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Multi-User Detection using Harmony Search Algorithm in CDMA Systems

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ABSTRACT
Major requirement of the next generation wireless communication systems is to provide higher data rates in transmission of signal in order to meet higher demand of quality services. Multi-User Detection is a field which comprises all aspects related to the detection of mutual users whose received signals are not orthogonal to each other. This generally corresponds to (non orthogonal) CDMA systems, because these systems have a large number of users whose signals overlap in frequency and time. DS-CDMA system is extensively used wireless communication technology. Use of Direct Sequence Spread Spectrum causes MAI (Multiple Access Interference) which in turn affects performance of DS-CDMA system. To distinguish user data in presence of Multiple Access Interference, various Multi-User detection techniques were suggested by different researchers. Objective of this paper is to provide survey on multi-user detection methods that are used for data modulation and compare the results of conventional multi-user detection algorithm with proposed Enhanced Harmony Search algorithm.
Keywords - DS-CDMA, Multi-User Detection, Multiple Access Interference

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I. INTRODUCTION

Requirement of communication channel is to accommodate multiple users at the same time. Conventional communication system has limitation of capacity because it uses either frequency or time sharing. Available bandwidth can be used to satisfy the requirement of multiple users with the help of spread spectrum techniques. In spread spectrum techniques, particular signal with allocated bandwidth is intentionally spread in frequency domain which results in signal with wide bandwidth. Spread spectrum technique utilizes frequency hopping, direct sequence or combination of both. Advantages of spreading technique include increased resistance to interference and noise. But this technique has the limitation because of Multiple Access Interference (MAI) which originates due to Direct Sequence Users. Multi-user Detection is going to be answer to this problem. Multi-user detection techniques were developed to distinguish user data in presence of Multiple Access Interference, Inter Symbol Interference and noise. In wireless communication, Direct Sequence Code Division Multiple Access (DS CDMA) has gained popularity in recent days because of efficient channel utilization.

Telecommunication systems methodologies based on DS CDMA are intrinsically affected by Multiple Access Interface because it is difficult to retain orthogonal spreading codes in mobile environment. In real time, orthogonal nature of codes cannot be maintained at the receiver side, because of channel delay spread. The correlation receiver cannot separate the signals for multiple users perfectly. Capacity of traditional detectors is restrained due to MAI. Multi-user Detection MUD techniques filter out Multi-user Interference from signal received by each and every users before making any kind of data decision, and hence offer substantial gain in performance and capacity.

DS CDMA receivers are categorized into Single User and Multi-user detectors. A single user detector recognizes data of single user at a time whereas Multi-user detector combinedly detects data from multiple users. In conventional CDMA techniques, single user detection is implemented, so that the interference between multiple users is considered as noise. This noise adds to the statistics of detection parameters and affects quality of signal detection. Sometimes single user and multi user detectors are also referred as decentralized and centralized detectors respectively [1].

In its most straight forward form, single user detector is a matched filter to the required signal and signals from other users are treated as noise. This self-noise can curb system capacity and jam out all communications whenever strong near-by signal is present (Near Far problem). In near Far

Effect, users that are close to Base Station are received at higher powers than those are far away, so that the signal which is away suffers performance degradation. To reduce the complication of Near Far effect, tight power control is need when signal transmission is being done. System capacity is optimum when all the signals reach base station with the same power level which forces use of power control circuits in transmitters.

II. MULTIUSER DETECTION

Multiuser detection (MUD) views all users as signals for one another, unlike single user detection in which each user is treated separately as a signal, with other users considered as noise or MAI. MUD can be implemented in both Base Station as well as mobile device. However, MUD is currently being used in uplink i.e. mobile to Base Station. The employment of MUD is more suitable in the uplink because all mobile devices broadcast to the base station and the base station has to detect all the user signals anyway.

Earlier work on multi-user detectors was based on the assumption that the receiver has knowledge of all user codes. Such detectors are suitable only for the uplink transmission. However, a detection technique is required for downlink that needs only desire user code. Detectors based on this principle are known as adaptive multi-user detectors [3].

Until the work done by Verdu, it was believed that the optimum detector for a given user was the matched filter. This misconception derived from the assumption that the receiver for user would naturally use its spreading code to de-spread the signal before proceeding to detect the bits for user. The de-spread versions from other users' spreading codes help with the detection of desired signal [2].

We can use multi-user detection to overcome the near far problem by considering known structure of MAI [8]. Computational Complexity of optimal multi-user detection exponentially increases with number of users active in the system. So, it is a major challenge to design detectors with minimal complexity but performance comparable to optimum detector. Several techniques have been proposed and few of them include, Minimum Mean Square Error (MMSE) detector, de-correlating detectors, multi-stage detectors etc.

