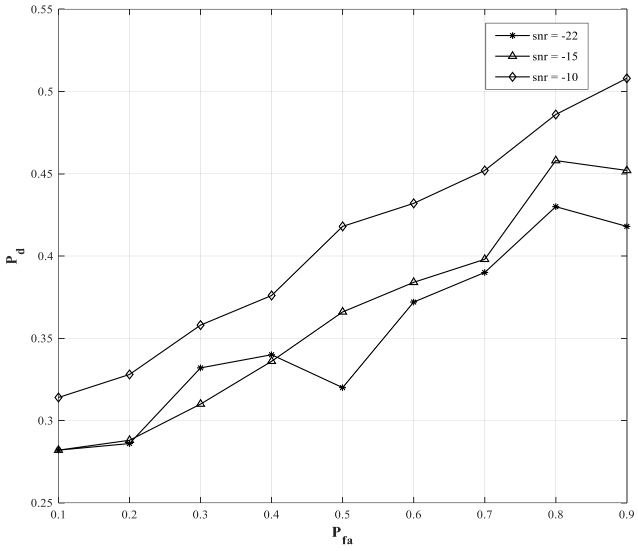

Fig.2. Probability of detection (P_d) versus Probability of false alarm (P_f) graph for ABC optimized eigenvalue based detection at different SNR values using Rayleigh fading channel

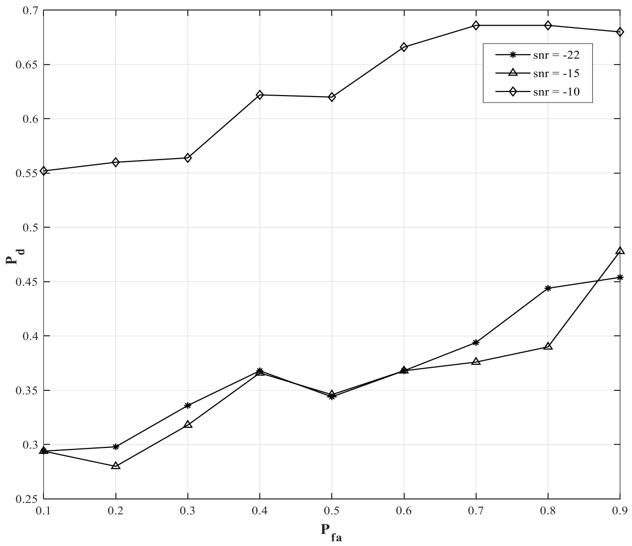

Fig.3. Probability of detection (P_d) versus Probability of false alarm (P_f) graph for ABC optimized eigenvalue based detection at different SNR values using Rician fading channel

The Fig.3 illustrates the performance evaluation of the proposed algorithm in Rician fading channel. It is clear from the simulation result that the value of P_d is higher at -10dB SNR level when compare with different SNR level (-10dB, -15dB and -22dB) which proves the good performance of ABC-EVD detection method at higher SNR.

The Fig.4 depicts P_f vs P_d curve of ABC optimized eigenvalue based detection method at different value of SNR (SNR = -10dB, SNR= -15dB and SNR= -22dB) using Nakagami fading channel. From Fig.4, it clear that the value of P_d is higher at -10dB SNR level when compare with different SNR level (-10dB, -15dB and -22dB) which proves the good performance of ABC-EVD detection method at higher SNR.

In Fig.5, probability of detection P_d is plot under H_1 against probability of false alarm P_f under H_0 where P_f changes from 0.1 to the desired value of 0.9. As from the Fig.5, it is clear that probability of detection of ABC Eigenvalue detection is greater than Eigen value detection at different points. From the graph, as the value of P_f increases, the detection probability also increases.

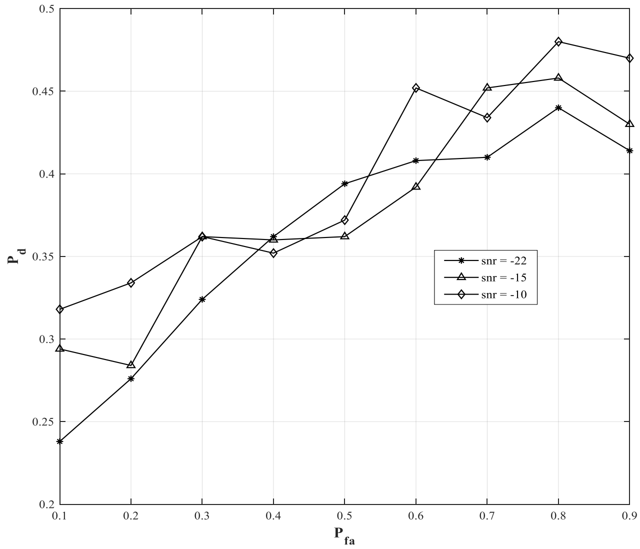

Fig.4. Probability of detection (P_d) versus Probability of false alarm (P_f) graph for ABC optimized eigenvalue based detection at different SNR values in Nakagami fading channel

