Simulation of QoS Parameters in Cognitive Radio System Using SMO Algorithm

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ABSTRACT- **Cognitive radio (CR) is the current growing technology in wireless communication field and has increase the ability to use the frequency spectrum more properly. The main objective of cognitive radios is to sense the surrounding and use primary user's vacant spaces and allot them to the secondary users without interference each other. This paper presents the optimal solution and optimizes the Quality of services (QoS) parameters to minimum i.e. smaller as compare other solutions which are induced by different optimization techniques Simulated Annealing (SA) and Genetic algorithm (GA). The proposed algorithm called spider monkey optimization algorithm (SMO). SMO is a swarm intelligence technique which works on foraging behaviour of spider monkeys. SMO is tentative and lapse based synergetic iterative process. Spider monkeys have been categorized as fusion-fission social structure (FHSS) based animals and they divides into smaller subgroups and search food. The proposed algorithm has been used to optimize the performance of QoS parameters in terms of minimum power consumption, minimum bit error rate (BER), maximum throughput, minimum interference and maximum spectral efficiency. The simulation results shows that the fitness scores obtained by the proposed algorithm i.e. SMO are better (smaller) than SA and GA algorithm in the optimization of QoS parameters of cognitive radio system. The proposed algorithm is better (smaller) than the existing algorithm.**

Keywords: Cognitive Radio, Fusion- Fission Social Structure, Genetic Algorithm, Quality of Services, Spider Monkey Optimization algorithm, Simulated Annealing

I. INTRODUCTION

In the last few years the number of users in wireless and mobile communications have been increasing day by day and due to these rapidly growing demand and increasing large number of users it cause the spectrum scarcity problem. The cognitive radio allows secondary users to use primary users bands but without interfering each other [1]. The FCC Federal Commission Communication [2] report shows that the spectrum has been used with new strategies i.e. spectrum is divided into licensed and unlicensed spectrum. Intialialy, when CR system came into existence it was realized that it utilizes frequency spectrum more accurately but the demands of usage of frequency spectrum has been increased with the large number of users. So in order to make it more reliable, time to time various optimization techniques comes to make it use more properly. Therefore, the optimization of cognitive radio in wireless communication network is a very important issue in the current wireless system. CR is first introduced by Mitola in 1999 [3], is a new technology to enhance the spectrum utilization and gives solution to the spectrum scarcity problem. Thus, CR is an intelligent device which continuously monitors the availability of frequency spectrum, sense the neighbour's presence and move to that channel while avoiding interference with licensed and unlicensed users. CR has conducted a change in wireless communication environment to control the spectrum scarcity problem and developing communication efficiency. Cognitive radio is generally executed with software defined radio (SDR) [4] which normally build up with machine learning and optimization algorithms that are able to perform with radio transmission parameters to fulfil environment requirements. Thus, DSA dynamic spectrum access [5] is also considered in cognitive radio system. The major purpose of use DSA is that it identifies the spectrum holes or white spaces and uses them for communication. However, for the proper utilization of frequency band and the secondary users use the primary users bands some quality of services parameters are also satisfied i.e. min power consumption, minimum bit error rate, maximum throughput, minimum interference and maximize spectral efficiency.

There are so many optimization algorithms works on improvement of QOS parameters such as simulated annealing, Genetic algorithm, ant colony optimization, particle swarm optimization [6-9] in which some works with three QoS parameters i.e. low power mode (minimum transmit power), emergency mode (minimum BER) and multimedia mode (maximum throughput) and others works with five objective parameters which are considered in this paper. SA works on five objectives and compares there result with GA and shows that SA is better than GA [6]. Ant colony optimization algorithm works on cognitive radio engine and gives their result after comparing with GA and shows that GA converges slowly as compare to ACO [7]. The proposed spider monkeys optimization algorithm works on five objective QoS parameters i.e. min power consumption, min BER, max throughput, min interference and max spectral efficiency. The same objective parameters are also performed by genetic algorithm and give their results. In this paper, Spider Monkey Optimization algorithm has been used first time to improve the parameters of CR system. SMO is very good in solving complex optimization problems. Thus SA in paper [6] had tested to optimization of CR system earlier and gives their results. In this paper, SMO has been applied to optimization of CR system and GA is also applying on the same parameters and has their own results. Therefore, SMO gives better results than that of GA and SA.

