A Comparative Study: Various Interleavers for IDMA Technology

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ABSTRACT—The recently proposed IDMA (Interleave Division Multiple Access) system, is a multiuser scheme where users are separated by unique interleaver sequences on the horizon of wireless communication world. This paper provides a comprehensive study of IDMA technology in communication system based on different types of interleavers such as orthogonal interleavers, power interleavers, prime interleavers, tree based interleavers and random interleavers. In this paper, we compare different interleavers based on computational complexity, bit error rate(BIR) and memory requirement. The few basic requirements for future wireless 4G systems includes low receiver cost, decentralized (i.e. asynchronous) control , simple treatment of ISI, cross cell interference mitigation, diversity against fading, power efficiency (long battery life), multimedia services, high user number, high throughput and high spectral efficiency.

Keywords—IDMA , ISI, BIR, 4G

I. INTRODUCTION

In wireless communication, A new multiple access scheme called interleave-division multiple access (IDMA) was recently proposed. In IDMA scheme, the users are allotted with user-specific interleaver in place of PN-sequences as allotted. A multiple access scheme IDMA, in which interleaver are used as the only means for user separation. A low-cost iterative chip-by-chip multi-user detection algorithm is described with complexity independent of the user number and increasing linearly with the number of path. In the past few years, the request for bandwidth has started to surpass the availability in wireless networks. Different techniques have been studied to improve the bandwidth, efficiency and increase the number of users that can be accommodated within each cell. Data rates up to 100 Mbps for high mobility and up to 1 Gbps for low mobility or local wireless are predicted. Systems fulfilling these requirements are usually considered as fourth generation (4G) systems. But 3G systems provide data rate of around 3.6-7.2 Mbps. Existing multiple access techniques used in 1G/2G/3G systems (such as FDMA/TDMA/CDMA respectively) are basically suitable for voice communication only and unsuitable for high data rate transmission and burst data traffic which would be the dominant portion of traffic load in 4G system.

IDMA offers a number of features: rate/power adaptation, MIMO According to Shannon, typical sequences are generated and superimposed, fast fading, frequency-selective fading, complexity is linear with respect to the number of layers, number of chips/number of users, number of receiver antennas, number of channel taps, and the number of iterations, delivers reliable Soft-output information, Resource allocation, Low delay. A 4G system is expected to provide a comprehensive and secure. all possible solution where facilities such as IP telephony, ultra-broadband internet access, gaming services and streamed multimedia may be provide to users [1] [2].

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II. IDMA Transmitter and Receiver Structures:

The upper part of Fig. 1 shows the transmitter structure of the multiple access scheme under consideration with K simultaneous users. The input data sequence ***d***k of user-k is encoded based on a low-rate code C, generating a coded sequence ***c***k ! [ck(1), . . . , ck(j), . . . , ck(J)]^T ,where J isthe frame length. The elements in ***c***k are referred to as coded bits.Then ***c***k is permutated by an interleaver !k, producing ***x***k ! [xk(1), . . . , xk(j), . . . , xk(J)]^T. Following the CDMA convention, we call the elements in ***x***k "chips". Users are solely distinguished by their interleavers, hence the name interleave-division multiple-access (IDMA).

