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Coded Cooperation Scheme using Duo-Binary Turbo Codes

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Abstract : In this paper, we propose an efficient coded diversity tehniques, which partition the codewords of each mobile and transmit portions of each codeword through independent fading channels using duo-binary turbo codes. In the proposed method, each mobile transmits different parts of the parities so that they can be cooperatively worked for the iterative decoding process at the base station. We compare performance simulation results of the the proposed method with a conventional coded diversity technique.

1. Introduction

When mobiles cannot support multiple antennas due to size or other constraints, conventional space-time coding (STC) cannot be used to provide uplink transmit diversity. To overcome such constraints, the cooperative diversity technique has been introduced. In this cooperative scheme, mobiles share their antennas to achieve uplink transmit diversity by repeating the received bits from the partner.

Recently, a different frame work called coded cooperation was proposed, where symbols are not simply repeated by the partner but encoded with various error correction coding techniques [1-5]. Especially, due to recent advances in turbo coding techniques, various coded cooperation techniques with turbo codes has been reported [1-3]. Following first coded cooperation technique using turbo codes in [1], various cooperative turbo codes combined with STC has been introduced in [2] and [3]. In addition, references [4] and [5] introduced coded cooperative diversity techniques using low density parity-check (LDPC) codes.

Comparing turbo coded cooperative diversity schemes in [1] and [3], it is evident that the performance of the coded cooperative scheme with iterative decoding at a relay shows much better performance. For this, the source sends a part of the available parities along with the systematic parts. While, the relay first recover the information from the iterative decoding process for the received symbols and sends the other part of the parities along with or without systematic parts. Considering this, we propose a turbo coded cooperative diversity scheme using rate compatible duo-binary turbo codes. We use double binary turbo codes as error correction coding technique for the coded diversity.

In section 2, we describe the basic concept of the conventional coded diversity techniques in [1]. In section 3, we introduce the proposed coded diversity scheme using duo-binary turbo codes. We present performance simulation results of the proposed scheme and compare them to those of the conventional schemes in section 4. Finally, we draw our conclusion in section 5.

2. Conventional coded diversity techniques

Cooperation between pairs of wireless users can provide diversity gain in the uplink of a wireless system. Partnering users achieve diversity through a signaling scheme that allows them to send their information using both of their antennas. The coded cooperative diversity scheme first introduced in [1], where the users share their antennas such that a portion of each user's code bits arrive at the base station through a different, independent fading channel. The users decide between continuing their own transmission in the second block, and relaying the other user's transmission in the second block, either by simply amplifying their received signals subject to their power constraint, or by fully decoding, re-encoding, and re-transmitting the messages.

Figure 1 shows the basic concept of the coded diversity technique introduced in [1], where they assummed time division duplexing (TDD) mode. The users segment their souce data into blocks that are augmented with a cyclic redundancy check (CRC) code, such that there are a total of K bits per source block, including the CRC bits. Each block is then encoded with an error correcting code so that, for an overall rate R code, we have $N = K/R$ total code bits per source block. The two users cooperate by dividing the transmission of their N-bit codewords into two successive time segments, or frames. In the first frame, each user transmits a rate $R_1 > R$ codeword with $N_1 = K/R_1$ bits. This higher rate code can be obtained, for example, by puncturing the original codeword. Each user receives and decodes his partner's first frame. If the user successfully decodes the partner's rate R_1 codeword, the user computes and transmits N_2 additional parity bits for the partner's data in the second frame($N_1+N_2=N$). For example, if the first frame was obtained via puncturing, these N_2 bits could be the puncture bits left out of the first frame.

