Performance of Parallel Interference Cancellation Technique in Multistage Multiuser Detection for DS-CDMA System

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Abstract— The 3rd generation mobile communication system will base on Code Division Multiple Access (CDMA) system, because CDMA system can provide more capacity than TDMA and FDMA systems. But signal will suffer from the interference called Multiple Access Interference (MAI).This problem can be reduced by using multi-user detection technique. This paper examines the Performance of Parallel Interference Cancellation Technique in Multistage Multi-user Detection for DS-CDMA System. The simulation has been carried out for synchronous DS-CDMA system by varying number of users and number of stages.

Keywords—Multi-user detection (MUD), multiple access interference (MAI), DS-CDMA, PIC

I. INTRODUCTION

The tremendous increase in demand for wireless services has caused a search for techniques to improve the capacity of current digital wireless communication. To bring this vision for future, major improvements in the current state of wireless technology are necessary. One type of wireless technology which has become very popular over the last few years is direct sequence code division multiple access (DSCDMA). Code Division Multiple Access (CDMA) is one of the several methods of multiplexing wireless users [1]. In CDMA, users are multiplexed by distinct codes rather than by orthogonal frequency band as in frequency-division multiple accesses (FDMA), or by orthogonal time slots as in time division multiple access (TDMA). In CDMA, all users can transmit at the same time. Also, each user is allocated the entire frequency spectrum for transmission; hence, CDMA is also known as spread spectrum communications [2]. In DS-CDMA system multiple access interference (MAI) is the major factor limiting the performance and, hence, the capacity of the system. The interference from other users is known as multiple access interference (MAI). This interference is the result of random time offsets between signals, which makes it impossible to design the code waveform to be completely orthogonal. While the MAI caused by any one user is generally small, as the number of interference or their power increases, MAI becomes substantial. Therefore, analysis of the effect of MAI on the system performance as well as ways to suppress MAI has been the major focus of CDMA research. There are two basics approaches to solve this problem. The first approach is based on the concept of single user detection. In this approach, we identify one of the users in the system as the desired user and treat all signals from the other users as interference. The receiver (for the desired user) detects only the desired user signal. The second approach is called multi-user detection [3]. The code and timing (or amplitude & phase) information of multiple users are jointly used to better detection of signal of individual user is known as multi-user detection. The important assumption is that the codes of the multiple users are known to the receiver a priori. Theoretically, receivers based on multi-user detection [4, 5] usually outperform, but are usually more complex than receivers based on single-user detection. The applicability of multi-user receivers depends on system design issues, such as the security of joint detection, the implementation complexity, and the availability of information required performing multi-user detection. For example, let us consider a typical wireless cellular system. It would be difficult to employ multi-user receivers at the mobile units for forward-link transmission because of the limitation on the implementation complexity and the availability of information about other users. However, multi-user detection could be a viable choice in the base-station for reverse-link transmission. Verdu's seminal work published in 1986, proposed and analyzed the optimal multi-user detector that proved to be much complex for practical DS-CDMA systems. Therefore, over the last two decades or so, research has focused on finding suboptimal multi-user detector solutions [6], which are more feasible to implement. The detection of CDMA signals using the conventional detection which consist of a bank of Matched Filter (M.F) leads to unacceptable performance degradation in terms of bit error rate (BER). This presents the need for more sophisticated detection strategies and signal processing, such as multi-user detection (MUD) to overcome this performance degradation. An overview of different MUD algorithms can be found in [10]. The Multistage Parallel Interference Cancellation (PIC) detection is one of the most interesting multi-user detection techniques. Its concept is to cancel the interference generated by the users. One of the most effective PICs comes from the iterative multistage method, where the inputs of one particular stage are the estimated bits of the previous stage. After interference cancellation, the new estimations, which should be closer to the transmitted bits, are fed into the next stage [11].

II. CONVENTIONAL DS- CDMA DETECTOR

Now-a-days single user matched filter detection technique is using in mobile communication. Although easy to implement, the performance severely degrades when the number of users goes up. The conventional detector [7] consists of a matched filter bank (a series of transversal filters in parallel), with one filter corresponding to each user as shown in Fig. 1. The received signal is correlated with the signature waveform of each user, and the output is used to determine the bits transmitted by each user.

