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Cooperative Spectrum Sensing for Cognitive Radio Networks using Firefly Algorithm

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Abstract –**The work presented in this paper is the Fusion technique for hybrid cooperative spectrum sensing using AND fusion of three secondary users for decision making. Energy detection based spectrum sensing method is the most common technique due to its simple operation and efficient detection rate for signals with higher SNR values. When the SNR level degrades, the performance of energy detector fails to give proper detection rate. This problem led towards development of an efficient spectrum sensing algorithm. In this regard, this research work includes the development of efficient and reliable spectrum sensing algorithm for cognitive radio network with the help of soft computing techniques in cooperative scenario. A Firefly Algorithm (FA) optimized model for conventional SVD based cooperative spectrum sensing has been presented.**

Keywords –**AND Fusion, CR, FA, PU, QoS, SNR, SVD.**

I. Introduction

Recent studies show that the fixed spectrum assignment policy enforced today results in poor spectrum utilization. To address this problem, cognitive radio (CR) has emerged as a promising technology to enable the access of the intermittent periods of unoccupied frequency bands, called white space or spectrum holes, and thereby increase the spectral efficiency. The fundamental task of each CR user in CR networks, in the most primitive sense, is to detect the licensed users, also known as primary users (PUs), if they are present and identify the available spectrum if they are absent. This is usually achieved by sensing the RF environment, a process called spectrum sensing. The objectives of spectrum sensing are twofold: first, CR users should not cause harmful interference to Pus by either switching to an available band or limiting its interference with PUs at an acceptable level and, second, CR users should efficiently identify and exploit the spectrum holes for required throughput and quality-of-service (QoS). Thus, the detection performance in spectrum sensing is crucial to the performance of both primary and CR networks. The detection performance can be primarily determined on the basis of two metrics: probability of false alarm, which denotes the probability of a CR user declaring that a PU is present when the spectrum is actually free, and probability of detection, which denotes the probability of a CR user declaring that a PU is present when the spectrum is indeed occupied by the PU. Since a miss in the detection will cause the interference with the PU and a false alarm will reduce the spectral efficiency, it is usually required for optimal detection performance that the probability of detection is maximized subject to the constraint of the probability of false alarm. Many factors in practice such as multipath fading, shadowing, and the receiver uncertainty problem may significantly compromise the detection performance in spectrum sensing.

The main objective of this paper is to implement a Firefly Algorithm (FA) optimized model for conventional SVD based cooperative spectrum sensing to detect the spectrum holes for maximum spectrum utilization. Improvement in bandwidth as a system parameter to improve the number of samples which in return improves the probability of detection in Noisy environment.

Fusion based hybrid cooperative spectrum sensing for cognitive radio is more reliable including the sensing by multiple secondary users and combining their results to obtain the required threshold for decision making, rather than considering the sensed data from any one of the secondary user.

II. Cognitive Radio

There are likely to be a variety of different views of what exactly would be a cognitive radio may be. Accordingly a definition of a cognitive radio may be of use in a number of instances.

"A cognitive radio may be defined as a radio that is aware of its environment and the internal state and with knowledge of these elements and any stored pre-defined objectives can make and implement decisions about its behaviour" [1].

"In general the cognitive radio may be expected to look at parameters such as channel occupancy, free channels, the type of data to be transmitted and the modulation types that may be used. It must also look at the regulatory requirements. In some instances

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knowledge of geography and this may alter what it may be allowed to do" [2].

According to Federal Communications Commission (FCC): "Cognitive radio: A radio or system that senses its operational electromagnetic environment and can dynamically and autonomously adjust its radio operating parameters to modify the system operation, such as maximize throughput, mitigate interference, facilitate interoperability, access secondary markets [3].

Cognitive radio is an intelligent wireless communication system that is aware of its surrounding environment (i.e., outside world), and uses the methodology of understanding-by-building to learn from the environment and adapt its internal states to statistical variations in the incoming RF stimuli by making corresponding changes in certain operating parameters (e.g., transmit-power, carrier-frequency, and modulation strategy) in real-time, with two primary objectives in mind:

- Highly reliable communications whenever and wherever needed.
- Efficient utilization of the radio spectrum.

Six key words stand out in this definition: awareness, intelligence, learning, adaptivity, reliability, and efficiency. Implementation of this far-reaching combination of capabilities is indeed feasible today, thanks to the spectacular advances in digital signal processing, networking, machine learning, computer software, and computer hardware.

