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Optimization of QOS Parameters in Cognitive Radio: A Survey

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Abstract—*Radio Cognitive (RC) technology is an innovative Technology which allowing the Unlicensed users to use the vacant spectrum when Licensed users are not using spectrum. In wireless communication scheme, the demands of users have been increased day by day so, it is essential to designing the Radio Cognitive (RC) based system. The main motive of this paper is to investigate and calculate the Quality of Services (QoS) parameters with their cost function. In certain area research of the cognitive radio has been done and investigates the usage of QoS parameters must discuss in this paper. The computationally efficient optimization algorithms like Genetic Algorithm, Simulated Annealing Algorithm Optimization (SA), Biogeographic based optimization (BB0) and BAT Algorithm Optimization used in literature to improve the quality of services parameters in Cognitive Radio are also discussed.*

Keywords*: Cognitive Radio, Quality of Services, Genetic algorithm, Simulated Annealing algorithm, BBO algorithm and BAT Algorithm, Multi objective.*

1. INTRODUCTION

In wireless communication, Radio Spectrum is one of the important and usable sub-sections of electromagnetic spectrum. It extended from frequency ranges of 3 Hz to 3000 GHz. The frequency range for the same is 3 Hz to 3000 GHz. Recently; the radio spectrum faces interference problems due to high user demand of data. Thus, the radio spectrum is regulated by national laws and is also synchronized by ITU in order to avoid the problem of interference [1]. It has been observed that the spectrum lies free for most of the time and is heavily occupied for the rest of the time, due to which, the spectrum scarcity problem arises. So, in order to avoid this problem, a technology called Cognitive Radio has been introduced.

The radio spectrum is used by two types of users, one is Licensed users and the other is Unlicensed users. The Licensed users do not use the spectrum for whole time, so sometimes the spectrum lies free which causes the problem of spectrum scarcity [2]. Consequently, to resolve this problem of spectrum scarcity, a new technology known as "Cognitive Radio" was introduced by J. Mitola in 1999. Cognitive Radio is an adaptive, intelligent radio that automatically detects the best available channels in radio spectrum and shifts the users to that particular channel [3].

In November 2002, FCC published a report about the design of a new spectrum that had been introduced to resolve the congested in frequency band. It allows the unlicensed users to use the licensed band as per the availability. So, efficiently utilization of radio spectrum is the main reason behind the designing of CR [4]. Previously, the mobile systems were statically assigned with the radio access network and the spectrum bands by using conventional wire systems. Due to this system, only some part of band faced overcrowding while the other parts were left with low traffic. Thus, the capacity and control of wireless system can be improved to a desired level at the time of using dynamic spectrum and also the use of limited radio resources can be optimized [5].

The four main purposes of Cognitive Radios are Spectrum sensing, management of spectrum, mobility of spectrum, and sharing of spectrum.

- **Spectrum sensing -** Sensing the spectrum is one of the main functions of CR. It identifies the unused spectrum and shares it with the user without any harmful interference.
- **Management of spectrum -**It takes care of the requirements of the user and provides them the best accessible channel for communication.
- **Mobility of spectrum -** It's main function is to define the process, when the radio users exchange their operational frequency. Basically, it targets the use of the spectrum in active manner and provides the best channel to users.
- **Sharing of spectrum** - It provides an effective spectrum scheduling method by allowing the cognitive radio users to shares spectrum bands of the primary users.

Apart from this, the Cognitive Radio system also fulfills the Quality of Services parameters. So, the unlicensed users can

easily use the empty bands of the licensed users. There are five QoS parameters, namely - Minimization power consumption, Minimization bit error rate, Maximization spectral efficiency, Minimization interference and Maximization throughput.

2. LITERATURE REVIEW

Seshadri Binaya Behera *et. al*., [6] proposed the Particle Swarm Optimization (PSO) Technique which is used to optimize the Quality of Services parameters of Radio cognitive system and these QoS parameters are useful to increase the efficiency of electromagnetic spectrum. This work of author in this paper is basically on problem of resource allocation and the swarm increases the fitness value by using the huge number of particles.

