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Research Paper

Four Arm Interleaver: Performance analysis

Engineering

KEYWORDS : CDMA, IDMA, LUT, GCLK

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ABSTRACT

Presently, a new multiple access scheme called interleave-division multiple access (IDMA) has attracted much attention, in which interleavers are the only means for user separation. It has been demonstrated that the IDMA can achieve near single user performance in multi-user environment with very low receiver complexity. This technique inherits many advantages from CDMA, such as diversity against fading and mitigation of the worst-case user interference problem. This paper presents a new concept of inerleaver called arm interleaver. We are going to discuss it's timing constraint, hardware requirement and device utilization.

1.Introduction

The performance of code-division multiple-access (CDMA) systems is mainly limited by multiple access interference (MAI) and intersymbol interference (ISI). In the light of the success of turbo codes, turbo-type iterative multi-user detection (MUD) has been extensively studied to mitigate MAI and ISI, and significant progress has been made [1]. Theoretical study shows that the optimal multiple access channel (MAC) capacity is achievable when the entire bandwidth expansion is devoted to coding. This suggests mixing coding and spreading using low-rate codes to maximize coding gain. But separation of users without spreading operation is not feasible in CDMA [2].

Introduction to IDMA

IDMA stands for Interleave division multiple access This scheme is used 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 [3][4]. 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) [4][5]. 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 multipath channels.

IDMA System

A. Transmitter Structure

The upper part of figure 2 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 $\boldsymbol{c}_k \equiv [c_k(1), \ldots, c_k(j), \ldots, c_k(J)]^T$, where J is the frame length. The elements in $\boldsymbol{c}_k$ are referred to as coded bits. Then $\boldsymbol{c}_k$ is permutated by an interleaver π_k, producing $\boldsymbol{x}_k \equiv [x_k(1), \ldots, x_k(j), \ldots, x_k(J)]^T$. Following the CDMA convention, we call the elements in $\boldsymbol{x}_k$ "chips".

We follow the convention of CDMA and call the basic elements in $c^{(K)}$ and $x^{(K)}$ "chips". Coder block can be either the same or different for different users. It can be an FEC code, or a spreading sequence (spreading is also a special form of coding), or a combination of the two. From a performance point of view, it is advantageous to use a low-rate FEC code [4][6] that can provide an extra coding gain.

The key principle of IDMA is that the interleavers { $\Psi^{(K)}$ } should be different for individual users. We assume that the interleavers are generated independently and randomly. For simplicity, we first consider time-invariant single-path channels with real channel coefficients and BPSK signaling.

After sampling at chip rate, the received signal from K users can be written as

$$r_j = \sum_{1}^{m} h^{(K)} x_j^{(K)} + n_j$$

j=1,2...J, (1)

Where $x_j^{(K)}$ is the jth chip transmitted by the Kth user, the channel coefficient for the Kth user and $\{n_j\}$ samples of a zero-mean additive white Gaussian noise (AWGN) with variance $\sigma^2 = N0/2$.

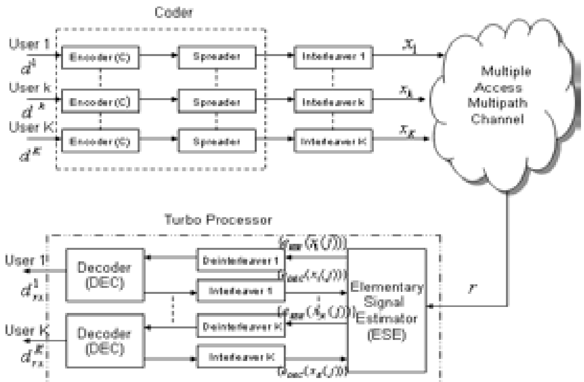

Figure 1. *IDMA Transmitter and Receiver*

B. Receiver Structure

Lower part of figure 2 shows the receiver section of IDMA system. This structure consists of an elementary signal estimator (ESE) and K single-user a posteriori probability (APP) decoders (DECs). The multiple access and coding constraints are considered separately in the ESE and DECs.

The outputs of the ESE and DECs are extrinsic log-likelihood ratios (LLRs) about $\{xk(j)\}$:

$$e(x_k(j)) = \log\left(\frac{\Pr(x_k(j)=+1)}{\Pr(x_k(j)=-1)}\right) \quad \forall k, j$$

Interleave-division multiple access (IDMA), in which interleavers used as the only means for user separation. IDMA inherits many advantages of CDMA system, such as diversity against fading and mitigation of the worst-case other-cell use interference problem [3]-[5]. In this each user has its own interleaver and each interleaver has its own interleaving index. These interleaving indexes are used to distinguish different users.

	CDMA with SUD	IDMA
Intera-cell interference	Sensitive	Suppressed by MUD
Cross-cell interference	Mitigated	Mitigated
Near-far effect	Sensitive	MUG

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Treatment for ISI	Rake receiver	CBC detection
Synchronization	No	No

Comparative table

This comparative table between CDMA and IDMA shows the advantages of IDMA over CDMA.

