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Cognitive Radio Spectrum Management

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***Abstract*—**The emerging Cognitive Radio is combo of both the technologies i.e. Radio dynamics and software technology. It involve wireless system with efficient coding, designing, and making them artificial intelligent to take the decision according to the surrounding environment and adopt themselves accordingly, so as to deliver the best QoS. This is the breakthrough from fixed hardware and fixed utilization of the spectrum. This software-defined approach of research is centralized at user-definition and application driven model, various software method are used for the optimization of the wireless communication. This paper focused on the Spectrum allocation technique using genetic algorithm GA to evolve radio, represented by chromosomes. The chromosomes gene represents the adjustable parameters in given radio and by using GA, evolving over the generations, the optimized set of parameters are evolved, as per the requirement of user and availability of the spectrum, in our prototype the gene consist of 6 different parameters, and the best set of parameters are evolved according to the application need and availability of the spectrum holes and thus maintaining best QoS for user, simultaneously maintaining licensed user rights. The analyzing tool Matlab is used for the performance of the prototype.

***Keywords*—**ASDR, Cognitive Radio, QoS, Spectrum.

I. Introduction

WIRELESS communication is increasing exponentially in last few years and the mobile communication adds as the catalyst to this revolution. *Electromagnetic spectrum* being natural resource, limited availability, and exponential demand are licensed by the different Government bodies like FCC (in U.S, etc.) in different Countries and since it is one of the major source of revenue it is always in hot spot for both government and Researchers, regular monitoring of these Spectrum shows that some spectrum are fully utilized, some are partially and mostly underutilized. This reports leads to new thought process, how to utilize the underutilized spectrum and fill the S*pectrum holes i.e.* the holes are the band of frequencies of primary user (Licensed user) at particular time when they are not utilized by the user, these gaps can be used by the secondary user (Benefiter) such that the primary user is not being disturbed nor his rights are compromised. Though research are ongoing on this subject long back, the term Cognitive radio is coined by the Joseph Mitola in 1999 [1]. He defined CR as smart radio that adopts itself according to the environment and user requirement, a smart radio that uses the licensed bandwidth when it is not utilized by the licenser; by doing so it can smartly utilize the bandwidth without violation of the licensed user usages. The CR life cycle includes the spectrum sensing, spectrum analyzing and decisions making [2]. This paper proposes the adoption method so as to adjust the radio parameters depending upon their best selection from the random gene parameters on the physical layer and we are moving forward to include the link (MAC), network and transport and application layer in our future work.

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II. Multi-objective Genetic Algorithm (MOGA)

A. Genetic Algorithm

The concept of GA was developed by Holland and his colleagues in the 1960s and 1970s [3]. GA simply explains representation of the data in chromosomes and gene form, manipulation of the data, selection mechanism for the best set of gene from the random data depending upon their fitness (using various fitness function), use of the operators for crossover and mutation, survival of chromosomes from generation to generation, and evaluation function to measure the fitness of the chromosomes. The first multi-objective GA, called vector evaluated GA (or VEGA), was proposed by Schaffer [4]. Later, several multi-objective evolutionary algorithms were developed including Multi-objective Genetic Algorithm (MOGA) [7], [15]-[17]. The genetic algorithm described in [6], the smallest unit, of which, is gene, each gene controls one or more properties of an individual and set of genes forms the chromosomes and collection of chromosomes form the population, the GA uses operators known as crossover and mutations. The GA initializes the population randomly and after selection of two chromosomes known as the parents, according to the fitness on crossover produces new child with new and modified set of chromosomes that carry genes from either parents in random order or the process continuously produces the best set and eventually move towards the best solutions. Over a period, the generations become stagnant and through the mutations, changes at the gene level are done so as to produce new variation in the population i.e. according to changes in the environment or requirement of individual. Mutations play a vital role in escaping population from the local optima and thus reintroducing genetic diversity back into the population increases the possibility of retaining good solutions and global optimal values.

B. MOGA

The genetic algorithm used for different parameters simultaneously i.e. parallel computing with constraints is known as MOGA.

