# Optimization of QoS Parameters in Cognitive Radio Using Grey Wolf Optimization Algorithm

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**Abstract: Cognitive radio technology is fastest growing technology in the field of wireless communication and it has the capability to usage of frequency spectrum in efficient manner. In this paper effort has been made to optimize QoS parameters of CR using Grey wolf optimization (GWO). The GWO is a meta-heuristic method and is motivated by hunting behaviour of Grey wolves (canis lupus) living in a pack. Grey wolves divided into four groups according to their priority that are alpha, beta, delta and omega. This technique is implemented by observing the grey wolves behaviour where some grey wolves search for prey in a multi-dimensional search space. In GWO, every grey wolf changes their location to get the suitable location. The idea of this algorithm is to find the best and shortest path to reach to the prey. The proposed method uses GWO for the optimization of Qos parameters in the way of five objectives such as BER, power consumption, throughput, spectral efficiency and interference. These objectives could be minimize or maximize according to the CR requirements. The proposed method substantially optimize the objective parameters of CR and simulation result shows a better performance when compared with other existing methods such as genetic algorithm (GA), Spider monkey optimization (SMO) and Stimulated Annealing (SA).**

**Key words:** ***Cognitive Radio, BER, Throughput, Power consumption, Optimization***

## I. INTRODUCTION

From the past years, the users and their demand are increasing in wireless communications so spectrum scarcity problem occurs. Cognitive radio is a self-standardized radio system which is computed and composed vigorously for the use of best wireless channels in its capacity. This type of radio significantly recognizes existing channels in the spectrum, and then subsequently it changes its transmission parameters to recognize more accomplished wireless communication within an available spectrum band in one region. This method creates management of dynamic spectrum. It has the efficiency of accomplishing extensive spectrum capabilities by increasing the wireless users to adapt the behaviour of surrounding environment and their adapting strategies. Cognitive Radio is a next generation wireless communication system technology. To reduce the drawback of conventional Wireless Networks cognitive techniques is used. Cognitive radio method has been proposed with an objective of spectrum utilization and spectrum management. CR occupied that spectrum which has been left vacant by the primary or licensed users. It gets to know the empty spectrum in licensed and unlicensed band, it utilizes the empty spectrum. Primary users have the ability to use spectrum anytime but secondary user uses opportunistically when spectrum is available.

Cognitive radio is executed using Software Defined Radios (SDR) [1] it enhances machine learning and optimizing algorithms which can modify radio transmission parameters as per environment parameter conditions. Basically, spectrum allocation for radio communication is fixed. For this allocation secondary users are not considered for the usage of spectrum provided for primary users. This creates empty radio spectrum. Hence to remove the mentioned problem, a new technique is proposed known as Dynamic Spectrum Allocation (DSA) [8] is measured. By mentioned method, secondary user usage of free or available spectrum band of primary users deprived of any interference. Main issue for CR is quality of service (QoS) in CR networks. For getting the Quality of Service, CR decides the best vacant spectrum bands. When the spectrum is free from primary user the secondary users uses the available spectrum opportunistically. While secondary users use an idle spectrum, that occurrence the primary user comes back it makes SUs to exit their communications and leave the current spectrum. Therefore, quality of service is difficult to be ensured for secondary users. Tim R. Newman [11] introduces a genetic algorithm, the main work of CR is to avail dynamic wireless channel environment radio parameters.so, The optimum radio's parameter of transmission for single transmission system and multicarrier systems are rectify by the CR decision engine. This paper

