Genetic Algorithm and Particle Swarm Optimization for Spectrum Sensing In Cognitive Radios

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Abstract – During the past decade, wireless industry has increased rapidly due to which demand for bandwidth has increased. Recent study shows that the main cause of spectrum scarcity is inefficient use of Electromagnetic (EM) spectrum which is actually present in large quantity. To manage this problem, Cognitive Radio is the best approach. It allows the radio to run on different parameters, learn from it and sense it. This paper focuses on the spectrum sensing based on popular optimization techniques: Genetic algorithm and particle swarm optimization. They both are evolutionary algorithm and helps in solving optimization problems. This paper emphasize on general review of both the algorithm and their advantage.

Index Terms – Cognitive Radio, Genetic algorithm, Particle Swarm Optimization, Spectrum Sensing.

1. INTRODUCTION

Radio spectrum is a natural resource and it is used mostly by transmitter and receiver in a wireless communication industry. In the past decade, receiver became more service oriented which automatically increases the demand of bandwidth that causes spectrum scarcity. There are many government authorities like FCC who administer license spectrum. Recent study shows that in some places theses spectrum causes the decrease spectrum efficiency. To deal with this situation Cognitive Radio has been introduced by Joseph Mitola in 1991. According to Mitola, CR cycle has three capabilities that is sense, decide and act[1]

CR senses the Radio Frequency (RF) environment and gives information about the presence or absence of primary user (PU). CR is capable of learning and sensing the spectrum and acknowledges it. After sensing, decision is made by the CR that whether to move on to other spectrum which is of similar frequency or wait for another. The decision can be either simple or complex depending on the past knowledge and future analysis.

1.1 Spectrum Sensing

Spectrum sensing is the main element of the spectrum management. It emphasize on sensing the presence of primary user PU. Spectrum sensing is the first step to employ cognitive radio technology. It is a big challenge for spectrum sensing to find the unused band which is of similar frequency and operate its function on it. Spectrum sensing is done through a real- time wideband spectrum sensing ability to detect the presence of weak primary signals in a wide spectrum range .After the spectrum holes have been recognized then the cognitive radio user can operate them for their transmission. The process of finding the spectrum hole is called spectrum sensing. [2]

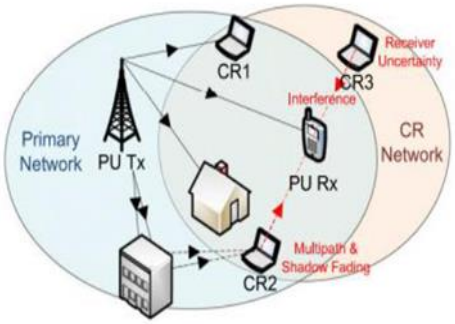

Fig 1: Principle of spectrum sensing

2. OPTIMIZATION

According to (Doyle 2009) "An optimization process can be defined as the process involve in selecting the "best" choice from the list of available choices in order to get some kind of goal".

2.1 Approaches for optimization

There are two types of optimization approach which can be involved in CR. One is "heuristic" and another is "meta-heuristic" approach. These are used to find solution from large search space.

The "heuristic" approach is less complex as compared to "meta-heuristic" as it includes many tricks to tackle local maxima and minima problems. So "meta-heuristic" is finest optimization method for Cognitive Radio. There are many other "meta-heuristic" approaches like hill-climbing, greedy and tabu search.[3]

2.2 Genetic Algorithm

The concept of GA was introduced by JH Holland in 1960. GA is excellent approach for solving complex optimization problems. The solution of the problem is the best pass on from previous generation. GA can be applied to various engineering optimization problems like finite automation, non-deterministic and machine learning.

The main advantage of GA over other techniques is that they are able to speed up the simulation result which is known as parallelism. It generates new population from the existing population that's why there is less chance of getting stuck into local extreme. There are many other benefits of GA like fast convergence which indicate that they can converge quickly on a problem. There are many devices on which GA can be implemented like DSP, FPGA. The re-usage and easy implementation.[4]

Advantages of GA

- Easy implementation and re-usage.
- It can handle large amount of variables.
- Unlike others it gives a list of optimum solution
- It is compatible with parallel computers
- It does not need any derivation information
- Both discrete and continuous variables can be optimized with GA.

GA approach

GA is based on "survival of fittest" which implies that only fittest particle will survive.

1. *Initialization* - A random population of n chromosomes is generated. This population contains all existing solution.
2. *Fitness measure* - In second step, the fitness value of each chromosome is calculated. The process of evolution contains following steps:

- Selection – In this process, select two chromosomes from a given population and consider them as parent. There are many selection procedure which helps in deciding the best parent like ranking selection.
- Reproduction – In this process, crossover is done on parent chromosomes that produce one or two offspring or child. Then these offspring is fed back into the population and they are considering as fittest among all and remaining least fit population is destroyed automatically.
- Mutuation – It replaces the parental population with new generated offspring and continues the algorithm.

3. *Test*- The above process is repeated until one optimum solution is obtained.

Chromosomes are basic building blocks of the GA. So selection occupies a very important role in chromosomes, we get many new generations after executing a several operation like crossover, selection and mutuation.

Fitness measure act as a filter which are used to filter only those individual which are below specified level. After the fitness measure, we get only best solution. After this step, GA will execute other task like selection, crossover and mutuation

GA in Radio Frequency Measure

As studied earlier, CR has three capabilities that is observe, decide and act so that input got from observation needs proper analysis in GA. To get, proper utilization, one must measure fitness value accurately for that we need a proper knowledge of quantity of chromosomes required.

GA operations

The important steps involved in genetic is finding two best chromosomes or fittest parent from the given population and calculate its fitness function and then perform different operations on it like selection crossover, mutuation and after that insert that new chromosomes or offspring into general population.