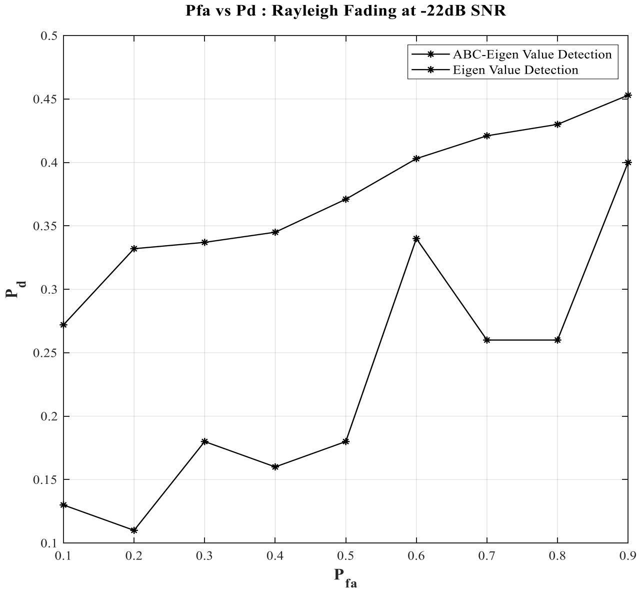

Fig.5. Comparison of ABC based Eigenvalue detection and simple Eigenvalue detection using probability of detection (P_d) versus Probability of false alarm (P_f) in Rayleigh fading channel at SNR equal to -22dB

6. DISCUSSIONS

- The proposed ABC based Eigen value detection method works far better at lower SNR values compared to the conventional Eigen value based detection schemes. This paper illustrates the simulation for different fading channels in different low SNR regimes.
- It is found, that this method works good even for SNR value as low as -22dB, which is the practically worst case.
- In Fig.5, the performance of ABC Eigen value detection method and conventional Eigen value detection method is compared. It is shown that with the proposed method, a higher probability of detection is obtained compared to the conventional method.

7. CONCLUSION

In this paper, a novel ABC based blind Eigen value detection scheme for spectrum sensing has been discussed. This method has been applied for various signal detection applications without prior knowledge of signal, channel, and noise power. The performance of the proposed scheme is evaluated for Rayleigh, Rician, and Nakagami fading channel and found to be more efficient in Rician channel. For Rayleigh fading channel, at SNR value of -22dB, the proposed ABC Eigen value based detection technique outperforms. Thus, using ABC algorithm, the optimal smoothing factor value is obtained, which is then used to optimize the threshold level and improve the system performance. As a future work this technique can be used for multiband cooperative spectrum sensing problems in cognitive radio systems. Thus for optimization of multiple parameters problems the proposed scheme can be further enhanced.

REFERENCES

[1] J. Mitola and G.Q. Maguire, “Cognitive Radios: making Software Radios More Personal”, *IEEE Personal Communications*, Vol. 6, No. 4, pp. 13-18, 1999.

[2] S. Haykin, “Cognitive Radio: Brain-Empowered Wireless Communications”, *IEEE Transactions on Communications*, Vol. 23, No. 2, pp. 201-220, 2005.

[3] A. Sahai and D. Cabric, “Spectrum Sensing: Fundamental Limits and Practical Challenges”, *Proceedings of IEEE International Symposium on New Frontiers Dynamic Spectrum Access Networks*, pp. 1-5, 2005.

[4] D. Cabric, A. Tkachenko and R. W. Brodersen, “Spectrum Sensing Measurements of Pilot, Energy, and Collaborative Detection”, *Proceedings of International Conference for Military Communications*, pp. 1-7, 2006.

[5] H.S. Chen, W. Gao and D.G. Daut, “Signature based spectrum sensing algorithms for IEEE 802.22 WRAN”, *Proceedings of IEEE International Conference on Communications*, pp. 1-7, 2007.

[6] A. Sonnenschein and P.M. Fishman, “Radiometric Detection of Spread Spectrum Signals in Noise of Uncertainty Power”, *IEEE Transactions on Aerospace and Electronic Systems*, Vol. 28, No. 3, pp. 654-660, 1992.

[7] R. Tandra and A. Sahai, “Fundamental Limits on Detection in Low SNR under Noise Uncertainty”, *Proceedings of*

International Conference on Wireless Communications, pp. 167-173, 2005.

[8] Mohd Hasbullah Omar, Suhaidi Hassan, Angela Amphawan and Shahrudin AwangNor, "SVD-based Signal Detector for Cognitive Radio Networks", *Proceedings of 13th International Conference on Computer Modelling and Simulation*, pp. 513-517, 2011.

[9] T. Yucek and H. Arslan, "A survey of Spectrum Sensing Algorithms for Cognitive Radio Applications", *IEEE Communications Surveys and Tutorials*, Vol. 11, No. 1, pp. 116-130, 2009.

[10] Srdjan S. Brkic and Predrag N. Ivanis, "Energy Detector Performance in Rician Fading Channel", *Serbian Journal of Electrical Engineering*, Vol. 10, No. 1, pp. 37-46, 2013.