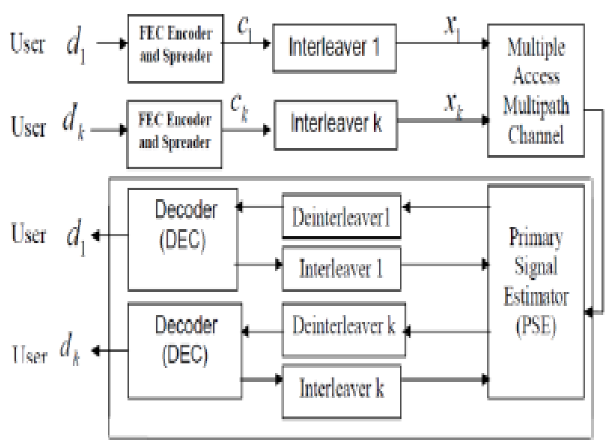

Figure 1.IDMA Transmitter and Receiver Structure

III. DIFFERENT TYPES OF INTERLEAVERS:

Interleaving is a process of rearranging the ordering of a data sequence in a one to one deterministic format. Interleaving is a practical technique to enhance the error correcting capability of coding. In turbo coding, interleaving is used before the information data is encoded by the second component encoder. The basic role of an interleaver is to construct a long block code from small memory convolution codes, as long codes can approach the Shannon capacity limit. Secondly, it spreads out burst errors [Ping 2004]. The interleaver provides scrambled information data to the second component encoder and decorrelates inputs to the two component decoders so that an iterative suboptimum-decoding algorithm based on uncorrelated information exchange between the two component decoders can be applied. The final role of the interleaver is to break low weight input sequences, and hence increase the code free Hamming distance or reduce the number of code words with small distances in the code distance spectrum. The size and structure of interleavers play a major role in the performance of turbo codes. There are a number of interleavers, which can be implemented.

A. Random Interleavers:

Random interleavers scramble the data of different users with different pattern. Patterns of scrambling the data of users are generated arbitrarily. Because of the scrambling of data, burst error of the channel is randomized at the receiver side The user specific Random Interleaver rearranges the elements of its input vector using a random permutation [Ping 2006]. The incoming data is rearranged using a series of generated permuter indices. A permuter is essentially a device that generates pseudo-random permutation of given memory addresses. The data is arranged according to the pseudo-random order of memory addresses. If random interleavers are employed for the purpose of user separation, then lot of memory space will be required at the transmitter and receiver ends for the purpose of their storage. Also, considerable amount of bandwidth will be consumed for transmission of all these interleaver as well as computational complexity will be increase at receiver ends.
After randomization of the burst error—which has rearranged the whole block of the data—the latter can now be easily detected and corrected. Spreading is the important characteristic of random interleavers.

B. MASTER RANDOM INTERLEAVER:

In the paper [3], L. Ping has proposed a new interleaver named power-interleaver (MRI) with this method, the interleaver assignment scheme is simplified and memory cost is greatly reduced without sacrificing performance. Here, only the power interleaver Φ is needed to be

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stored. Let the power interleaver be $\pi_1=\Phi$ .After completing the detection cycle for user 1, the interleaver can be updated from $\pi_1=\Phi$ to $\Phi(\pi) = \Phi^2$.This procedure continues recursively. Numerical results show that the new interleaver generation method, so-called 'power-interleavers', can take the place of random-interleavers without performance loss. The drawback of this scheme is to consume higher access time for user securing interleaver where Φ^n is the user number. Simulation result shows that similar results have been obtained as that achieved with Random Interleavers, but considerable amount of memory space has been saved.

C. Cyclic Shift interleaver

Cyclic shift interleaver is proposed in [4] [5] context of IDMA where users with low rate FEC coding are separated by different interleavers. The advantage is only single pattern has to be stored. The use of cyclic shifts for generation of multiple interleavers is motivated by an observation for multiuser detection which showed that asynchronous between users i.e. the user's signals arrive with different delay at the multiuser receiver, allows to separate them as well as user specific random interleavers even if the same interleaver is used for all users (13).It was proposed to construct the interleaver pattern π_k for k users from a common interleaver π by user specific cyclic shifts Δ_k , and interleaving of particular pattern by itself as indicated in fig.3 about D=3 such cyclic shift and self-interleaving operations, the same performance as with randomly chosen interleavers could be obtained in IDMA with synchronous users. The permutation P of the circular-shifting interleaver is defined by

$$P(i) = (ai+s) \bmod L$$

Satisfying a<L, a is relatively prime to L, and s<i where i is the index, a is the step size, and s is the offset. The following table shows a circular-shifting interleaver with L=8, a=3, and s=0.

Index	0	1	2	3	4	5	6	7
Circular shift Permutation	0	3	6	1	4	7	2	5

Table 1. Cyclic -Shift Interleaver mechanism

D. Diagonal Interleaver

The diagonal interleaver is a modification of the block interleaver (Morelos–Zaragoza, 2001). Instead of reading column-wise, the matrix is read diagonally from left to right and top to bottom.