III. MULTIUSER DETECTION TECHNIQUES

Multi-user Detection (MUD) algorithms can be roughly categorized into optimum and sub-optimum detection. Suboptimum techniques are then further divided into Linear, non-linear and adaptive techniques. Linear MUD detectors involve applying linear transformation to the matched filter outputs. De-correlating detector and MMSE equalizer are two commonly used detectors in this category.

In non-linear algorithms, successive or parallel interference cancellation methods are used. Successive Interference Cancellation (SIC) involves cancellation of interfering users from the output of matched filters, whereas in Parallel Interference Cancellation (PIC), detector cancels the MAI estimates from matched filter output in parallel manner [7].

3.1 CONVENTIONAL MULTIUSER DETECTORS

In conventional detector or the matched filter detector, the incoming signal is correlated with the desired user's time reversed spreading waveform, and then the output is sampled out. This method of detection comes straight from single user designs. It is assumed that there is other user in the system and therefore is not resilient to fading channels or PN sequences with considerable cross correlation.

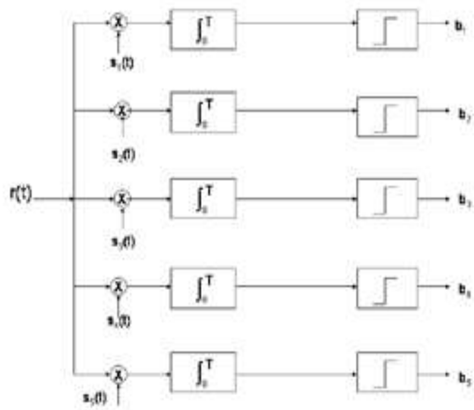

Figure 1: Conventional Matched Filter Detector

With the increase in number of active users in the system, MAI also increases and is exposed to variations in power among multiple users. A powerful interfering user will increase the MAI, suppressing the desired user. MAI may cause high bit error rates which eventually decrease system capacity.

Power Control can be used to overcome this Near Far problem, but at the expense of increased complexity at both the receiver and the transmitter. To implement power control, the mobile unit detects the power of the received base station signal and transmits at the inverse of the power. Use of sectored antennas can reduce MAI. Particular area of coverage is focused with the help of these antennas, thus eliminating effects of users in different sectors. In order to remove the MAI and the near far effect, a mixture of source coding and power control is used.

3.2 DECORRELATING DETECTOR

In de-correlating detector, inverse of the correlation matrix user spreading codes and then it is applied to the output of traditional detector. De-correlation technique is viable only at the base station where there are no limitations on power consumption. One of the advantage of de-correlation detector over conventional detector is that former removes all multiple access interference. Also, power of each user need not be estimated or controlled from transmitter side. One of the disadvantages of this technique is that it cannot remove ISI introduced because of channel dynamics. It also suffers from noise enhancement problem. Despite of the limitations, this detector will outperform conventional detector when the spreading codes used are not orthogonal.

The de-correlating detector accomplish the same effectiveness as the optimal multiuser detector and has linear (if number of users is considered) computational complexity. The de-correlating detector was shown to completely remove the multiple access interference, if the code sequences of the users are linearly independent, at the cost of intensifying the additive white Gaussian (AWG) receiver noise. The de correlating detector of [4] and [5] is centralized and non repetitive or non iterative.

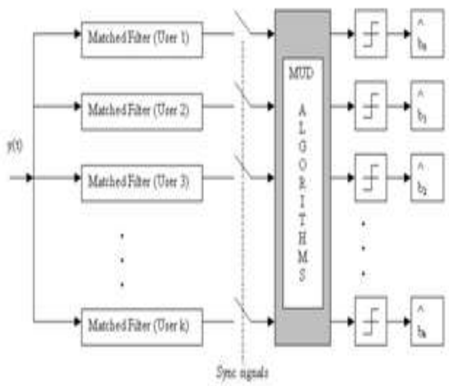

Figure 2: Conventional Multi-user Detector

MAI as well as ISI can be eliminated with help of more general form of de-correlating detector known as zero forcing detectors. Zero forcing multi-user detector also experiences same noise enhancement issue. Minimum mean squared error (MMSE) equalizer is introduced to improve performance in presence of noise.

3.3 MINIMUM MEAN SQUARED ERROR (MMSE) EQUALIZER

ZF equalizer suffers more from noise gain than the traditional MMSE equalization. For the random multipath channels synthesized in Monte-Carlo simulations [6], near common zeroes were encountered in a small percentage of the trial runs. These nearly common zeroes cause the norm of the ZF equalizer to be very large which leads to large noise gain. The noise gain is so large for these particular channels that they dominate the BER performance of the ZF equalizer.