II. PROPOSED WORK

Spider Monkey Optimization algorithm is one of the latest swarm intelligence techniques. SMO is population based suppositious meta- heuristic and has been applied to solve complex optimization problems. SMO is latest algorithm as it is used in few problems up to now [10-13]. SMO algorithm is positioned on foraging behaviour of spider monkeys and this activity motivates JC Bansal [10] to gives description about SMO algorithm. The spider monkeys distribute according to fusion-fission social structures based animals (FFSS). They are social in behaviour and alive in groups of up to 40-50 individuals. They split it out into subgroups and formulate the procedure to examine the food. A female is head of the group and have answerable for food source; occasionally, if she does not get plenteous food for their group then she splits the group into smaller subgroups that explore separately. The head of smaller group is also a female and the group size of smaller subgroup range from (3 to 8) members per group. For communication the smaller subgroup members generally use visual and vocal cords. SMO algorithm works on behaviour of spider monkeys and gets optimization values with local maxima and local maxima. Thus optimization solution is used in many problems to get the perfect values.

A. Major steps of spider monkey optimization (SMO) algorithm:

There are some phases of spider monkey optimization algorithms which are regulate by the spider monkeys are listed below:-

1) Initialization phase: At initial stage, SMO originates existing range of spider monkeys presents in the group whose population is examined as 'N', where each spider monkey 'SM_i' i.e... (i= 1, 2…………N) is a vector of dimension having value D. At this moment, D is the number of variables used in the optimization problem and SM_i represents the ith spider monkey in the population. Each spider monkey SM corresponds to the possible solution of the values under considered the problem. Each SM_i is initialized as follows:

$$SM_{ij} = SM_{minj} + U(0, 1) * (SM_{maxj} - SM_{minj}) \quad (1)$$

2) Local Leader phase mode: After deciding initialization phase, local leader phase is the second phase. In this phase, the particular step occurs when every single spider monkey (SM) renews its actual position stationed on instruction of the local leader existence as well as local group member's existence. If the fitness value of the updated location is higher than that of the old location. Then the Spider Monkeys update its location with the evaluated new one. The location update equation used in this situation for ith SM is as follows:

$$SM_{newij} = SM_{ij} + U(0, 1) * (LL_{kj} - SM_{ij}) + U(-1, 1) * (SM_{rj} - SM_{ij}) \quad (2)$$

3) Global leader phase mode: Subsequently, fulfils the requirement of local leader phase, the global leader phase (GLP) comes the next one to starts. In GLP phase, all the SM's update their present location using existence of Global leader and local member's existence. The location update equation for this phase is as follows:

$$SM_{newij} = SM_{ij} + U(0, 1) * (GL_j - SM_{ij}) + U(-1, 1) * (SM_{rj} - SM_{ij}) \quad (3)$$

In this phase, the existing positions of spider monkeys are updated based on the action of probabilities, which are estimated using their fitness.

$$Prob_i = 0.9\ fitness/max\_fitness + 0.1 \quad (4)$$

4) Global leader learning (GLL) mode: GLL is the next phase, in this phase the present position of the global leader is renewed by applying greedy (insatiable) selection in the population presents in that particular area i.e. the region of the Spider Monkey having perfect or accurate fitness in the population is selected as the renewed position of the global leader. After that, it is noted that the global leader location is updating as per the requirement or not and if it is not updating the position correctly, then the Global Limit Count which is already selected is incremented by 1.

5) Local Leader Learning (GLL) mode: In LLL phase, the position of the local leader member is renewed by executing insatiable selection in that particular group i.e. the region of the SM having perfect fitness in that group is preferred as the renewed position of the local leader. Besides that the renewed position of the local leader is correlated with the old one and if the local leader is not renewed then the Local Limit Count is incremented by1.

6) Local leader decision (LLD) mode: In LLD phase, it determines that if any local leader member location is not renewed up to a present fixed threshold value called Local Leader Limit and then all the constituents of that group renew their existing positions either by random initialization or by using joined information from Global Leader and Local Leader through eq.2.5 based on the pr.

$$SM_{newij} = SM_{ij} + U(0, 1) * (GL_j - SM_{ij}) + U(0, 1) * (SM_{ij} - LL_{kj}) \quad (5)$$

It is clear from the above equation that the renewed dimension of this SM is turned on towards global leader and repels from the local leader. Thus the position update is changing and the member's existing position changes to new position.