0	1	2	3	4
5	6	7	8	9
10	11	12	13	14

Table 2. Diagonal process

E. CYCLODIAG INTERLEAVER:

In paper [6], M. Shukla, N. Anil kumar, V.K. Srivastava and S. Tiwari proposed a new interleaver "Cyclodiag Interleaver" which is a combination of cyclic interleaver and diagonal interleaver. Cyclodiag interleaver supports randomness and orthogonality in limited number user area with user not exceeding 20 at a time. Simulation results of Cyclic Diagonal Interleaver with AWGN channel without fading & without coding with power allocation, with data length=1024, spread length=16, and iteration=20 and for number of users=20.

F. **TREE BASED INTERLEAVER**

In IDMA system, each user has a specific interleaver $\{\pi_k\}$ having length equal to chip length 'J'.A considerable amount of memory will be required to store the indices for these interleavers.

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The tree based interleaver is basically aimed to minimize the computational complexity and memory requirement that occurs in power interleaver & random interleavers respectively [3].

In a tree based interleaver generation, two randomly generated interleavers are chosen. Let $\pi_1$and π_2 be the two random interleavers. The combinations of these two interleavers in a particular fashion as shown in the fig.(2) are used as interleaving masks for the users [3].

The allocations of the interleaving masks follow the binary tree format. The interleaving masking diagram is shown in figure 2 for 14 users which may be enhanced for higher count of users. It is clearly shown through the figure 2 that, for obtaining the interleaving sequence related to 14th user, it needs only 2 cycles.

$\pi_{14} = \pi_2(\pi_2 (\pi_2))$ …………(1)

$\pi_7 = \pi_1(\pi_1 (\pi_1))$ …………(2)

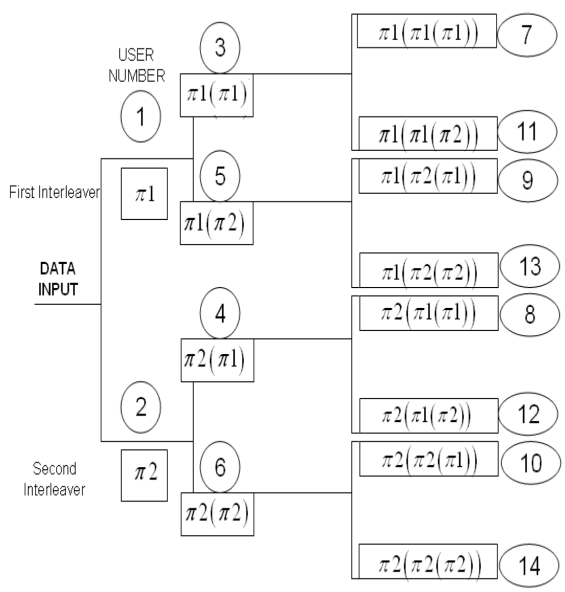

Figure 2. Tree Based Interleaver mechanism

G. Prime Interleaver:

In IDMA, different users are assigned different interleavers which are weakly correlated [7]. The computational complexity and memory requirement should be small for generation of interleavers. The Prime Interleaver proposed by Ruchir Gupta et al[8] is basically aimed to minimize the bandwidth and memory requirement that occur in other available interleavers with bit error rate (BER) performance comparable to random interleaver. In generation of prime interleaver we have used the prime numbers as seed of interleaver. Here, user-specific seeds are assigned to different users. For understanding the mechanism of prime interleaver, let us consider a case of interleaving n bits with seed p. First, we consider a Gallo is Field GF (n). Now, the bits are interleaved with a distance of seed over GF (n).In case, if {1, 2, 3, 5, 6, 7,8… n} are consecutive bits to be interleaved with seed p then location of bits after interleaving will be as follows:

1===> 1
2===> (1+p) mod n
3===> (1+2p) mod n
4===> (1+3p) mod n
. ..
n===> (1+(n-1)p) mod n