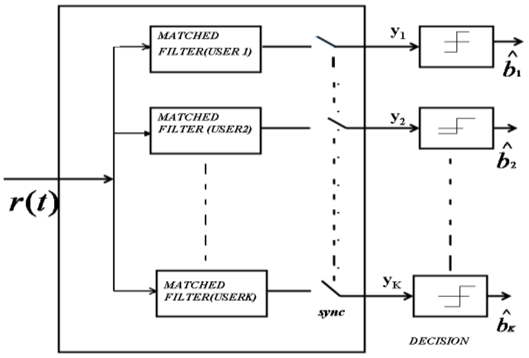

Figure:1 Matched filter bank

This detector relies on the fact that the signature sequences of any two users are close to orthogonal. It is to be noted that the matched filter receiver is not optimal (in the sense of maximizing the likelihood function) in the presence of MAI. Assuming there are K direct–sequence users in an synchronous single path BPSK real channel, the base band received signal can be expressed as

$$r(t) = \sum_{k=1}^{K} A_k(t) S_k(t) b_k(t) + n(t) \text{-----(1)}$$

Where $A_k(t)$, $s_k(t)$ and $b_k(t)$ are the amplitude, signature code waveform and modulated data of the kth user respectively and $n(t)$ is Additive White Gaussian Noise (AWGN), with a two sided power spectral density of $N_o/2$ W/Hz [13]. The sampled output of the kth matched filter is given by

$$y_k = \int_0^T r(t) s_k(t) dt$$

$$y_k = \int_0^T \left[\sum_{j=1}^{k} A_j b_j s_j(t) + n(t) \right] s_k(t) dt$$

$$y_k = A_k b_k + \sum_{j \neq k}^{K} A_j b_j \int_0^T s_k(t)\, s_j(t)\, dt + \int_0^T s_k(t)\, n(t)\, dt$$

Where

$$\rho_{kj} = \int_0^T s_k(t) s_j(t) dt$$

ρ_{kj} is the crosscorrelation of the spreading sequence between the kth and jth user. The decision is made by

$$\hat{b} = \mathrm{sgn}(y_k)$$

The single user matched filter receiver takes the MAI as noise and cannot suppress it. In matrix form, the outputs of the matched filter as

$$y = RAb + n \qquad (2)$$

Where **R** is the normalized crosscorrelation matrix whose diagonal elements are equal to 1 and whose (i,j) elements is equal to the crosscorrelation, $\rho_{i,j}$, **A**=diag{A_1,……,A_k}, **y** =[y_1,……..y_k]^T , **b**= [b_1,……..b_k]^T and n is a Gaussian random vector with zero mean and covariance matrix σ^2**R** [11].

III. CONCEPT OF MULTISTAGE PARALLEL INTERFERENCE CANCELLATION

This Parallel Interference Cancellation (PIC) detector estimates and subtracts out all of the MAI got each user in parallel. The s'th stage of this detector uses decisions of the (s-1)'th stage to cancel MAI present in the received signal. Thus, maximization is over one bit a time, instead of over k bits. The Fig.2 shows this concept.

The conventional detector is used in the first stage to estimate the data symbols. The other stages perform, for each user, signal reconstruction and subtraction of the estimated interference from all other users [7] [9].

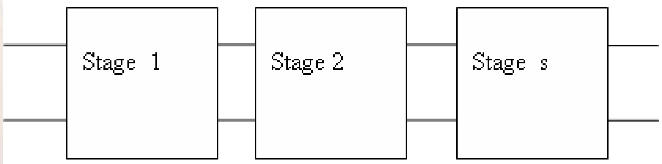

Fig. 2 The concept of multistage detector

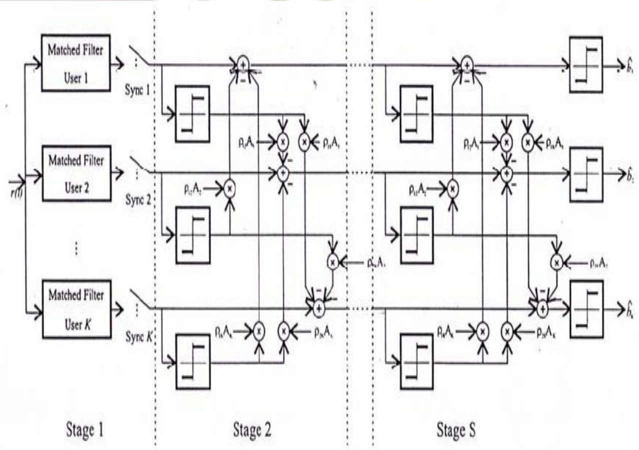

Figure (3) Multistage PIC Detector

In the Multistage PIC detector the interference is cancelled from the matched filter outputs or outputs of previous stages by using the estimates of the data symbols as well as the known cross-correlations between users as shown in figure(3). In the S-stage PIC detector, the
decision for the stage s+1 can be expressed as [8]:

