



A User-Spread Interleave Division Multiple Access System

P. Niroopan, Yeon-ho Chung

Department of Information and Communications Engineering, Pukyong National University, Busan, South Korea

ABSTRACT: In this paper, we propose a User-Spread Interleave Division Multiple Access (US-IDMA) system that employs two way user separation using interleavers and spreading sequences to improve the performance of the system with more secure and reliable communications compared with the conventional IDMA system. These spreading sequences are not only as random as user data and independent of current symbols, but also dynamically changes from one symbol to another according to the user data. Therefore, this system offers enhanced security and privacy, due to the fact that the sequences make unwanted detection of the data by unintended receivers practically impossible. Also, simulation results show that the proposed system improves the bit error rate performance of the system in flat fading channel.

Keywords: IDMA, Interleaver, Multiple access, Spreading, User data

I. INTRODUCTION

A new multiple access scheme called Interleave Division Multiple Access (IDMA) [1], [2], which is a special case of Code Division Multiple Access (CDMA) [3], was recently proposed as a spread spectrum multiple access scheme. Unlike a CDMA system, a user-specific spreading sequence is not used in the IDMA system. Instead, user-specific interleavers are adopted as the only mechanism for user separation where interleaver that gives the name to IDMA has an important role in the system architecture. As such, the IDMA utilizes a low-complexity iterative multiuser detection process in the receiver.

In this paper, we propose a User-Spread IDMA (US-IDMA) system with user spread data. The conventional IDMA system uses repetition code only for improving the bit error performance of the system. Without the repetition code, IDMA systems give poor performance over the propagation channel and also affected by multiple access interference. Thereby without avoiding redundancy by the repetition code, we replace using the spreading sequence which is different for each user that also helps to mitigate multiple access interference in the IDMA system. Here we use randomly generated user data as a spreading sequence [4]–[6]. These dynamically changing spreading sequences make unwanted detection of the data from an unintended receiver practically

impossible. To recover the despreading sequences in the receiver, we use the genetic search algorithm and Markov chain analysis that help to refine despreading sequences and updates in an optimal manner [7].

The remainder of this paper is organized as follows. In Section II, we present a brief introduction of transceiver structure in the IDMA system. Then, US-IDMA is described in Section III. In Section IV, numerical simulation results are presented and Section V concludes with remarks.

II. IDMA SYSTEM

The transmitter and receiver structures of an IDMA system with K -simultaneous users are shown in Figure 1. At the transmitter, the block size of N -length information bits from each user- k is denoted as $d_k = [d_k(0), \dots, d_k(N-1)]^T$, $k=1, 2, \dots, K$. The data sequence is encoded using a convolutional code into $b_k = [b_k(0), \dots, b_k(N_C-1)]^T$. That is, the code rate is defined as $R_1 = N/N_C$. Then each bit of b_k is again encoded using a low rate code such as a spread encoder with a rate of $R_2 = 1/S_k$, where S_k is a spreading factor. Thus, the overall code rate is $R_1 R_2$, which produces a chip signal. The second encoder output is fed into the user specific interleaver $(\pi_1, \pi_2, \dots, \pi_K)$ for user separation, which generates $x_k(j)$, $j=1, 2, \dots, J$, where J is the user frame length. The resultant signal is then transmitted through the multiple access channel.

