Tradeoff Analysis of Bit-Error-Rate (BER) in Cognitive Radio Based on Genetic Algorithm

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Abstract

We know that the radio electromagnetic spectrum is a natural resource and efficient usage of the inadequate natural resource is one of the greatest challenges of today's wireless communication system just like petrol, coal and water. The efficient use of the available licensed spectrum is becoming more and more critical with increasing demand and usage of spectrum, so this is an urgent need and requirement for the rapidly increasing number of wireless users and also for the conversion of voice oriented applications to multimedia applications. With efficient spectrum use, there are some parameters which also play an important role in the efficiency and performance of a system. One of them is Bit Error Rate (BER), the analysis i.e. optimization (minimization) of BER get better results. The aim of this study is to analysis BER theoretically as well as practically and shows the comparisons between them. In this paper, we analysis BER for better efficiency, high performance and maximum throughput in cognitive radio system based on Genetic Algorithm (GA).

Keywords: *Radio spectrum, Cognitive Radio, Bit Error Rate (BER), Optimization, Genetic Algorithm (GA).*

1. Introduction

Just like petroleum, wood, water and coal, the natural frequency spectrum is limited and needs to be use more judicially in order conserve it. It is clear that current static frequency allocation schemes cannot accommodate demands of the rapidly increasing number of higher data rate devices. Therefore; dynamic usage of the spectrum must be distinguished from the static usage to increase the availability of frequency spectrum. For this purpose, Cognitive Radio is proposed as a new technology that provides optimum satisfaction of user requirements like effective spectrum usage and also the smart and secure communication environment.

The transmission scheme of primary users not only occupy licensed bands in frequency, time and space, but also creates a problem with secondary user in a more complicated and structured manner. This problem is removed by cognitive radio which is aware of its environmental, internal state, and location. The radio autonomously adjusts its operations to achieve designed objectives (Mitola 2000). The another way of explaining, the cognitive radio is that it first senses its spectral environment over a wide frequency band, and then adapts the parameters to maximize spectrum efficiency with high performance, while co-existing with legacy wireless networks (Haykin 2005). There are some parameters which affect the performance of the communication system are like power or energy, bit error rate, data rate, bandwidth and channel capacity etc.

2. Cognitive Radio

The term, cognitive radio, can formally be defined as follows (FCC Report 2002):

"Cognitive Radio is a radio for wireless communications in which either a network or a wireless node changes its transmission or reception parameters based on the interaction with the environment to communicate efficiently without interfering with licensed users."

The cognitive capability of a cognitive radio enables real time interaction with its environment. This interaction helps to determine the appropriate communication parameters in order to adapt the dynamic radio environment. The radio analyzes the spectrum characteristics and changes the parameters at real time to

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provide a fair scheduling among the users that share the available spectrum. With this approach to solve the issue of scarcity of available radio spectrum, the Cognitive radio technology is getting a significant attention. The primary feature of cognitive radio is the capability to optimize the relevant communication parameters given at a dynamic wireless channel environment.

There have been implementations of GA based cognitive radio implementations, but the performance of these algorithms has not been thoroughly analyzed. The fitness functions employed in these algorithms have also not been explored in detail. Specifically, the analysis comes from finding the non-dominated solutions in the solution space, which is known as Pareto front. Genetic algorithms (GA) are used to optimize multi-objective problems, and can produce the Pareto Front. After the Pareto front has been optimized, the final challenge is to make a decision about the waveform on the Pareto front which stands for Quality of Service satisfaction.

3. Bit Error Rate (BER)

Bit error rate (BER) of a communication system is defined as the ratio of number of error bits and total number of bits transmitted during a specific period. In digital transmission or digital communication system, the number of bit errors is the number of received bits of a data stream over communication channels that have been altered due to noise, interference, distortion or bit synchronization errors in the system. The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a considered time interval. BER is a unit less performance measure, often expressed as a percentage (%).