In case of radio wireless communication the parameters are important and deciding factors for effective transmission of data, the parameters such as Frequency, Data rate, Modulation type, BER, Code rate, Signal power [9] are some of the important factors that affect transmission. All these parameters effect individually or globally on each other. Since their percentage can vary according to the need and availability of the spectrum, MOGA is effective algorithm approach to autonomously adopting radios. Recent research [9] also shows that fitness function plays vital role in the GA. This paper proposes three basic models depending upon the user type and accordingly the results are studied, all three models use MOGA for solving the fitness function and finding out the best available set of parameters.

III. Spectrum Optimization

A. Cognitive Radio

The CR technology is considered for the real time transactions. It consists of three basic modules Spectrum Sensing, Spectrum Predicting and Spectrum management. Fig. 1 shows the Cognitive Radio Cycle.

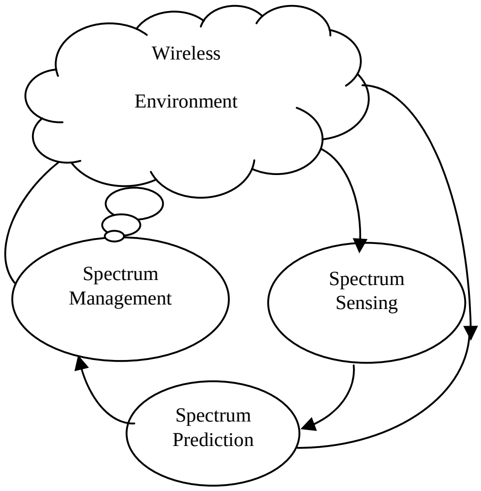

Fig. 1 Cognitive Radio Cycle

The Software defined process does continues scanning of available spectrum (Spectrum Sensing) [5], [10], [14] and figure out the spectrum holes [18] available between them, on the basis of which the future spectrum holes are predicted (Spectrum Prediction) and the data needed to be transferred are adjusted accordingly; depending upon the availability of holes, (Spectrum Management). Spectrum Management manages user requirement, sending of the data through the best set of available holes depending upon selection through various fitness functions, follow of compatibility norms with each other and with hardware, checking of the user data for noise and interference that can harm the licensed transmission, follows licensed norms and regulation, various Government regulations, user friendly, *environment friendly*, and most importantly QoS. As described in section II above, the Genetic Algorithm are well suited for solving multi-objective optimization and decision problems, these are reasons for taking GA for solving the radio's adaptive process.

B. Chromosomes Structure

In this paper Wireless communication uses the Genetic algorithm for solving multi-objective solutions, the PHY and MAC layer parameters described in IEEE 802.1 explained in [11], [12] are represented as traits encapsulated in genes of the chromosomes Fig. 2.

Power	Frequency	BER	MOD	Data Rate	COD

Fig. 2 Six Parameters Showing the Chromosomes Structure

Each chromosome is represented as shown in Fig. 2 and it is a set of gene represented in the form of real values and integers. Process consists of

1: Generation of the random matrix [8], population of chromosomes.
2: Selection of the best set chromosomes using the fitness function
3: Crossover of the chromosomes
4: Mutations for variation in the population
5: Termination of the loop till the given number of generations or desired result.

C. Fitness Function

It is the filter for selection of the chromosome for the next generation, it is the function that help to remove the weak and below the specification chromosomes and increase probability of best, optimized and desired set of chromosomes, for the next generation, thus maintaining the QoS. We have used three types of the function for the selection of optimized set of chromosomes:

1: User has fixed type of data and values are known to the user.
2: User knows the priority of the traits in terms of percentage.
3: User requirements as well as availability of the spectrum continuously changing, future holes perditions are done on the basis of the previous holes present and result of one generation becomes QoS Value for the next generation.

TABLE I
Comparison Chart for Various Types of User

Details	Value Known	Priority in Percentage	Requirement continuously changes
User type	Particular type of signals	Signals varies	Signals varies
Results	Specific	Average	Approximate
Interface	Give the values	Give the priority in form of percentage	Easy to work
Area of Work	Spectrum fixed	Some Type of Spectrum	Used for the vast range.