7) *Global leader decision (GLD) mode*: GLD is the last phase in the SMO algorithm. In this phase, the global leader member location is checked simultaneously step by step and if it is not renewed up to a fixed number of iterations given called Global Leader Limit, then the global leader divides the population into smaller groups. Firstly, the population is divided into two groups and then three groups and so on till the maximum number of groups (MG) are formed. Each time in GLD phase, LLL process is originated to decide on the local leader in the recently fashioned groups. Sometimes, few conditions occurred in which maximum number of groups is formed and even then the position of global leader is not updated then the global leader combines all the groups to form a single group.

Algorithm 1: Spider Monkey Optimization Algorithm

Input: initialize population, LL_{limit}, global leader limit (GL_{limit}), perturbation rate (P_r)

Output: calculate fitness function
Step 1: BEGIN
Select local leader and global leader
Step 2: apply greedy selection based on fitness
Step 3: while (destruction rule is not fulfilled) do
Step 4: generate new position by self-experience, local and group member's experience
Step 5: apply insatiable selection process between existing position and newly generated position based on their fitness
Step 6: calculate the probability P_i
Step 7: Produce new position selected by probability P_i
Step 8: update position of local and global leader by using greedy selection process
Step 9: update the position of local leader by using local leader limit LL_{limit}
Step 10: update position of global leader by using global leader limit (GL_{limit})
Step 11: end while

III. COGNITIVE RADIO PARAMETERS, OBJECTIVES AND FITNESS FUNCTION EVALUATION

Cognitive radio is a technology which has real time interaction with the environment and this interaction helps to finds how users are communicate with in the CR system. CR produces some QoS parameters which defines how system has been utilized by users. CR system having transmission parameters, environmental parameters with this it utilize some set of service performance objectives.

A. Cognitive Radio Transmission and Environmental Parameters

1) Transmission parameters: operate as the selection variable of the CR system. These transmission parameters or selection variables must be well defined before developing fitness function of various objectives. For simulation of CR system optimization the transmission parameters performance range is used by the SMO algorithm and GA algorithm is given in table I.

TABLE I
SIMULATION PARAMETERS

PARAMETERS	VALUES
Transmission power (P)	0.158 to 251mW
Bandwidth (B)	2 to 32 MHz
Modulation index	2 to 256
Modulation type	QAM
Time division duplexing (TDD)	25 to 100%
Symbol rate (Rs)	125 ksps to 1Msps

2) Environmental parameters: These parameters produce information to the CR system on the surrounding environment characteristics. This sensed data helps the cognitive engine on making decision after calculating fitness function. The environmental parameters used in this paper are considered as bit error rate (BER), signal-to-noise ratio (SNR), noise power and channel loss.

B. Cognitive Radio Objectives

The radio system has different desirable objectives which improves the wireless communication environment. In this paper we will discuss five Cognitive radio objectives i.e.

- Minimize power consumption
- Minimize bit error rate
- Maximize throughput
- Minimize interference
- Maximize spectral efficiency

C. Fitness Function for Cognitive Radio System

For optimization of cognitive radio system, the fitness function should be assigned to monitor the searching direction. So to fulfil the desired targets, five different objectives QoS parameters have been formulated. It has to be noted that these objectives parameters are same that are formulated in previous paper [6-8]. The design goals have been kept same for comparison purpose.
The pseudo code for fitness functions are given below:

Algorithm 2: Fitness function of QOS parameters

Input: transmission parameters (P, M, B, TDD, Rs) considered for satisfying QOS parameters
Output: fitness function (x, w)
BEGIN:
Check QOS parameters requirements (min power, min B.E.R, max throughput, min interference, max spectral efficiency)
Define fitness functions x(1)= f_{min_power} , x(2)= f_{min_ber}, x(3)= $f_{max\_throughput}$, x(4)= $f_{min\_interference}$, x(5)= $f_{max\_spectraleff}$
Assign proper weight (w_1, w_2, w_3, w_4, w_5) for fitness function
While iteration <= $iteration_{max}$ **do**
Restore weight (w1, w2, w3, w4, w5) for each fitness function according to current channel conditions
While (f_p is optimized minimum) **do**
Calculate f_{min_power} = 1- P/P_{max}
End while
While (f_{ber} is optimized minimum) **do**
Calculate f_{min_ber} = log10 (0.5)/log10 (P_{be})
End while
While ($f_{throughput}$ is optimized maximum) **do**
Calculate $f_{max\_throughput}$ = 1 – log2 (M)/log2 (M_{max})
End while
While ($f_{interference}$ is optimized minimum) **do**
Calculate $f_{min\text{-}interference}$ = ((x (1) +x (3) +x (4))-(P_{min}+B_{min}+1))/ (P_{max}+B_{max}+Rs_{max})
End while
While ($f_{spectral\ efficiency}$ is optimized maximum) **do**
Calculate $f_{max\text{-}spectraleff}$ = 1-((x (2)*B_{min}*x (5))/(x (3)*M_{max}*Rs_{max}))
End while
While (final fitness calculated) **do**
Calculate final=w (1)*$f_{minpower}$+w (2)*f_{minber}+w (3)*$f_{maxthroughtput}$+w (4)*$f_{mininterfernce}$+w (5)*$f_{maxspectral}$
End while
END