As an example, let assume 10 bits of data is transmitted as a bit sequence:

0 1 1 0 0 0 1 0 1 1,

and suppose the following bit sequence is received at receiver side:

0 <u>0</u> 1 0 <u>1</u> 0 1 0 <u>0</u> 1,

The number of bit errors (the underlined bits) in this case is 3. The BER is 3 incorrect bits divided by 10 transferred bits, resulting in a BER of 0.3 or 30%.

a) Factors affecting the BER

In a communication system, the receiver side BER may be affected by:

- Transmission channel noise.
- Interference.
- Distortion.
- Bit synchronization problems.
- Attenuation.
- Wireless multipath fading, etc.

b) The BER may be improved by:

- Choosing strong signal strength (unless this causes cross-talk and more bit errors).
- Choosing a slow and robust modulation scheme or line coding scheme.
- Applying channel coding schemes such as redundant forward error correction codes.

It is the likely that a single error bit will occur within received bits of independent rate of transmission. There are many ways of reducing BER. Here, we focus on channel coding techniques.

A channel in mobile communications can be simulated in many different ways. The main considerations includes the effect of multipath scattering, fading and Doppler shift that arises from the relative motions between the transmitter and the receiver. In our simulations, we have considered the two most commonly used channels: the Additive White Gaussian Noise (AWGN) channel where the noise gets spread over the whole spectrum of frequencies and the Rayleigh fading channel.

4. Genetic Algorithm

Genetic algorithm (GA) is the technique based on evolutionary computation to find approximate solutions to the optimization problems. Genetic algorithms are inspired by the Darwin's theory of evolution which is best or simply the survivor among the available pool is an evolved solution. The evolutionary computation may involve techniques like inheritance, mutation, selection and crossover to provide the best possible optimization.

In 1992 John Koza introduced “Genetic Programming” (G.P.). Since the introduction, the G.A's have been used to solve difficult problems like, Non deterministic problems and machine learning as well as the evolution of simple programs, pictures and music. The main advantage of Genetic Algorithm over the other methods is their parallelism. It travels and search spaces that use more individuals for the decision-making so they are less likely to get fixed in a local extreme like other available decision-making techniques. The GA uses a population of

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chromosomes that represent the search space and determine their fitness by a certain criterion (fitness function). In each generation (iteration of the algorithm), the most fit parents are chosen to create offspring, which are created by crossing over portions of the parent chromosomes and then possibly adding mutation to the offspring.

The Genetic algorithms approach is used for the optimization of the decision- making module in the radio. They are well suited to the multi-objective functions due to their convergence behavior towards the optimized solution and help the radios in adaptation for the decision-making process. Apart from this, the genetic algorithms also provide the optimization in decision making with multiple advantages. They provide flexibility in problem analysis, as long as the chromosome and the objective functions are defined properly. The convergence behavior of the genetic algorithm is really helpful in our application, i.e. the Cognitive Radios. This algorithms may have a long convergence time for an optimal solution but normally do not take much time to give very good solutions [7].

Outline for the Genetic Algorithms:

1. Start: Generate a random initial population of n chromosomes that consists the available solutions for the problem.

2. Fitness: Imitate the fitness of each of the chromosomes in the initial population.

3. New population: Reproduce, according to the following steps until the next generation completes.

4. Selection: Select two chromosomes that have the best fitness level among the current population.

5. Crossover: In this step two selected chromosomes considering the crossover probability are crossover, to form the off springs for the next generation. If this operation is not performed the children would be the exact copy of the parent chromosomes.

6. Mutation: Transform the new offspring at each defined mutation point, considering the mutation probability and places it in the new population.

7. End Condition: Repeat the above steps until certain condition (maximum no of population or the desired optimum has been reached), has been met. [7]

A representation for the chromosome must provide the information about the solution that it represents. The most popular of all representations is the binary string. Where each bit in the string can represent the chromosome characteristics or the whole string cumulatively can do this. The use of integer or real number representations for the chromosomes can also be useful.

5. Simulations and Results

In the real world problem such as the problem arrangement with this paper, the found solutions solve the objective solutions even when they are conflicting, that is, minimizing one function may also degrade other functions. For example, minimizing BER and minimizing power simultaneously generate a divergence because of the single parameter i.e. transmit power, which affects each objective in a different manner. Obtaining the optimal set of decision variables for a single objective minimizes power and often the outcome is non-optimal set with respect to other objectives, e.g. minimize BER.

