ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 6, Issue 4, October 2016

Review of Different Optimization Techniques used for Multi-User Detection in CDMA Network

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Abstract — Code Division Multiple Access is a methodology used by varied communication technologies like wireless communication, radio technology etc. it's a kind of multiplexing, that permits various signals to occupy one transmission channel, optimizing the use of available bandwidth. Different signals have different codes in this. However, generally because of a large number of users, interference results between them which leads to increased bit error rate and also near far problem. Optimization has played a very important role in finding a solution to this problem. The problem can range from finding the shortest path as in traveling salesman problem, to finding the best transmission power to minimize the BER within the signal. Nature has provided several examples of optimization like evolution, bird flying pattern, ants finding food etc and these examples are converted into mathematical models to resolve various optimization problems by varied mathematicians. In this paper, a review of various optimization techniques employed in optimization of Multi-User Detection in CDMA system are described. The objective of optimization is to reduce the Bit Error Rate and increasing the number of users. Comparative study of various optimization techniques is summarized and discussed.

***Keywords*—Optimization; Multi-User Detection; CDMA; Genetic Algorithm; Particle Swarm Optimization; Biogeography based Optimization algorithm.**

I. INTRODUCTION

Code Division Multiple Access is a kind of multiplexing, that permits various signals to occupy a single transmission channel and also the different signals have different codes in this. The most common wireless technology is DS-CDMA (Direct sequence code division multiple access) within which the stream of the information of various signals is split into small pieces, each of which is allocated across to a frequency channel across the spectrum. The redundant chip code helps the signal to resist interference and put together permits the initial information to be recovered if the data bits are damaged throughout the transmission.

Optimization issues are developed to resolve the complicated problems with some best-known set of probable solutions iterating over multiple times variable the values at tiny steps unless the target function reaches its global minima. [1].

Optimization techniques are applied over wireless networks additionally therefore on boost the performance of the system. One kind of wireless technology that has become extremely regarded over the previous few years is Direct sequence code division multiple access (DS-CDMA). During this system, several users transmits the data at identical time over a standard channel using pre-assigned codes referred to as the spreading codes, but these codes are not related with each other. The performance of single user CDMA systems is restricted by Multiple access interference (MAI), that if not controlled can severely degrades the standard of reception.

The near-far drawback is a important issue that affects the user capability and performance of CDMA system. [2] [3].

TO remove these problems, Multi-user detection (MUD) is taken into account collectively of the key techniques for the communication system. This reduces the MAI and solves near-far problems and improves the capability of system. The optimum detector is taken under consideration as best detector to cut back near far effect but its complexity increase exponentially by 2K where K is range of users. [2] Many optimization techniques are there for optimization of the system like Genetic algorithm, Particular swarm optimization, artificial bee colony optimization, Spider monkey optimization, bees algorithm, firefly algorithm technique, etc. We'll be observing Genetic algorithmic rule, Particle Swarm optimization algorithm and Biogeography based optimization algorithmic etc. The next sections describe the algorithms however as cite the literatures that have applied the techniques over CDMA system. At the end, a conclusion is presented.

II. LITERATURE REVIEW

In 2008, Wen et al. [23] works on specific swarm optimization technique for the multi user detection of cdma system of code division multiple access system. in order to keep up the matter of near far moreover on reduce the complexity of CDMA, it uses some parameters like variety of users, population size, signal to noise ratio, power efficiency, etc, that are improved consistent with the user necessities thus on cut back the quality. in this paper the author compares PSO with GA and when comparison the output can be created with reduced computational complexity and provides the optimum resolution.

In 2009, Krishnanand K.R et al. [24] conferred a comparative study of results of 5 evolutionary algorithms: Genetic Algorithm (GA), Particle Swarm optimization (PSO) rule, Artificial Bee Colony (ABC) algorithm, Invasive Weed optimization (IWO) algorithm and Artificial Immune (AI) algorithm when applied to some standard purpose of reference of multivariable functions. In this paper, the results shows that Artificial Immune algorithm and Invasive Weed optimization techniques performed very better when as compared to different algorithms, which helps to reduce the

ISSN: 2277-3754
ISO 9001:2008 Certified
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Volume 6, Issue 4, October 2016

near far problem moreover on reduce complexness of the system with the better effectiveness moreover as better efficiency.