IV. Simulation results of various Interleavers:

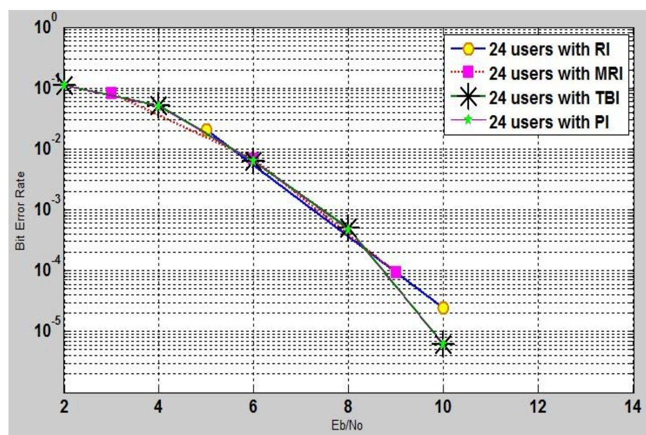

Figure 3. Comparision between RI,MRI,TBI,PI

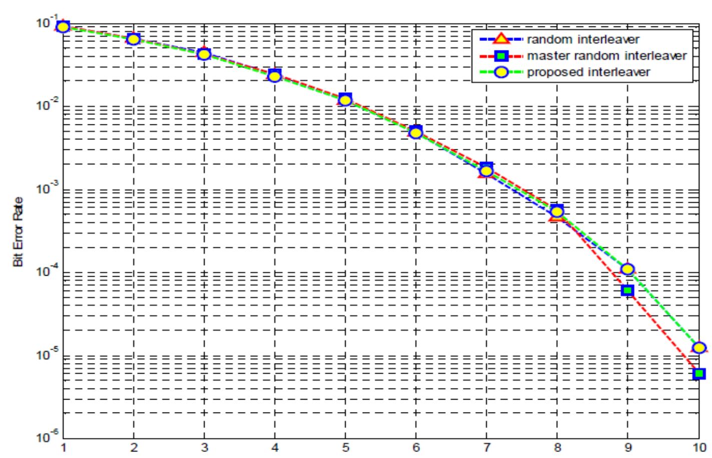

Figure 4. Comparision between RI,MRI, and CI

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V.COMPARISION BETWEEN ALL INTERLEAVERS:

Parameters	RI	MRI	CI	DI	Cyclodiag Interleaver	TBI	PI
Memory requirement	High	Low	Lower than PI	Lower	High	Low	Lowest
Bandwidth requirement of Interleaver(30 users)	$1.5x10^6$	$0.01x10^6$	Low	Less than CI	High	$0.02x10^6$	$0.0001x10^6$
Complexity	High	Very high	High than PI	Lower than CI	High	Low	Little high than TBI
Bite error rate for Eb/NO =10 (24 users)	10^{-4}	10^{-4}	low	High	Limited to 20 users	$0.4x10^{-4}$	$0.5x10^{-4}$
BER in coded environment for Eb/NO = 10 (24 users)	$0.6x10^{-5}$	$0.6x10^{-5}$	low	High	High	$0.4x10^{-6}$	$0.4x10^{-6}$
BER in uncoded environment for Eb/NO = 10 (24 users)	$0.6x10^{-4}$	$0.2x\ 10^{-4}$	low	High	High	$0.2x10^{-5}$	$0.2x10^{-5}$
Specific user cross correlation	Low	Low	High	High	High	High	High

VI. SCOPE IN IDMA

There are many areas open for further improvements and research in IDMA systems such as in interleaving scheme for memory optimization, improvement in coding schemes, automatic repeat request, synchronization issues, and peak-to-average power reduction, and in modulation schemes. Apart from this, diversity techniques may also implemented in IDMA systems for superior performances in wireless communication.

VII. CONCLUSION

In this paper, comparisons between different Interleavers have been made on the basis of parameters like complexity, bit error rate (BER), memory requirement etc. Among all the comparisons discussed so far, the features of Tree Based Interleavers and Prime interleavers shows their suitability for the IDMA technology for fourth generation communication On the basis of above comparison in table, we can see that tree based interleavers and prime interleavers perform better than other interleavers. But if we consider 24 users and calculate the bit error rate then we find that these all interleavers have almost same performance shown. Tree based interleaver has low complexity than other interleavers in consideration.

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