D. Spectrum Allocation Process

The theme of our work is spectrum management and optimization. This involves the user to enter its QoS requirements of the application it is using. The continuous scanning of the RF Environment is done by CR receiver and on that basis the spectrum holes are predicted; on analyzing the spectrum holes [13] and comparing them with users QoS requirements, if found compatible, the process of testing is terminated otherwise set of testing is carried on till optimum set of solutions is achieved. All the simulation work is done using Matlab. On this basis three type of models are proposed for sending the data using the available holes in the licensed spectrum

1. Primary user spectrum has fixed types of holes, like in television transmission most of the time the spectrum is underutilized, the set of testing is done at user level so as to find the optimum set of values of QoS requirement, since the holes are almost same, the CR device filters secondary user using various functions and through genetic algorithm, finds the desired set of values to be transmitted. The testing is done till the desired set of values is obtained or maximum number of generations is reached. By using this technique of spectrum management we assume that, as the generations go on the fitness values take a higher value till it gives the desired set of values required. As the fitness function removes the weak and chromosomes below desired specifications, its individual fitness value increases. As shown in Graph1 the overall fitness value takes the lower value as the generations proceed and at the end it becomes constant with all the generations, and this shows that desired set of values are derived.
2. Primary user defines the priority of the parameters in the form of percentage like email requires lesser bandwidth as compared to video or live chat which requires high data rate with less S/N ratio for low latency and negligible packet loss. The user sets the priority of the traits in form of percentage and accordingly the spectrum values are derived using G.A. While derivation we have considered that percentage values are such that no factor is ignored nor becomes negative, since the percentage of the traits are not equal, that is 6 variable, to simplify the calculation we have taken one fixed value of percentage for Modulation rate as well as the last variable value as 100 minus sum of other percentages.
3. Both, Primary user holes as well as Secondary user values are, uncertain. The testing is done to get the desired set of values. In this it is assumed that continuous scanning is providing the data, both, for the primary user as well for the secondary user; since the requirement and availability of data is continuously changing, CR device matches compatibility between them so that secondary user can send the data using primary user spectrum without interfering with Primary user's rights and protocols and both have win-win situation.

E. Results of the Simulation Work

First Case: Primary user spectrum has fixed types of holes: As the generation goes on, GA generates the set of values, having lower overall fitness value, leading to overall lower cost. The results in the Fig 3 shows that for few generations the fitness value remain constant, it is the mutation that make change in the basic chromosomes and bring the variation in the population, adopting for the lower cost value, giving continuous improvement generation after generations, similar to the humans that produces better population generation by generations, adapting the changes that are required to survive, giving population that is more adaptable to the environment and have better chance of survival.

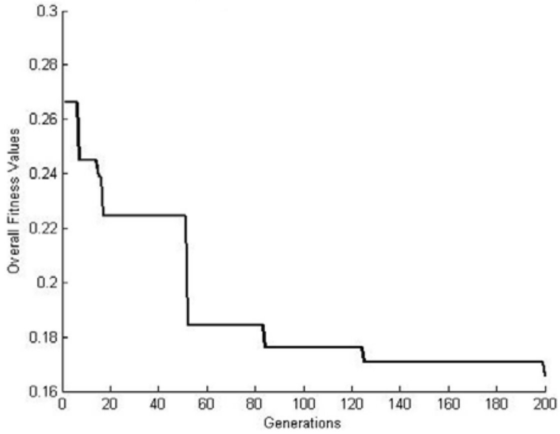

Fig. 3 Case1: Overall Fitness V/S Generations

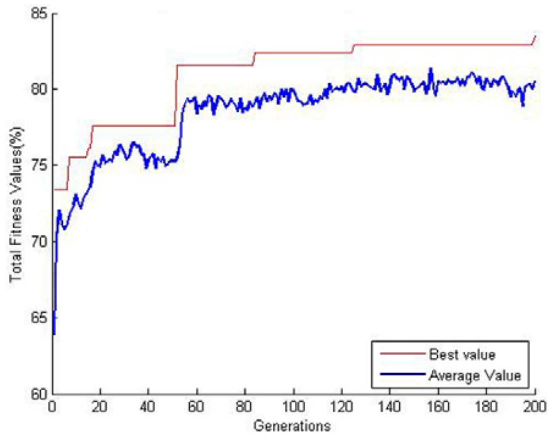

Fig. 4 Case1: Best value and Average Value V/S Generations

Fig. 4 shows Best fitness value and average value versus the generations, as the generations goes on the fitness value takes higher value compared to the previous one as well the average fitness value also increases with generation resulting attaining of better value from the previous generation.

Fig. 5 shows the individual trait Frequency, Power, BER, MOD type, Data Rate versus the Generations respectively.

