Optimize Spectrum Allocation in Cognitive Radio Network

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Abstract. With rapid evolution in wireless devices increases the demand for radio spectrum. To solve spectrum underutilization problem cognitive radio technology is introduced. Cognitive radio technology is next generation technology which allows non-licensed user to use electromagnetic spectrum without interfering licensed user. To use white space in radio spectrum one should sense the spectrum perfectly. Once sensing is done, the distribution of the spectrum among the secondary user is also challenging task. Optimizing is the process to find best solution among the available solutions. Radio environment is random in nature. Due to fast convergence property of the genetic algorithm can use to find optimal solution for spectrum allocation problem to maximizing spectral utilization. Problem is modeled as Multi Objective Problem (MOP), considering that function as fitness function and evaluating the best allocation among all. Firstly defining target objective function that is minimizing Bit Error Rate (BER), maximizing throughput and minimizing power, then using aggregate sum approach, it converts all single objective function into one MOP. Than mathematically applying the fitness function in software so we get graphical representation. We have check convergence of algorithm first. Than we simulate result for single channel and multichannel performance. By observation of graphical parameter we have simulate results for real scenario and get optimum parameter for given situation.

Keywords: Cognitive radio · Spectrum allocation · Primary user
Secondary user · Dynamic spectrum access · Genetic algorithm

1 Introduction

Over the last two decades the use of wireless devices rapidly, which increase the shortage of spectrum resource. Generally Electro Magnetic (EM) spectrum is regulated by governmental bodies like Federal Communication Commission (FCC). According to FCC 70% of the spectrum stays unused most of the time [1]. Figure 1 shows the distribution of signal strength among large band of frequency. The fixed spectrum allocation was serve well in the past but increases the wireless devices the fixed spectrum policy cannot work well.

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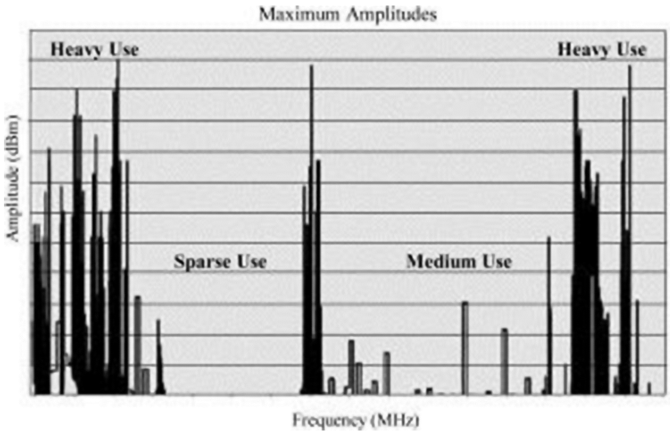

Fig. 1. Spectrum usage [1]

To solve the underutilization problem Cognitive Radio (CR) works well. CR is capable of transmitting in the licensed band without causing harmful interference to the Primary User (PU). "Cognitive Radio" can be defined as the radio that can change its transmission parameter based on interaction with environment [2]. There are two characteristics of the CR that are cognitive capability and cognitive re-configurability [3]. Cognitive capability defines as the ability to capture or sense the information from radio environment. In more specific word CR allows Secondary User (SU) to detect, which portion of the EM band is not in used. Select the best available channel according the SU's requirement, there are so many SUs are accessing the band so coordinating the channel access among all SUs and vacant the channel when primary user wants to use the channel. All functionality related to each other is described in Fig. 2.