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describes the exact set of particular transmission system and fitness functions of multicarrier for GA application but convergence rate is so slow. Sebastien Herry [12] authors aims to find a secondary user parameters using genetic algorithm. For secondary user network they find a solution for objective parameters that fit into primary user network holes. Maninder Jeet Kaur [13] in this the author focused on various optimization techniques on allocation of spectrums for secondary users; the Genetic algorithm technique is applied and compared. They have predicted that the secondary users already specified the requirement of QoS and the sensing of the secondary holes is carried out but complexity is present. Ankur dixit [14],They proposed Particle Swarm optimization algorithm to optimize transmission and environmental parameters with objective (Bit error rate, spectral efficiency, throughput, power consumption). The objective function fitness value in various types and networks are inspected in MATLAB. They get to know that the PSO has 70% better convergence time than Genetic algorithm. PSO technique is fast, reliable and efficient for primary user in cognitive radios but complexity increases. W.F.Abd-El-Waheda [15], Their approach is combining of two exploratory optimization techniques that are PSO with GA. Their methodology is, combine the advantages of both techniques and it obtains two characteristics advantage. First, the algorithm is generated with fixed arbitrary elements which passes over the search space while this scenario of the travelling an advancement of these elements is achieved by adding PSO and GA together. Another one is, to control velocity of the particles, they presented improved compression factor. The result shows that the proposed methodology is better in terms of capacity to find the optimum solution globally. Pyari Mohan Pradhan[16], In the wireless environment, optimization of already defined fitness function used by evolutionary algorithm. They took three evolutionary algorithms these are GA, PSO and ABC and analysed their behaviour in different mode in the existence of spectrum interference. Their results are associated by the convergence characteristics and geometric metrics of two. The result shows that for cognitive engine ABC technique has better design as compared to compared techniques. Kuldeep singh kaswan[17],This paper represents the application area where Artificial intelligence technique has applied. This works on real time parameter optimization problem. They simulated that ABC is well worked for various applications like general assignment problem, cluster analysis, constrained problem optimization, structural optimization, and advisory system. It has also been applied to software engineering for software testing and parameter estimation in software reliability growth models. ABC also plays an important role in medical, as used in MR brain image classification, face pose estimation, bioinformatics etc. We can find more applications regarding ABC techniques. Deepika.S[18], This paper represented throughput maximization for secondary user in full duplex(FD) cognitive radio n/w by ABC techniques. They show how throughput maximization occurs by ABC by optimizing the detection threshold including restraints on the probability of mis-detection by the fusion centre. Their results shows that the Artificial Bee Colony optimization technique has less computational complexity, high convergence speed and more flexible than Particle Swarm optimization technique. Thus the throughput of secondary user in full-duplex (FD) cognitive radio network is maximized by optimizing the detection threshold. Deepak K. Tosh [19], They proposed a method, multi-evolutionary algorithm based Genetic Algorithm (NSGA-II) to define the required transmission parameters for multicarrier system like Non-dominated Sorting criteria. Fitness function is shown for all criterions and for composite function. All this is done for radio parameters. In this scenario, the adaptation of parameters is done for unconstrained optimization for multi-objective parameters and approached an algorithm centered on NSGA-II for the optimization of CR transmission parameters and we analyzing the fitness score by taking iterations with respect to time till optimum result does not get. They get best individual fitness value considering two objectives for multi-objective optimization. The convergence time is low for NSGA-II. Abdelfatah Elarfaoui [20], they proposed crossover method and it has methodology of weighted sum for different parameters. It is also called Combined Single-Heuristic Crossover by GA. Parameters to be taken are: min BER, min power consumption, spectral efficiency, min interference and maximizing throughput. This work represents the flexibility in implementation and adapting behavior of transmission parameters. This technique can be used with other meta-heuristic to increase the solution's quality without increasing complexity and time execution but more quality of service can get after using more performance objectives so future work can be motivated on proposing new metaheuristic optimization technique which decide spectrum management problem. Timothy R. Newman [21], they represents various approaches to increase the convergence time and improve the performance results by multi-objective GA. They come to know GA-based approaches have the benefit to be capable of discover huge parameter spaces by treating multiple solutions in parallel. Compared to other techniques for optimization, genetic algorithms allow easier implementations for multi-objective optimizations, where NSGA-II [22] is one of many implementations. They get to know GA method using weighted sum has fastest approach but slightly worse than NSGA-II. Weighted sum method gives higher result on throughput but not MOGA. N.Ali Saoucha [23], this paper signifies an algorithm which is based on real-coded GA. Various trials can be initiated on different parameters of the algorithm. Standard GA (De Jong setting) with binary coding has been compared to get the suitable results. From the result analyses we get to know that proposed algorithm have best convergence speed according to other standard Gain [24] which is created on a binary coding and setting of

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GA parameter standard but the analyses shows them, De Jong setting is not best optimum for the QoS optimization problem in CR. Maninder Jeet Kaur [22], They proposed modified GA that is Adaptive genetic algorithm (AGA). This approached method is compared with conventional genetic algorithm. This has achieved by the same set of circumstances and parameters. Primarily the CGA is simulated. The GA pseudo code is created for gradually implementation of GA or the same set of conditions and environments are applied to the proposed AGA in which the crossover and mutation rates are preset. They get to know the proposed AGA have better results than CGA.AGA adaptive capabilities are more as compared to CGA and AGA converges faster than CGA. AGA has higher fitness value and also has the proficiency to achieve the balance between multiple objectives more efficiently. In adaptive genetic algorithm the convergence stability reaches at 95% which is the best convergence fitness value. By this proposed method, premature convergence related problem get solved because it regulates to the suitable Crossover and mutation rates to decrease, exertion of searching for both rates, since the presentation is not linear so that balance b/w these parameters have to be maintained. ZHAO Jun-hui [23], They proposed a method for fitness of individual chromosome by scale of linear transformation, for decreasing, the effect of unusual individuals escaping from the premature iterations for evolution, and trying to compete with individuals afterwards progress iterations and also specifies for parameter adjustment, an adaptive crossover, with algorithm of mutation probability this certify that the population have variety and convergence. This method improves given algorithm and converges fast to the global optimum solution and removes premature convergence problem of GA. They get optimum solution in large convergence time.

| Transmission Parameters | Environmental Parameters |
|---|---|
| **Transmit Power (P)**—Raw transmission power. | **Bit-Error-Rate (BER)**--- Number of error present in existing bit. |
| **Modulation Type (Mod)**--- Type of modulation format | **Signal-to-noise ratio (SNR)**--- amount of noise in a desired signal. |
| **Modulation order (M)**--- Number of symbols that are given for modulation format | **Noise power (N)** --- Power produced by random EM process. Noise power Magnitude in dB |
| **Bandwidth (B)**---Bandwidth of transmission signal in Hz | **Battery Status**--- Predictable energy left in batteries |
| **Packet Size (L)**--- Transmission packet size in bytes | **Power Utilization**--- Power utilization of present configuration |
| **Symbol Rate (Rs)**--- Number of symbols per second | |

Table 1 List of Transmission Parameters and Environmental Parameters

In this some QoS parameters must be fulfilled, when frequency band of primary users utilizes by the secondary user. The QoS parameters are power consumption, bit error rate, throughput, spectral efficiency and interference. Here are various algorithms for optimization that gives advancement of QoS parameters like genetic algorithm, Stimulated annealing, PSO and ACO [3-6]. The work has been done on five QoS parameters for optimization that are BER, interference, throughput, spectral efficiency and power consumption according their needs it minimize or maximize. GWO simulating parameters are same as in GA, SA and SMO. Comparison has done with these parameters, stimulated annealing uses the same parameters as used in GA and gives better results than GA [3]. The analyzed results of Stimulated annealing compare with the Spider monkey optimization algorithm, obtained SMO have better analysis than GA and SA [7]. In order to urge better result than SMO, GWO has proposed called grey wolf optimization that also works on above defined parameters. For improving the CR parameters GWO algorithm is used for the first time.