Ismail AlQerm *et. al*., [7] introduced an optimization scheme i.e Adaptive multi objective optimization scheme (AMOS) – this scheme used for the resource management of Cognitive Radio so as to increase the utility of spectrum and evaluate the performance of the network. In this paper, this optimization scheme is engaged for the phase of optimization in the radio's decision making engine by using six objectives, functions and Adaptive Multi objective Optimization Scheme uses adaptive Genetic algorithm for estimating definite parameters like Minimum power consumption Mode, Minimum delay Mode, Minimum Bit Error Rate (BER) Mode, Minimum Interference Mode, and Maximum Spectral efficiency Mode and Maximum throughput Mode. After that, we compare this optimization scheme with other meta-heuristic techniques such as mutated Ant colony optimization (MACO), Artificial Bee colony algorithm (ABC), Particle Swarm Optimization (PSO) and Genetic algorithm proposed by Newman and accomplishes the maximum score of objectives and the fastest convergence technique compared with other techniques.

Kiranjot Kaur *et. al*., [8] works on the optimized Quality of Services (QoS) parameters of radio system using Simulated Annealing optimization technique. In this paper, Simulated Annealing has been used to encounter the quality of services (QoS) parameters that are determined by the users in terms of maximum throughput mode, minimum transmit power mode, minimum Bit Error Rate mode, maximum spectral efficiency mode and minimum interference mode. Then, after simulation results obtained by simulated annealing and compared with the cost function of objective and various QoS parameters of genetic algorithm and it has been observed that Simulated Annealing is outperforming the Genetic Algorithm for optimization in Cognitive Radio system.

Ali h.Mahdi *et. al*., [9] proposed the Optimization of Adaptive Discrete Particle Swarm and the author has discussed about the Genetic Algorithm (GA) as a recognized evolutionary algorithm for adaptation and Cognitive Radio (CR) systems optimization. The convergence speed in Genetic algorithm is generally slow. So, the conventional Particle Swarm Optimization (PSO) has been used in the radio systems but it only decreases the computational cost of Genetic Algorithm. The research is based on Adaptive this algorithm for variation of transmission parameters of system and

Attainment the Quality of Service (QoS) parameters are requirements of a Cognitive Radio node using optimization of Multi Objectives. Hence, obtained Simulation results indicated that ADPSO has fastest convergence speed and high values of cost function and these cost functions are compared to Genetic Algorithm and the conventional Particle Swarm Optimization.

Nan Zhao *et. al*., [10] presented the optimization of cognitive radio using mutated ant colony optimization (MACO) techniques. The study of paper was based on the technology of cognitive radio system and in previous years the optimization of cognitive engine using the genetic algorithm (GA) optimization technique. The study of CR related papers gives the idea that the GA convergence of Genetic algorithm is slow and performance of CR can still be enhanced by using MACO technique. MACO algorithm gives the brilliant performance when it is applied to the radio engine. The simulation obtained results of MACO algorithm shows that the cost function obtained by the cognitive radio engine is better than the Ant Colony Optimization.

Kiranjot kaur *et. al*., [11] proposed the optimization of cognitive radio using BAT algorithm (BA) optimization technique. Optimization of a multi user radio cognitive in a dynamic fading environment, especially Nakagami m fading has been introduced in this paper. The cost functions have been reformed to comprise the effects of fading. BAT algorithm is applied to optimization of the transmission parameters of the multiple secondary users. Standard IEEE 802.22 WRAN has been monitored to decide the range of multiple secondary users' parameters. The comparison of the obtained Results of BAT algorithm with the ones procured by Ga, Sa and Bbo algorithm to show that Bat algorithm's upper hand in the optimization of cognitive radio.

