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Grey Wolf Optimized SVD based Spectrum Sensing

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Abstract – **Cognitive radios or software defined radios (SDR) can autonomously adjust their system parameters according to their operational environment. Particularly, cognitive radio allows unlicensed users to access the primary user's spectrum until the transmission from unlicensed users does not severely degrade QoS at the primary user. This paper proposes a cognitive radio framework for the optimization of sensing time for maximum throughput and optimization of spectrum sensing for maximum probability of detection. The optimization is accomplished using Grey Wolf Optimization (GWO). Simulation results validate the importance of research on the basis of the probability of detection, sensing time and error rate performance.**

Keywords –**CR, GWO, QoS, SDR, SVD.**

I. Introduction

At present, the exploitation of much of the radio spectrum allocated under license is inefficiently performed due to the fixed allocation policies of the frequency bands. The inefficient use of spectrum, when examined as a function of frequency, time and space, has been demonstrated by recent studies [1]. The constraints imposed by current regulatory policies are the main constraints on the efficient use of spectrum. As a result, some frequency bands are used intensively and are congested, while other regions of the spectrum are partially or totally unoccupied most of the time. To support the increasing demands of new wireless communications technologies and services, more efficient spectrum management schemes are needed. On the other hand, the success of the services in the bands of free access has motivated the development of novel technologies that allow the use of the spectrum in an intelligent, coordinated and opportunistic way, without harming the existing services. Cognitive radio (CR) is a technology with the potential to dramatically change the way the radio spectrum is currently used and at the same time increase its availability for new wireless communications services [2].

The original idea of cognitive radio was introduced by Mitola in [3], where it was defined as "the point at which wireless PDAs and related networks are, in computational terms, sufficiently intelligent with respect to radio and The corresponding terminal-to-terminal communications to detect the eventual communication needs of the user as a function of the context of use and to provide the radio resources and wireless services best suited to their needs. The research highlights the potential of radio cognitive technology to increase the flexibility of current wireless communications services through a knowledge representation language called RKRL (Radio Knowledge Representation Language).

The concept of cognitive radio originally formulated by Mitola has been reviewed and reformulated by several authors. According to Haykin, "Cognitive radio is an intelligent wireless communications system that is aware of its surroundings and uses the understanding-by-building methodology to learn from its environment and adapt its internal state to statistical variations in radio frequency stimuli (E.g., transmission power, carrier frequency and modulation type) in real time, with two fundamental objectives: to make efficient use of the spectrum and to provide highly reliable communication [4].

The radio frequency spectrum is a limited characteristic asset that is divided into spectrum bands. With Cognitive Radio being utilized as a part of various applications, the territory of spectrum sensing has become progressively vital [5-6]. As Cognitive Radio technology is being utilized to provide a method for utilizing the spectrum all the more productively and its ability of Cognitive Radio frameworks to get to spare sections of the radio spectrum, and to continue observing the spectrum to guarantee that the Cognitive Radio framework does not create any undue interference depends totally on the spectrum sensing components of the framework.

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While examining its strengths, we focus on the problems that this technology, through its use, could address in the process of patient follow-up.

The quality of the deployed network infrastructure is certainly one of the key success factors of medical informatics. Pillar of information exchanges, communication networks are confronted with new challenges related to the heterogeneity of communicating objects and the diversity of services. Whether for health or not, services and applications are increasingly insatiable in resources, yet limited. Interference is increasing and the desire for patient mobility, in particular, requires connectivity everywhere. Added to these constraints are the remaining performance or broadband issues that are critical to some categories of medical content such as multimedia. These different issues have increased the demand for more flexible or smarter communication solutions that can accommodate application requirements. Cognitive Radio is seen for this purpose as a very promising technology.

Present networking techniques performs sub-optimally due to its inadaptability to changing environment conditions. Furthermore, fixed spectrum allocation results is a serious problem associated with these techniques which results in improper resource utilization. Cognitive radio technology is solution to such problems, which improves spectrum utilization by opportunistically sharing unused spectrum with unlicensed users in such a way that they do not interference with primary users. The CRN technology permits non-legitimate users to operate in vacant frequency bands to improve the communication between a pair of cognitive users. Cognitive radios or software defined radios can autonomously adjust their system parameters according to their operational environment. Particularly, cognitive radio allows unlicensed users to access primary user's spectrum until the transmission from unlicensed users does not severely degrade QoS at primary user [7].

II. Proposed Method

The purpose of signal detection is to test the existence of primary user's signal in receiver. For the signal detection, there are two kinds of hypothesis: H_0, which means primary user's signal does not exist; H_1, which means primary user's signal exists. The two hypothesis are given respectively by formula as follows:

$$H_0: x(n) = \eta(n) \quad (1)$$

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

Where $\bar{s}(n)$ is the received signal samples including the effects of path loss, multipath fading and time dispersion, and $\eta(n)$ is the received white noise assumed to be identically distributed signal, and with mean zero and variance σ_η^2.

The received signal at receiver can be given as:

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

Where, P is the number of source signals i.e. number of transmitters, $h_j(k)$ is channel response and N_{ij} is the order of the channel.

