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# In Cognitive Radio the Analysis of Bit-Error-Rate (BER) by using PSO Algorithm

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***Abstract*—**The electromagnetic spectrum is a natural resource and hence well-organized usage of the limited natural resources is the necessities for better communication. The present static frequency allocation schemes cannot accommodate demands of the rapidly increasing number of higher data rate services. Therefore, dynamic usage of the spectrum must be distinguished from the static usage to increase the availability of frequency spectrum. Cognitive radio is not a single piece of apparatus but it is a technology that can incorporate components spread across a network. It offers great promise for improving system efficiency, spectrum utilization, more effective applications, reduction in interference and reduced complexity of usage for users. Cognitive radio is aware of its environmental, internal state, and location, and autonomously adjusts its operations to achieve designed objectives. It first senses its spectral environment over a wide frequency band, and then adapts the parameters to maximize spectrum efficiency with high performance. This paper only focuses on the analysis of Bit-Error-Rate in cognitive radio by using Particle Swarm Optimization Algorithm. It is theoretically as well as practically analyzed and interpreted in the sense of advantages and drawbacks and how BER affects the efficiency and performance of the communication system.

***Keywords*—**BER, Cognitive Radio, Environmental Parameters, PSO, Radio spectrum, Transmission Parameters

## I. Introduction

THE changing of parameters in cognitive radio is based on the active checking of external and internal radio environment such as radio frequency spectrum, user behavior trends and network state in every 100 msec in cognitive radio communication system. As cognitive radio (CR) is a radio or system which is used for communication purpose and it is a combination of the many pagers, PDAs, cell phones and other gadgets used today. They will come together over the next decade to surprise us with services previously available to only a small select group of people, all made easier by wireless connectivity and the Internet. The complexity possible in a Software Defined Radio (SDR) [23], [24] has now reached the level where each radio can conceivably perform beneficial tasks that help the user, help the network, and help minimize spectral congestion. Some radios are able to demonstrate one or more of these capabilities in limited ways. A simple example is the adaptive Digital European Cordless Telephone (DECT) wireless phone, which finds and uses a frequency within its allowed plan with the least noise and interference on that channel and time slot.

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The three major applications that raise an SDR's capabilities to make it a CR [2]: Spectrum management and optimizations is the major task of Cognitive Radio, Interface with a wide variety of wireless networks, leading to management, control and optimization of network resources and Interface with a human, providing electromagnetic resource to support the human in their activities.

There are some parameters which affect the performance of the cognitive radio system which are power or energy, bit error rate, data rate, bandwidth and channel capacity etc. but out of these bit error rate plays a important role in the performance, capability and ability of the communication system either wired or wireless.

## II. Cognitive Radio

It is an intelligent wireless communication system that is aware of its surrounding environment, learns from the environment and adapts its internal states to statistical variations in the incoming RF stimuli by making corresponding changes in certain operating parameter in real time [10]. The term spectrum efficiency, as used in the SDR Forum Cognitive Radio Working Group, refers to increasing the efficiency of how spectrum is assigned and used to support one or more wireless services in one or more geographical locations in either a concurrent or time-based manner. One scenario involves use of licensed spectrum by unlicensed users using protocols and etiquettes to minimize the potential for interference to licensed users in the system [2].

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 [11]. The radio analyzes the spectrum characteristics and changes the parameters at real time to 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.

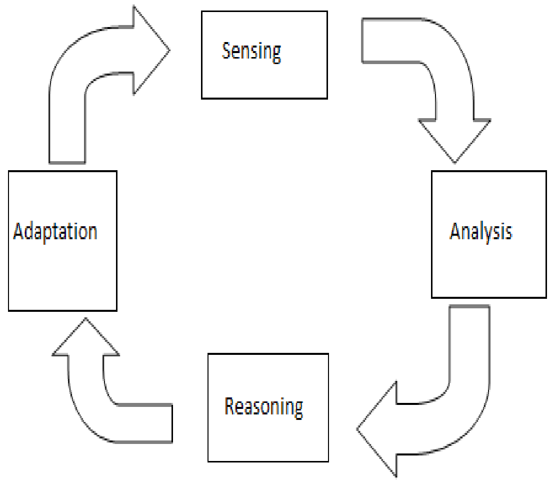


Fig. 1 Cognitive Radio Cycle

A Cognitive SDR radio can provide communications services that allow users to designate a priority or a value for each particular communications task. For example, email might be given a higher priority than streaming video. Cognitive radios could be aware of the requirements that different applications on a radio have for data throughput rates, latencies, and quality of service levels. These services become increasingly important as users multiplex applications and executing applications in parallel.