Table 1: List of algorithm worked on QoS Parameters

optimization Algorithm	Authors	QoS Parameter	Publication Year
Genetic Algorithm [12]	T. R. Newman*, Brett A. Barker*,	BER, Power consumption, Throughput	2007
Genetic Algorithm [13]	Timothy R. Newman* and Joseph B. Evans*	Spectral efficiency, Interference, BER Throughput and spectral efficiency	2008
Binary ant colony Optimization [14]	Muhammad Waheed*and Anni Cai*	BER, Power consumption, data rates	2009
Particle swarm Optimization [15]	Zhijin Zhao*, Shiyu Xu*, Shilian Zheng* and Junna Shang*	BER, Power consumption, Throughput	2009

Mutated ant colony [10]	Nan Zhao*, Shuying Li* and Zhilu Wu*	Multimedia mode, Low power mode, Emergency mode	2011
Adaptive Discrete PSO [9]	Mohamed A. Kalil* and Andreas Mitschele*-Thiel	Power consumption, data rate, Bit Error rate	2012
Genetic algorithm [16]	Ankit Awasthi*and Vipul Awasthi*	Quality of services, bandwidth, noise-Delay, received signal strength indictor	2013
Simulated Annealing [8]	Kiranjot kaur*, munish Ratan*, and Manjeet Singh Patterh*	Spectral efficiency, BER, Throughput Interference, Power consumption	2013
Adaptive multi objective [7]	Ismail AlQerm*and Basem Shihada*	BER, Spectral efficiency, throughput, Power consumption, Interference	2014
Biogeography Based optimization Technique [17]	Kiranjot kaur*, munish Ratan*, and Manjeet Singh Patterh*	Power consumption, spectral efficiency BER, interference, throughput	2014
Particle Swarm optimization [6]	Seshadri Binaya Behera*	Power consumption, Interference, BER Throughput, spectral efficiency	2015
BAT algorithm optimization	Kiranjot kaur*, munish Ratan*, and Manjeet Singh Patterh*	Power consumption, interference, BER throughput, spectral-efficiency	2017

3. QOS PARAMETERS OF COGNITIVE RADIO

Quality of services (QoS) parameter is one of the main issues that have been identified in the Cognitive Radio. The primary users of CR system has license to use the radio spectrum but the secondary users does not have any license to use the radio spectrum accordingly. Only when the spectrum is lying free then the secondary users have authority to usage the radio spectrum. Therefore, the QoS parameters are responsible to make sure that the unlicensed users can communicate without the interference with licensed users and the more number of unlicensed users can use the radio spectrum of CR system.

There are five QoS parameters that has to be fulfilled the licensed users and unlicensed users are given

- Spectral efficiency parameter
- Interference parameter
- Throughput parameter
- Bit Error Rate parameter
- Power Consumption parameter

- **Spectral Efficiency Parameter:** This parameter gives the knowledge about the signal that can be transmitted over a specified bandwidth for the improvement of system. The cost function of spectral efficiency parameter is given as

$$f\,mx\ spectral\ eff = 1-(M\times Bmin\times Rs)/(B\times Mx\times Rx) \quad (1)$$

where, B specifies the bandwidth, Bmin is the Minimum bandwidth and Bx Maximum bandwidth, TDD denoted the Time division duplexing, and the maximum symbol rate is denoted by Rx

- **Interference parameter:** Interference parameter must be reduced for better communication**.** The cost function for interference parameter is given as

$$f\,min\ int = \{(P + B+TDD) - (Pmin + Bmin +1)\}\ /(Px + Bx + Rx) \quad (2)$$

where, B specifies the bandwidth, Bmin is the Minimum bandwidth and Bx Maximum bandwidth, TDD denoted the Time division duplexing, and the maximum symbol rate is denoted by Rx

- **Throughput parameter:** The rate at which the signal can be effectively transmitted through the CR system is named as throughput. The cost function of Throughput parameter is given as

$$f\,max\ throughput = 1-\log2\,(M)/\log2(Mx) \quad (3)$$

where, M indicates the Single Carrier Modulation Index and (Mx) denotes the Maximum Modulation index.