## II. COGNITIVE RADIO

Cognitive radio have real time interface with the environment and it supports the communication in CR system. Cognitive radio has QOS parameter which tells system utilization by the users. CR has transmission and environmental parameters that are utilized with performance objective parameters.

## III. COGNITIVE RADIO TRANSMISSION AND ENVIRONMENTAL PARAMETERS

Environmental Parameters: Environmental parameters defines the characteristics of external or surrounding and the data present in these characteristics are operation state of radio information that are located internally, and information about environment of wireless channel that present externally. This kind of information is used in decision making process for helping the manager in CR.

Transmission Parameters: These Parameters are tuned in system of Cognitive Radio. It tunes its equivalent values from the optimum parameters. These parameters are bit error rate (BER), channel loss, modulation index, signal-to-noise ratio (SNR), time division duplex in percentage (TDD), bandwidth (B), and symbol rate (Rs). For the simulation analysis of CR system the performance range of transmission parameters that are used by the Grey wolf optimization, Spider monkey optimization, Stimulated annealing and Genetic algorithm has given in table 1.

### *A. Performance objectives:*

Fitness function determines the solution fitness (how solution is close to desired or optimum solution).In wireless environment, we have to optimize the multi-fitness

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functions and its objectives. A set of Pareto optimum solution get after the optimization of multi objective functions. From the defined set, user has to choose a solution that depends on the requirement of quality of services. Therefore, basic optimization requires the sum of optimization of all fitness functions. In this paper, we have taken five performance objectives or fitness functions that are: power consumption, interference, BER, throughput and spectral efficiency.

**BER minimization:** Minimization of BER is the common requirement in wireless communication. This objective defines to reducing the extent of errors in complete set of bits. The main purpose of these objective parameters is to improve the communication signal for the radio system. BER is the amount of error present in the total number of bits. Communication system for single carrier, BER is expressed as

$$f_{min\_ber} = 1 - \frac{log_{10} 0.5}{log_{10} P_{be}} \quad (1)$$

where $P_{be}$ is bit error rate probability. BER should be minimized. Communication systems for multicarrier, the complementary fitness function $f_{multicarrier\ min\_ber}$ are attained by interchanging $P_{be}$ to $\overline{P_{be}}$ .

**Throughput maximization:** Maximizing the throughput objective means the maximum amount of information gathering. *Throughput* defines as the maximum amount of data can be transferred from one place to another in a given amount of time. It should be maximized in communication system.

$$f_{maximum\_throughput} = \frac{log_2(M)}{log_2 M_{max}} \quad (2)$$

where M represents modulation index and $M_{max}$ represents maximum modulation index. For the multicarrier communication systems, its complementary fitness function for is represented as $f_{muticarrier\_maximum\_throughput}$ .

For real time scenario, there are different restrictions factors which decide the performance of primary and secondary user networks like power dissipation, rate of change of environment and interference etc. There are two constraints, here are following: Maximum power transmission limit for secondary user and Maximum tolerable power of interference for primary user.

**Minimization of power consumption:** Minimization of power consumption is defined itself. This objective parameter is to guide a system to a minimum power consumption state. Power consumption should be minimized. Fitness function for power consumption is indicates as:

$$f_{minimum\_power} = 1 - \frac{P}{P_{max}} \quad (3)$$

where P represents transmission power, $P_{maximum}$ represents maximum transmission power. The complementary fitness function $f_{multicarrier\_min\_power}$ is attained by interchanging P from $\sum_{i=1}^{N} \frac{P_{i0}}{N}$ where $P_i$ is the transmitted power on the $i_{th}$ sub-carrier for multicarrier communication systems.

**Minimization of interference:** Minimization of interference, it removes the large noise floor regions in the spectrum of wireless communication. Communication system has main problem of interference because of spectrum sharing environments. The fitness function is generated to minimized optimization of interference. When using cognitive radio system, the secondary user can't intermediate with primary user is the first priority.

$$f_{min\_interference} = \frac{\{(P+D+TDD)(P_{min}+D_{min}+1)\}}{(P_{max}+D_{max}+R_{smax})} \quad (4)$$

Where D= single carrier bandwidth, $D_{min}$ = min bandwidth and $D_{max}$ = max bandwidth, TDD = Time division duplexing and $R_{smax}$ = max symbol rate.

**Maximization of spectral efficiency :** The complete information that is transmitted above a give bandwidth is defined as Spectral Efficiency and it can be expressed as:

$$f_{max\_spetral\_eff} = 1 - \frac{B*M_{max}*R_{smax}}{M*B_{min}*R_s} \quad (5)$$

Spectral efficiency should be maximized for the optimization problem so that more information can be transmitted with the limited amount of bandwidth.