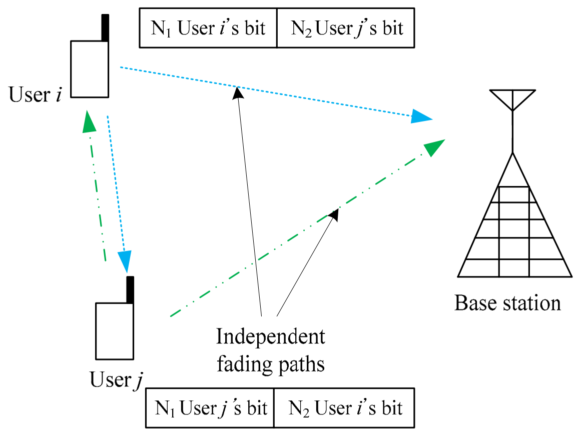

Figure 1. An example of coded cooperative diversity

Whenever a user is unable to successfully decode his partner's message, the user will revert to a noncooperative mode by calculating and transmitting N_2 parity bits for his own message. If a user successfully decodes the partner but not vice versa, both users will transmit the partner's bits in the second frame. These bits are optimally combined at the base station prior to decoding . The base station needs to know whose bits each user transmitting in the second frame.

As a error correction coding scheme for the coded cooperative diversity, they used the rate compatible turbo codes with memory size of 4, rate 1/4 mother codes, and generator polynomial G(23, 35, 27. 33) in octal given in [6]. The implementation of coded diversity using the turbo codes is shown in Figure 2. Turbo codes employ two constituent recursive systematic convolutional (RSC) codes with an internal interleaving [7]. The codeword for the first frame is obtained using the first RSC codes. Upon successful decoding of the partner, the user interleaves the source bits over the *K*-bit block and transmits the parity bits corresponding to the second RSC code.

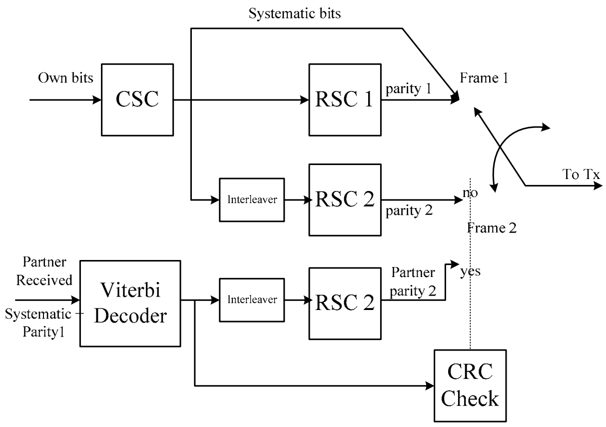

Figure 2. Turbo encoding in a coded diversity scheme

The error correction capability of the RSC code with the Viterbi decoder is certainly lower than that of the trubo code. Therefore, instead of sending parities of RSC, if we send the puntured parities of turbo codes itself, then this can highly improve the decoding performance at the partner's terminal due to much higher coding gain from iterative decoding.

3. Proposed method

3. 1 Basic concept

In this section, we introduce a coded cooperation scheme using a rate compatible duo-binary codes. As in the conventional scheme, we assume TDD mode. In the first frame, the users transmit their own first set of *N* bits to the partner and the base station. First set was comprised of systematic information and parity 1. Each user receives and decodes the received partner's first set. If the first frame of the partner is successfully decoded, then at the second frame, the user transmits the systematic information and parity 2 for the partner. Or if the first frame of the partner is not successfully decoded, then at the second frame the user transmits the repetition of the first frame. Each user always transmits a total of *N* bits per source block over the two frames. In the following sub-sections, we first introduce duo-binary turbo codes, and then apply it to the conventional coded cooperation scheme. Then, we introduce our proposed scheme with duo-binary turbo codes.

3. 2 Duo-binary turbo codes

Duo-binary turbo codes use double binary circular recursive systematic convolutional (RSC) codes. It is defined as a channel coding scheme for Digital Video Broadcasting – Return Channel via Satellite (DVB-RCS) and IEEE 802.16e [8][9]. "Double binary" means that a couple or two bits are fed into the encoder with interleaving at the same time. Figure 3 shows encoder diagram of the duo-binary turbo codes. In this turbo encoder two recursive systematic convolutional codes are concatenated in parallel. In this encoder, for systematic information of "AB", the first RSC generates parity bits of "Y1W1" and the second RSC after the interleaver generates parity bits of "Y2W2" . In the natural order, all couples "AB" are transmitted first, followed by all couples "Y1Y2" that remain after puncturing and then all couples "W1W2" that remain after puncturing.