The detection techniques performance can determined through two probabilities: probability of false alarm (P_f) is probability of incorrectly detection of primary user in the frequency band that is case H_0 and probability of detection (P_d) is probability of correctly detection primary user in frequency band that is case H_1.

$$P_d(\in, \tau) = Q\left[\left(\frac{\in}{\sigma_\mu^2} - 1\right)\sqrt{\frac{\tau f_s}{2\gamma+1}}\right] \quad (4)$$

$$P_f(\in, \tau) = Q\left[\left(\frac{\in}{\sigma_\mu^2} - 1\right)\sqrt{\tau f_s}\right] \quad (5)$$

Here, τ is the sensing time, f_s is the sampling frequency, W is the bandwidth and $\in$ is the detection threshold.

The throughput is given by [8]:

$$Throughput = K[\log_2 N_t + \log_2 M] \quad (6)$$

Where K is the number of primary users, N_t is the Line of Sight (LOS) of transmitting antennas and M is the cardinality of the modulation scheme (in power of 2).

Furthermore, the Bit Error Probability (P_e) is given by [8]:

$$P_e = Q\left[\frac{\sqrt{2 \propto PB}}{NR}\right] \quad (7)$$

Where P is the transmitted power, B is the frequency of operation, N is the noise Power, R is the symbol rate and α is a constant.

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:

$$R = U \sum V^* \quad (8)$$

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

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number of sampling points and k is the number of dominant singular values. here, $k = 2$ and $L = 14$.
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.
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.

Threshold Determination

In general model of spectrum sensing, a threshold must be determined to compare with the decision statistic of sensing metric in order to determine the presence of primary user signal. The decision static is defined as the ratio of maximum to minimum eigenvalues as follows:

$$T = \lambda_{max}/\lambda_{min} \quad (9)$$

Probability of false alarm and decision threshold are derived based on limiting distribution of eigenvalue based on random matrix theory. The detection threshold, γ, must be estimated for a required probability of false alarm, by the above decision statistic. The probabilities of detection and probability of false alarm are derived based on asymptotical (limiting) distributions of eigenvalue which is less complicated and mathematically tractable. The detection threshold in terms of desired probability of false alarm is calculated by:

$$\gamma = \left(\frac{\left(\sqrt{N_s}+\sqrt{L}\right)^2}{\left(\sqrt{N_s}+\sqrt{L}\right)^2}\right) \times \left(1 + \frac{\left(\sqrt{N_s}+\sqrt{L}\right)^{\frac{2}{3}}}{(N_s L)} . F_1^{-1}\left(1 - P_f\right)\right) \quad (10)$$

Where

N_s = Number of Samples
L = Smoothing factor
P_f = Probability of false alarm
P_d = Probability of detection
γ = Threshold value

F^{-1} represents the inverse of cumulative distribution function (CDF) of Tracy widom distribution of order 1. Tracy widom distribution is Probability distribution function of the largest Eigenvalues of random Hermitian matrix.
The proposed research work uses GWO algorithm for the optimization of the sensing time to achieve maximum throughput. Additionally, the spectrum sensing is also optimized by GWO to accomplish greater probability of detection. The GWO technique is explained in the following heading.

Grey Wolf Optimization (GWO)

1. Grey wolves wander in search of its prey depending on the alpha, beta and delta positions. They go away (divergence) from each other in search of a prey and gather again (convergence) while attacking the prey [9]. This divergence can be mathematically given by A and convergence is represented by C.
$$\vec{A} = 2.\vec{a}.\vec{r}_1 - \vec{a} \quad (11)$$
$$\vec{C} = 2.\vec{r}_2 \quad (12)$$
Where, $\vec{r}_1$ and $\vec{r}_2$ are random vectors:
2. The initialization of GWO population is given by at counter iteration t=0:
$$X_i = (1,2,3 \ldots \ldots \ldots n) \quad (13)$$
3. Further A, C and a are also initialized
4. Now the fitness function for each searching agent is evaluated and is represented as:
X_α denotes best searching agent
X_β denotes 2nd best searching agent
X_δ denotes 3rd best searching agent
5. If the total no. of iterations is given as $t = n$, then
For $(t = 1; t \leq n)$
Using above equations update the position of searching agents
End for
6. Update A and C coefficients
7. Evaluate fitness function for each searching agent
8. Update $X_\alpha, X_\beta, X_\delta$
9. Set $t = t + 1$ (iteration counter increasing)
10. Return best solution X_α

GWO Working

1. The GWO resolves the optimization problem by generating the best solutions available during iterations.
2. The encircling behaviour gives an idea about the neighbouring circle around the solution which could be further extended into sphere (as shown in Figure 1).
3. A and C coefficient vectors help solutions to have random radii hyperspheres.
4. The hunting behaviour permits the solution to define the exact location of the prey.
5. Values of a and A are responsible for exploitation and exploration.
6. If the value of A decrease, then total number of iterations are equally divided and assigned for exploitation and exploration respectively.