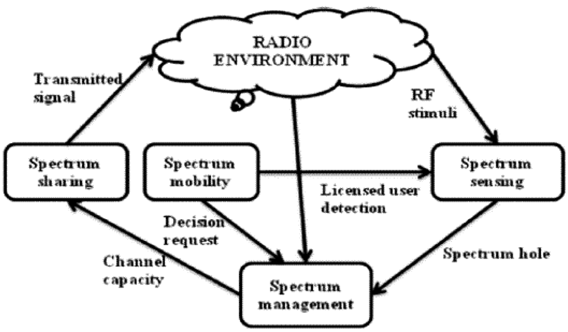

Fig. 2. Flow diagram of CRN

The main function of cognitive radio is summarized as follows:

Spectrum sensing: A CR can only use the vacant band of the radio spectrum, which is not currently used by primary user. Therefor CR should monitor the available spectrum, capture their information and detect the spectrum hole [3]. Spectrum management:

based on spectrum availability, the channel is allocated to SU according to its criteria [3]. Spectrum sharing: since there are multiple users are accessing the spectrum hole, CR access should be coordinate in order to avoid the collision between them [3]. Spectrum mobility: when primary user wants to use the channel the SU have to vacant that channel to avoid interference with PU and switch to other channel [3].

2 Cognitive Radio Operating Parameters

To developing cognitive radio control system we must define some control parameters to the system. The quality and quantity of control parameter decide how accurate system performance is.

2.1 Transmission Parameter

CR takes advantage of control parameters. These control parameters are input to the fitness function. Fitness function is the scalars score how well the fitness value met the optimum value. For generation of fitness function we must have some list of parameters. These transmission parameters specifically used as control parameters. We used three control parameter are transmission parameter, modulation scheme and modulation index to construct the fitness function [4, 5].

2.2 Environmental Parameter

Environmental measures inform system about surrounding. They may be internal or external information. Internal parameters are regarding to internal state of the mobile device e.g. battery life. Environmental parameters are classified into two categories that are primary parameters and triggering parameters. Primary parameters are directly put into fitness function. So the effect of primary parameters observed from the fitness function i.e. noise power and interference power. Triggering parameters are supervised by the system that is battery life. If system found low battery it automatically switch low power weighing scenario [4, 5].

2.3 Performance Objective

In wireless communication there are lots of desirable performance objectives to achieve desire Quality of Service (QoS) of mobile device. Here we choose three performance objectives that are minimizing BER, minimizing power and maximizing throughput. There is no particular method to optimize all objective function simultaneously but there is always trade off.

Minimizing BER. Fitness function of BER required three control parameters, those are Transmission power, modulation index and modulation type. Environmental parameters noise power. Specifically we used m-ary PSK modulation type. The formula for probability of BER is as follows [4, 5, 7, 9].

$$P_{be} = \frac{2}{log2(m)} Q\left(\sqrt{2 * log2(m) * \gamma} * sin\frac{\pi}{m}\right) \tag{1}$$

Objective function for minimizing BER for single carrier system is,

$$f\text{min}_{\_ber} = 1 - \frac{\log 0.5 - \log P_{be}}{\log 0.5 - \log 10^{\wedge -6}} \tag{2}$$

For multicarrier objective function we have,

$$f\text{min}_{\_ber} = 1 - \frac{\log 0.5}{\log\left(\overline{P_{be}}\right)} \tag{3}$$

Where, $\overline{P_{be}}$ is the average BER over N independent subcarriers.

Maximizing Throughput. Control parameters are modulation index and modulation scheme are utilize by objective function [4, 5, 7].

$$f\text{max}_{\_throughput} = 1 - \frac{\sum \log mi}{N \log m_{max}} \tag{4}$$

Where mi is the number of bits per symbol m_{max} is the maximum modulation index and N is the number of sub carriers.

Minimizing Power. Fitness function consist three control parameters are transmission power, modulation index and modulation type [4, 5, 7].

$$f\text{min}_{\_power} = \sum_{i=0}^{N} 1 - \left(\frac{P_i}{P_{max}}\right) \tag{5}$$

P_i is the transmitting power, N is the number of subcarriers and P_{max} is the maximum value of the power transmitted for any subcarrier.