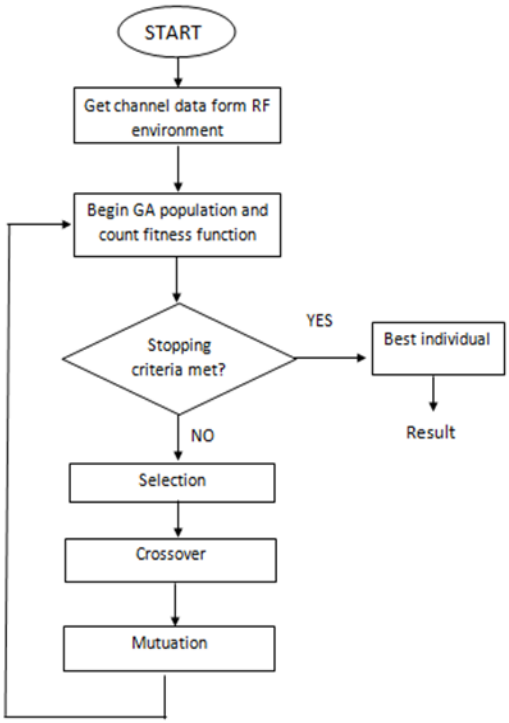

Fig 2: Flow chart of Genetic algorithm

2.3 Basic structure of GA

While (end of termination condition)

For n=1

Initialize population

Evaluate fitness function

Increment n

For (c=1; check if chromosomes <2)

Randomly choose x_1 and x_2 from given population

Produce two new chromosomes x_1^{new} and x_2^{new} by crossover operation of x_1 and x_2 ;

Execute mutuation operation on x_1^{new} and x_2^{new}

Calculate fitness function of x_1^{new} and x_2^{new}

Insert x_1^{new} and x_2^{new} into X^{new}

End for

3. PARTICLE SWARM OPTIMIZATION

PSO is a heuristic global approach which is inspired from the social behavior of birds, fishes and insects. [6][7] PSO is another good technique for solving optimization problems. It was introduced by James Kennedy and Russele Ebeshart in 1995. We can take example of flock of birds who always move in the same direction without colliding. They all communicate message in such a way that all birds takes mutual decision. They all search for food and cooperate with the one who is closest source of food (potential solution). They don't have any leader in their group or swarm still they have good communication with each other and make best solution. A particle which is closest to food or have better condition spread the message among all the birds and they start moving to that place. [8]

Elements of PSO

Swarm: It is collection of particles in search space.

Particle: Particle can be fish or insect whose comparison is required.

Fitness Function: It is a function whose value needs to be optimized.

Personal best position: It is a position which is based on personal experience

Global position: It is a position which is based on global decision.

Vector update: It is used to measure the speed and direction of particle at any point of time.

In PSO, in iteration each particle solution is evaluated by the objective function being optimized. Initially PSO select random particle within the search space or population. In figure given below the initial position of four particle PSO algorithm seek out global maximum in one dimensional search space. All the possible solutions lies in the search space along the x-axis the curve signify the objective function. Unlike GA, PSO has no knowledge of objective that is which particle is near or far from local or global maximum. PSO works on objective function to calculate the fitness value. Each particle takes its own decision and maintains its own position. [8]

PSO algorithm consist of three steps

(a) Evaluate the fitness of individual particles

(b) Update individual and global or personal best position

(c) Update velocity and position of each particle

Let ith particle's velocity at iteration t is $vl_i(t)=\{vl_{i1}(t),vl_{i2}(t),\ldots\ldots vl_{iD}(t)\}$. Following equations update the velocity and position of the particles :

$$vl_{id}(t+1) = IWvl_{id}(t) + A_1r_1(t)[pb_{id}(t)-ps_{id}(t)] + A_2r_2(t)[gb_d(t)-ps_{id}(t)] \quad (1)$$

$$ps_{id}(t+1) = ps_{id}(t)+vl_{id}(t) \quad (2)$$

Where d= {1,2,3,4,……,D} is the dimension of the search space, IW is the inertia weight and A_1,A_2 are the acceleration constants. r_1,r_2 are the two random numbers in the range[0,1]

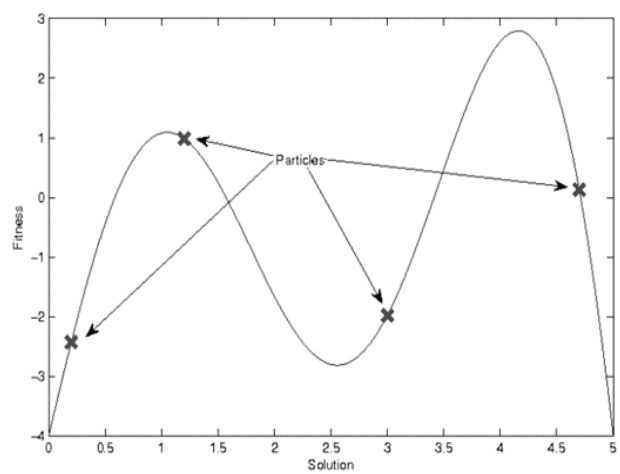

Fig 3: Initial state of PSO

4. CONCLUSION

Hence Cognitive radio is used for enrichment of spectrum efficiency. Even though many works has been done on power allocation of Cognitive Radio but very limited focus is done on evolutionary algorithm. In this paper we discussed about two optimal algorithms that is PSO and GA which are inspired by

the nature for solving various complexities.PSO gives low complex optimal solutions as compared to GA whereas GA seems to be arrive at final value in fewer generation than the PSO and also GA is better in implementation and parallism.In future work the author will compare both the algorithms under different cognitive parameters so that more will be the throughput and less will be the sensing time.

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