- **Bit Error Rate parameter:** It gives the information about the number of bit errors created in per unit time, that should be decreased and improvement of the overall Bit Error Rate in the transmission. The cost function for bit error rate parameter is given such as

$$f\,min\ ber = \log10\,(0.5)/\log10\,(Pbe) \quad (4)$$

Where, (Pbe) specifies the probability of the bit error.

- **Power Consumption parameter:** The total amount of power use in the system should be reduced. The cost function of Power consumption parameter is given as

$$f\,min\ power = P/Px \quad (5)$$

Where, P denotes the Average Power of system and Px is available maximum power of the system.

4. OPTIMIZATION TECHNIQUES

Optimization is a process which uses the best values of inputs so as to obtain the Maximum/Minimum value of output with smaller amount. Optimization is normally based on the behaviour of nature like animals, ants, flies, bacteria's and many more that's why it is named as swarm intelligence optimization and evolutionary techniques based on evaluation of biologically like Reproduction, Selection, Recombination and mutation .

After studying the literature view of many researchers in their research in Cognitive Radio, we can state that numerous optimization algorithms has been used such as -BAT, BBO,SA and GA to optimize the QoS parameters of CR.

In our survey we have considered few algorithms and discussed about them.

A. Ant colony Optimization

Ant Colony Optimization (ACO) technique is first time introduced by Dorigo and Di Caro [18]. This algorithm is basis on the foraging behaviour of the real ants so this algorithm is called ACO algorithm. The main aim of the real ants is to finds the shortest path between the food and their nest.

ACO Meta heuristics technique is based on the co-operative approach of foraging of real ants. This method contains, some artificial ants perform a sequence of processes iteratively. An artificial ant tracing out a specific path selecting probabilistically one element at a time, until obtains an entire solution vector. Nan Zhao *et. al*. [10] first time applied ACO algorithm for optimization of cognitive radio and then after they are proposed MACO (mutated ant colony optimization) algorithm to find the results. In the previous papers cognitive engine problem were solved by using genetic algorithm but they indicate that the convergence of Genetic algorithm is slow so they applied MACO to the cognitive engine problem to get the better results.

Muhammad Waheed *et. al*. [14] used the binary version of optimization of ant colony optimization algorithm. The researchers compared their obtained results with GA and it shows that their simulation results of this algorithm are better than genetic algorithm in terms of Convergence speed and also cost function value.

B. Simulated Annealing

Simulated Annealing (SA) Algorithm is inspired by an analogy to annealing of solids. In 1953, Metropolis proposed this algorithm. The SA algorithm in this paper simulates the cooling of material in a heat bath. This process is called annealing [19]

Kaur *et. al* [11] proposed the optimization of cognitive radio system using Simulated annealing technique and this is applied to several combinatorial optimization problems. The basic idea of SA analogy is the approach which freezing the Liquids and formerly crystallize. If the liquid at the high temperature then their molecules are moves freely with respect to each other. When the liquid temperature is lowered, then the molecules of liquid lost their movement and liquid initiates to solidify. The molecules of the liquid arranged in the crystallize structure, if the liquid is cooled slowly enough and the liquids is cooled rapidly then crystallize structure liquid does not form, but in its place formulae a solids whose molecules of liquid will not be in the minimum energy state so this algorithm aims to attain a global optimal by slowly converge to get a final solution.

C. Biogeography based Algorithm

In 1960s, Edward Wilson and Robert MacArthur began working together on mathematical biogeography models, their work culminating with the classic 1967 publication the Theory of Island Biogeography [20].

