A Survey on Optimization Techniques for Spectrum Sensing in Cognitive Radio

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***Abstract*—** In recent times, it has been a tremendous advancement in Wireless Technology. Wireless networks are in high demand due to increasing number of users day by day. The requirement of large bandwidth for high speed data services has increased the demand for additional radio spectrum for wireless technology. The scarcity of radio spectrum has become a challenge for the conventional fixed spectrum assignment policy assigned by Federal Communication commission (FCC). Cognitive radio (CR) is a new paradigm in the area of wireless communication system for effective utilization of radio frequency (RF) spectrum. Cognitive Radio (CR) is used to maximize the available spectrum utilization. When the primary user (PU) does not access the channel, at that time cognitive radio (CR) will allow using the spectrum to communicate with other CR. Spectrum sensing is the principal task of cognitive radio through which it accurately determines the licensed user's existence (signal) and identifies the available vacant spectrum. Optimization techniques like Genetic Algorithm (GA), Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO) and Teaching Learning Based Optimization (TLBO) are discussed here to meet the user's Quality of Service (QoS) needs in the Cognitive Radio.

Keywords*—Cognitive Radio (CR), Dynamic Spectrum Access (DSA), Genetic Algorithm (GA), Ant Colony Optimization (ACO), Teaching Learning Based Optimization (TLBO), Particle Swarm Optimization (PSO).*

I. INTRODUCTION

Due to rise in number of users day by day and rapid development in wireless technology, available spectrum is not enough to meet current requirements.

The spectrum is not utilized by the licensed users effectively and some of the holes remain vacant because of conventional fixed spectrum assignment policy assigned by FCC as shown in Fig. 1. So, it is indeed necessary that the spectrum should be utilized effectively to meet growing demands from users. So Federal Communications Commission (FCC) has published a report by designing new spectrum strategies to solve the problem of overcrowded bands and allow secondary users to use licensed bands accordingly.

The usage of spectrum is concentrated on certain portions of spectrum bands whereas considerable portion of spectrum remains unutilized. Hence to improve the effective utilization of spectrum in real time and provide efficient communication the concept of Cognitive Radio technology is introduced.

Secondary users use the spectrum when the primary users are not using it in Cognitive Radio (CR). Cognitive radio has the capability of sensing the spectrum in the real time environment.

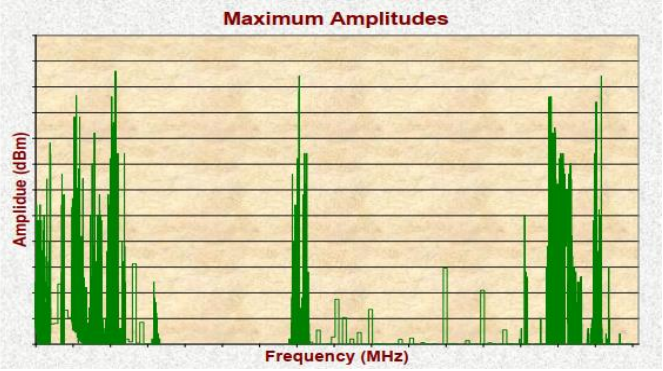

Fig.1 Spectrum Utilization

By changing its various parameters, CR can acquire information from the environment and gets adapted to the environment accordingly. Thus a cognitive radio can sense the spectrum in a better way. Main objective of the cognitive radio is to sense the spectrum, learn from the environment and adapt to the environment. Primary users, has the highest priority for the spectrum usage. Secondary users have to vacant the spectrum as soon as primary users appear. Secondary users can not interferer the operation of the primary users.

The major functions of cognitive radio can then be categorized as [16]: • Radio scene analysis: In this function, the unused frequency band is detected. • Channel state estimation: The task is concentrated on finding the channel. • Spectrum management: The principal aim of this task is effective spectrum sharing of the free channels detected in the spectrum sensing stage.

The main and most key task of the cognitive radio is the procedure of searching used spectrum of primary user (*spectrum sensing*). Once the white spaces are identified, the cognitive user must select the best available channel that meets Quality-Of-Service (QoS) requirements and its communication (*spectrum management*). During the occupation of the channel by the CR user if licensed user (i.e. Primary User) want to use this channel, then CR user immediately terminate their transmission and slightly migrate to another unused channel due to a lower priority than the primary user (*spectrum mobility*). Also, In a CR network, there is some scheduling mechanism to ensure that all CR user get equal opportunities on accessing the spectrum (*spectrum sharing*).

By the spectrum sensing, the CR user is able to find temporally idle spectrum, which is known as spectrum hole or white space. If the licensed user comes active for communication then CR user has to use another spectrum holes or change its transmission parameter to avoid interference. The spectrum holes [1], [2], [3], [4], [5], [6], [7], [8] theory is illustrated with the help of Fig.2.

