Reducing Computational Complexity in DS-CDMA using Swarm Optimization Techniques

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Abstract— **In commercial CDMA systems the signal strength is extensively effected by the Multiple Access Interference(MAI). Many techniques have been employed to reduce the effect of MAI. In the beginning Matched Filters are being used to handle MAI problems. In Multiuser detectors following two filters, code matched filter and multiuser linear filter are used to handle the MAI problem. But because of asynchronous operation of these filters the computational complexity of the system is increased. And hence the efficiency of the system drastically effected. This Multiuser technique is based on sub-symbol and in the sub-symbol scheme, data symbols of the users are partitioned Matched filter techniques have been successfully utilized in IS-95 standard). But with in to sub-symbols such that the resulting sub-symbols from different users are time aligned at the receiver side.**

The optimal linear filters operate in each sub-symbol interval, and the filtered outputs are processed using various evolutionary Algorithms. With the matched filter technique the number of users become limited in DS-CDMA. When the number of users are increased in DS-CDMA, the bit error rate(BER) for individual user is also increased. Researchers have used many techniques to eradicate this problem. In this research paper two swarm optimization techniques(PSO & GA) have been used to handle the problem of computational complexity problem. The comparison is made in between these two techniques. It is analyzed that PSO has a edge over GA in reducing computational complexity.

Keywords: CDMA, Multiple Access Interference, Matched Filters, Bit error rate, Particle swarm optimization(PSO), Genetic Algorithm(GA)

I. INTRODUCTION

In present cellular systems The DS-CDMA system is a multi-user spread spectrum system that eradicate the problems of frequency reuse. In FDMA and TDMA systems, the Signals of the user not overlap with each other both in the time domain or in the frequency domain, respectively. A unique code ia assigned in the CDMA system which modulates the signal of each user and transmissions took place at the same time with the same frequency. These unique codes assigned to the user signals in a CDMA system is always equal to the number of users which are active. These modulating codes of the signals of the users are also called a spreading code or spreading sequence or chip codes

This research work employ two Evolutionary algorithms which are based on the swarm combinatorial optimization.. These two techniques based upon the principal of the individual and society interaction which a has bases from the group behaviour or individual learning and experience. The Particle swarm optimization(PSO) technique is more robust and very much Effective in solving MUD problem. in our analysis the MUD problem is treated using evolutionary techniques GA and PSO..

II. SYSTEM MODEL

A single user Direct Sequence spread spectrum system can be easily converted in to a Multiuser Spread spectrum system . Because structures of these transmitter and receiver are similar and the channel which is a Multiuser channel is obtained just by using the principle of the superposition of many single user channels. We assumes and we regard the signals of the other users as additive white noise for the detection of a particular user's signal at the base station. Because of this assumption, direct sequence spreading results in frequency spread spectrum are very similar to the additive white noise.

In the Wireless cellular communication system especially in DS-CDMA system we not only need to understanding the transmitter and receiver models but also we need to know the about the wireless channel through which the active signal is going to travel. In this section receivers used for the DS-CDMA systems have been introduced. A single user matched filter receiver is among the simplest of all DS-CDMA receivers. The Zero forcing detectors along with the minimum mean squared error detectors are described in the paper in detail.

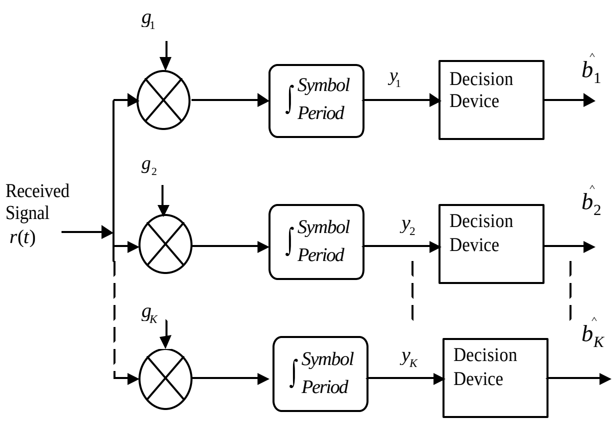

Figure.2.1 Single User matched filter

$$s(t) = \sum_{k=1}^{K} A_k b_k g_k(t) \quad \text{..............(1)}$$

$$r(t) = s(t) + n(t) \quad \text{................(2)}$$

A. The Single User Matched Filter

Single User Matched Filter(SUMF) is used in the basic CDMA receiver. It is usually implemented as a correlator. It is also called conventional detector. In this detector the signal of each user is demodulated separately without having any knowledge or any previous informations about the signals of all other users. For each user there is one SUMF detector at the base station. The final output of each detector obtaimed has no effect on other signals.

