CORRELATION BASED ANALYSIS OF MASTER RANDOM INTERLEAVER AND TREE BASED INTERLEAVER

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Abstract: In this paper we consider the design of practical interleavers for interleaver division multiple access (IDMA) systems. A set of interleavers is considered to be practical if it satisfies two criteria one it is easy to generate (i.e., the transmitter and receiver need not store or communicate many bits in order to agree upon an interleaver), and second no two interleavers in the set "collide". We show that a properly defined correlation between interleavers can be used to formulate a collision criterion, where zero-correlation (i.e., orthogonality) implies no collision. Computing the correlation among non-orthogonal interleavers is generally computationally very expensive, so we also design an upper-bounding technique to efficiently check whether two interleavers have low correlation. We then go on to propose several methods to design practical interleavers for IDMA: one method to design orthogonal interleavers, and two methods to design non-orthogonal interleavers (where the upper-bounding technique is used toverify their cross-correlation is low). Simulation results are presented to show that the designed practical interleavers perform as well as random interleavers in an IDMA system.

***Index Terms*—IDMA, orthogonal interleavers, correlation between interleavers**

I. INTRODUCTION

Interleaver division multiple access (IDMA) is a technique that relies on different interleavers to separate signals from different users in a multiuser spread-spectrum communication system. In [1][2], an IDMA system that uses randomly and independently generated interleavers is presented. With these interleavers, the IDMA system in [1] performs similarly and even better than a comparable CDMA system. The condition for IDMA to be successfully implemented is that the transmitter and receiver agree upon the same interleaver. For random interleavers, the entire interleaver matrix has to be transmitted to the receiver, which can be very costly. Our goal is to construct nonrandom interleavers for IDMA that perform as well as random interleavers and satisfy two design criteria:

- They are easy to specify and generate, i.e., the transmitter and receiver can send a small number of bits between each other in order to agree upon an interleaver, and then generate it.
- The interleavers do not "collide".

2. Fundamentals of IDMA:

This paper presents an asynchronous interleave-division multiple-access (IDMA) scheme for spread spectrum mobile communication systems, in which users are distinguished by different chip-level interleavers instead of by different signatures as in a conventional CDMA system incorporating the principle[3]. The scheme considered is a special case of CDMA in which bandwidth expansion is entirely performed by low-rate coding. For convenience, it may be referred as interleave-division multiple-access (IDMA). This scheme inherits many advantages from CDMA such as dynamic channel sharing, mitigation of cross-cell interferences, asynchronous transmission, ease of cell planning, and robustness against fading. It also allows a low complexity multiple user detection techniques applicable to systems with large numbers of users in multi path channels. In this paper, an effort has been made to study of proposed IDMA scheme by different researchers. A very low-cost chip-by-chip iterative detection algorithm is explained with complexity independent of user number and increasing linearity with the path number. The advantages of using low-rate coded systems are demonstrated analytically. We will show that the proposed IDMA scheme can achieve performance close to the capacity of a multiple access channel.

3. Master random interleaver generation method:

In an IDMA scheme, each user has a user specific

interleaver {Π *k*} having length equal to chiplength 'J'. Therefore, a considerable amount of memory will be required to store the indexes for these interleavers.
To minimize this memory cost problem, a master random interleaver method is proposed in this paper, a master interleaver *Φ* is taken, and the subsequent k-interleavers are generated using $\Pi k = \Phi_k$.
where $\Phi_k(c)$ is defined as

$$\Phi_1(c) = \Phi(c) \quad \ldots\ldots\ldots..(1)$$

$$\Phi_2(c) = \Phi(\Phi(c)) \ldots\ldots.(2)$$

where Φ is an ideal random permutation.
This method not only reduces the amount of information exchange between Base Station (BS) and Mobile Stations (MSs), but also greatly reduces the memory cost in comparison to random interleaver.
In generation of interleaver, if the intermediate variables like Φ2 , (Φ2) 2, are not stored, then for generating the interleaving sequence for the k_{th} user , (k-1) cycles are needed[4]. Even if the intermediate values are stored, it is mentioned that a maximum of 2(n-1) cycles are needed for generating the required interleaver, if 2(n-1) <k<2 n, where n>1 is an integer. Master Random Interleaver is also known as Power Interleaver