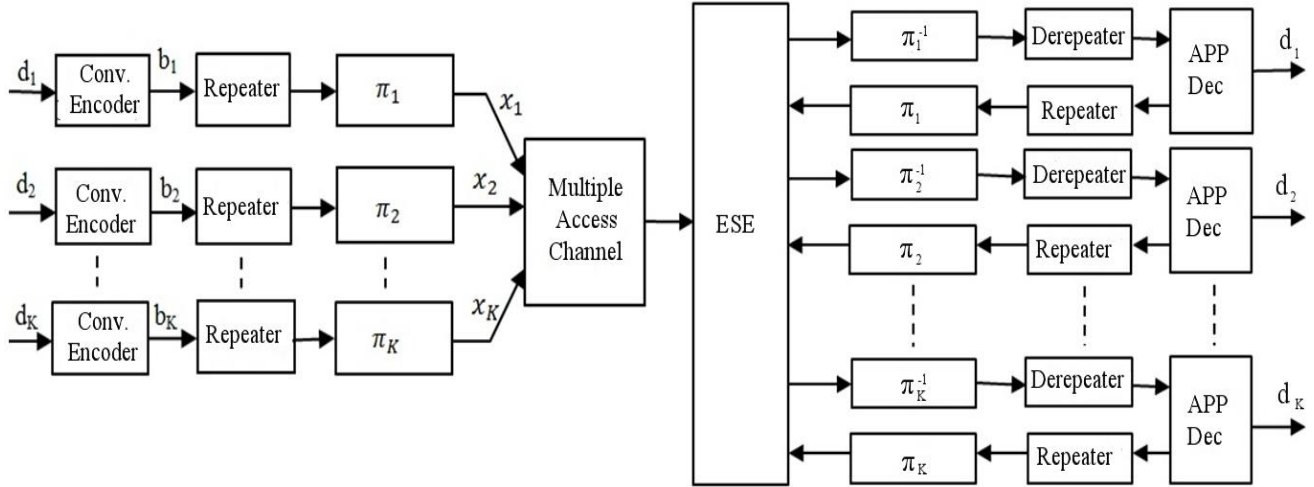


Figure 1. The IDMA system

In the receiver, the received signal is given by

$$r(j) = \sum_{k=1}^K h_k x_k(j) + n(j), \quad j = 1, 2, \dots, J \quad (1)$$

where h_k is the channel gain for user- k , x_k is the corresponding transmitted signal and n is the additive white Gaussian noise (AWGN) process with zero mean and variance, $\sigma^2 = N_0/2$. It is assumed that the channel coefficients $\{h_k\}$ are known a priori at the receiver.

This received signal is passed to a multi-user detection (MUD) receiver that consists of an elementary signal estimator (ESE) and K a posteriori probability (APP) decoders (DECs), one for each user. The ESE performs chip-by-chip detection to roughly remove the interference among users. The outputs of the ESE and DECs are extrinsic log-likelihood ratios (LLRs) about $\{x_k\}$ defined as

$$e(x_k(j)) = \log \left[\frac{p(y | x_k(j) = +1)}{p(y | x_k(j) = -1)} \right] \quad (2)$$

Those LLRs are further distinguished by $e_{ESE}(x_k(j))$ and $e_{DEC}(x_k(j))$, depending on whether they are generated by the ESE or DECs. In the ESE section, y in (2) denotes the received channel output while for the DECs, y in (2) is formed by the deinterleaved version of the outputs of the ESE block.

$$e_{ESE}(x_k(j)) = \log \left[\frac{p(r(j) | x_k(j) = +1, h_k)}{p(r(j) | x_k(j) = -1, h_k)} \right] \quad (3)$$

where $e_{ESE}(x_k(j))$ of each user is estimated depending on channel coefficients $\{h_k\}$ of each user.

$$e_{DEC}(x_k(j)) = \log \left[\frac{p(e'_{ESE} | x_k(j) = +1, c)}{p(e'_{ESE} | x_k(j) = -1, c)} \right] \quad (4)$$

where e'_{ESE} is derepeater data of the deinterleaved version of the outputs from the ESE block and c is the code constraint by convolutional code. These results are then combined using a turbo-type iterative process for a pre-defined number of iterations. Finally the DECs produce hard decisions on information bits for each user.

III. US-IDMA SYSTEM

The US-IDMA system model is shown in Figure 2. In the transmitter, the block size of N -length information bits from each user- k is encoded using a convolutional code. These coded data fed into spreading sequence generator to spread the data. We have developed a practical method to generate spreading sequences instead of repeater in the transmitter of the IDMA system. This spreader structure not only spreads the information bits but also separates data from the individual users. Note that the users' spreading sequences are random and changing dynamically from symbol to symbol. We use shift registers for the spreading sequence.