2.4 Multi Objective Goals [9]

We propose sum aggregate approach to combine single objective functions to one objective function as fitness function. Each objective function is multiplied by weight value and sum of each weight together gives us single scalar value that is 1.

$$f_{multicarrier} = w_1 * f\text{min}_{\_ber} + w_2 * f\text{max}_{\_throughput} + w_3 f\text{min}_{\_power} \tag{6}$$

2.5 Genetic Approach [8]

In general solution to any problem represent by binary string. If these strings allow going under binary growth, good strings are split and poorer fitness string are die out. This decision is taken by the fitness function. Genetic algorithm possesses these characteristics. Flow diagram of genetic algorithm is shown in Fig. 3. GA is implemented using four basic steps are initialization, fitness measure, reproduction of new population and stopping criteria.

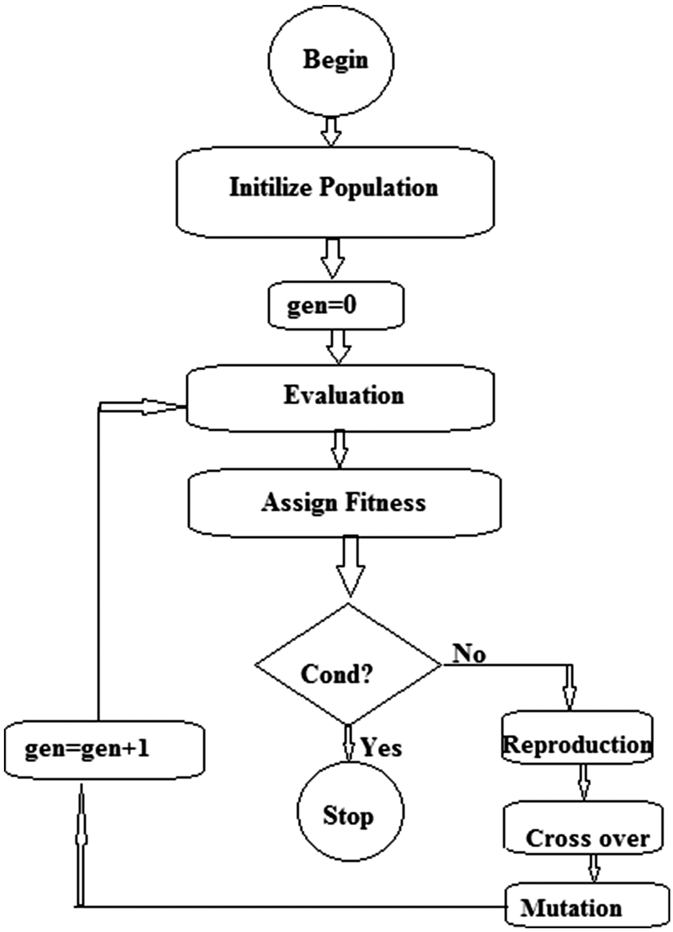

Fig. 3. Flow diagram of genetic algorithm [4]

Initialization: A random initial population of ‘n’ (number of initial population) chromosomes is generated. This population contains the available solutions for the specified problem.

Fitness Measure: Evaluation of the fitness of an initial population’s chromosomes.

Construction of New Population: Try the following steps to reproduce, until the production of the next generation completes.

Selection: A selection of chromosomes will be done in a way such that these chromosomes have the better level of fitness in the current available population.
Crossover: The crossover is done to make new individuals for the incoming generation. So with the defined probability of crossover, selected chromosomes reproduce to form new individuals.
Mutation: The new created individual will be mutated at a definite point.

Stopping Criteria: The process is repeated with all the above mentioned steps until a desired optimum solution is obtained or a set of maximum numbers of the population are generated. This stage is termination stage. The genetic algorithm process detailed previously continues until a termination condition has been reached. Common termination conditions includes, A solution that satisfies minimum criteria is found, A fixed number of generations is reached, A specified computation time is reached and The fitness scores have plateaued such that successive generations show no improvement.

To implement the GA there are still several factors to consider, like creation of chromosomes, types of encoding used to perform the genetic algorithms, selection of the optimum chromosomes, and different criterion such as defining the fitness measure.