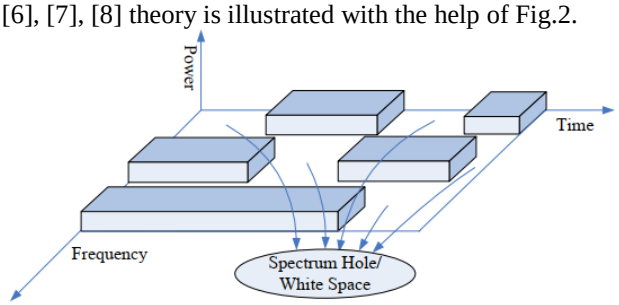

Fig.2 Spectrum Hole Concept

Many optimization techniques are used to find the optimal solution for performance improvement of spectrum sensing. The optimization techniques optimize the parameters and make them possible as per the required maximum and minimum criterion. In this paper, we consider optimization techniques used for spectrum sensing.

II. GENETIC ALGORITHM

The basic concept of Genetic Algorithm (GA) is designed to simulate processes of evolution. Here the evaluation is the process of optimization. This algorithm obeys the principles of the survival of the fittest. It is normally used in case where the search space is large and cannot be effectively solved by classical (conventional) optimization method. Unlike the classical method here we put the series of a solution called population to the objective function rather than making a single solution [12] [18].

Initial population is given which made of from different feasible solution. After given this population, the optimization algorithm finds the best chromosomes and rejects the unfits. A fitness score by means of the maximization of our objective function is evaluated to find which generations are most appropriate for surviving to the forthcoming generation. The generation who gives highest score are nominated for surviving. Successive generations are formulated in the following three steps.

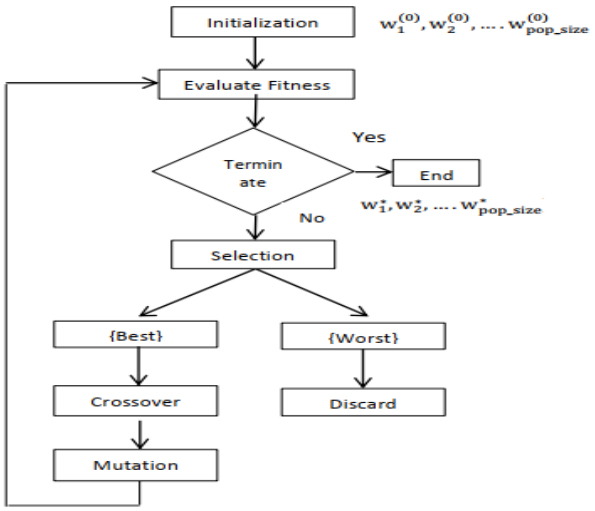

Fig.3 Flow chart of Genetic Algorithm

- Selection
- Crossover
- Mutation

The last two processes are repeated most of the time. This evaluation and generation process is done iteratively to raise the proportion of fit members. When the stop criteria is satisfied either by number of iteration or achieved some predefined fitness then algorithm stop and resultant value gives optimal solution. The flowchart of GA is shown in Fig.3.

III. ANT COLONY OPTIMIZATION (ACO)

Ant colony optimization (ACO) algorithm was derived by the movement of the ants for finding the food sources. In ACO, the ants search the food and take back [13] to the nest. The ant then leaves a substance known as pheromones when go back to the nest. The amount of pheromone placed, which may be subject to amount and quality of the food sources, this pheromone will guide other ants to the food. The other ants obey the paths where pheromone is larger. Following are the three main function of ACO optimization method. The flowchart of ACO is shown in Fig.4.