## IV. PROPOSED METHOD OF GWO ALGORITHM

In 2014,Grey wolf optimization was first introduced by Mirjalili et al. It is one of the latest meta-heuristic nature inspired algorithm. It is motivated by grey wolves (canis lupus). The knowledge of this algorithm comes by the grey wolves behavior that lives in a pack. As shown in Figure 2.1they always live in a group and creates firm social dominant hierarchy. This hierarchy is created as alpha, beta, delta and omega [8, 9].

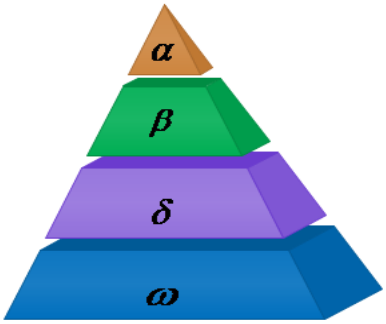


**Fig.1. Grey wolf hierarchy (ascendency falls from top down) [9]**

Alpha ($\alpha$) are the leaders that are liable for decision making process like sleeping time, hunting time, wake up time etc.

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for the pack but there are any kind of independent behavior has also viewed, where alpha monitors the further wolf in the pack. It has both members male and female. In mean, alpha wolf called as leading wolf because their decision must be monitored by the pack [8]. The $\boldsymbol{\alpha}$ wolf gives entry to mate in the pack and it is not important to be strong member from the pack members but it manages the pack. This represents that the discipline and organization is very important from the power strength.

The second phase in given hierarchy for them is Beta ($\boldsymbol{\beta}$). The $\boldsymbol{\beta}$'s are the secondary wolves or second helping hand for alpha wolves. Beta wolves obey the orders of alpha wolves but when alpha wolves become weak and passes away the beta wolves takes the responsibility. Beta command on other low level wolves but respect the order of alpha. It gives suggestions to the alpha along with maintains discipline among the pack.

The beta supports the judgment of alpha all over the pack and contributes response to alpha

The third phase in hierarchy considered as Delta ($\boldsymbol{\delta}$). Providing details to alpha and beta is the work of delta. Sentinels Hunters, Elders, Caretakers and Scouts comes in this group.

Scouts has gaze on the boundaries and warns the pack for the threat. Sentinels work as guard; they shield and assure pack protection. Hunter hunts the prey and help alphas and betas to provide food for the pack. Experienced wolves are the elders and considered as alpha and beta. Lastly, ill, injured and weak wolves in the pack are taken care by the Caretakers wolves.

Omega ($\boldsymbol{\omega}$) is final hierarchy of grey wolf. They are last that are permitted to eat. Omega is general wolves that have not so much work in the pack, but after losing them, whole pack struggles internal fighting and dispersion. Omega wolves maintain the decorum in the group. They also work as babysitters for the group.

GWO is implemented by observing the 225ehaviour of grey wolves where specific grey wolves search for prey in a multi-dimensional search space. The position variables are the grey wolves particular location and the objective function and its fitness value can be obtained by the distance measurement from grey wolf to prey. To get best position, wolf changes their position from one to other. The main aim of this algorithm is to get the best and shortest path to reach to the prey. According to C.Muro et al. [9] there are four processes for each individual movement.

(a) Tracking, Searching, Chasing and Approaching to prey.

(b) Enclosing, Pursuing and Harassing prey.

(c)Hunting.

(d) Attacking of Prey.

Calculated model of the hunting techniques and design method of GWO are represented below.

### *A. Tracking, Searching, Chasing and Approaching for prey*

To represent in mathematical order, as shown in Fig.2, the wolves in social hierarchy during GWO process, we select fittest solution as alpha. Subsequently, other best solution called as beta and delta individually. Least solution called as omega.

In GWO process of optimization is directed by $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$ and $\boldsymbol{\delta}$. Omega wolves follow these wolves. The grey wolves divide their position for searching a prey.

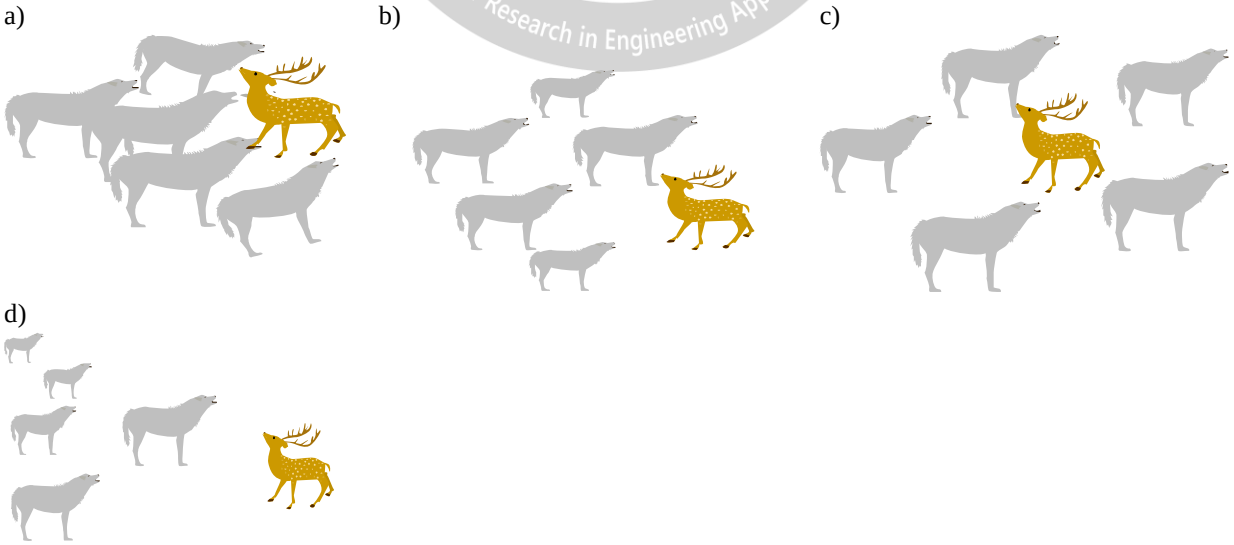


**Fig.2. Behaviour of grey wolves while hunting: (a) searching, tracking, impending, and chasing victim (b) following and harassing of victim (c) enclosing prey (d) static state and attack.**