IV. RESULT ANALYSIS

In this paper, the fitness function of performance objective parameters are simulated by using proposed algorithm SMO and the same objectives parameters are simulated by using GA algorithm and their results are compared with the existing algorithm i.e. SA algorithm results [6]. Thus, the simulation is carried out to evaluate different performance parameters such as power consumption, bit error rate, throughput, interference and spectral efficiency.

A. Minimize Power Consumption

In this objective parameter the amount of power consumed by the Cognitive Radio system is minimized.

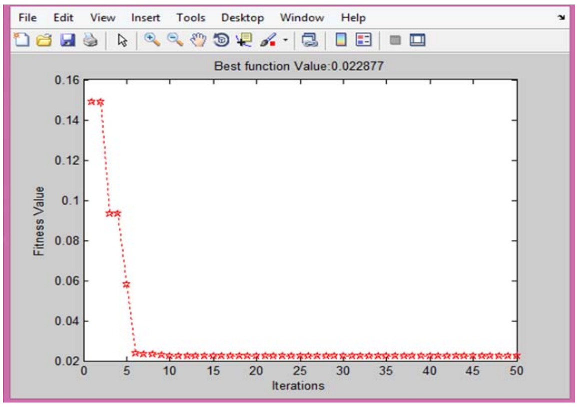

Figure 1(a): Fitness Function Convergence characteristics for minimum power consumption mode in case of SMO.

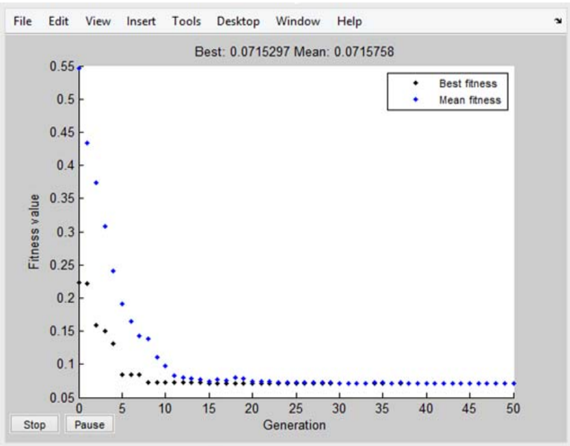

Figure 1(b): Fitness Function Convergence characteristics for minimum power consumption mode in case of GA.

The simulation results obtained by the proposed algorithm SMO and the GA are shown in figure 1 (a) and (b). These figures show the variation of iteration and generation with the fitness value. When the number of iterations in case of SMO and number of generation in case of GA is increased then the fitness value is reduced to minimum. So, the lesser the amount of fitness value obtained from the algorithm the system works more accurately.

B. Minimum Bit Error Rate (BER)

The bit error rate (BER) is the number of bit errors per unit time. The bit error ratio is the number of bit errors divided by the total number of transferred bits during a studied time interval

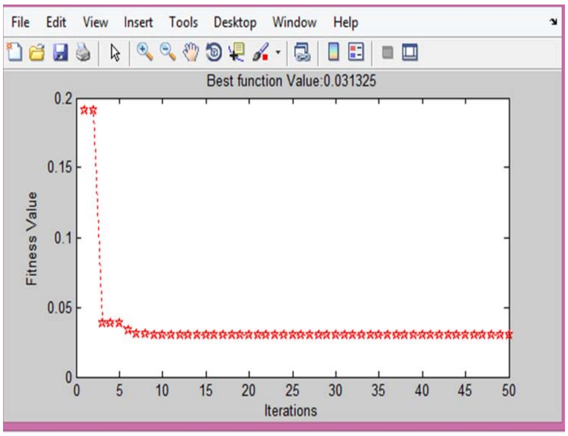

Figure 2(a): Fitness Function Convergence characteristics for minimum bit error rate mode in case of SMO