*The cognitive SDR can support communications by using different methods which are:*

1) Prioritized connection use rules
2) Time of transmission optimization
3) Appropriate channel bandwidth to match endpoint coding/decoding schemes
4) Adaptive compression to balance bandwidth usage.

## III. Bit Error Rate (BER)

In communication system the bit error rate 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 (%).

While the basic concept of BER measurement is simple send a data stream through the system and compare the output to the input its execution is not trivial. Over an infinitely long period of time, we can assume that a data transmission is a random process. However, we don't want to wait forever to make a BER measurement! So a pseudorandom data sequence is used for this test. We call it "pseudo" random because we cannot create a truly random signal using deterministic (mathematical) methods. Fortunately, some smart mathematicians have worked out sufficient approximations of random behavior so we can quickly make accurate BER measurements.

## IV. PSO Algorithm

The particle swarm optimization (PSO) [27], [28] is a computational method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. PSO optimizes a problem by having a population of candidate solutions, here dubbed particles, and moving these particles around in the search-space according to simple mathematical formulae over the particle's position and velocity. Each particle's movement is influenced by its local best known position and it's also guided toward the best known positions in the search-space, which are updated as better positions are found by other particles.

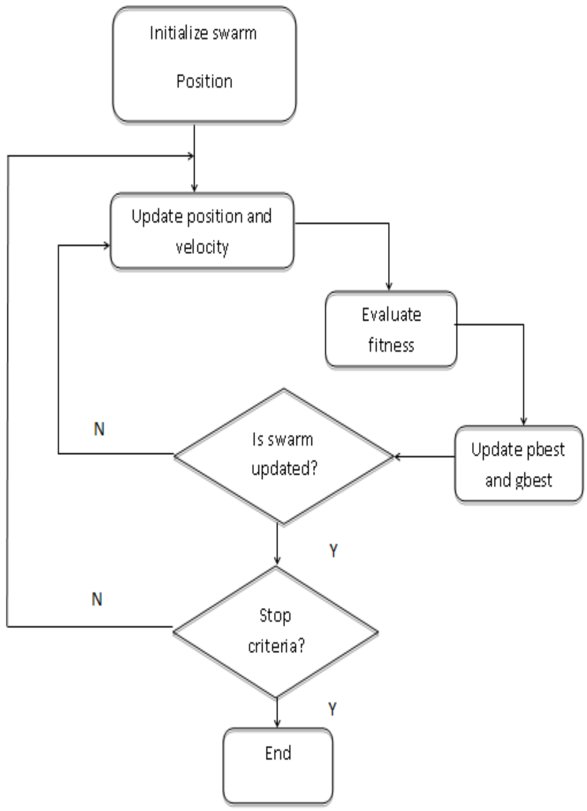


Fig. 2 PSO Flowchart

This is expected to move the swarm toward the best solutions. Particle swarm optimization algorithm is originally credited to Kennedy, Eberhart and Shi [27]. It was first proposed for simulating social behavior, as a stylized representation of the movement of organisms in a bird flock or fish school. The algorithm was simplified and it was observed to be performing optimization. The book by Kennedy and Eberhart describes many philosophical aspects of Particle

Swarm Optimization and swarm intelligence. An extensive survey of PSO applications is made by Poli and which gave the idea to use PSO for different applications in different fields of engineering.The PSO is a metaheuristic so it makes few or no assumptions about the problem being optimized and can search very large spaces of candidate solutions. However, metaheuristics such as PSO do not guarantee an optimal solution is ever found. More specifically, PSO does not use the gradient of the problem being optimized, which means PSO does not require that the optimization problem be differentiable as is required by classic optimization methods such as gradient descent and quasi-Newton methods. These are some disadvantages of PSO algorithm as compare to other. But there are some special features that are PSO can also be used on optimization problems that are partially irregular, noisy, change over time, etc.

