Multi-User Detection In DS-CDMA System Using Biogeography Based Optimization

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Abstract

To attain large information rates, code division multiple access (CDMA) is a well-built aspirant for the downlink of cell phone communications. However, while transmitting any signal over fading channel, the performance of CDMA system is highly affected. For that reason, Multiuser detection (MUD) and channel estimation play a significant function for overcoming the interference and characterizing the channel. In this paper, biogeography base optimization (BBO) algorithm introduced for multiuser detection CDMA system. The objective of BBO algorithm is used to minimize the error rate of the user transmitting signal. According to immigration rate and emigration rate, the optimal solution of the detection problem is decided. Therefore, the user detection complexity and the interference of user transmitting signal are resolved. Proposed multiuser detection algorithm is appropriate for run time user identification process; since the detection complication and the required time are concentrated. The proposed approach is implemented in MATLAB working platform and the performance measures are examined. The error rate of proposed algorithm is compared with harmony search algorithm, enhanced harmony search algorithm, and without multiuser detection procedure.

1. Introduction

In Digital cellular radio systems, the allocated bandwidth and radio cell infrastructure can be made capable with minimum cost and maximum performance by incorporating multiple access schemes [3]. The multiple access schemes are Code Division Multiple Access (CDMA) and Multi-Carrier Code Division Multiple Access (MC-CDMA). CDMA is an efficient method of bandwidth allocation and is used in many to one wireless communication channels [2] [18]. In MC-CDMA, higher system capacity is hypothetically promised by passing on multiple CDMA spreading signatures to each user at the transmitters and by applying sophisticated multiuser detection (MUD) schemes at the receivers and innate frequency diversity of wideband channels is well subjugated by scattering each symbol across multiple sub
In recent days, the multiuser interference is treated as a part of the information rather than noise in joint multiuser detection [8] [9]. For multiuser detection, preceding research has focused on designing suboptimal receivers in synchronous CDMA model with low computational complexity and provides a better performance than a linear detector [5]. In many multiuser communication systems, multiuser detection for the symbol-synchronous Gaussian CDMA channel has established significant consideration over the past 15 years due to the problem of multiple-access interference (MAI) [6] [10]. From both theoretical and engineering perspectives, the area of multiuser communication is one of vast concern [17]. To conquer the range of problems, multiuser detection can be used by exploiting the recognized structure of the multiple access interference to efficiently demodulate the non orthogonal signals of the users [1] [7]. MUD for CDMA systems typically depends on a number of priori channel estimates. These are obtained either blindly or by means of training sequences. The covariance matrix of the received signal is generally replaced by the sample covariance matrix [13]. It can be used to lessen MAI in direct-sequence a CDMA system which significantly improves the system performance compared with the conventional matched filter (MF) reception [15]. Performance close to optimal has been achieved by focusing on practical multiuser detectors in current research. To this end, the belief propagation (BP) is applied to multiuser detection recently. The posterior probability of tentatively predicted bit vector increases iteratively by BP and is exposed to congregate to the global maximum likelihood (GML) in large random spreading CDMA [14]. For the probabilistic inference problem BP algorithm was initially used, which is the problem to compute the marginal probabilities of the interested variables [16]. In the direct sequence code division multiple access (DS-CDMA) technology, all the users allocate the entire frequency band accessible at the identical time. Because of, it is possible due the scattering sequence with short chip period, which is used in order to spread the user information beside the entire obtainable bandwidth spectrum, in addition to serves as an identification code for each user, providing several level of multiple access interference immunity. The heuristic algorithms are plays an important role due to the nature of the non deterministic polynomial difficulty posed by the wireless multi-user detection optimization problem. This challenge is to attain appropriate data detection performance in solving the connected hard complexity problem in a polynomial time. To overcome this problem, various types of optimization algorithm based detection methods are discussed. The optimal maximum likelihood is one of the comprehensive search which takes out an all the justifiable permutations of the transmit symbols of every users. Obviously, this technique has a complication so as to exponentially rise by means of the number of users, in addition to with the number of bits per symbol, which inspires the expansion of concentrated difficulty close to optimal MUDs. In favour of instance, genetic algorithm (GA), evolutionary programming, particle swarm optimization, ant colony optimization (ACO), sphere decoding, and Markov chain Monte Carlo supported detectors have found support within low complication near optimum MUDs. Furthermore, the ACO based MUDs are accomplished for realizing a lower bit error rate and a lower complexity than the GA supported MUDs. But, the non-iterative algorithm is effectively performed and lower complexity which compared to iterative based detection. In this paper, an effective swarm intelligence algorithm is introduced named as BBO to improve the performance of MUDs based CDMA system. The detailed description of proposed detection model is explained in the following section. In this paper, BBO algorithm is introduced for detecting multi-user MUD in DS-CDMA system. The detailed description of CDMA system and the multi-user detection algorithm are explained in the following section.