In this work, the results on BER versus E_b/N_0 are obtained both theoretical and genetic algorithms. Using simple CR parameter as shown in Table 2 can be obtained as Bit-Error-Rate (BER) and corresponding Signal-to-Noise Ratio (SNR). The length of chromosome utilized by proposed GA has been shown in Fig. 1 which represents individual in the population. The genetic parameter used for GA shown in Table 3. The simulation results were observed by several hundred times.

Table 1: Values of Cognitive Radio Environmental Parameters

Parameter	**Symbol**	**Min. Value**	**Max. Value**	**Step Size**
Noise Power	N	-110dBm	-25dBm	-1dBm

Table 2: Values of Cognitive Radio Transmission Parameters

Parameter	**Symbol**	**Min. Value**	**Max. Value**	**Step Size**
Transmit Power	P	-35dBm	35dBm	1dBm
Bits in each Symbol	K	2	2	
Bandwidth	B	1Mhz	10Mhz	1Mhz
Symbol Rate	R	1Mbps	8Mbps	1Mbps

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Table 3: Genetic Parameter Settings

Genetic Parameters	**Proposed**
Population Size	20
Maximum generation	100
Crossover type	Single-point
Crossover rate	0.8-0.95
Mutation type	Randomly change the integer value within given range
Mutation rate	0.1

P	K	B	L	R	N

Fig. 1 Chromosome Lengths

Genetic Algorithm has been implemented using Eq. (1).The theoretical and GA computational values have been recorded as shown in Table 4. The coordinate axes are used to represents the comparison between BER and SNR. The y-axis represents the score for BER, while the x-axis is the score for the ratio of the energy per bit (E_b) to the noise power spectral density (N_0).

$$P_{be} = \frac{2}{k} Q \left(\sqrt{2 k \gamma} \sin \frac{\pi}{M} \right) \quad (1)$$

The parameter x corresponds to the decision vector of variable used as inputs to the fitness functions. For every curve, as the fitness score for BER objective decreases, the value for the E_b /N_0 increases. This trade-off analysis has to be made by using optimization function. In this paper, fitness functions using the defined set of parameters has been developed, that are used by Cognitive Radio engines to establish a single optimal transmission parameter result to get the optimal solution.

Table 4: Theoretical and GA Comparison of BER

E_b / N_0 (dB)	Theoretical BER	GA BER
-15	0.400	0.380
-10	0.330	0.320
-5	0.213	0.213
0	0.079	0.078
5	0.006	0.059
10	3.87×10^{-6}	0.000

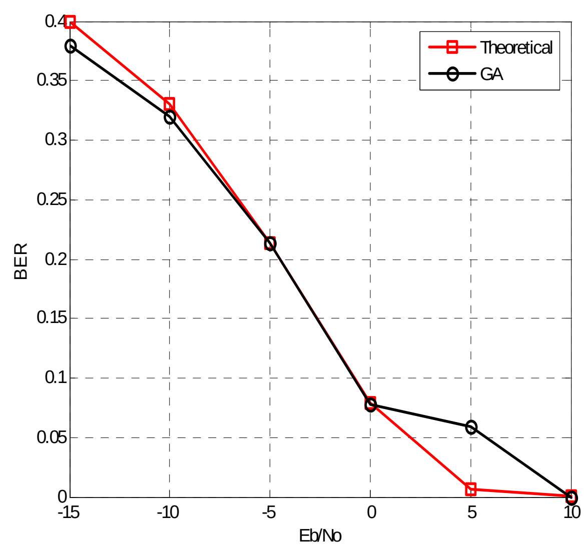

Fig. 2 Theoretical and GA Comparison of BER

6. Conclusion

In this paper the contributions has been made in the area of Cognitive Radio. The research work achievements of this hypothesis are following: Multi-objective cost functions, which set up the relationships between the environmental parameters, transmission parameters, and objectives of Quality of Service performance, were developed. This work discovered that the Genetic Algorithm based system approach was more robust and offers an interface that permits the user to easily adjust

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Cognitive Radio parameters such as BER which increase the performance, reliability and capability of the system.

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