## V. Simulations And Results

In real world problem such as the problem arrangement with this paper, the solutions found solve the objective solutions even when they are conflicting, that is, when minimizing one function may 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 as minimize power, often outcome in a 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 by using particle swarm optimization algorithm. Using simple CR parameter as shown in Table 4 can be obtained as Bit-Error-Rate (BER) and corresponding Signal-to-Noise Ratio (SNR). The length of chromosome utilized by proposed PSO has been shown in Fig. 3 which represents individual in the population. The genetic parameter used for PSO algorithm is shown in Table 3. The simulation results were observed by several hundred times.

TABLE I
Values Of Cognitive Radio Environmental Parameters

| Parameter | Symbol | Min. Value | Max. Value | Step Size |
|---|---|---|---|---|
| Noise Power | N | -20dBm | -15dBm | 1dBm |

TABLE II
Values Of Cognitive Radio Transmission Parameters

| Parameter | Symbol | Min. Value | Max. Value | Step Size |
|---|---|---|---|---|
| Transmit Power | P | -25dBm | 20dBm | 1dBm |
| Bits in each Symbol | K | 2 | 2 | |
| Bandwidth | B | 1Mhz | 4Mhz | 1Mhz |
| Symbol Rate | R | 2Mbps | 8Mbps | 1Mbps |

TABLE III
Particle Swarm Particle Parameter Settings

| Parameters | Proposed |
|---|---|
| Population Size | 20 |
| Maximum generation | 1000 |

| | | | | |
|---|---|---|---|---|
| P | K | B | R | N |

Fig. 3 Individual lengths

PSO has been implemented using eq. (1). The theoretical and PSO computational values have been recorded as shown in Table 4. In the coordinate axes, y-axis represents the score for BER, while the x-axis represents the score for the ratio of the energy per bit ($E_b$) to the noise power spectral density ($N_0$).

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

The parameter $x$ corresponds to the decision vector of variable used as inputs to the fitness functions. In Fig. 4 the curve shows that the fitness score for BER objective decreases, the value for the $E_b / N_0$ increases respectively. 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 develop, that are used by Cognitive Radio engines to establish a single optimal transmission parameter result to get the optimal solution.

TABLE IV
Theoretical And Pso Comparison Of BER

| $E_b / N_0$ (dB) | Theoretical BER | PSO BER |
|---|---|---|
| -30 | 0.48 | 0.43 |
| -20 | 0.44 | 00.3 |
| -10 | 0.327 | 0.24 |
| 0 | 0.078 | 0.02 |
| 10 | $3.87 \times 10^{-6}$ | 0.04 |
| 20 | $1.04 \text{ X } 10^{-45}$ | 0.00 |
| 30 | 0.00 | 0.00 |

The proposed Particle Swarm Optimization follows the theoretical values as shown in Fig. 4. It is clear that PSO can be used to optimization of BER tradeoff analysis with respect to Signal to Noise Ratio (SNR) in cognitive radio for better performance, reliability and capability of the system in emergency services also.

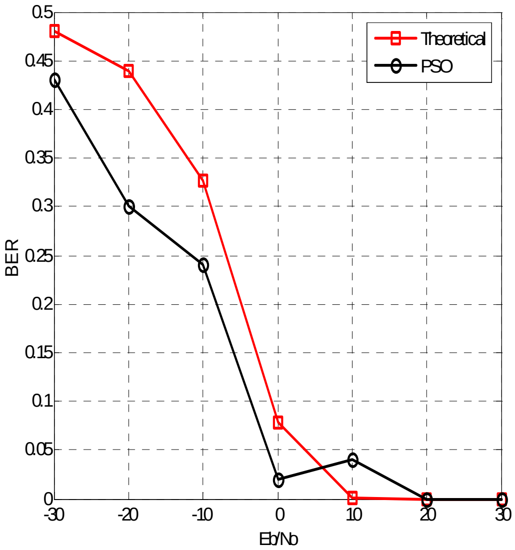


Fig. 4 Theoretical and PSO Comparison of BER

## VI. Conclusion

In this paper a many contributions have been made in the area of Cognitive Radio. The research work achievements of this paper are the 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 Particle Swarm Optimization based system approach was more robust and offers an interface that permits the user to easily adjust Cognitive Radio parameters such as BER in communication systems for better performance, reliability and capability of the system.

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