Second Case: Figs. 6-8 show graphs for the second case in which the priority of primary user is defined in percentage and CR device selects desired set from the secondary user population.

Third Case: Figs. 9-11 are graphs for third case in which both Primary user holes as well Secondary user values are uncertain.

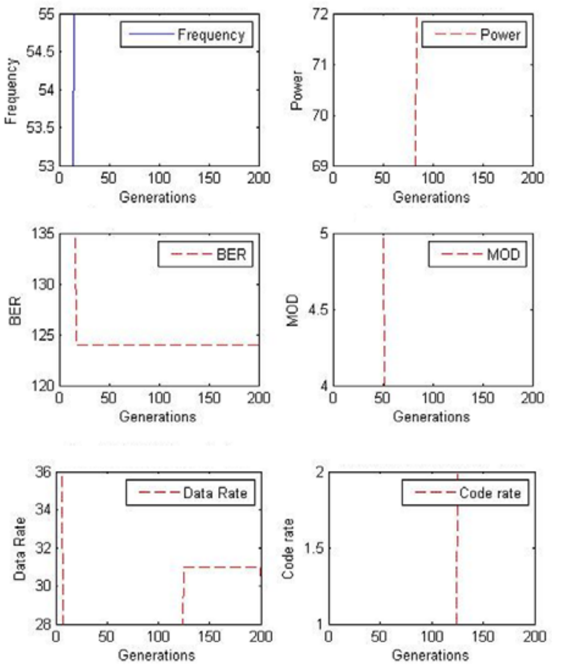

Fig. 5 Case1: Individual Frequency, Power, BER, MOD type, Data Rate, Code Rate versus Generations

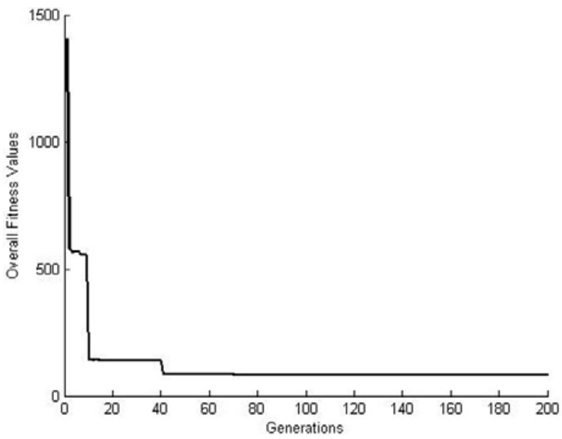

Fig. 6 Case2: Overall Fitness V/S Generations

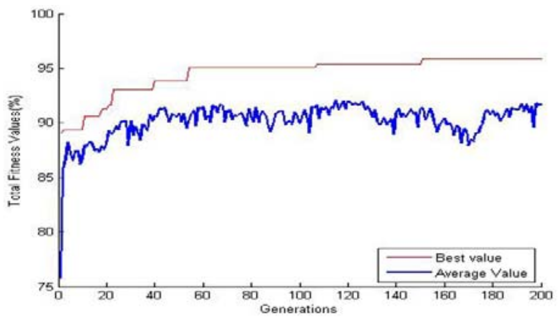

Fig. 7 Case2: Best value and Average Value V/S Generations

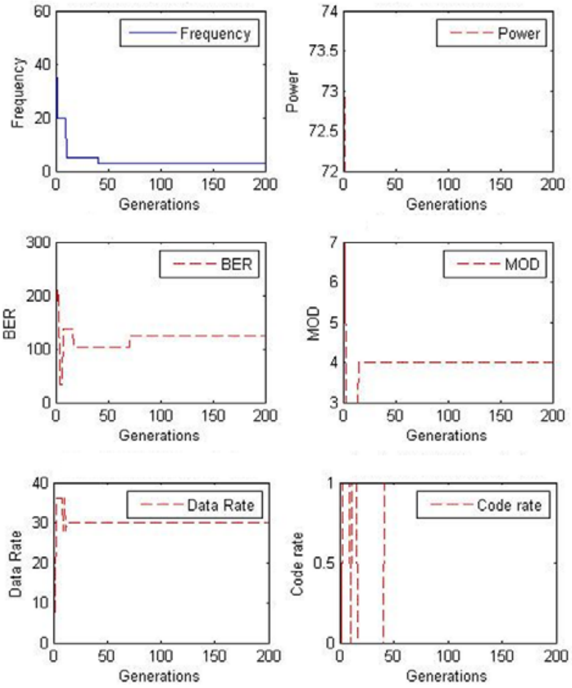

Fig. 8 Case2: Individual Frequency, Power, BER, MOD type, Data Rate, Code Rate versus Generations