2. Modelling of DS-CDMA system

In this paper, multi user detection models used examine the characteristics of transmitting data to the receiver side. The general structure of DS-CDMA system is illustrated in figure 1. Here the transmitted signal of $N^{th}$ user is denoted as $x_N(t)$ and the received signal is denoted as $y_N(t)$. The binary date transmitted by the $N^{th}$ user is denoted as $a_N(t)$. In CDMA system, the transmitter side consists of user transmit data, transmitter and demux. The receiver side is
consisting of channels and detectors. The transmitted signal by $N^{th}$ user is expressed [29] in equation (1). The data of the transmitted signal is represented as $a_N(t)$ and signature of spread signal is represented as $e_N(t)$ which are described in equation (2) and (3) as follows. Transmitted signal by $N^{th}$ user,

$$x_N(t) = \sqrt{2R_N} a_N(t) e_N(t) \cos(f_c t + \theta_N)$$  

Data of the transmitted signal by $N^{th}$ user,

$$a_N(t) = \sum_{j=-\infty}^{\infty} a_{N,j} r_T(t - iT)$$  

$$e_N(t) = \sum_{j=-\infty}^{\infty} e_{N,j} r_T(t - iT_c)$$

Where, $\theta_N$ is the phase of $N^{th}$ user, $r_T$ is the rectangular pulse with amplitude 1 and duration $T$, $r_T$ is the clip rectangular pulse with amplitude 1 and clipping duration $T$, $R_N$ is the signal power, and $f_c$ is the carrier frequency.

The transmitted signal of user $N$ is applied to the demux which is the combination of data of the signal $a_N(t)$ and the signature of spread signal $e_N(t)$. The bit duration of the data $a_N(t)$ is $T$ and the clipping duration of the signature spread signal $e_N(t)$ is $T_c$ respectively. From demux, the signal is processed and the processing gain of the signal is depends on the bit duration and the clip duration. The processed signal is applied to the receiver side channels. The receiver signal $y_N(t)$ of the transmitted signal is described [21] as follow.

Received signal by $N^{th}$ user,

$$y_N(t) = g(t) + \sum_{N=1}^{M} \sqrt{2R_N} a_N(t - \lambda_N) e_N(t - \lambda_N) \cos(f_c(t - \lambda_N) + \theta_N)$$

Data of the received signal by $N^{th}$ user,

$$a_N(t - \lambda_N) = \sum_{j=-\infty}^{\infty} a_{N,j} r_T(t - \lambda_N) - iT$$

Signature of spread signal by $N^{th}$ user,

$$e_N(t - \lambda_N) = \sum_{j=-\infty}^{\infty} e_{N,j} r_Tc((t - \lambda_N) - iT_c)$$
Fig. 2. Signal Channel model of CDMA system.

Where, $g(t)$ is the White Gaussian Noise \([22]\), here common noise model is used for all \(N\) users; therefore $g(t)$ is common for all the users. In equation (4), the value of $\theta_N$ is uniformly distributed from 0 to $2\pi$. When the transmitted data is received to centre, the random delay be occurred which is denoted as $\phi_N(t - \lambda_N)$ and the spread signal is denoted as $e_N(t - \lambda_N)$. The correlation of the output signal is estimated by obtain from the data bit and the signal level. This estimation is used to improve the multiuser detection processes. The channel model of the CDMA system is illustrated in figure 2.

In the channel model of the CDMA system, the transmitted signal by different users are represented as $x_1(t)$, $x_2(t)$ and $x_N(t)$ respectively. The transmit signal is multiplexed with codes $C_1$, $C_2$ and $C_N$. Then, White Gaussian Noise $g(t)$ is added with the signal which is the signal of receiver signal. Finally, the signal is applied to the matched filter bank and received to the users $y_1(t)$, $y_2(t)$, and $y_N(t)$ respectively. The output signal is the combination of user transmitted signal and the reference codes of corresponding signal. Using this CDMA model, the multi user detection is performed by BBO algorithm. Here, the detection is examined by noise ration of the signal. The detailed discussion of BBO algorithm is explained in the following section.