4.Tree based interleaver:

The Tree Based Interleaver is basically aimed to minimize the computational complexity and memory requirement that occurs in power interleaver and random interleavers respectively.
In a Tree Based Interleaver generation, two randomly generated interleavers are chosen, let Π 1 and Π 2 is the two randomly selected interleavers. These interleavers are tested to have zero cross correlation between each other. The combinations of these two interleavers in a particular manner as shown in the figure 16 are used as interleaving masks for the users.

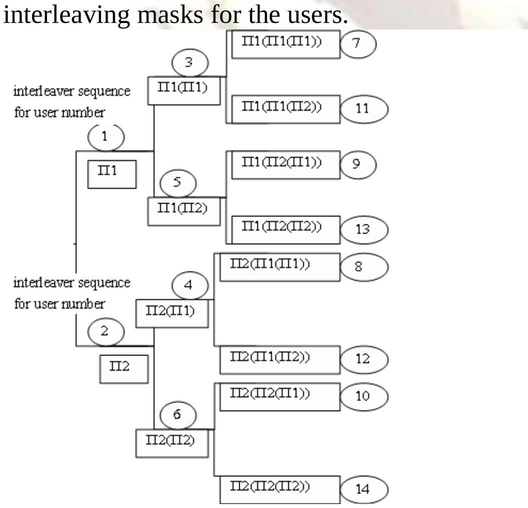

Figure 1. Interleaving Figure mask allocation for the proposed Tree Based Interleaving scheme.

The allocations of the interleaving masks follow the tree format. The interleaving masking diagram is shown upon fourteen users only for the shake of simplicity. It is shown through the figure that, for obtaining the interleaving sequence of the 14th user, it needs only 2 cycles of clock, as compared to many more cycles needed in case of master random interleaver method.
Π 14 = Π 2 (Π 2 (Π 2)).

5. Correlation:

The correlation of two interleavers is the important thing in the IDMA system. The sequences of different interleavers must be different. There must be no relation in any two interleaver sequences. If correlation between two sequences is '1' means they are strongly related to each other i.e. they can be superimposed on each other. If the correlation between two sequences is '0' means they are orthogonal to each other.
The correlation of any two sequences lies between -1 to +1. If the correlation is near to '0' that means that these sequences are not matches to each other. For orthogonality condition the value should be near to zero.

5.1Mathematically Correlation is define as :

Let X1 and X2 be two variables with joint pdf p(x1, x2). We define their joint moment of order (k, n) as

$$E[X_1^k X_2^n] = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x_1^k x_2^n p(x_1, x_2) dx_1 dx_2 \quad \ldots\ldots(3)$$

When k=n=1. then the joint moment in such a case is known as correlation. Hence, correlation is defined as

$$E[X_1 X_2] = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x_1 x_2 p(x_1, x_2) dx_1 dx_2 \quad \ldots\ldots.(4)$$

5.2Correlation between Interleaver

Since the separation of users is achieved by interleavers, an obvious interleaver design criterion is that every two interleavers out of a set of interleavers "collide" as little as possible. The goal in this section is to define correlation among interleavers for IDMA in order to measure the level of "collision" among interleavers.
Unlike in classical turbo coding/decoding, where the task of a single interleaver is to decorrelate different sequences of bits, here we have a set of interleavers, that not only need to decorrelate different bit sequences, but also different users[5][6]. The correlation between interleavers should measure how strongly signals from other users affect the decoding process of a specific user. Hence, the additive noise should not play a role in the correlation of interleavers, and throughout this section, we consider the noiseless IDMA system. In that case, a non-turbo decoder depicted in Figure 2 suffices, where the decoder for user j

consists of the user-specific deinterleaver π−1 and a despreader.