The SUMF is a maximum-likelihood detector. It maximizes the signal-to-noise ratio (SNR) for a particular user for this it does not consider the signals of other users. That is why it is called the optimal detector. This way the de-spread and demodulated signal of the user looks like only additive white noise (AWN). And we are well aware that in case of additive white Gaussian noise (AWGN) the probability of error for the single user is also going to be minimized. Hence the assumption which made on the bases that signals from other users sharing the same channel can not be considered and will be true only when the spreading sequences of all the users will be orthogonal to each other. So the signal is received at the base station after passing through the wireless propagation channel. But one problem arise because of non-zero cross-correlations between spreading sequences which lead to multiple access interference (MAI) and this increases rapidly with the increase of number of users.

All Current DS-CDMA receivers use the method of SUMF detection. For detection a replica of the spreading sequence of the user interested is locally generated This locally generated replica is used with the incoming signal and we say this operation as correlated. It is very much clear from Fig. 2.1. Here the assumption is made that the symbol-long portion of the locally generated spreading sequence correlates weakly with spreading sequences of the other users. So because of this weakness the correlation is performed over a symbol period . The particular symbol in The output of the SUMF is given by Eq.3

$$Y_i(t) = \int_{\substack{Symbol \\ period}} r(t) K_i(t - t_j) \ldots \quad (3)$$

Here $r(t)$ shows the received signal and tj represents the channel delay for the *j-th* user. When the system is a synchronous system the above equation is converted to

$$y_i(t) = \sum_{j=1}^{Nu} T_{ij}(t) A_j(t) d_j(t) + n(t) \ldots\ldots \quad (4)$$

B. Orthogonal Sequences

If we want that our DS-CDMA system to be synchronous, Then we must have to ues the orthogonal sequences. Because of this application MAI is completely eliminated and optimum performance is achieved by SUMF detector. The demodulated signal for the *i-th* user from equation 4 can be written as

$$y_i(t) = R_{ij}(t) A_i(t) d_i(t) + n_i(t) \ldots. \quad (5)$$

Here all obtained cross-correlation terms are supposed to be zero.

C. Semi-orthogonal sequences

We have stated that in Synchronous DS-CDMA we use the orthogonal sequences and because of zero cross-correlation with each user signal MAI problems becomes more severe as the number of users are increased. Here comes the Semi-orthagonal sequences. The cross correlation properties of Semi-orthogonal sequences are appears to be better than those of orthogonal sequences. In this system at the base station Symbols from all users are received asynchronously. But one sensitivity of this system is that these are performed only when the transmission instants of individual users can not be controlled accurately and efficiently. In these situations spreading sequences are selected in such a way that the cross-correlation is minimized and as a result the MAI is reduced. The examples of good cross-correlation properties are Gold and Kasami sequences. Kasami sequences have a tri-valued cross-correlation. When the operation is synchronous operation we can obtain MAI directly from equation (5). We have considered a system with two users to perform a quantitative analysis of Multiple access Interference (MAI).

The SUMF outputs from can be written as:

$$y_1(t)=R_{11}(t)A_1(t)\,d_1(t)+R_{12}(t)A_2(t)\,d_2(t)+n_1(t)\,..(6)$$

$$y_2(t)=R_{21}(t)A_1(t)\,d_1(t)+R_{22}(t)A_2(t)\,d_2(t)+n_2(t)\,..(7)$$

We have to consider that the error probability for the synchronous DS-CDMA channel entirely depends on the following parameters:

i) Relative magnitudes of the received signals.

ii) Cross-correlation values of the spreading sequences.

iii) Power of the additive white Gaussian noise

III. Swarm Optimization Techniques

In this research work swarm optimization techniques have been employed for optimization. These techniques are based on the genetic evolutionary theory. This theory is being employed to apply sequence code division multiple access (DS-CDMA) in communication systems. In this research we have analyzed new biological processes for different phases of an evolutionary algorithms. During this application we have considered specially the technique, multi-user detection(MUD) problem. And the channels considered are multipath fading channels. The results are considered and compared with ML Detector. The results when compared with the optimum solution (ML - maximum likelihood) we come to the conclusion that the detection based on evolutionary swarm techniques gives an optimum solution even for severe system operations and hostile channel conditions. In order to find out the optimum performance the complexity of each swarm optimization is determined and compared with others user signal This comparison is based on the required computational time and required number of computational operations.

While considering the complexity Problems many proposals of solutions have been proposed by researchers for employing the heuristic algorithms especially the swarm optimization techniques. These techniques are used to increase DS-CDMA communication systems performance and its capacity. Considering these proposals the optimum solutions are obtained very efficiently by using two swarm optimization Techniques. These techniques are PSO AND GA. . The Above mentioned techniques are significantly faster than conventional point-by-point search techniques which are previously used. These Techniques are very much effective especially when large solution spaces are required for effective communications.