III. Proposed Methodology

Cooperative Spectrum Sensing

The main idea of cooperative sensing is to enhance the sensing performance by exploiting the spatial diversity in the observations of spatially located CR users. The cooperative sensing for primary signal detection can be formulated as a binary hypothesis problem as follows [4], [5], [6], [7]:

$$x(t) = \begin{cases} n(t), & H_0 \\ h(t).s(t) + n(t), & H_1 \end{cases} \qquad (1)$$

Where $x(t)$ denotes the received signal at the CR user, $s(t)$ is the transmitted PU signal, $h(t)$ is the channel gain of the sensing channel, $n(t)$ is the zero-mean additive white Gaussian noise (AWGN), H_0 and H_1 denote the hypothesis of the absence and the presence, respectively, of the PU signal in the frequency band of interest. For the evaluation of the detection performance, the probabilities of detection P_d and false alarm P_f are defined.

Singular Value based Detection (SVD)

In linear algebra, the singular value decomposition (SVD) is a factorization of a real or complex matrix, with many useful applications in signal processing and statistics. Formally, the singular value decomposition of a $M \times L$ real or complex matrix R is a factorization of the form:

$$R = U \sum V^* \qquad (2)$$

Where U is a $M \times M$ real or complex unitary matrix, Σ is a $M \times L$ rectangular diagonal matrix with nonnegative real numbers on the diagonal, and V^* (the conjugate transpose of V) is a $L \times L$ real or complex unitary matrix. The diagonal entries $\Sigma_{i,i}$ of Σ are known as the singular values of R. The M columns of U and the L columns of V are called the left-singular vectors and right-singular vectors of R, respectively.

Steps to SVD algorithm:

Step 1: Select number of columns of a covariance matrix, L such that $k < L < N - k$, where N is the number of sampling points and k is the number of dominant singular values. here, $k = 2$ and $L = 1$

Step 2: Factorized the covariance matrix.

Step 3: Obtain the maximum and minimum eigenvalue of the covariance matrix which are $\lambda_{\max}$ and $\lambda_{\min}$.

Step 4: Compute threshold value γ.

Step 5: Compare the ratio with the threshold. If $\lambda_{\max}/\lambda_{\min} > \gamma$, the signal is present, otherwise, the signal is not present.

Data fusion Centre which is a centralized entity performs data fusion over sensing data received form several secondary users using data fusion rules given below:

AND based Data Fusion

AND based data fusion algorithm operates on logical AND operation performed over results obtained from several sensing elements. The output of the algorithm float over two states:

$$PRIMARY\ DETECTED = \begin{cases} 1 & if\,all\ sensing\ elements\ report\ detection \\ 0 & otherwise \end{cases} \qquad (3)$$

In this way AND based cooperative spectrum sensing outputs a detected primary signal if and only if each sensing elements reports detection of the presence of primary signal.

OR based Data Fusion

OR based data fusion algorithm operates on logical OR operation performed over results obtained from several sensing elements. The output of the algorithm float over two states:

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$$PRIMARY\ DETECTED = \begin{cases} 1 & if any\ sensing\ element\ reports\ detection \\ 0 & if\ none\ sensing\ element\ reports\ detection \end{cases} \quad (4)$$

In this way OR based cooperative spectrum sensing outputs a detected primary signal if any of the sensing element reports detection of the presence of primary signal.

Threshold Determination

Here the singular value decomposition (SVD) is applied for the acknowledgement of received signal whether it is correlated to primary user or not. Here the received signal is changed into matrix form then its SVD is calculated. The proposed research work uses Firefly algorithm for the optimization of the matrix prior to the SVD. Finally SVD is applied on the optimized value of L i. e. size of matrix. Threshold optimization is performed using Firefly algorithm which is explained as follows:

Firefly Algorithm (FA)

The Firefly algorithm is a bio-inspired meta-heuristic introduced by Dr. Xin-She Yan at Cambridge University [8]. The algorithm is based on the principle of attraction between fireflies and simulates the behaviour of a swarm fireflies in nature, which gives it many similarities with other meta-heuristics based on the group's collective intelligence, such as the Particle Swarm Optimization (PSO) algorithm, Artificial bee colony (ABC) optimization algorithm and the Bacterial Foraging Algorithm (BFA) [8, 9]. According to recent bibliographies, the performance of the Firefly algorithm in solving optimization problems exceeds those of other algorithms, such as genetic algorithms. This has been justified by recent research, where the performances of this algorithm have been compared with those of some known algorithms [8, 9].