In 2010, Nan zhao et al. [26] proposed a ant colony optimization (aco) algorithms to review the local minima problem as well as reduce the complexity. This algorithmic rule will expand the penetrating range and avoid local minima by indiscriminately or random modification in one or a lot of components of the local best solution, that is that the alteration operation in genetic algorithmic rule. the performance of ant colony algorithm can return better and it reduces the complexity, which may be enlarge the penetrating range and it avoids the local minima by introducing the alteration mechanism to the aco algorithms. so, the performance of ant colony optimization is nearly a similar procedure complexity and it reduces the local minima drawback.

In 2013, Zhendong yin et al. [27] introduce the optimization technique that is known as artificial bee colony algorithm that is predicated on the behavior of honey bee swarm. In ABC algorithm, a colony of artificial bees look for artificial food sources optimizes the matter and notice the simplest parameter that helps to minimize an objective function. Then the artificial bees discover a population of initial resolutions and improve them by applying the behavior which moves towards the simplest solution

B.Sathish Kumar et al. [32] work on new optimization algorithm known as Hybrid Firefly algorithm optimization technique. In this paper, to overcome the noise and interference problems, hybrid firefly optimization algorithm based on the evolutionary algorithm is proposed. The proposed algorithm is compared with the existing multiuser detection algorithm such as particle swarm optimization, genetic algorithm and Hybrid firefly optimization algorithm based on evolutionary algorithm. The simulation results show that performance of the proposed algorithm is better than the existing algorithm and it provides a satisfactory trade-off between computational complexity and detection performance.

In 2016, Santosh N Nemade et al. [28] work on biogeography based mostly optimization (BBO) algorithm to achieve large data rate of cdma network. in this paper, biogeography based mostly optimization algorithmic rule introduces the multiuser detection of cdma system. the target of bbo algorithmic rule is to attenuate the error rate of the user transmitted signal. during this algorithmic rule. According to the immigration rate and emigration rate, the best solution of the detection drawback is determined. Therefore, the complexity of user detection still because the interference of the transmitted signal square measure to be reduced. then, the performance of bbo algorithmic rule is compared with harmonic search algorithmic rule. Also, the user detection performances of those algorithms are compared with completely different range of users still as range of iterations. Then from the analysis, bbo algorithm has performed higher than the improved harmonic search algorithm. The convergergence time of bbo algorithmic is less and also the complex city is reduced.

In 2016, Amanpreet Kaur [29] works on the new optimization technique that is Spider monkey optimization (SMO) and apply it to resolve near far drawback in code division multiple access. In this paper, the author compares the SMO algorithmic rule with the particular swarm optimization (PSO) as well as genetic algorithm (GA).The simulation results shows that however SMO algorithmic rule is effective to reduce complexity as well as near far drawback of the MUD-CDMA. The results show the benefits of SMO compared to different ways because it will resist higher noise level, keep down BER and lower complexity. In this work SMO, PSO and GA algorithms are used for the optimization and SMO performs far better than others. Furthermore different algorithms like Hybrid fire fly, Cuckoo search, Bat algorithm. Moreover, it's a valuable approach for real time multiuser detection in cdma network system.

II. GENETIC ALGORITHMS APPLIED OVER CDMA SYSTEM

The first evolutionary-based technique introduced within the literature was the Genetic algorithm (GA). GA was developed based on the Darwinian principle of the 'survival of the fittest' and also the process of evolution through copy. [3] based on its incontestable ability to achieve near-optimum solutions to large issues, the GA technique has been employed in several applications in science and engineering. Despite their advantages, GA may require long processing time for a near optimum resolution to evolve. Also, not all issues lend themselves well to a solution with GA.