In this work two heuristic algorithms are analyzed and these a are based on the swarm optimization Principal. these algorithm were originally proposed by Kennedy and Eberhart. In these techniques the individual-society interaction, learning suffers influence from the group behavior. Learnings from the individual behavior are main theme used for optimization. These swarm optimization techniques are very efficient. The MUD problem is also treated very effectively.

It appears that in most of the practical engineering cases, MUD based on Evolutionary techniques results in almost optimu m and efficient. These results are very close to the performance obtained by the by the Optimum Multiuser Detection. But because of the advantages of smaller detection time smaller computational cost there is an attractive trade off in convergence speed and computational complexity.

A . *GA Algorithm*

a. *Population Size: In* genetic algorithms the population size choice is an important factor. This is very important for the computational cost. The solution quality is also determined by this. When population size is very small the performance can be Poor. The effective performance depends upon the individual behavior and experience. This small population size covers only a small part of the total search area that we called the universe. And when the population size is large. We will be able to get a sufficient informations. These informations covers the wide area of the problem. But this large population size may not be able to avoid premature convergences for local solutions rather for global solutions. Because of large population size large computational resources are in our hands and very long unnecessary period of time will be utilized which may slow the initialization process which in turn will make the computational Process sufficiently large.

b. *Reproduction:* Reproduction is a process of evolutionary algorithm in which candidate vectors or the individuals, are copied according the their fitness values. The individuals with high fitness values have greater probability to form the next generation efficiently. And individuals with lower fitness values have lower probability to take part to form the next generation . Some of the candidates which may have low fitness values may have higher probability to take effective part to form next generation.

B. *The Particle Swarm Opimization*

In PSO (Particle Swarm Optimization) a flock is searching over the solution landscape. It is represented by sampling points. This flock of swarm is going to converge on the most efficient regions of Landscape. The trajectory of the particle is defined by Velocity so that the particle is moving through the solution space always. Best efforts are made to adopt back to a previous the previous efficient position or an attraction towards the best area discovered by the neighbors itself. The convergence of a particle swarm depends upon social pressure of neighbors and individual fitness and individual experience.

IV. The Swarm Topology

PSO particle is a member of one or more neighborhoods. These particles are related with each other socially. In PSO all particles belongs to the same single neighborhood this is when neighborhood is defined to be global. Name g is used for the particle which has best fitness value. In PSO when the neighborhoods are local Every particle belongs to at least n+1 neighborhoods contrary to global). Where n is the neighborhood size. Particles are being visualized in a circle, where each particle is the center of a neighborhood of n/2 predecessors and n/2 successors in the search space. When we consider a swarm of N = 5 with a neighborhood size of n = 2 this ia an example. In this example each particle is a member of three overlappings in the search space.

In PSO all group of particles are randomly distributed in the space. They have their own position and velocity. We can represent the d-th dimension of the i-th particle position at time t is represented by the equation below.

$$x_{id}(t) = x_{id}(t-1) + v_{id}(t-1) \ldots\ldots. \quad (8)$$

Here $v_{id}(t-1)$ is the i-th particle velocity in its d-th dimension and time $(t-1)$. In our research MUD problem is analyzed, for such type of problem we have used discrete model for the algorithm so that we utilize some probabilistic methods. We have considered number of dimensions as being the number of users. Hence in the Equation below each $K \times 1$ vector Rpresents the particle i.

$$x_i(t) = \left[x_{i1}[t] x_{i2}[t] .. x_{ik}[t] \right]^T, ...i = 1,2,3...p \ldots.(9)$$

The previous velocity for speed speed calculation is represented by ? and $U_{I1}[T]$ and $U_{i2}[t]$. Thses have dimension K diagonal matrices. In equation 9 each element x_{id} assumes the "0" or "1" values respectively. This we have considered in discrete mode for position choice. We obtained this inserting a command of choice in the algorithm. Which is dependent of the velocity of the particle. Velocity is being adjusted by the a probabilistic mode. For this the sigmoid function being adopted here as shown by equation 10.

$$S(a) = \frac{1}{1+e^{-a}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

This function is limited in the interval (0, 1). $S(a)$ which approaches to 0 when a ? ∞ and to 1 when $a \rightarrow \infty$. PSO particle position is further representd by the following equation.

$$IF..S(v_{id}[t]) \supset r_{id}[t], ..Then...x_{id}[t+1] = ..else..x_{id}[t+1=0] \ldots..(11)$$

In above equation $r_{id}[t]$ is a Random variable modeled through $.U(O,1)$. V_{max} is a factor which is added to the algorithm model to escape from a local maxima. Because of this addition the velocity is limited in the range $[\pm V_{max}]$. A minimum probability that the bit change this factor is being inserted in the velocity calculation. This make it possible for the algorithm to escapes from forthcoming local maximuma. This brings an effective improvement in the performance. The algorithm works efficiently if we consider the required parameters of the algorithm The Table below compares the probability with the V_{max}. The table shows this probability as a function of the V_{max} value. It is very much clear from the table that when the particle velocity crosses the limits $[\pm V_{max}]$. So when the particle velocity crosses the limit the bit change will be probable. Table shows the probability of bit changes as a function maximum velocity.