5.2.1. Definition of Correlation and Orthogonal Interleavers

Definition 1*:* Let π_i and π_j be two interleavers and let w and v be two words. We define the correlation $C(\pi_i, w, \pi_j, v)$ between π_i and π_j with respect to the words w and v as the scalar product between π_i (f(w)) and π_j(f(v)):

$C(\pi_i, w, \pi_j, v) = \{ \pi_i (f(w)), \pi_j (f(v))\}$. …….(5)

Definition 2: Two interleavers πi and, πj (where πi ≠ πj) are called orthogonal, if for any two words w and v, we have

$C(\pi i, w, \pi j, v) = \{ \pi i (f(w)), \pi j (f(v))\} = 0$…… (6)

It is easy to verify that if a set of mutually orthogonal interleavers is used in the IDMA system.In this sense, zero-correlation (or orthogonality) implies no "collision" among interleavers.

5.2.2 Bound on the Number of Orthogonal Interleavers

If S is the spreading length**.** for any block length *l*, a set of orthogonal interleavers has at most *S* elements, i.e., the number of orthogonal interleavers is at most *S*.

5.2.3. Bounding the Correlation between Interleavers

We have shown that it is impossible to find a set of more than S orthogonal interleavers. If we want to build an IDMA system that allows more than S simultaneous users, we need to use interleavers with non-zero correlation[7]. However, evaluating the correlation between two interleavers with respect to every possible pair of two words is very computationally complex. This is because there are 2l possibilities to choose the first word and other 2l possibilities to choose the second word. In this section we suggest a method for upper bounding the correlation between interleavers.

For two "good" interleavers, the correlation term in (1) should be close to 0. For i ≠ j or w ≠ v,[8] this is equivalent to minimizing the magnitude

$$|C(\pi_i, w, \pi j, v)| = |\{ \pi_i (f(w)), \pi j (f(v))\}| \ . (3)$$

In order to find upper bounds for (3), some definitions are helpful. From now on, we assume that i ≠ j or w≠ v and l ≥ 3.

The value of cross correlation is leis between -1,+1. if correlation is 1 it means the same interleaver is compared there is no difference in interleaver.

6. CORRELATION ANALYSIS:

the correlation may be defined for different user specific interleavers as-

User i = data 1

User j = data 2

XOR of user i and user j = data1 XOR data2

Now calculate

The No. of 1's after XORing the both user data= M

The No. of 0's after XORing the both user data= N

Now correlation= (No. of 1's ~ No. of 0's)/ (Total No. of bits)

= (M-N)/(M+N)

6.1 Simulation Result:

A. Performance of Uncoded IDMA For all the simulations in this paper, the IDMA decoding algorithm described in was used. The simulated curves in Figures 2 represent the average bit error rate of all users as a function of Eb/No[dB]. We have used the parameters *S* = 8 and *l* = 50. For every curve, the transmission of more than 20 blocks per user was simulated. For 8 users, the number of iterations performed in the decoding algorithm is 5. The used decoder is sub-optimal in the sense that the channel we use is not noiseless.

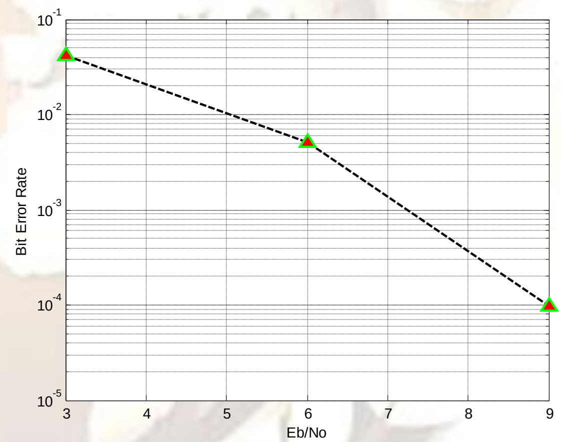

Fig 2.Performance of uncoded IDMA.