3. An overview of BBO algorithm

The BBO is one of the optimization algorithms which keep on a set of candidate solutions called habitats \([23]\). The features of the habitats i.e. vector parameter is called a Suitability Index Variable. The habitats performance index is utilized to measure good solution which is equivalent to fitness of the optimization algorithm. The steadiness between the new species arrive and the old species be converted into extinct which depends on number of species present on the island. In this algorithm, each species has its own immigration rate and emigration rate which are represented as $\lambda$ and $\mu$ respectively. This rate is described depends on number of species on the island that is the population of islands. If more species inhabit the island, then the immigration rate $(\lambda)$ reduces; otherwise, the emigration rate $(|\mu|)$ increases. A high habit suitability index of among the total number of species is to be selected as successive solution. The emigration and immigration rates of the species $x$ among the total number of species $X$ to be determined as follow,

\[
\text{Emigration rate}(\mu_x) = I \left(1 - \frac{x}{N}\right) \tag{7}
\]

\[
\text{Immigration rate}(\lambda_x) = \frac{EX}{N} \tag{8}
\]

Where, $\mu_x$ and $\lambda_x$ are the emigration rate and immigration rate of species $x$, $I$ is the maximum emigration rate, $E$ is the maximum immigration rate and $BN$ is the population size. The performance of the relationships between the number of species vs. immigration rate and emigration rate is illustrated in figure 3. In the following section, the detailed description of BBO algorithm for proposed approach is described as follow,
3.1. Multi-user detection in DS-CDMA depends on Biogeography based optimization

In this section, the detailed description of biogeography optimization algorithm is explained in the view of multi-user detection. The objective of the proposed approach is to minimize the error rate of the noise of transmitted date. For that, $N$ numbers of users are selected with bits of transmitting message data. As per the input parameters, the objective function is formed which helps to minimize the error rate of the transmitting signal. The user and the transmitted message of the user are considered as the species and the habits of the species. According to that, the rate of the species is decided the optimal solution of CDMA system multi user detection problem. The pseudo code, steps and flow chart of the algorithm for proposed approach is illustrated as below. The pseudo code of the algorithm for multi-user detection is explained as follow,

*Initialize the population of $N$ candidate solutions (habitats) to a problem $X_s$*

While not termination criterion

For each $X_s$, set emigration probability $\mu_s$ fitness of $X_s$. With $\mu_s \in [0, 1]$

For each $X_s$ set immigration probability $\lambda_s = 1 - \mu_s$

For each individual $Z_s (x = 1, 2, N)$

For each independent variable index $s \in [1, n]$

Use $\lambda_s$ to probabilistically decide whether to immigrate to $Z_s$

If immigrating then,

Use $(\mu_s)$ to probabilistically select the emigrating individual $X_s$

$Z_s(s) \leftarrow X_j(s)$

Endif

Next independent variable index $s \leftarrow s + 1$

Next independent variable index $Z_s$

Next individual : $x \leftarrow x + 1$ and $X_s \leftarrow Z_s$

Next generation

End

Fig. 3. Relationship between the Number of Species vs. Immigration rate and Emigration rate
3.2. BBO Algorithm Steps for Multi-user Detection:

The BBO algorithm steps for multi-user detection in CDMA system is explained as follow,

Step 1: Initialize the N number of users, the transmitting data signal of the users and the code of the data signal.
Step 2: Then, the transmitting signal is processed by the inclusion of noise signal $g(t)$ and calculate the quality of the receiving signal. Here, the signal quality is measured by the bit error rate measurement. These evaluations are depends on the immigration rate and emigration rate of BBO algorithm
Step 3: Apply the migration operation of the evaluated signal.
Step 4: Apply mutation operation.
Step 5: Evaluate the error or check if the noise of the user transmitted signal is reduced in the receiver side. After the results of this evolution, the best solutions are select and neglect the worst solutions or the corresponding habits.
Step 6: Replace the worst solution by the new habits which are not considered in the evaluation.
Step 7: Evaluate the objective function and sorting the best solution.

The above steps are repeated till to reach the optimal evaluation i.e. termination criteria satisfied. If the evaluation stage is satisfied; then select the satisfied results. Otherwise, update the optimize variable and again proceed the detection procedure. The flow chart for BBO algorithm is illustrated as follow.