3 Simulation and Results

GA simulation converges very fast to the optimal value. Once it reaches nearer optimum, if we increase number of iteration which increases the processing time with little

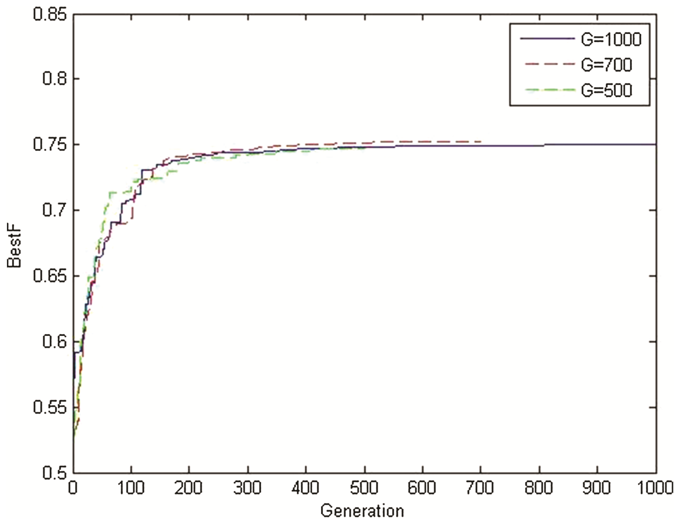

Fig. 4. Fitness convergence plot for varying number of generation

improvement in the fitness. Processing time is critical factor in wireless communication. Getting optimum iteration is also challenging task (Fig. 4).

Begin with single objective function, minimize BER performance objective results. Figure 5 shows a standard fitness convergence graph obtained from the GA system. This figure shows the results from varying channels in the system. It can be seen that a system with a single channel converges much faster than the system with 2 channels as well as the processing time needed to calculate the fitness over a 2 channel system. To highlight the effect of the increasing number of channels in the system, Table 1 shows the optimal generation where the highest fitness was found for each system. Again, for a single channel system, the system is able to find the best value much earlier than the system with 2 channels.

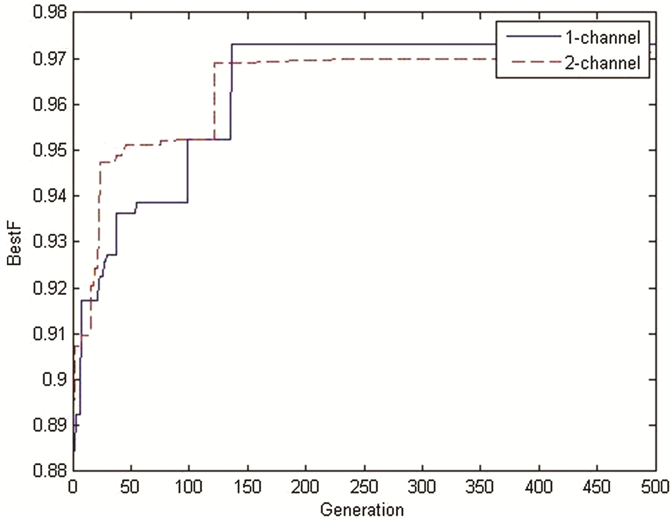

Fig. 5. Fitness convergence graph for varying number of channel

Table 1. Comparative analysis of varying number of channel

Channel	Iteration (G)	Time elapsed to run code (s)	Best fitness
1	500	29.2169	0.9796
2	500	42.5030	0.9766
1	600	37.2530	0.9850
2	600	51.4660	0.9114

3.1 Multi Objective Performances

Simulation setup for multi-objective function, we have power varying from 0.01 to 2.56 normalized values for 8 bit chromosome. In which 6 bits used for power allocation and 2 bit for assigning modulation index, varying from 2, 4, 8 and 16. Now a days higher modulation index also used for practical purpose so we can increase one bit in chromosome. That gives us eight different possibilities for modulation index. So the system performance is enhanced. The comparative analysis of 8 bit chromosome and 9 bit chromosome is shown in Figs. 6 and 7 as length of chromosome increases we have more combination of chromosome.