Vmax	1	2	3	4	5
100[1-	2	10	3	1	0
(Vmax]%	5.95	.93	.76	.01	.58

V. Results And Discussions

The simulation results of PSO-MUD have been compared with other algorithms. The system is assumed to be Synchronous multiuser detection system and the channel is AWGN channel. For spreading codes 31 bits Gold Sequence have been used. In simulation bits have been transmitted. Through the AWGN channel. Signals are received by Single user bound, conventional detector(MF), GA -MUD and PSO-MUD.

Simulation results shows the Performance comparison under different SNRs. It is very much clear from the simulation results that Bit Error Rate(BER) of PSO-MUD is lower as compare to all other detectors. Results shows that PSO-MUD in DS-CDMA has much better capability against bit error than of GA -MUD.

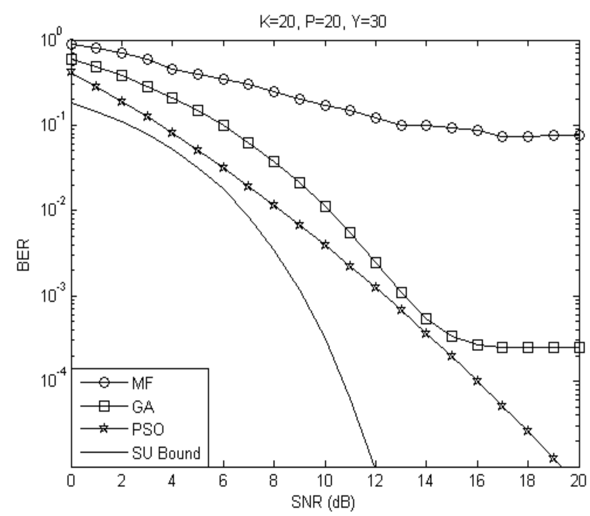

Figure. 5.1: Performance comparison of GA -based MUD and PSO-based MUD having computational complexity 600 for 20 user synchronous DS-CDMA system

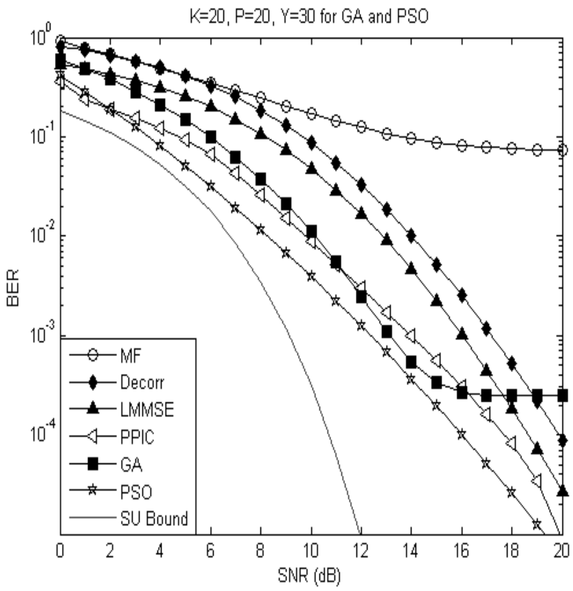

Figure. 5.2 Performance comparison of GA-based MUD and PSO-based MUD with other sub-optimal multi-user detection schemes for 20 user synchronous DS-CDMA system

Figures 5.1 and 5.2 show the Performance comparison of GA - based MUD and PSO-based MUD. With other sub-optimal multi-user detection schemes for 20 user 20 particles and 30 iterations synchronous DS-CDMA system. Figure shows that when signal to noise ratio is very small the performance of PPIC is better even than PSO but with the increase of signal to noise ratio the performance of PSO becomes better than all sub-optimal Detectors.

VI. COCNCLUSION

The PSO-MUD is a promising algorithm. The parameters optimization in a synchronous receivers shows that the PSO Swarm optimization technique reach very fastly the optimum ML performance and is stable for many different system's operation point (load, and Eb/N0), Provided the optimized parameters remains constant. The two swarm optimization Techniques are robust fast converging in a fast mode, even with high load condition, in spite of a slow initial convergence.

These swarm optimization techniques have a complexity of the same order, with the GA-MUD resulting the smaller number of operations for the two analyzed loading (K = 16 and K = 32 users). But for the MUD problem the PSO swarm technique results in a good complexity × performance tradeoff, having the smaller computational complexity than the GA-MUD; however this complexity difference tends to be marginal as loading increases.

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