The MMSE faces much less from these problems. We know that, for most of the channels, there is a slight improvement in MMSE performance, but in case of the bad channels the MMSE is much better. The overall result is that the MMSE, even though MMSE is basically available for the same computational effort (although it needs to know the SNR), it greatly outperforms the ZF equalizer when it comes to average performance.

Though MMSE detector does not achieve minimum BER, it has proved its usefulness in achieving optimal near-far resistance. In MMSE receiver, Mean Square Error (MSE) of the matched filter output is minimized with the help of some linear transformation [9].

IV. HARMONY SEARCH ALGORITHM

For optimization, people have traditionally followed algorithms based on calculus that give gradient information in order to figure out the right direction to the optimal solution. However, we know that discrete variables cannot have derivatives. To overcome this problem, the harmony search (HS) algorithm has used a novel stochastic derivative [10] which uses the experiences of musicians in Jazz improvisation and can be applicable to discrete variables [11].

Basic steps for Harmony Search algorithm can be summarized as follows,

Step 1: Problem Formulation - Harmony search algorithm is designed to solve optimization problems. Thus, to apply HS algorithm, first of all we need to construct problem statement with objective function and its constraints.

Step 2: Algorithm Parameter Setting - Once problem is formulated in optimization environment, we need to set algorithm parameters with random values. In Harmony Search Algorithm, we select parameters such as pitch adjusting rate (PAR), harmony memory size (HMS), harmony memory consideration rate (HMCR) etc.

Step 3: Random Tuning for Memory Initialization

Step 4: Harmony Improvisation - Now algorithm selects a value from total set of values in HM and improves it in order to get optimal performance.

Step 5: Memory Update If new value in HM is better than the previous one then it is store in the memory and harmony memory is updated.

Step 6: Performing Termination - If the search algorithm clears termination condition or optimal function value is obtained, computation of HS memory is halted.

V. RESULTS

The proposed harmony search algorithm used for multiuser detection in CDMA system was implemented in MATLAB for performance analysis. Bit error rate is used as performance measurement characteristic of proposed algorithm. Fig. 3 shows performance of system when number of users is 2, 4 and 6.

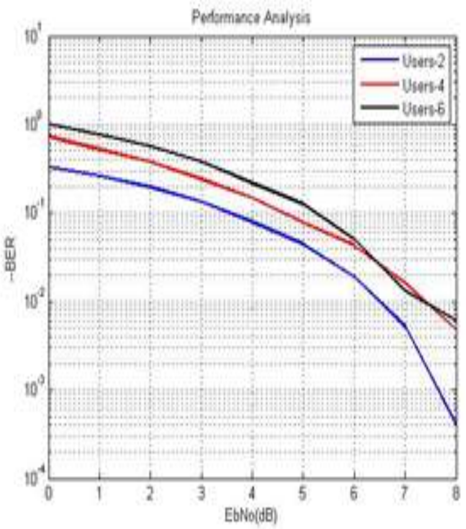

Figure 3: Performance Analysis

`Then, Bit Error Rate performance of proposed HS algorithm was compared with conventional multi-user detection method.

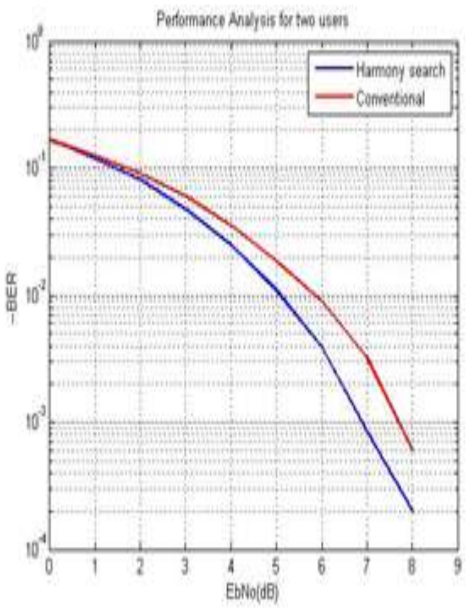

Figure 4: Comparison of Algorithm **Temp**

VI. CONCLUSION

In CDMA systems, performance depends on how efficiently multiple users are detected when they arrive simultaneously at the base station. While detecting user signal, detection algorithm must consider Multiple Access interference that is generated due to use of direct sequence spread spectrum techniques used in DS-CDMA. With increase in number of users present at specific time, hardware complexity as well as computational complexity increases.

Use of harmony search algorithm in CDMA user detection has improved performance of system. Bit Error Rate is also improved significantly when compared with traditional multiuser detection algorithms.

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