From the output of BBO algorithm, appropriate data detection performance is improved. The detecting performance is varied as per the immigration rate and the emigration rate of the habits. Using BBO algorithm, the optimal
Table 1: CDMA System and Channel Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Accepted Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of users</td>
<td>50</td>
</tr>
<tr>
<td>Modulation</td>
<td>BPSK</td>
</tr>
<tr>
<td>Process gain</td>
<td>50</td>
</tr>
<tr>
<td>Spreading Sequence</td>
<td>50</td>
</tr>
<tr>
<td>SNR</td>
<td>$\epsilon [-3, 10]$</td>
</tr>
<tr>
<td>System loading</td>
<td>1</td>
</tr>
<tr>
<td>Near far effect</td>
<td>$NER = 0 \text{ dB}$</td>
</tr>
</tbody>
</table>

Table 2. Implementation parameters BBO algorithm.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of iteration</td>
<td>50</td>
</tr>
<tr>
<td>Number of iteration</td>
<td>50</td>
</tr>
<tr>
<td>Population size</td>
<td>50</td>
</tr>
<tr>
<td>Mutation probability</td>
<td>0.04</td>
</tr>
<tr>
<td>Emigration rate</td>
<td>0 to 1</td>
</tr>
<tr>
<td>Immigration rate</td>
<td>0 to 1</td>
</tr>
</tbody>
</table>

The path of user detection is found without any information interference. The implementation of the CDMA system, the BBO algorithm and the performances are explained in the following section.

4. Results and Discussion

The proposed multiuser detection method in CDMA system was implemented in MATLAB working platform. Here, the BPSK modulation technique was used for modulating the transmitting signal of the transmitter. Detection effectiveness of proposed method is examined with different users. The bit error rate (BER) evaluation method is used for measuring the performance of proposed method. The implementation parameters of CDMA system and BBO algorithm are tabulated in Table I and II. Initially, the random number of users $N$ is selected between 1 to 4 and the number of bit to be transferred as 102. The error rate probability curve of the modulation technique is plotted with the signal strength $\frac{E_b}{N_0}$ in dB. The performance of error curve plot without using MUD is illustrated in figure 5.

In figure 5, the bit error rate of the user transmitting signal is high without using detection algorithm. Therefore, the number of received bits data stream above a communication channel is distorted due to interference. Then, the BBO based detection algorithm is applied and bit error rate is evaluated. The performance of BBO algorithm is compared with harmonic search and enhanced harmonic search algorithm [24]. The comparative performance is given in figure 4. In the comparative analysis, the BBO algorithm has less bit error rate when compared with harmonic search and enhanced harmonic search algorithm.

When the number of users increases, the error rate of the signal is obtained in optimization algorithm by stochastic way. So, the bit error rate performance BBO algorithm is observed by increasing number of users. The comparative performance of error rate and the number of users are illustrated in figure 4. From the performance, the proposed algorithm detects the most of the user messages when compared to other two methods. In harmonic search algorithm, the detection rate is very less that is the receiver signal interference error is high. But, the initial interference of enhanced harmonic search is reduced and it is increased at convergence time. In figure 4, the proposed method reduces the error rate to 0.09, the enhanced harmonic search algorithm is reducing the error rate to 0.12 and the harmonic search algorithm reduces the error rate to 0.16.

Then, the user detection of the BBO algorithm, the enhanced harmonic search and the harmonic search techniques are analysed with 50 iterations. The comparison performance of number of iteration vs. error rate is illustrated in figure 5. From that, it is clearly understand the BBO algorithm takes less convergence time. When compared to enhanced harmonic and tradition harmonic search algorithm, the BBO algorithm meets the best solution from the
iteration number 15. Consequently, the computational complexity of BBO algorithm is less which analysed from the number of essential number of operation for each detector is existed.

5. Conclusion

A BBO algorithm was introduced for multi-user detection in CDMA system. The BBO algorithm was used to minimize the error of transmitting signal which helps to reduce the information loss. The performance of BBO algorithm is compared with harmonics search algorithm, enhanced harmonic search algorithm and without detection algorithm. Also, the user detection performances of these algorithms are compared with different users and number of iterations. From the analysis, BBO algorithm has performed better than that enhanced harmonic search and harmonic search algorithm. In addition, the convergence time of BBO algorithm is less and the computational complexity are reduced.

References


5. Fumihiro Hasagawa, Jie Luo, Krishna R. Pattipati, Peter Willett and David Pham, *Speed and Accuracy Comparison of Techniques for Multiuser Detection in Synchronous CDMA* IEEE Transactions on Communications, Vol.52, No.4, pp.540-545, 2004