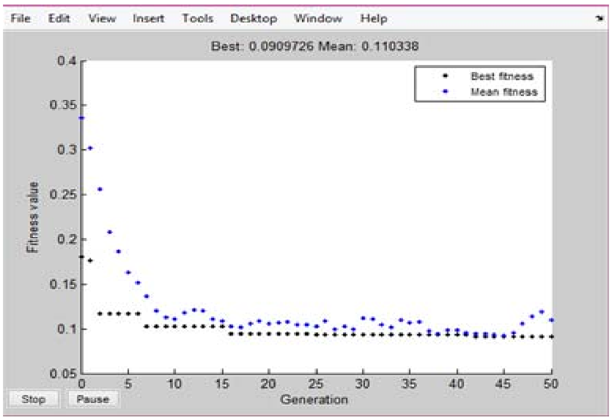

Figure 2(b): Fitness Function Convergence characteristics for minimum bit error rate mode in case of GA

C. Maximize Throughput

Throughput is the rate of successful message delivery over a communication channel. The main objective of use of throughput is that the overall transmission data through the system is increased with lesser no. of time. That is why the fitness function obtained by proposed algorithm i.e. SMO is less than other optimization technique. The main motive of less amount of fitness function is that the larger number of data is transmitted through a system.

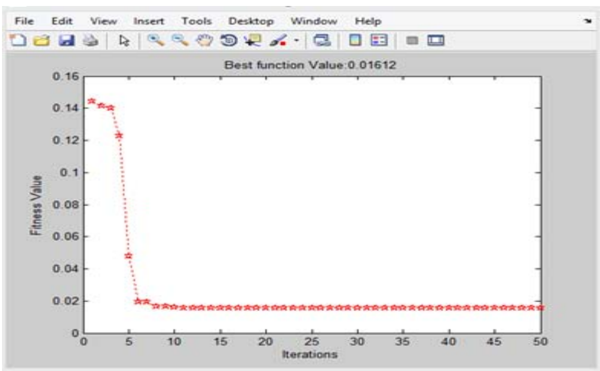

Figure 3(a): Fitness Function Convergence characteristics for maximize throughput mode in case of SMO

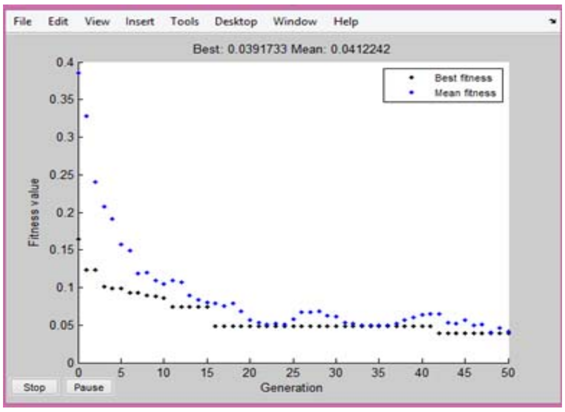

Figure 3(b): Fitness Function Convergence characteristics for maximize throughput mode in case of GA

D. Minimum Interference

The one of the objective of CR system is interference. The different optimization algorithm had already worked on minimizing the interference. Thus the main goal is only that to reduce the radio's interference contributions

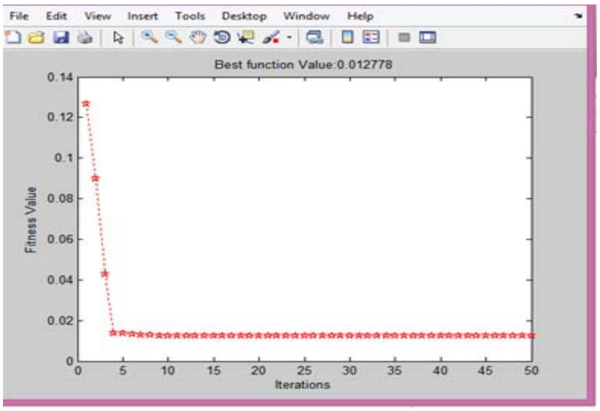

Figure 4(a): Fitness Function Convergence characteristics for minimum interference mode in case of SMO