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Take a $B\vec{M}$ with arbitrary values to make the hunt executor divides to prey. $W\vec{M}$ are random weights in search space for finding the prey. $W\vec{M}$ vector also represents the problems to approaching the prey. So, the searching through $B\vec{M}$ and $W\vec{M}$ allows this algorithm to search the space globally.

**a) Enclosing prey:**

The $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$ and $\boldsymbol{\delta}$ wolves have best location and omega updates their position according to the rest wolf position. Grey wolves encircle victim while hunting. Encircling behavior can be shown by $C\vec{M}$. Below equations has been proposed for the mathematical model of encircling behavior.

$$C\vec{M} = |W\vec{M}.Y\vec{L}(t) - \vec{Y}(t)| \quad (6)$$

$$\vec{Y}(t+1) = X\vec{L}(t) - B\vec{M}.C\vec{M} \quad (7)$$

where t represents existing iteration, $B\vec{M}$ and $C\vec{M}$ are the vector constants, $Y\vec{L}(t)$ indicates location vector for victim, $Y(t)$ shows location vector for grey wolves

$$B\vec{M} = 2\times \vec{a} \times \overrightarrow{v1} - \vec{a} \quad (8)$$

$$W\vec{M} = 2\times \overrightarrow{v2} \quad (9)$$

where $\overrightarrow{v1}$ and $\overrightarrow{v2}$ are arbitrary vectors. $\vec{a}$ Component is linearly decreased from 2 to 0.

**b) Hunting:**

After encircling, Identification of the location of prey carried by grey wolves. Alpha monitors for hunting to all of them. Beta and Delta also takes contribution in hunting. The optimum location of prey is difficult to interpret. We mathematically visualize the grey wolves behavior while hunting, and let that alpha has the finest solution. To search the position of the prey, Beta and Delta are capable. After that save the best obtained solution and help other agents to inform its location with reference of the location of best search agent. The below equation are follows regarding the hunting behaviour of alpha, beta, delta can be represented as:

$$\overrightarrow{CM}_{\alpha} = |C\vec{M}_{\alpha}.Y\vec{L}_{\alpha}(t) + \vec{Y}| \quad (10)$$

$$\overrightarrow{CM}_{\beta} = |C\vec{M}_{\beta}.Y\vec{L}_{\beta}(t) + \vec{Y}| \quad (11)$$

$$\overrightarrow{CM}_{\delta} = |C\vec{M}_{\delta}.Y\vec{L}_{\delta}(t) + \vec{Y}| \quad (12)$$

Lastly, the various category wolves' position is improved as follows:

$$\vec{Y}_{\alpha 1} = \vec{Y}_{\alpha} - B\vec{M}_1.\overrightarrow{CM}_{\alpha} \quad (13)$$

$$\vec{Y}_{\beta 1} = \vec{Y}_{\beta} - B\vec{M}_2.\overrightarrow{CM}_{\beta} \quad (14)$$

$$\vec{Y}_{\delta 1} = \vec{Y}_{\delta} - B\vec{M}_3.\overrightarrow{CM}_{\delta} \quad (15)$$

$$\overrightarrow{Y(t+1)} = \frac{\vec{Y}_{\alpha 1} + \vec{Y}_{\beta 1} + \vec{Y}_{\delta 1}}{3} \quad (16)$$

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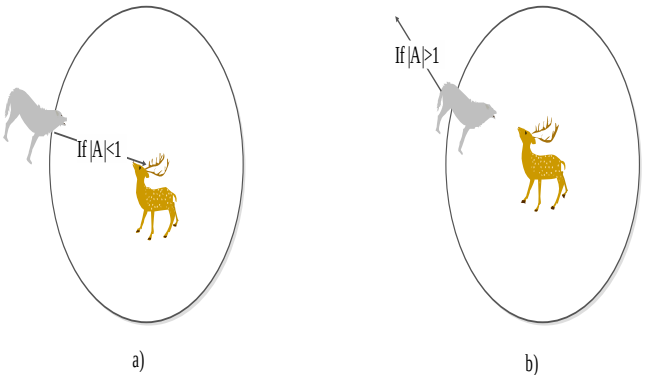


**Fig.3.Prey attacks versus Search prey**.

**a) Attacking prey (exploitation)**

When the prey becomes still then grey wolves stop its hunt. We arithmetically simulate model, decrease the value of $\vec{a}$ for approaching the prey and deviation range of $\overrightarrow{L(t)}$ is also decreases by $\vec{a}$ . $\overrightarrow{L(t)}$ Is arbitrary value in interval of [-a,a] and $\vec{a}$ is lessen to 2 to 0. When $\overrightarrow{L(t)}$ lie in interval [-1, 1] that means the following location of examine manager in middle of its present location and position of prey. Fig 3 (a) Indicates if $|L(t)|$ <1 the wolves attack the prey.