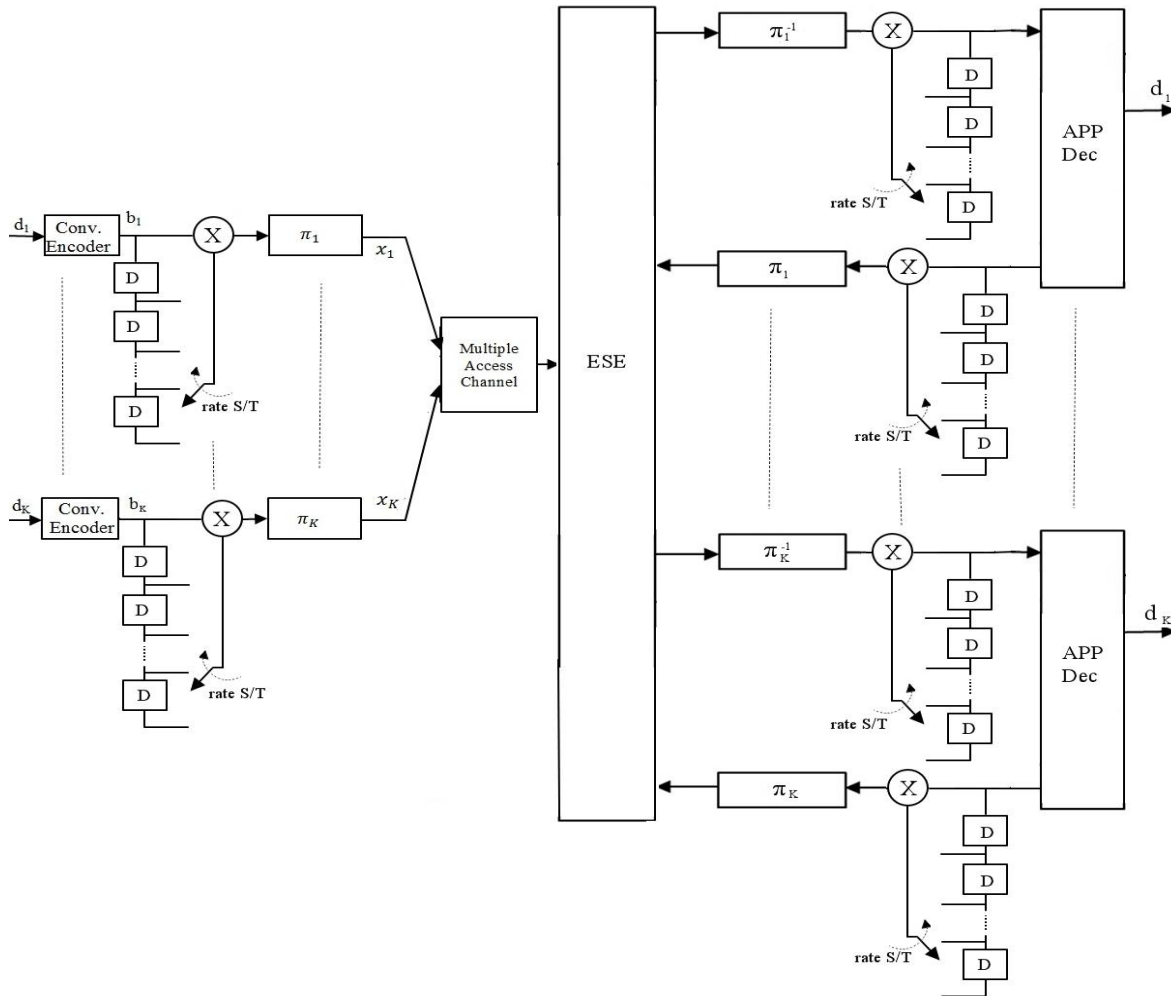


Figure 2. The US-IDMA system

Initially, all shift registers are initialized with '1'. The all '1' sequence is multiplied by the first coded data. After outputting the first sequence from the generator, the shift registers shift one bit right. This process continues for all data. Thus, the spreading sequences are changing dynamically according to the user data. This spread data is fed into the user specific interleavers ($\pi_1, \pi_2, \dots, \pi_K$). The resultant signal is then transmitted through the multiple access channel.

The US-IDMA receiver employs a chip by chip detection process same as the conventional IDMA system. The received signal is first estimated by Elementary Signal Estimators (ESE) and fed into the deinterleavers. The deinterleaved data is despread and decoded using a Posteriori Probability (APP) decoder. The process is run iteratively for a given number of iterations. For the despreading, initially we assign the same spreading

sequence (all '1') for spreading and despreading in the receiver. In the detection process, the spreading and despreading sequences are then provided by the decoded data for each user.

The severe multiple access interference and error propagation in the receiver may cause the despreading sequences to be mismatched with spreading sequences. We consider the recovery of the spreading sequence at the receiver without a priori knowledge. The received signal strength would determine the integrity of the recovered spreading sequence and would thus affect bit decisions subsequently. For the error checking of the despreading sequences, we use genetic search algorithm and Markov chain analysis [7]. These algorithms help to refine despreading sequences and update in an optimal manner.



IV. SIMULATION AND RESULTS

The simulation results are presented to analyse the performance of the US-IDMA system. We implemented a system using the Matlab Simulink. The parameters are used in the simulation as follows. At the transmitter, 1024 randomly generated information bits of each user are encoded by the convolutional code of $(23, 35)_8$. The different lengths of spreading sequences are used. The system employed the BPSK modulation. The transmission path of the system is considered as flat fading channel. It is assumed that all users in the system use the same energy level. The bit error rate (BER) performance of the proposed system is analysed.