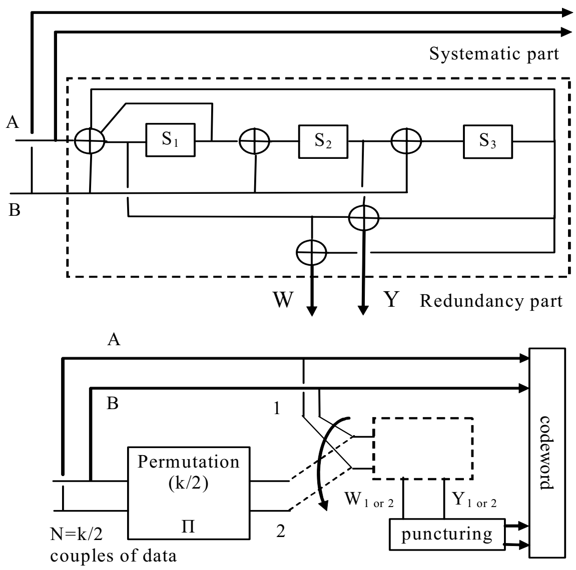

Figure 3. Encoder structure of duo-binary turbo codes

3. 3 Conventional scheme with duo-binary turbo codes

Let us first apply this duo-binary turbo code to the conventional method in [1]. The codeword for the first frame is obtained using the first RSC codes. User transmits source bits of "AB" and parity bits of "Y1W1" to the partner and base station simultaneously. Upon successful decoding of the partner, the partner interleaves source bits of "AB" of the user over the *K*-bit block and transmits the parity bits of "Y2W2" corresponding to the second RSC code to base station. If the first frame of the user is not successfully decoded at the partner, the user will interleave own source bits of "AB" and encode it and transmit the second set of parity bits from the second RSC for his own source block to the base station. In the base station, received codeword is decoded via iterative decoding. Figure 4 shows the concept of the operational principle.

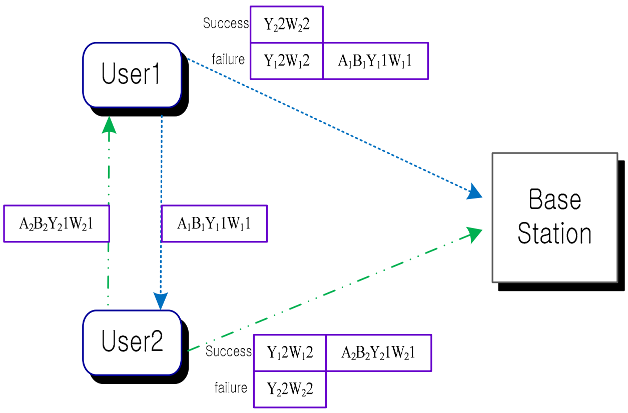

Figure 4. Conventional coded diversity using duo-binary turbo codes

3. 4 Proposed scheme with rate compatible codes

In order to enhance the performance, we apply a modified approach to the conventional cooperative diversity. Instead of sending output from the first RSC, each user sends a punctured turbo coded bits of “Y1Y2” to the partner and base station simultaneously. Then, decoder of the partner operates an iterative decoding. Upon successful decoding of the partner, the user transmits another set of parities of “W1W2”, which have not been transmitted by the partner. If the first frame of the partner is not successfully decoded, the user will transmit another half parity bits of “W1W2” for his own source block.