Genetic algorithm contains a four stage life cycle that is described below:

A. Initialization

Initially several individual solutions are at random generated to create an initial population covering the entire range of possible solutions (the search space).

B. Selection

During every consecutive epoch, a proportion of the present population is selected to breed a new generation. Individual solutions are selected through a fitness-based method like wheel choice, wherever fitter solutions area unit generally more possible to be selected .

C. Reproduction

The next step is to generate a second generation population of solutions from those selected through genetic operators: crossover (also known as recombination), and mutation. For every new answer to be created, a combine of "parent" solutions is selected for breeding from the pool selected previously. New set of parents area unit selected every time and therefore the process continues till a replacement population of solutions of acceptable size is generated.

D. Termination

This generational process is continual till a termination condition has been reached. Here the fixed variety of

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ISO 9001:2008 Certified
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generations reached is taken as the criteria for the termination of the program.

Parameters	Values
Modulation scheme	BPSK
Spreading codes	Walsh
No. of subcarriers	4
GA selection method	Fitness proportionate
GA mutation method	Binary mutation
GA crossover method	Uniform crossover
GA mutation probability	0.1
GA crossover probability	1

Basic simulation parameters used in GA in MUD of CDMA

Genetic Algorithms are employed by several researches so as to optimize the mutli-user detection in CDMA system. [5][6][7] used Genetic algorithm so as to optimize the multi-user detection. Ergun et al. [5] proposed a hybrid approach that employs a genetic algorithm (GA) and a multistage detector (MSD) for the multiuser detection problem during a code-division multiple-access communications system. Yen et al. [6] proposed a spatial diversity reception assisted multiuser code-division multiple-access detector supported genetic algorithms (GAs). Yen et al. [7] proposed a novel multiuser code division multiple access (CDMA) receiver based on genetic algorithms, that collectively estimates the transmitted symbols and attenuation channel coefficients of all the users.

IV. PARTICLE SWARM OPTIMIZATION APPLIED OVER CDMA SYSTEM

Particle swarm optimization (PSO) is another optimization technique combining the psychology principles in the biological process computation [9], [10]. PSO has been impelled by simulating the social behavior of organisms such as fish schooling and bird flocking. PSO includes an easy conception and may be implemented by a number of lines of code using primitive mathematical operators. It is computationally economical in terms of memory and speed [9]. In this paper, it is shown that PSO has benefits over GA for with efficiency finding the optimum or near-optimal solutions [11], [12]. PSO will benefit from the past experience of memory of the population. Interaction among the cluster provides a tug toward the good solution [9]. PSO was originally developed for optimization of a continuous variable. A distinct binary PSO algorithm was planned in [13]

Soo et al. [8] applied particle swarm optimization (PSO), to develop a suboptimal MUD strategy. The de-correlating detector (DD) or linear minimum mean sq. error (LMMSE) detector is used as the first stage to initialize the PSO-based MUD. Then, the PSO algorithm is applied to observe the received information bit by optimizing an objective perform incorporating the linear system

No. of Iterations	Fitness value	No. of selected features
23	0.9291	21
13	0.9291	25
12	0.9134	23
14	0.9213	19

Average performance characteristics of PSO-based [30]

LMMSE detector. Lu et al. [14] proposed a new binary algorithm that derives from standard PSO conception and named BEP algorithm. They applied the BEP and binary PSO (BPSO) to solve the multiuser detection issues within the CDMA system.

Simon et al [15] presented the paper on biogeography based optimization in 2008. They presented the mathematical background of biogeography. Mathematical models of biogeography describe however species migrate from one island to another, however new species arise, and how species become extinct. In this paper [16],Geographical aras that are compatible as residences for biological species are said to have a high habitat suitability index (HSI) [17],features that correlate with HSI include such factors as precipitation, diversity of vegetation, diversity of geography features, land area, and temperature. SIVs are often considered the independent variables of the habitat, and HSI can be considered the dependent variable.