Kaur *et. al*. [18] proposed the optimized the CR using of Biogeography Based Algorithm (BBO).This is a global optimization algorithm that is stimulated through the biogeographic Science. The mathematical biogeography model describes how the species arises, migrates from one habitat (Island) to another habitat. BBO algorithm searches for the global optimal value mainly finished by two steps: First step is Migration and second step is Mutation. These steps regulated by Immigration rates and Emigration Rates of the species in the habitat and also usage the sharing the information between the species habitats. It has been applied to Cognitive Radio system for optimization of its various transmission parameters to meet the Quality of service that are defining by the user named power Mode, Bit Error Rate Mode, Throughput Mode, Interference Mode and Spectral Efficiency Mode. Using biogeography-based optimization algorithm, the obtaining results are compared with the results of genetic algorithm (GA) for the several Transmission parameters.

D. BAT Optimization

BAT Algorithm (BA) is a meta-heuristics Algorithm for global optimization. BAT Algorithm is first time introduced by Xin – She Yang in 2010 [21]. This algorithm is inspired by the echolocation Behavior of Micro bats, with the varying Emission pulse rate and loudness based stochastic optimization technique produces the social behavior of insects.

Kaur *et. al*. [19] uses BAT Algorithm for optimization technique to solving the cognitive radio (CR) optimization problem. This algorithm has been applied to Cognitive Radio system, since channels of licensed band allocating the primary users are affected by the Nakagami-m fading [22]. The Nakagami-m fading affected channel is being sharing by a number of secondary users, while trying to them avoiding interference between them. The optimum transmission parameters of cognitive users have been attained by forming multi-objective cost functions to achieve the desired parameter of quality of service (QoS) in terms of Minimizing transmit power, Minimizing BER, Minimizing interference, Maximizing spectral efficiency and Maximizing Throughput .

Table 2 shows the comparison between GA, SA, BBO algorithm and BAT algorithm and the information used for this is being depicted from the literature review. As Optimization of CR system is considered to be a problem minimizer, therefore decreasing cost function indicates the better performance of BAT Algorithm. Even the values of the cost function obtained by using this algorithm are also more optimized as compared to the obtained results by other three techniques. In addition that, the single objective value of each mode is also better in BAT algorithm.

Table 2: Comparative Analysis of Algorithm

Scenario Operating Modes	Values of Cost and single objective functions	Genetic Algorithm [8] and [11]	Simulated Annealing Algorithm [8]and [11]	Bio-geographic based optimization Algorithm [17] and [19]	BAT Algorithm [11]
Maximizing Spectral Efficiency Mode	Cost Function	0.0380	0.0194	0.0251	0.0164
	Power	0.9577	0.9992	0.9823	0.9995
Minimizing Interference Mode	Cost Function	0.0786	0.0492	0.015	0.0130
	Bit Error Rate	2.2643e-009	4.5974e-10	0.0010	1.1723e-009
Maximizing Throughput Mode	Cost Function	0.0635	0.0238	0.0187	0.0178
	Throughput	1	1	1	1
Minimizing Bit Error Rate Mode	Cost Function	0.0867	0.0700	0.0425	0.0417
	Interference	0.06281	0.0448	0.0338	0.0311
Minimizing Power Mode	Cost Function	0.0547	0.0366	0.0308	0.0265
	Spectral Efficiency	0.0175	0.0145	0.0158	0.0088

5. CONCLUSION

This paper represents the optimization of Quality of Services (QoS) parameter of radio system using different algorithms. Cognitive radio is emergent technology in the existing world, thus the overall discussion is about increasing the efficiency of system by using different types of optimization technique namely genetic algorithm, simulated annealing algorithm, and Biogeographic based algorithm, BAT algorithm and comparison of the literature results. To improve the QoS parameters the authors used different algorithms in literature in this field and a certain improvement outcomes is given such as GA, SA, BBO, BAT, have some features in expressions of finding the best cost function of five Modes of objectives and in order to gives the solution of complexity of problems.

At end, after studying the literature review carefully, we can conclude that the BAT algorithm is best algorithm among the other algorithms discussed in the paper.

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