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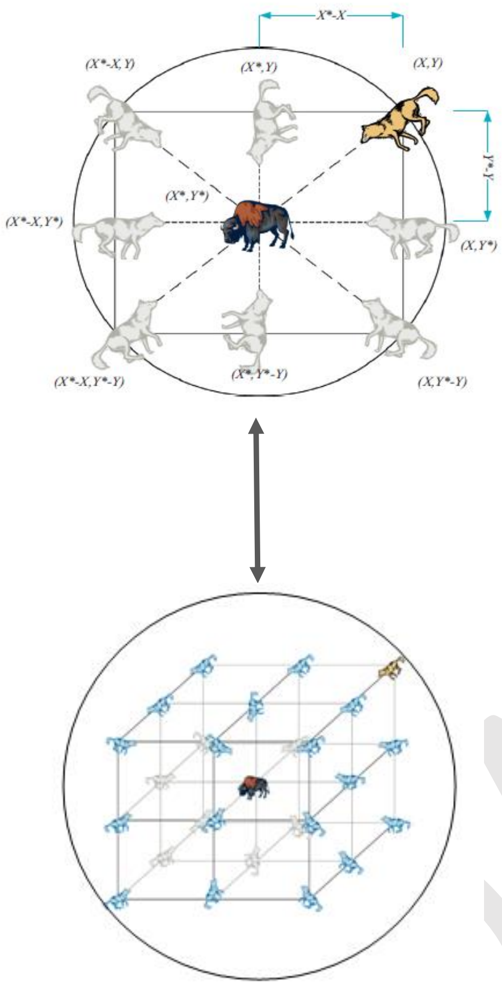

Figure 1: Extension of encircling shape into sphere [9]

III. Simulation And Results

The performance of proposed algorithms has been studied by means of MATLAB simulation.

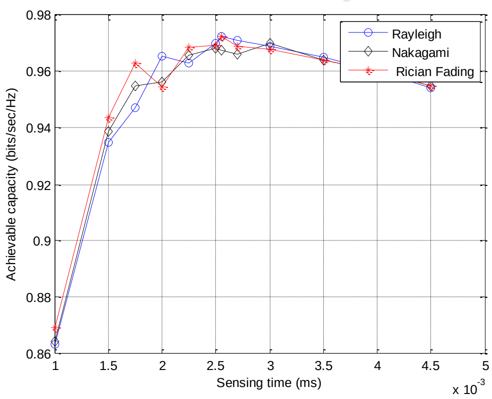

Figure 2: Comparative graph for sensing time

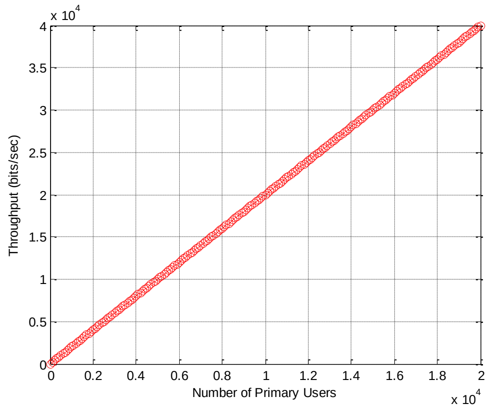

Figure 3: Graph for throughput

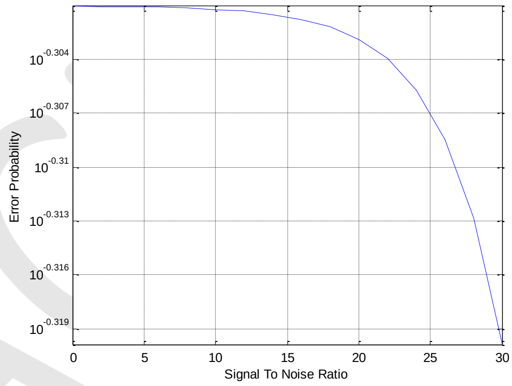

Figure 4: Error probability graph

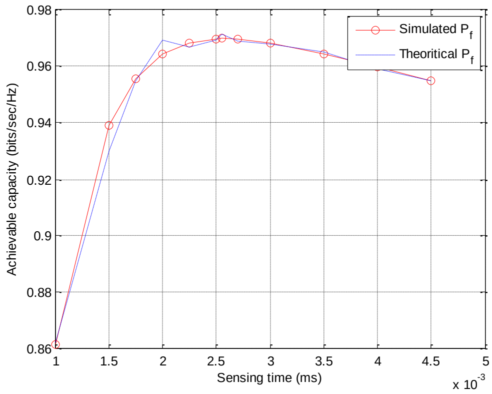

Figure 5: Achievable capacity

IV. Conclusion

GWO optimization of sensing time and spectrum sensing technique is accomplished to enhance the performance of cognitive radio system. The impact of false alarm probability, sensing time and error probability is shown on the performance of spectrum sensing algorithm.

On the basis of simulation results presented, it can be concluded that the proposed research work enhances the error performance while keeping sensing time as low as possible and capable of

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operating in both Low and High SNR regions. Based on the above observation, the importance of proposed research in field of Cognitive Radio technology can be justified.

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