Figure 5 shows the operational principle of the proposed method. The major difference between the conventional method and the proposed method is the decoding complexity at each user terminal. In the conventional method, we need a single (or one step) Viterbi decoder to recover the information sent by the partner. On the other hand, the proposed method needs an iterative decoder, and this will definitely lead to highly enhanced performance at the expense of the decoder complexity and processing delay.

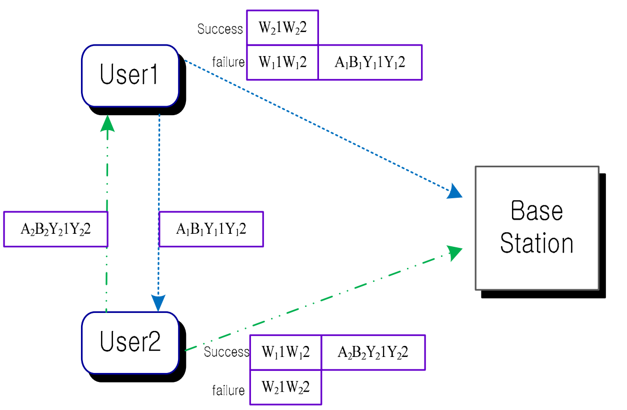

Figure 5. Proposed coded diversity using duo-binary turbo codes

4. Simulation results

In order to compare the performance of the above methods, we present bit error rate (BER) performance simulation results on a Rayleigh fading channel. In the simulation, we use duo-binary turbo codes with rate 1/2 between users and with rate 1/3 between a user and the base station. In all cases, the source block size is K = 212 bits. We investigate the BER performance of the proposed scheme at iteration numbers of 1 and 8 for between users. We set the maximum iteration numbers to 8 for between a user and the base station. We assume the signal is modulated by QPSK scheme, and transmitted over Rayleigh fading channel. Further we assume that the receiver has perfect knowledge of the channel.

Figure 6 shows BER performance of the proposed and conventional coded diversity techniques using duo-binary turbo codes.

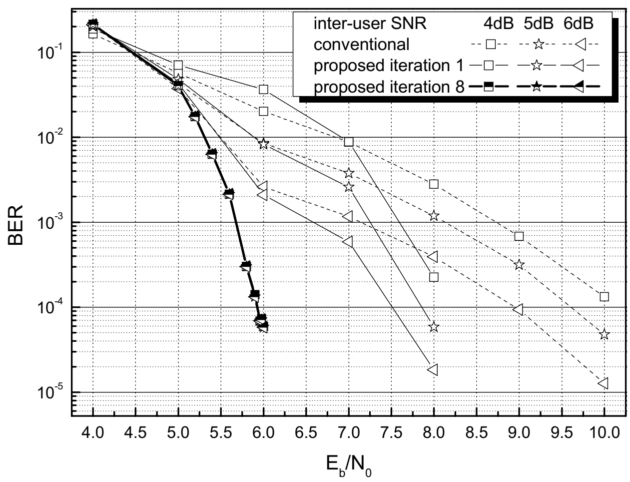

Figure 6. BER performance at the base station in Rayleigh fading channel.

As shown in the figure the proposed method shows high performance improvement. For example, at BER of 10^{-3}, a coding gain of about 1dB is achieved over the proposed method, with just a single iteration of decoding for the received signal from the partners when inter-user SNR is 4dB. In addition, a coding gain of about 2dB is achieved over the proposed method, with 8 iterations of decoding at the user terminal at the same inter-user SNR. At BER range of about 10^{-5}, the coding gain of the proposed method is increased more than 4 dB.

5. Conclusion

In this paper, we presented coded cooperation schemes using duo-binary turbo codes. We used rate compatible turbo codes, and a user sends its own and partners’ data with different parity information, so that they can be cooperatively worked at the base station. The proposed coded diversity scheme shows improved performance especially when the inter-user SNR is larger than 4dB, and this performance improvement can be achieved at the expense of decoder complexity at each user terminal. As it can be easily expected, if we increase the number of iterations at a user terminal, the performance can be highly enhanced.

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