In this paper we are going to discuss concept of interleavers, four arm interleaver, it's timing behavior, it's hardware requirement like flip flop, adder substractor and device utilization like LUT's and GCLK.

2.Interleaver

Interleavers are meant to permute the user's data at transmitter end according to a predefined pattern. That permuting pattern should be known to the receiver so that it can de-interleave the incoming data. It means that the transmitter should send the permuting pattern to the receiver.

In IDMA systems, different interleavers are assigned to different users. In theory, the user-specific interleavers can be generated independently and randomly. If this is the case, the base station (BS) has to use a considerable amount of memory to store these interleavers, which may cause serious concern when the number of users is large. Also, during the initial link setting-up phase, there should be messages passing between the BS and mobile stations (MSs) to inform each other about their interleavers. Extra bandwidth resource will be consumed for this purpose if the interleavers used by the BS and MSs are long and randomly generated.

Interleavers are also used to rectify burst error. Burst error corrupts the block of data. By using interleavers, bits are randomized in time. So, at receiver after de-interleaving block of error is randomized.

2.1. Four Arm Interleaver

In four arm interleaver there are four interleaving sequences that are generated randomly and independently. These four sequences are used for interleaving other users.

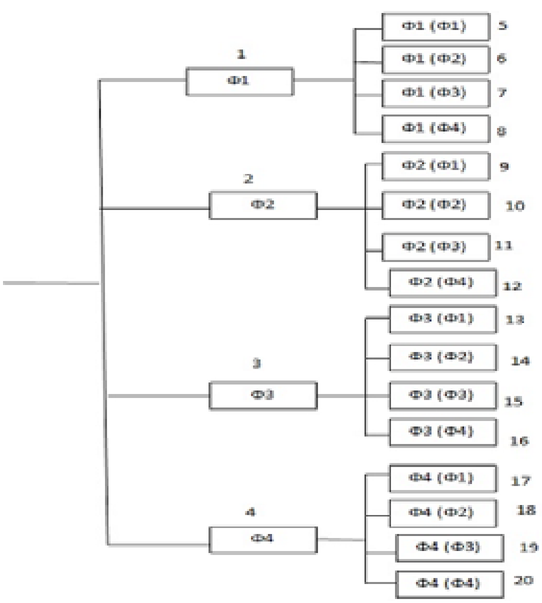

Figure 2.*Interleaving mask allocation for the proposed Four Arm Interleaving scheme.*

For example, let the four master sequences be (Φ_1) , (Φ_2) , (Φ_3) , and (Φ_4) and now all the users can be assigned an interleaver with the help of these four master sequences as in tree based interleaver. In four arm interleaver the memory requirement and complexity decreases with respect to random interleaver and master random interleaver. Figure shows the permutation behavior of four arm interleaver by which it scrambles the input data of users.

For 8 users with 8 bits each of each user

In this section we are going to compare various results of four arm interleaver with power interleaver or master random interleaver. These results are given below in tabulated form.

	Master-random Interleaver	Four Arm Interleaver
D Flip-Flop	3520	1216
Adder/Substractor	1152	396
Comparator	576	189
MUX	2592	864

Table 1: *Summary of Hardware*

In table 1 master random requires large number of hardware because as the number of users increases the number of loops increases and due to this large number of temporary variables are required to store the intermediate data. Master random requires large number of hardware as the number of user increases.

	Master-random Interleaver	Four Arm Interleaver
Register	3528	1219
FF	3528	1219

Table 2: ***Final Register Report***

According to the results, it is observed again that four arm interleaver has the least requirement of registers and flip flops. Requirement of registers and flip flops are highest for master random interleaver.

	Master-random Interleaver	Four Arm Interleaver
No. of slices	48245	15531
No. of 4 input LUT	94812	30507
No. of IOs	129	129
No. of GCLK's	1	1

Table 3: ***Device Utilization***

GCLK is global clock that is provided to all the components that require clock in parallel which means that only one clock is required. LUT is the basic building block in Xilinix, used to generate these interleavers. Again in this context four the requirement in four-arm interleaver is minimum in accordance with the results.

	Master-random Interleaver	Four Arm Interleaver
Minimum period	264.074 ns	207.653 ns
Maximum frequency	3.787 MHz	4.816 MHz

Table 4: ***Timing Summary***

This comparison shows the maximum frequency at which these interleavers can operate. This maximum frequency represents how fast these interleavers can interleave user's data. According to this maximum frequency, the period of operation of interleavers are decided. Four arm interleaver requires less time to operate.

3.Conclusion

As we can see that four arm interleaver generates each sequence of random pattern with four independently generated patterns, the memory requirement decreases in comparison with power interleavers. The permuting pattern that has to be send at receiver also decreases. Due to decrease in this complexity, maximum operating frequency increases and the hardware requirement decreases.

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