Figure 3 and Figure 4 show the performance comparison between the US-IDMA system and the conventional IDMA system with 5 and 10 simultaneous users, respectively. The different spreading lengths used for simulation are 16 and 24. When the spreading length is 16, the performance of the US-IDMA system shows comparable performance to the conventional IDMA system. However, when the spreading length increases, the US-IDMA system outperforms the conventional IDMA system. Also, when the number of users increases, the US-IDMA system gives better performance compared with the conventional IDMA system.

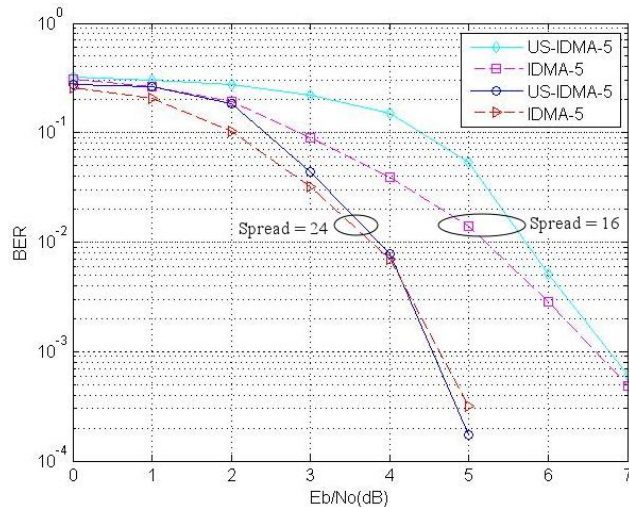


Figure 3. BER performance comparison between conventional IDMA and US-IDMA with K = 5

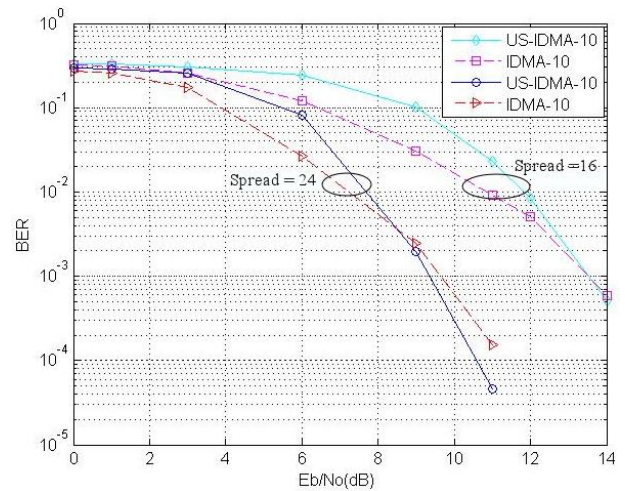


Figure 4. BER performance comparison between conventional IDMA and US-IDMA with K = 10

V. CONCLUSION

We have proposed the User-Spread IDMA (US-IDMA) system with user data spreading sequences. These sequences are dynamically changing from one symbol to the next according to the user data. As a result, the user data based spreading sequences make unwanted detection by unintended receivers practically impossible. Therefore, the US-IDMA system gives more secure and reliable communications compared with the conventional IDMA system. Also spreading sequence helps for the user separation. Thereby, US-IDMA system uses two way user separations using the user specific interleaver and user specific spreading sequences that improve the performance of the US-IDMA system. The simulation results show that the proposed system improves the bit error rate performance significantly as the spreading sequence length and the number of users increase.

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Biography



P. Niroopan received B.Sc. of Eng. degree in Electrical and Electronic Engineering from University of Peradeniya, Srilanka in 2010. He currently is working towards the M.E. degree at Pukyong National University, South Korea. His research interest is multiple access techniques in wireless communications systems



Yeon-ho Chung received the BEng. degree in Electronic Engineering from Kyungpook National University, Daegu, Korea, in 1984, MSc. degree in Communications and Signal Processing from the Imperial College, the University of London, U.K., in 1992 and Ph.D. degree in Electrical Engineering and Electronics from the University of Liverpool, U.K., in 1996. He has now been working as a Professor of the Dept. of Information and Communications Eng., Pukyong National University, Korea. From December 2004 to February 2005, he joined the Mobile Communication Research Laboratory of Plymouth University, U.K. as a visiting research fellow sponsored by the Ministry of Education, Science and Technology, Korea. He was also a visiting professor in the Pennsylvania State University, University Park, U.S.A. from August 2006 to December 2007. From August 2008 to July 2012, he served as Executive Director of the Office of International Relations, Pukyong National University, Busan Korea