$$\hat{b}_k^{(s+1)} = \mathrm{sgn}(z_k^{(s+1)})$$

Where $z_k^{(s+1)} = y_k - \sum_{j \neq k} A_j \rho_{jk} \hat{b}_j^{(s)}$

And $z_k^{(1)} = y_k$

The PIC detector requires to know the amplitudes of the received signals of all the users. Since this information is not directly available at the receiver, the received amplitudes have to be estimated. A common way to do this is to use the matched filter outputs or outputs of a previous stage, which are both referred to as soft decisions, as a joint estimation of the detected bits and the received signal amplitudes. In this case the decision statistic of PIC detector could be rewritten as [9]:

$$z_k^{(s+1)} = y_k - \sum_{j \neq k} z_j^{(s)} \rho_{jk}$$

PIC algorithm

$\hat{b}^{(1)} = \mathrm{sgn}(y)$ /*hard decision for M.F. ouput*/

For s=2 to s /*repeat cancellation s-1 stages*/

For k=1 to k /*subtract the interference from each user Signal at each stage*/

$$z_k^{(s)} = y_k - \sum_{j=1}^{k} A_j (R_{ij} - diag(R_{ij})) \hat{b}_j^{(s-1)}$$

End

$\hat{d}^{(s)} = \mathrm{sgn}(z^{(s)})$ /*hard decision generator*/

End

IV SIMULATION RESULTS

From Fig. 4 (a) to Fig (c) shows the bit error rate performance of the multi stage multi user detector for different user and different stages combinations. The number users increases the system performance is degraded but number of stages increases the signal to noise ratio increases. We have compared the different plots. Plotted the graphs between bit error rate and signal to noise ratio for users 10, 20, and 30 respectively for 5-stage multi-user detector.