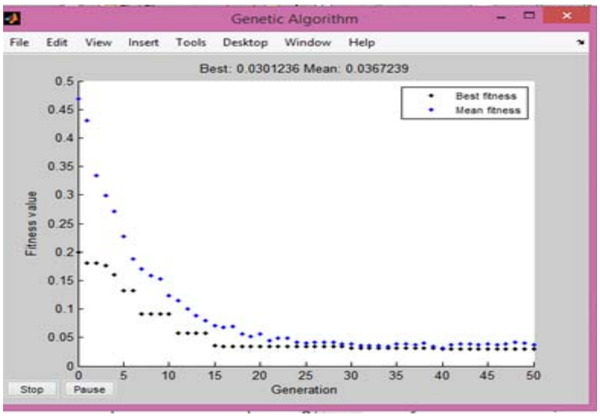

Figure 4(b): Fitness Function Convergence characteristics for minimum interference mode in case of GA

E. Maximum Spectral Efficiency

Spectral efficiency refers to the information rate that can be transmitted over a given bandwidth in a specific communication system. The main objective of use of spectral efficiency is that it maximizes the efficient use of the frequency spectrum.

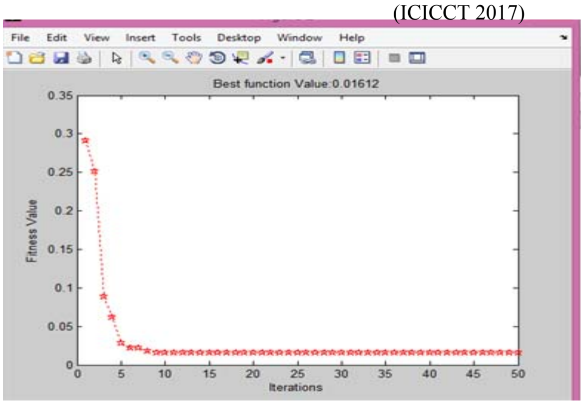

Figure 5(a): Fitness Function Convergence characteristics for maximize spectral efficiency mode in case of SMO

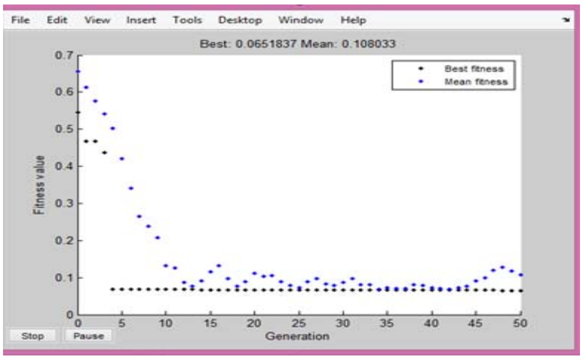

Figure 5(b): Fitness Function Convergence characteristics for maximize spectral efficiency mode in case of GA

The fitness function convergence characteristics for different performance objective are performed by proposed algorithm SMO for certain QoS parameters and same parameters are also apply for GA are shown in figure 1 (a & b), 2 (a & b), 3 (a & b), 4 (a & b) and 5 (a & b) respectively.

Thus, the proposed algorithm technique SMO and also GA algorithm apply for same objective parameters having fitness functions are compared with the existing algorithm i.e. Simulated annealing from the previous paper [6].

Table II
COMPARISON TABLE OF DIFFERENT OPTIMIZATION TECHNIQUES

Scenarios	**Spider Monkey Optimization algorithm**	**Genetic algorithm**	**Simulated annealing**
Minimum power consumption	0.02287	0.07151	0.03618
Minimum bit error rate	0.03132	0.09097	0.070041
Maximize throughput	0.01611	0.03917	0.02380
Minimum interference	0.01277	0.03012	0.04924
Maximum spectral efficiency	0.016119	0.06518	0.019472

The table II shows the comparison results obtained by techniques SMO and GA algorithm with the SA algorithm. These results show that the SMO algorithm is better (smaller) than the other two techniques in different scenario.

V. CONCLUSION

In this paper, we have proposed SMO algorithm to minimize the optimization problem in CR system. The main aim of using optimization algorithm in CR system is to optimize the desired objective and reached them to local maxima and local minima. The simulation results are obtained after implementation of SMO algorithm to the CR system. The GA is also applying to the same fitness objectives parameters and has results. Thus, the comparative study of proposed algorithm SMO and GA to the existing algorithm SA shows that the fitness score obtained by SMO algorithm is better (smaller) as compared to the SA and GA.

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