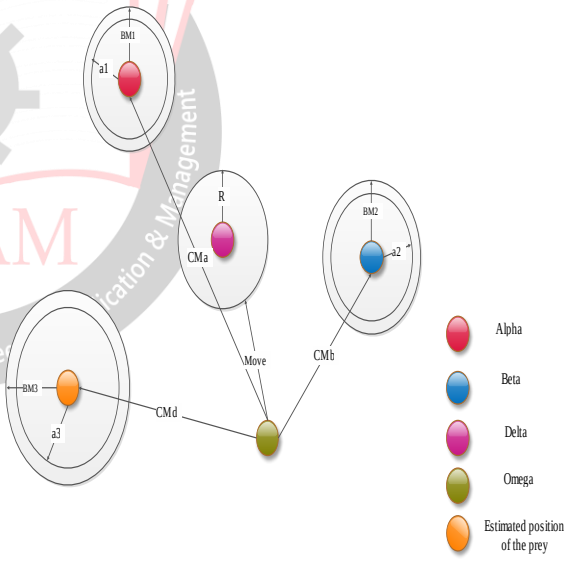


**Fig.4.GWO Position updating [9]**

In GWO, the alpha, beta and delta update their position and attack to victim.

We have to update $\bar{a}$. The $\bar{a}$ parameter adjusts between exploration and exploitation.

$$a = 2 - t\frac{2}{max.iter} \quad (17)$$

where t is the number of iteration and max.iter is the total number of iteration.

For the purpose of operation of multi-objective, weighted sum approach has been implied in CR system. It permits

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system to combine one objective function into one summative multiple objective functions.

$$Max f_{single} = w_1 * f_{minimum\_ber} + w_2 * f_{minimum\_power} + w_3 * f_{maximum\_throughput} + w_4 * f_{maximum\_spectral\_eff} + w_5 * f_{minimum\_interfernce} \quad (18)$$

**GWO algorithm**

Initialize the population of grey wolf
Initialize a, C$\overline{M}$ and B$\overline{M}$.
Find out the examine manager fitness of individual
$\vec{Y}_\alpha, \vec{Y}_\beta, \vec{Y}_\delta$ is the best examining manger priority wise.
While (t< no. of max. iterations)
For individual examine manager
Current examine manager gets changed by equation (11).
Change a, C$\overline{M}$ and B$\overline{M}$
Find out the examine manager fitness for all
Change $\vec{Y}_\alpha, \vec{Y}_\beta$ and $\vec{Y}_\delta$
t incremented by 1
End while
Return $Y_\alpha$

This equation [18] represents that every objective is multiplied by a weight and added with them to provide optimized parameter set. Weights are given that values find the search direction to get the optimized results. Table 2 shows the weights of given mode.

**Table 2 Weighting vectors for five objective mode**

| Modes | Weight vectors [w1, w2, w3, w4, w5] |
|---|---|
| Power Minimization mode | [0.45 0.10 0.20 0.15 0.10] |
| BER minimization mode | [0.10 0.50 0.10 0.10 0.20] |
| Throughput Maximization mode | [1.10 0.15 0.50 0.15 0.10] |
| Interference Minimization mode | [0.10 0.10 0.20 0.50 0.10] |
| Spectral efficiency minimization mode | [0.10 0.15 0.15 0.10 0.50] |

## V. RESULT AND DISCUSSION

The simulation has been done on MATLAB software 2015 version. The GWO algorithm is proposed in this paper and for the simulation process fitness function objective parameters are defined. The result has been carried out for the analysis of GWO for the simulation of cognitive radio parameters. The simulation has done on different objective parameters such as bit error rate, power consumption, throughput, spectral efficiency and interference. Grey wolf optimization has been applied to CR system with single carrier that achieves different objectives by MATLAB. For the simulation process, simulation parameters have been defined and four algorithms has compared for analysis purpose.

Objective parameters also have been defined above for the simulation process Simulation is applied on five objectives. These objectives are directed by simulation parameter as shown in table 3. The work has been done on different modes and each mode has their own optimized value.

While GWO simulation in power minimization mode, the number of generation is taken as 50. In this simulation, as number of generation increases, the fitness value get reduced and arrived at minimum value. The fitness value reduced to the best of minimum value.

Therefore, the mode of power consumption works more correctly, after obtaining the simulated fitness value less or minimum as per requirement. Fig 5 (a) represents the optimized or best value of minimum power consumption in GWO algorithm.

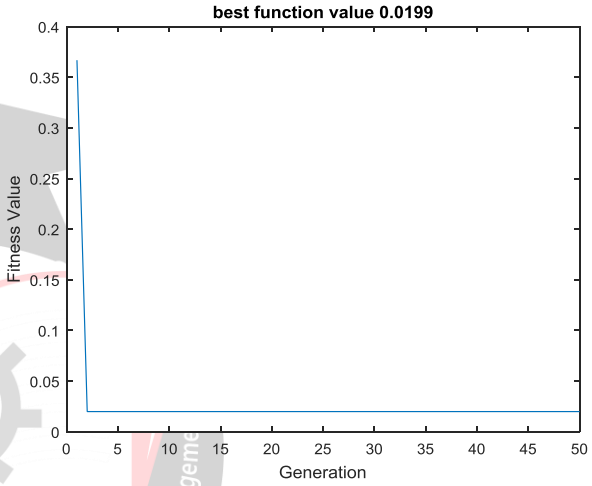


**Fig.5 (a). Convergence Characteristics of minimum power consumption**

In the simulation of BER minimization mode, the desired result is to get minimum error. The Fig 5(b) shows that as the number of generation increases, the fitness value gets reduced and we get the best optimized value at that point. This value is the best optimized value so that system can work efficiently. Fig 5(b) shows its best fitness value for BER by GWO.