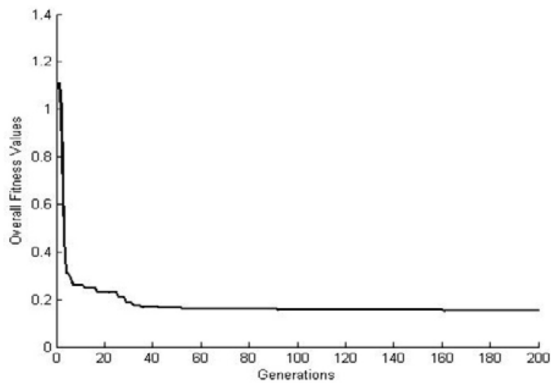

Fig. 9 Case3: Overall Fitness V/S Generations

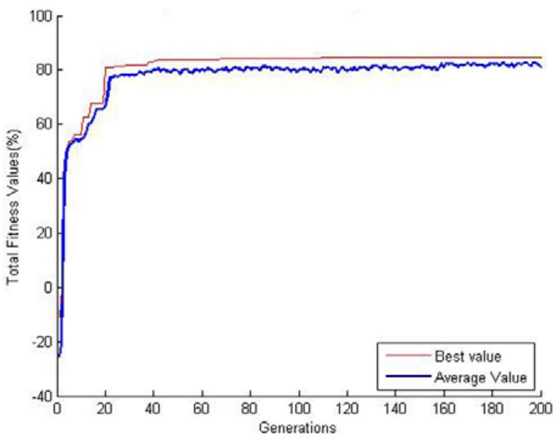

Fig. 10 Case3: Best value and Average Value V/S Generations

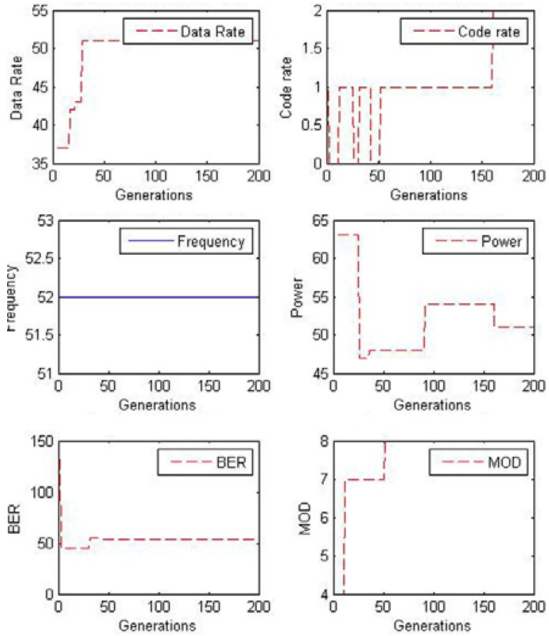

Fig. 11 Case3: Individual Frequency, Power, BER, MOD type, Data Rate, Code Rate versus Generations

IV. Conclusion & Future Work

The above study shows that various traits effect the transmission and thus responsible for the QoS. All three modes of input shows CR is continuous improvement process and as the generations go on the improvement in their average and overall fitness go on. Generations after generation's removal of the undesired values, retention of useful values through elitism as well addition of the new values through mutations and all at real time resulting in the lower cost and continuous improvement in quality. The graphs shows however individual traits varies with generations the overall fitness decrease and average and best value increases and become constant in seventy – ninety percent range. In future research the scope of improvement in the percentage is still there for the range by using better fitness functions.

Research in this area is required as cognitive radio are considered as smart radio of the future which are not only used for the communication though it is seen as the replacement of all gadgets that can communicate, validating object, in robotics, e-health services, intelligent transport system, Space science, emergency network, military networks, etc. and research also required to provide suggestions for changes in International Govt. licensing polices, coupling between various telecom corporate houses, software development & implantation and the most important technology adoption by common man.

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