The algorithm takes into consideration the following three points [8, 9]:

1. All fireflies are unisex, which makes the attraction between these is not according to their sex.
2. The attraction is proportional to their luminosity, so for two fireflies, the less luminous will move towards the brightest. If no firefly is bright than a particular firefly, the firefly will move randomly.
3. The brightness of fireflies is determined according to an objective function (to be optimized).

IV. Simulation and Results

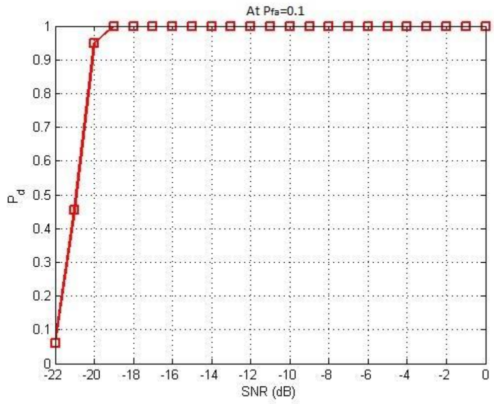

Figure 1: SNR v/s P_d graph for $P_{fa} = 0.1$

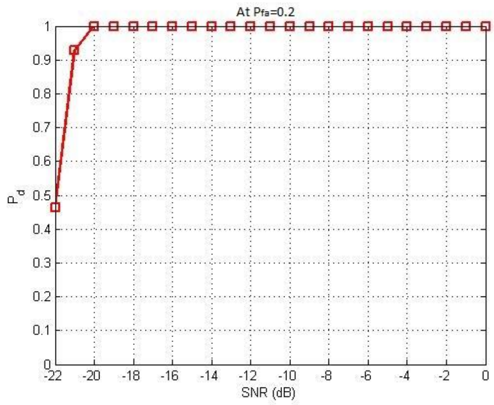

Figure 2: SNR v/s P_d graph for $P_{fa} = 0.2$

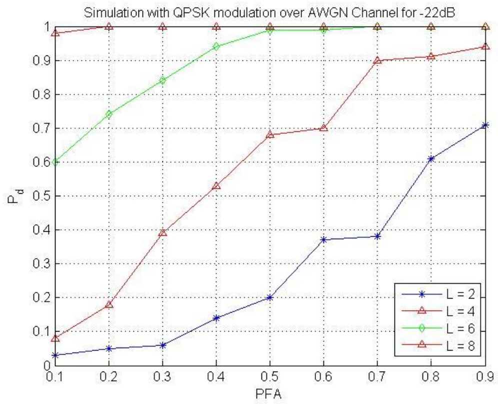

Figure 3: P_{fa} v/s P_d graph for FA optimized SVD based detection for different values of smoothening factor L

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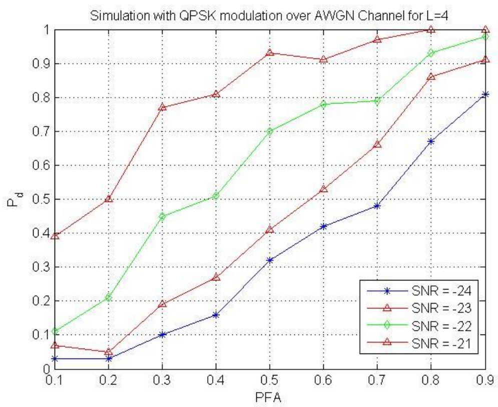

Figure 4: P_{fa} v/s P_d graph for FA optimized SVD based detection for different values of SNR

V. CONCLUSION

This paper proposes the performance analysis of Singular Value based Detection (SVD) using Firefly Algorithm (FA) for spectrum sensing. Here the FA is used to select a value of smoothening factor with objective of highest probability of detection. The fitness function comprises of full scenario where we generate a random standard signal (modulated and filtered) and transmitted it to channel of defined SNR, we have taken lowest SNR value, signal received at each cognitive secondary user is collected and arranged in Hankel matrix with a random value of smoothening factor and detection probability has been calculated. Now this value of detection probability is analyzed by FA and an update in the value of smoothening factor has been performed. With this update the whole process is repeated iteratively. At the end we got smoothening factor for which we are getting highest probability of detection then reference value of smoothening factor. So that we can conclude that optimal value smoothening factor gives better decomposition of signal thus increases detection probability.

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