It suggests that less amount of fitness function conclude to large amount of data transmission through the CR system.

Fig. 5(c) represents its best fitness value applied on GWO. The simulation of minimum interference mode is desired to get the result with minimum value.

The Fig. 5(d) shows that as the number of generation increases, the fitness value gets reduced and gets the best optimized value at that point. This value is the best optimized value so that system can work efficiently. Fig 5(d) shows its best fitness value for interference minimization by GWO.

The objective of the simulation in Spectral efficiency mode is to maximize the efficiency of spectrum at the maximum rate but the frequency requirement is less. At minimum

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fitness, the spectral efficiency is high so that at less frequency rate we can send maximum amount of information. Fig 5(e) shows the fitness value of maximum spectral efficiency.

**Table 3. Parameters for Simulation [7]**

| PARAMETERS | VALUES |
|---|---|
| Bandwidth | 2 to 32 MHz |
| Transmission power (P) | 0.158 to 251 Mw |
| Modulation index | 2 to 256 |
| Time division duplexing | 25 to 100% |
| Modulation type | QAM |
| Symbol rate (Rs) | 125 kbps to 1Mbps |

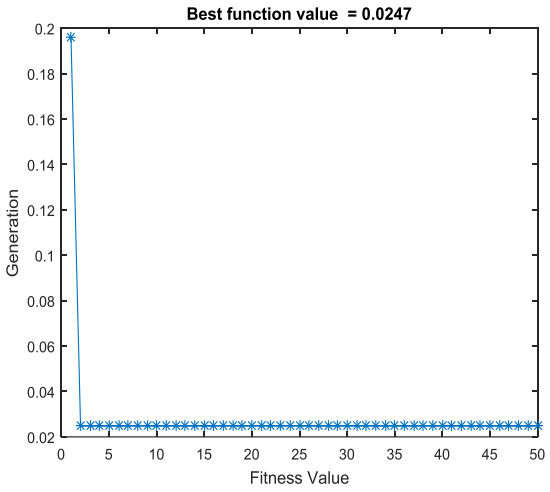


**Fig.5 (b). Convergence Characteristics of minimum BER**

**Table 4 Comparative Results obtained by GA, SA, SMO and GWO algorithm objectives.**[3,7]

| Objective modes | Algorithm | Transmitted power(mW) | Modulation index(M) | Bandwidth (MHz) | Time division duplexing (in%) | Symbol Rate(Rs) (in kbps) | Fitness Score |
|---|---|---|---|---|---|---|---|
| **Power Consumption Minimization mode** | GA | 04.39 | 256 | 02.04 | 31.40 | 698.01 | 0.071512 |
| | SA | 3.64 | 256 | 21.86 | 56.24 | 915.72 | 0.036618 |
| | SMO | 2.69 | 256 | 18.36 | 60.02 | 900.01 | 0.22876 |
| | GWO | 0.258 | 256 | 02.02 | 70.15 | 928.12 | 0.01992 |
| **BER Minimization mode** | GA | 16.83 | 256 | 02.01 | 65.60 | 839.98 | 0.090974 |
| | SA | 25.83 | 256 | 02.40 | 85.60 | 901.88 | 0.070041 |
| | SMO | 28.67 | 256 | 02.01 | 72.41 | 910.54 | 0.031325 |
| | GWO | 32.68 | 256 | 02.1 | 92.05 | 905.28 | 0.0247 |
| **Throughput Maximization mode** | GA | 04.41 | 256 | 02.00 | 43.40 | 812.18 | 0.039174 |
| | SA | 15.27 | 256 | 02.00 | 33.80 | 923.85 | 0.02380 |
| | SMO | 20.42 | 256 | 02.00 | 35.03 | 954.18 | 0.0161123 |
| | GWO | 36.17 | 256 | 02.00 | 50.18 | 973.02 | 0.011639 |
| **Interference Minimization mode** | GA | 07.66 | 256 | 02.00 | 65.80 | 353.48 | 0.030121 |
| | SA | 15.23 | 256 | 02.00 | 47.30 | 636.24 | 0.049242 |
| | SMO | 18.12 | 256 | 02.00 | 38.26 | 800.14 | 0.0127736 |
| | GWO | 25.41 | 256 | 02.00 | 34.61 | 875.43 | 0.011837 |
| **Spectral efficiency Minimization mode** | GA | 12.37 | 256 | 02.01 | 29.40 | 962.49 | 0.065183 |
| | SA | 34.57 | 256 | 02.00 | 59.60 | 999.18 | 0.019472 |
| | SMO | 38.24 | 256 | 02.00 | 71.57 | 922.81 | 0.0161197 |
| | GWO | 40.26 | 256 | 02.00 | 78.42 | 998.03 | 0.015825 |

Throughput is defined as the transfer of amount of information successfully through communication channel. The aim of this objective is to consume throughput is that the transmission rate of information is increases, when time reduces. Therefore, this is the reason for fitness function

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generated by the approached method i.e. GWO is less than the other method of optimization.