Biogeography based optimization

BBO uses 2 elementary operations for iteration in order to optimize the solution aka to optimize the cost operate. These 2 operations are explained below:

A. Migration

Suppose that we have a problem and a population of candidate solutions that can be described as vectors of integers. each integer within the solution vector is considered to be an SIV. Further suppose that we have some way of assessing the goodness of the solutions. Those solutions that are sensible are considered to be habitats with a high HSI, and those that are poor are considered to be habitats with a coffee HSI. HSI is analogous to “fitness” in different population-based optimization algorithms (GAs, for example). High HSI solutions represent habitats with several species, and low HSI solutions represent habitats with few species.

We use the expatriation and immigration rates of every answer to probabilistically share data between habitats. With likelihood, we tend to modify every answer supported different solutions. If a given answer is chosen to be changed, then we tend to use its immigration rate to probabilistically decide whether or not or to not modify every quality index variable (SIV) in this solution. If a given SIV during a given solution is chosen to be changed, then we tend to use the emigration rates of the opposite solutions to probabilistically decide that of the solutions should migrate a at random selected SIV to solution.

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ISO 9001:2008 Certified
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B. Mutation

Cataclysmic events will drastically modification the HSI of a natural habitat. they can also cause a species count to differ from its equilibrium value (unusually large flotsam arriving from a neighboring habitat, disease, natural catastrophes, etc.). A habitat's HSI will, therefore, modification suddenly because of apparently random events. we model this in BBO as SIV mutation, and we use species count probabilities to determine mutation rates.

Parameters	Value
Number of iteration	50
Population size	50
Mutation probability	0.04
Emigration rate	0 to 1
Immigration rate	0 to 1

Parameters of used in BBO [31]

Each population member has an associated probability that indicates the likelihood that it had been expected a priori to exist as a solution to the given drawback. Very high HSI solutions and extremely low HSI solutions are equally improbable. It is, therefore, possible to change to another solution. This can be implemented as a mutation rate that is inversely proportional to the solution probability.

First, we note that though BBO is a population-based optimization algorithm it doesn't involve reproduction or the generation of "children." This clearly distinguishes it from reproductive methods similar to GAs and biological process ways. BBO also clearly differs from ACO, because ACO generates a new set of solutions with each iteration. BBO, on the opposite hand, maintains its set of solutions from one iteration to the next, relying on migration to probabilistically adapt those solutions.

Nemade et al. [18] in 2015 presented a novel approach to solving multi-user detection drawback in DS-CDMA using biogeography based optimization technique. The technique is tested with Harmonic Search algorithm and enhanced Harmonic Search algorithm so as to check the performance. In each cases, BBO algorithm is faster because it took less range of iteration to converge to zero BER and efficient as the BER is managed to be zero for ten users simultaneously whereas different algorithms maintained it best to nine users.

V. ANALYSIS AND DISCUSSIONS

After analyzing all the 3 optimization techniques, we can discuss the outcome and evaluate each of them theoretically. Genetic Algorithms requires 'n' range of generations to improve upon and thereby converge to a solution, given the amount of dimension, the solution is applied for. Thus, GA based solutions will be slower further as slower to adapt to new changes in network as needed by CDMA based networks with dynamic range of users.

Particle Swarm based optimization depends on the flocking behaviour of birds finding food that again tends to be slow given the amount of dimensions. If number of birds is a smaller amount or more, the solution gets affected because of the less range of local best solutions, the global best may not be the optimum best solution. Additionally with a lot of number of birds increased, the simulation will be slower because of higher range of local solution tends to generate more than one optimally best solution.

BBO out of all 3 shows way more important improvement as BBO algorithmic rule as tested by Nemade et al. [18] tends to showcase the effectiveness in converging faster towards a solution.