1. Auto solution construct
2. Pheromone Update
3. Daemon Action

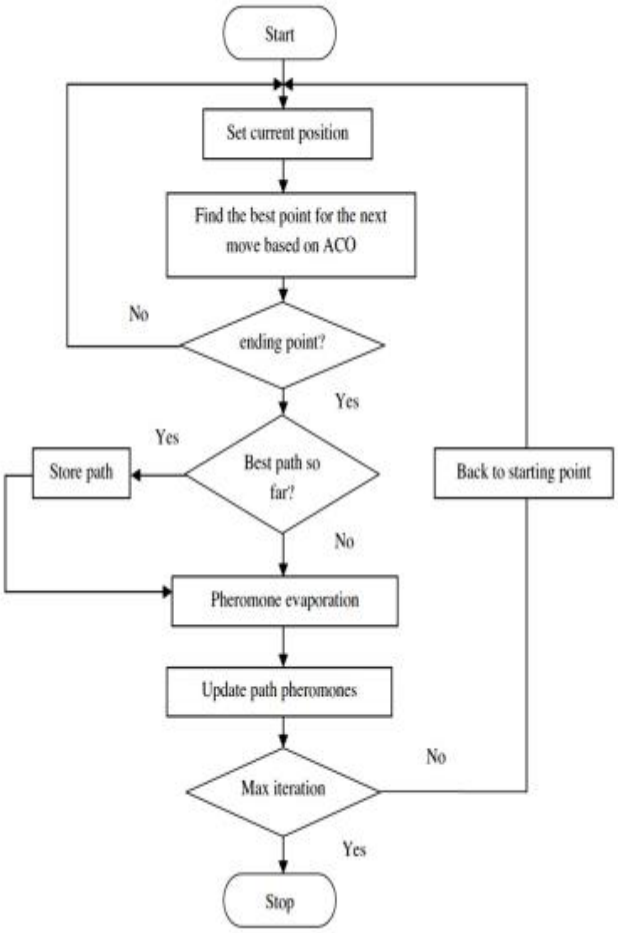

Fig.4 Flow chart of ACO

IV. PARTICLE SWARM OPTIMIZATION (PSO)

Particle swarm optimization (PSO) is a population based optimization techniques which inspired by the behavior of flock of bird or fish for search of food [14] [15]. This behavior of bird can be useful to design the optimization algorithms. Here each particle/bird fly in the sky, those particle/bird are close to food, it simply chirp loudly and other bird follow this bird. If another bird which are more close to food as compared to first one, it again chirp loudly and remaining all bird circulating around it. In this way the objective (food) is achieved. Each particle is a latent solution to the optimization problems and travels in the direction of the best optimal solution based on past experience. PSO algorithm is very simple, high converge capability and easier to implement.

PSO have two main equations expressive the velocity and the position of the particle at particular time. After each iteration, the position and velocity is modified until terminating conditions satisfied. The termination conditions can be number of iteration of some predefined fitness value.

V. TEACHING LEARNING BASED OPTIMIZATION(TLBO)

The following are the limitation associated with classical (conventional) methods:

The efficiency of this method is very much depends on the size of feasible solution, variable size and constraint in the design problem • This method do not gives generic solution • Most of the method tends to get hang to a sub-optimal point • Classical method cannot be effectively applied on a parallel machine. • Classical optimization methods are very much depends on class of constraint functions i.e. linear, nonlinear etc. • Conventional methods are very much depends on nature of variables used in the optimization problem i.e., linear, nonlinear etc.

Teaching–Learning-Based Optimization (TLBO) is advanced method proposed by Rao et al [9], [10], [17] which is based on the impact of a teacher on the outcomes of learners. The outcomes can be in the form of marks, grade or reward. In the classroom, the teacher shares his knowledge, concept and idea with a student. The performance of the teacher is reflected to a student in the form of their result, marks or grade. Obviously, good teacher trains the student property for improvement of their result.

TLBO is also an evolutionary nature-inspired population based optimization algorithm. The process of teaching-learning and optimization terminology are related by following

- Population = class or group of learners
- Design variables = subjects
- Fitness value= learners‟ result.

The working of TLBO process has two phases:

(1) Teacher Phase (2) Learner Phase.

The ‘Learner Phase’ concern with learning through the mutual communication between students and the ‘Teacher Phase’ concerned with learning from the teacher. The flow chart is shown in Fig.5

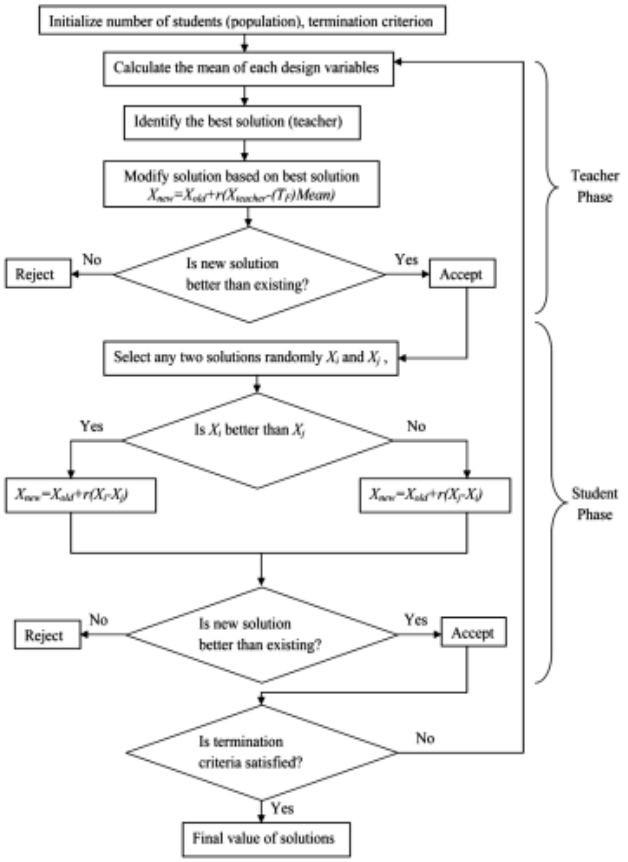

Fig 5 Flow chart of TLBO

VI. CONCLUSION

The allotment of spectrum as per the Quality of Service for the required applications is a major research field in the cognitive radio application. CR is an intelligent radio network technology that can adaptively and automatically detect vacant channels in wireless spectrum and improve the spectral utilization of the spectrum. Spectrum sensing is the important task to be performed by CR to meet this requirement. Different optimization techniques for spectrum sensing in cognitive radio network like Genetic Algorithm (GA), Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO) and Teaching Learning Based Optimization (TLBO) are discussed to find the optimal solution for spectrum sensing.

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