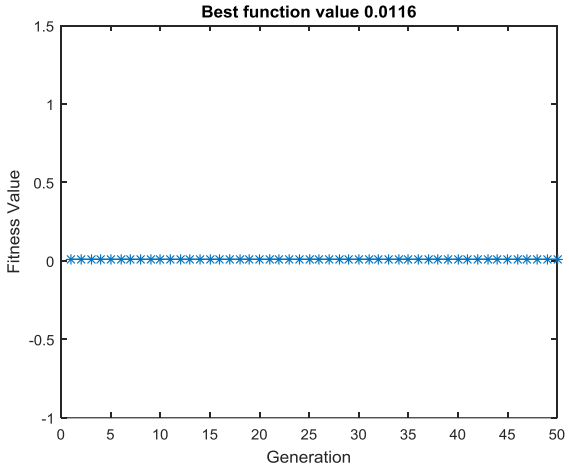


**Fig.5 (c) Convergence Characteristics in mode of maximum throughput**

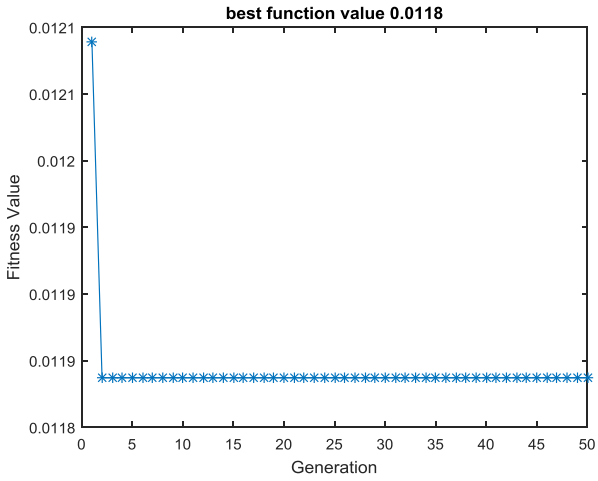


**Fig.5 (d). Convergence characteristics in mode of minimum interference**

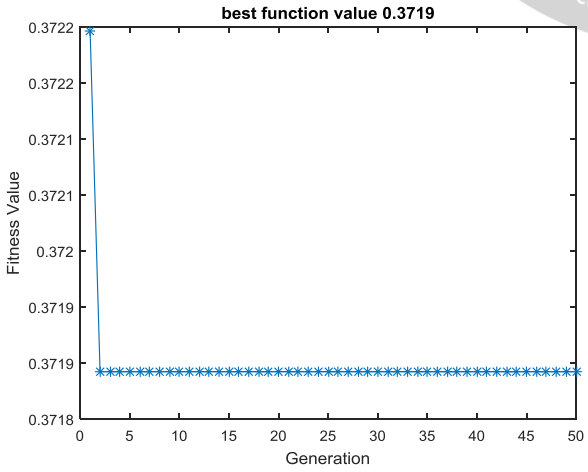


**Fig.5 (e) Convergence Characteristics in mode of maximum spectral efficiency**

## VII. CONCLUSION

The GWO has proposed to optimize the difficulty in CR system in this paper. GA, SMO, SA fitness value are compared with GWO and analyses each objective parameters. The primary goal of algorithm for optimization in cognitive radio structure is to adaptation or optimization of preferred objective and attains to minima and maxima locally. The simulation result is obtained after applying GWO to the objective parameters of cognitive radio system. Here are four different algorithms in different operating modes and compare their results. These algorithms are also applied to the same objective parameters for comparing the results. In the power consumption mode, BER mode, maximum throughput mode and maximum spectral efficiency mode, GWO performs better than other with less fitness score. In wireless communication, the noise interference must be very less and GWO signifies the least interference than existing algorithms. So we prefer GWO over the SMO, GA and SA. GWO algorithm is suitable for parameter optimization for better result than other existing algorithms.

There is various numbers of issues resultant from this area of work that can be persistent further.

- Numerous other probable nature inspired machine learning techniques present that can be applied to the CR system for further achievement and exploration of this working area.
- We can propose our new algorithm to get better results.
- There are various exploration exists if we change the weighting combination that will affects the performance of the system.
- The fitness function generated by the hypothetical equations that are not appropriate and occasionally cannot estimate the environmental parameters accurately.

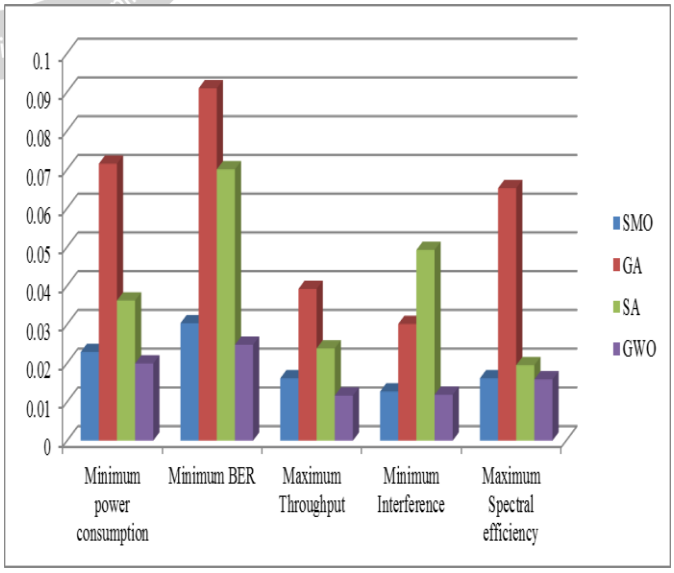


**Fig 6. Comparative fitness value for respective algorithms**

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