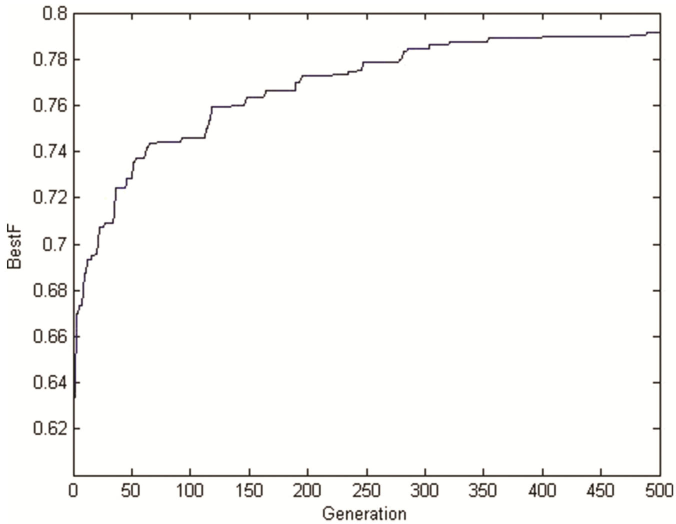

Fig. 6. Fitness convergence curve for 8 bit chromosome

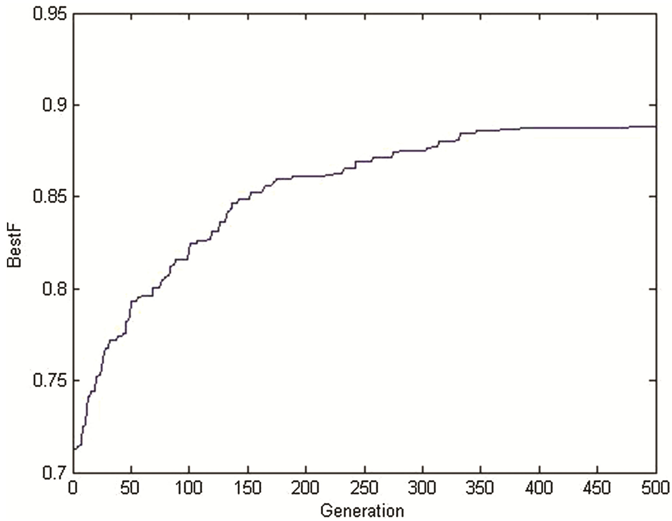

Fig. 7. Fitness convergence curve for 9 bit chromosome

Each subcarrier has a random channel attenuation N, using this value and the vector weights, the GA has optimized the transmission parameters for different mode of operation. Weights to different mode as shown in Table 2. Results are shown for voice application (Fig. 8).

Table 2. The weight value of three different modes

	Voice	Download	Low power
W1 (BER)	0.75	0.10	0.15
W2 (power)	0.10	0.15	0.75
W3 (Throughput)	0.15	0.75	0.10
Best fitness	0.7673	0.9297	0.8736