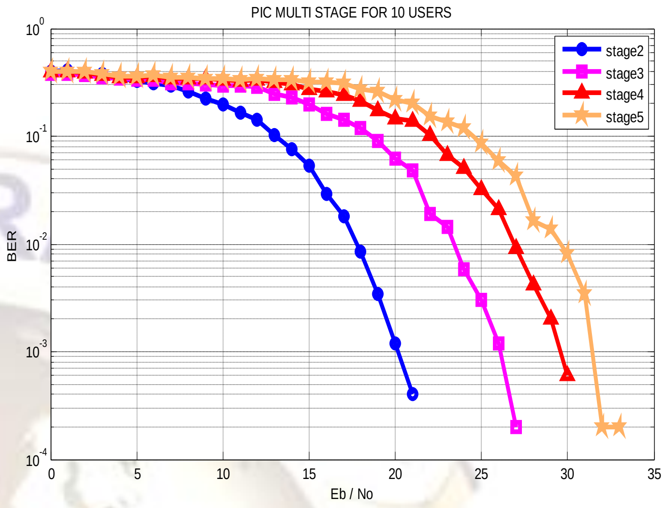

Fig. 4 (a) : Multi stage for 10 users

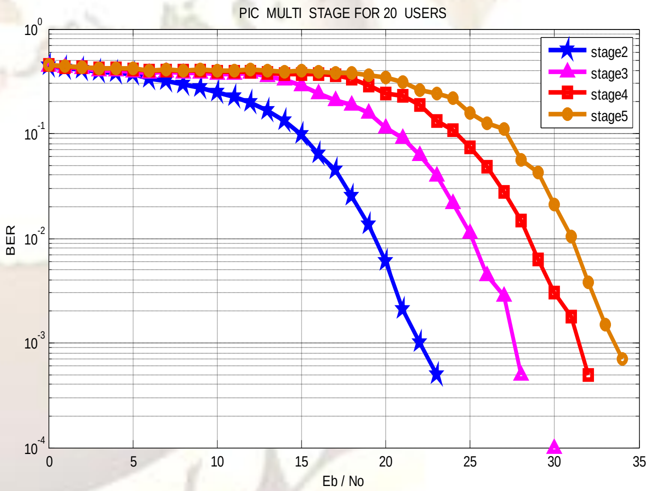

Fig. 4 (b) : Multi stage for 20 users

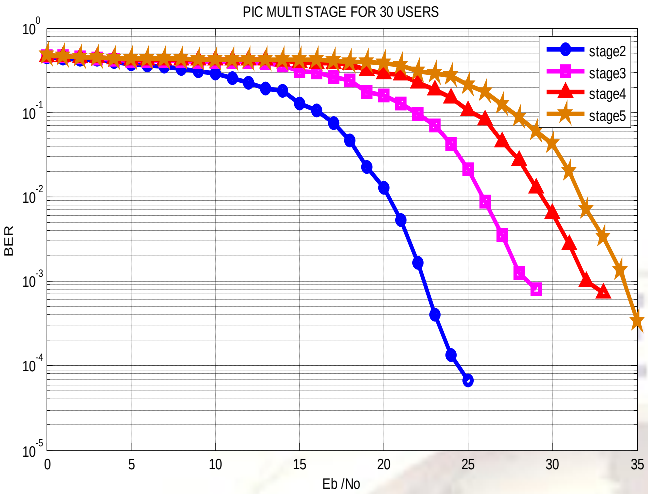

Fig. 4 (c) : Multi stage for 30 users

From Fig. 4 (a) to Fig (e) shows the bit error rate performance of the multi stage multi user detector for different user combinations. The number users increases the system performance is degraded

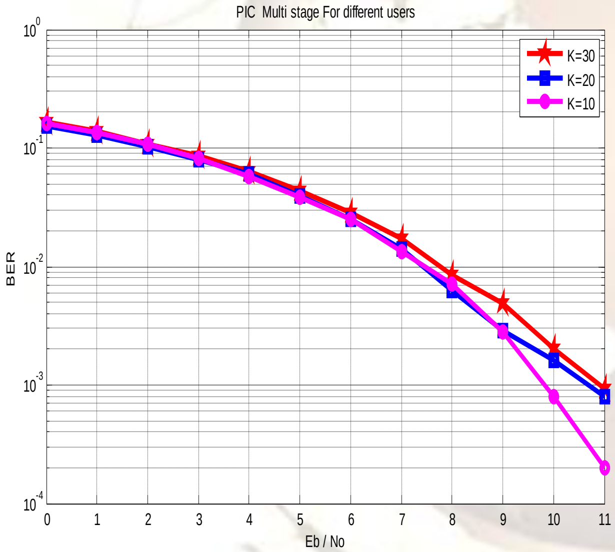

Fig. 4 (d) : Multi stage pic for different users

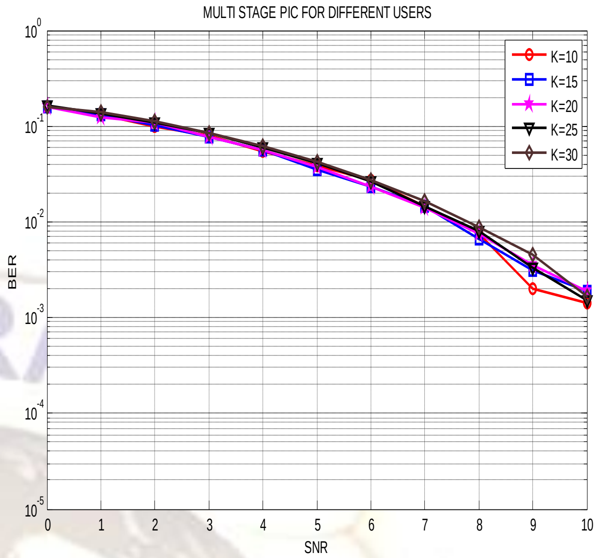

Fig. 4 (e) : Multi stage pic for different users

VI CONCLUSION

The paper deals with two basic concepts, i.e., multistage detector and multi-user detector. In multistage detector the number of stages increases, the detection is more reliable and bit error rate (BER) also decreases but after 5th stage, there is increase in BER because of increases the multiple access interference between users. The multi-user concept gives mainly two advantages in comparison to single user detector; it eliminates the near-far problem and also it reduces the multiple access interference (MAI) so BER is reduced, thus the capacity of the system will increased.

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