B. Correlation of Interleavers: For master random interleaver no. of users n=64 ,data length m=32 the correlation is

Columns 1 through 16

0.2500 -0.2500 -0.1875 0.0625 -0.1250 -0.1250 -0.1250 -0.1875 -0.3125 -0.2500 -0.2500 -0.1875 0 0 0.0625 -0.2500

Columns 17 through 32

-0.1875 -0.2500 -0.3125 -0.3750 -0.6250 -.3750 -0.5000 -0.6250 -0.6875 - 0.6250 -0.6875 -.5000 -0.6875 -0.7500 -0.8125 -0.8125

Columns 33 through 48

-0.8750 -1.0000 -1.3125 -1.4375 -1.6250 -.6250 -

2.0000 -1.9375 -1.8750 -1.9375 -2.0000 -.6875 -1.7500 -1.8125 -1.5625 -1.5625
Columns 49 through 63
-1.5625 -1.1875 -1.2500 -1.4375 -1.3125 -.6875 -1.6875 -1.6250 -1.8750 -2.0625 -2.1250 -.1875 -2.2500 -2.3125 -2.1250

And final correlation is -1.0060of

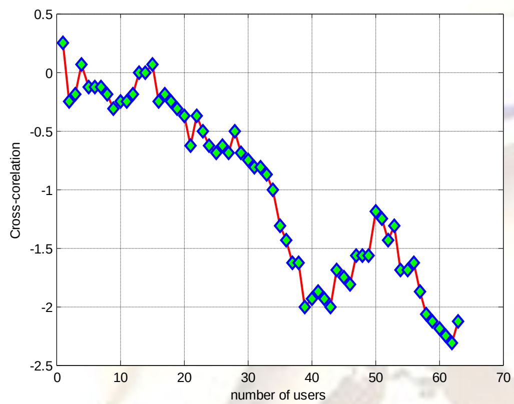

Fig 3.Mater Random interleaver cross-correlation performence

For tree based interleaver no.of users n=64 data length m=32 the correlation is
Columns 1 through 16
0.1875 0.2500 0.1250 0.1250 -0.0625 -0.2500 -0.1875 -0.2500 -0.0625 -0.1875 -0.0625 0 0 0.0625 0.0625 0.0625
Columns 17 through 32
0.0625 -0.1250 0 0.0625 0.1250 0.1250 0.0625 0 0.0625 0.1875 0.1875 0.2500 0.3125 0.3750 0.3750 0.3125
Columns 33 through 48
0.3125 0.2500 0.1875 0.3125 0.3750 0.6875 0.7500 0.5625 0.4375 0.4375 0.4375 0.3125 0.1875 0.0625 0.1875 0.1250
Columns 49 through 63
0 0.1250 0.3125 0.3750 0.3750 0.3125 0.4375 0.4375 0.5625 0.5625 0.5625 0.5625 0.4375 0.5000 0.5625

The final correlation is 0.2212

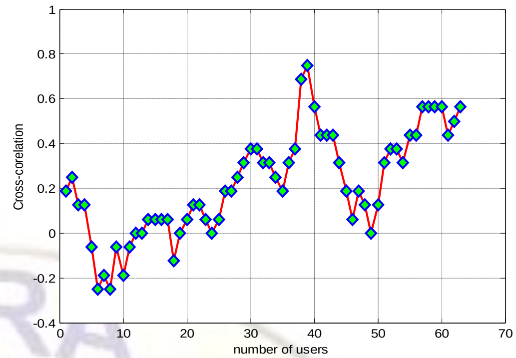

Fig4.Tree Based Interleaver cross-correlation performance.

So we can conclude that if we increase the no. of users the correlation value of mater random interleaver is increased but the correlation value of tree based interleaver is decreased which is near about 0 this is the reason behind the better performance of Tree Based Interleaver.

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