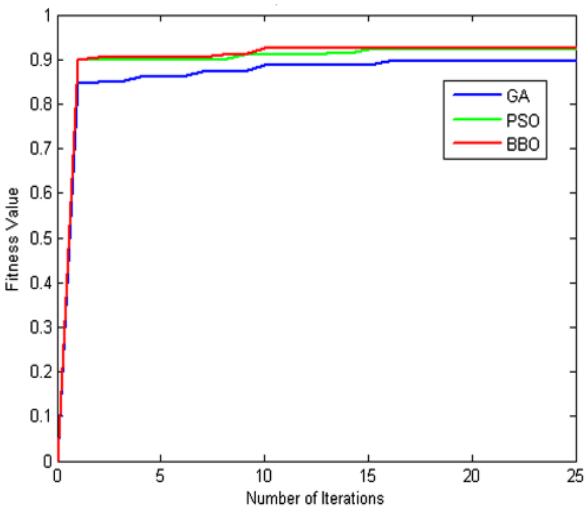

Fig 1: Comparison of GA, PSO and BBO in order of Best Fitness Achievement with Number of Iterations [22]

In figure 1, the three algorithms are compared based on the maximum fitness achievement in terms of best fitness value as well as number of iterations required. BBO achieved best fitness compared to PSO and GA in minimum number of iterations as well. GA proved inefficient in terms of converging to best results.

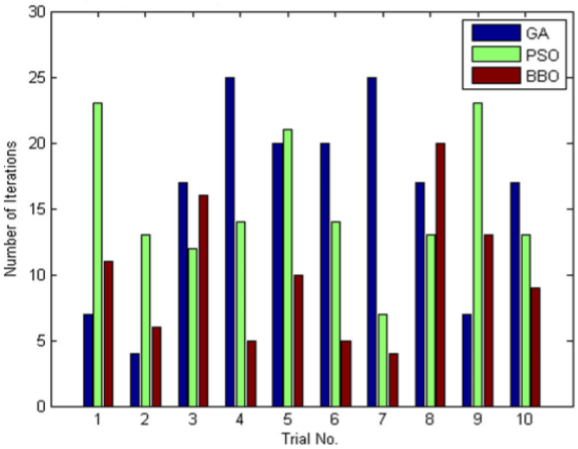

Fig 2: Comparison of Iterations to Best Fitness Achievement vs. Trials [22]

The figure 2 shows 10 different trails with number of iterations required to achieve best fitness value. BBO again proved highly efficient in converging in minimum number of iterations. PSO failed completely and shows that it requires maximum time in order to reach best fitness.

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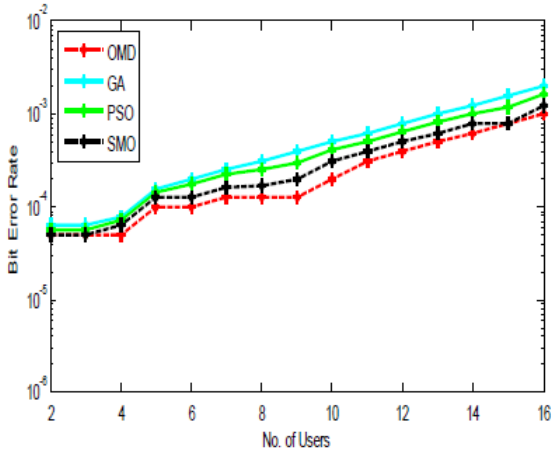

Fig 3: comparison of BER v/s no. of users [29]

In figure 3 we compare BER performance against number of active users K at SNR= 10 dB for CDMA system. It can be shown that SMO detector has a better BER performance than PSO at same K.

VI. CONCLUSION

In this paper, the optimization techniques related to Multiuser detection in CDMA system are reviewed. Three optimization techniques namely Genetic Algorithm, Particle Swarm Optimization and Biogeography based Optimization algorithms are considered. It is concluded that in Genetic algorithm, there is a one single solution whereas in Particular swarm optimization, there is a multiple set of solutions. Further a theoretical discussion is provided which shows that BBO optimization algorithm is better in terms of speed and optimization. PLEASE EXPLAIN.

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ISO 9001:2008 Certified
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