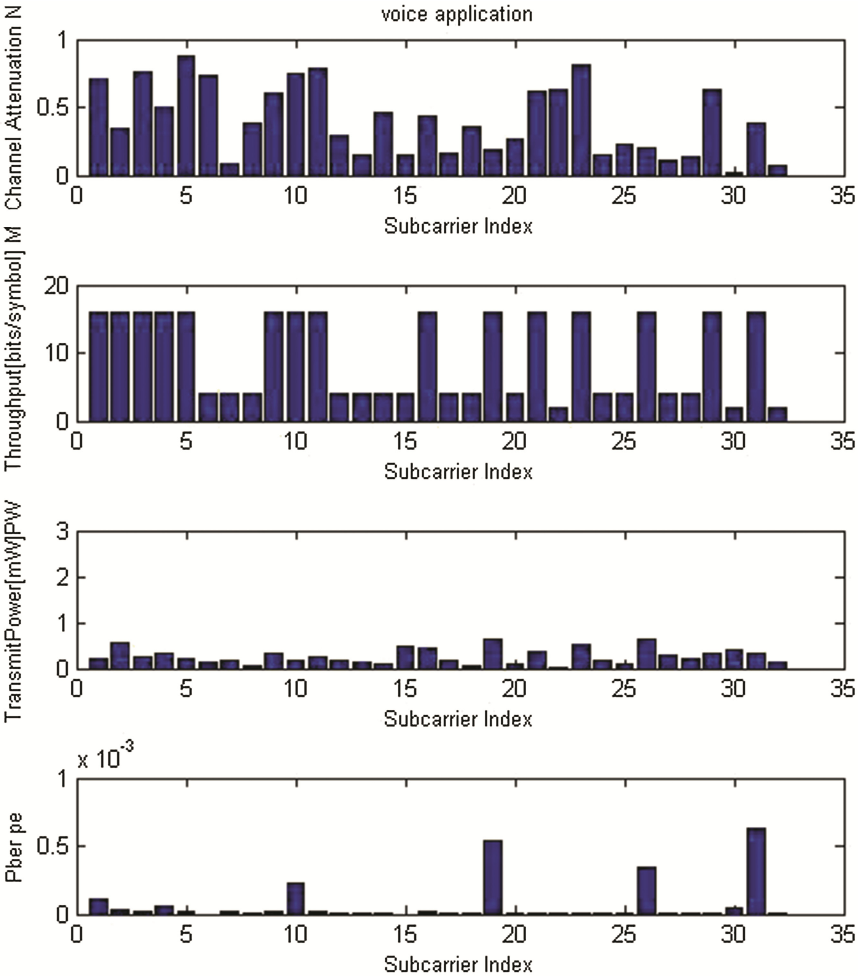

Fig. 8. Optimum solution set for voice application

4 Summary

This paper introduced an implementation of a multicarrier cognitive radio that uses a genetic Algorithm as the decision method. We have introduced several fitness functions that are used to score how well a parameter set match the given objectives. A 32 subcarrier system was then simulated using three separate scenarios. The results of these simulations proved that the fitness functions steer the evolution of the GA in the correct direction to optimize the given objectives for each scenario. An increase in the initial population will decrease the chances of premature convergence of the algorithm, but the execution time will increase accordingly. As time play very important role, single channel approach can be used to minimize time.

References

1. FCC: FCC. 03-322-notice of proposed rule making and order. Technical report, Federal Communications Commission, 30 December 2003
2. Muchandi, N., Khanai, R.: Cognitive radio spectrum sensing: a survey. In: International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT). IEEE (2016)
3. Ghosh, G., Das, P., Chatterjee, S.: Simulation and analysis of cognitive radio system using Matlab. Int. J. Next-Gener. Netw. **6**(2) (2014). 31. K. Elissa, "Title of paper if known," unpublished
4. Newman, T.R., et al.: Population adaptation for genetic algorithm-based cognitive radios. Mob. Netw. Appl. **13**(5), 442–451 (2008)
5. Varade, P.S., Ravinder, Y.: Optimal spectrum allocation in cognitive radio using genetic algorithm. In: 2014 Annual IEEE India Conference (INDICON). IEEE (2014)
6. Hamza, A.S., Elghoneimy, M.M.: On the effectiveness of using genetic algorithm for spectrum allocation in cognitive radio networks. In: 2010 High-Capacity Optical Networks and Enabling Technologies (HONET). IEEE (2010)
7. Pradhan, P.M., Panda, G.: Pareto optimization of cognitive radio parameters using multiobjective evolutionary algorithms and fuzzy decision making. Swarm Evol. Comput. **7**, 7–20 (2012)
8. Pradhan, P.M., Panda, G.: Comparative performance analysis of evolutionary algorithm based parameter optimization in cognitive radio engine: a survey. Ad Hoc Netw. **17**, 129–146 (2014)
9. El-Saleh, A.A., Ismail, M., Ali, M.: Pragmatic trellis coded modulation for adaptive multi-objective genetic algorithm-based cognitive radio systems. In: 2010 16th Asia-Pacific Conference on Communications (APCC). IEEE (2010)