A Simple Cooperative LDPC Coding Scheme

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***Abstract*—Cooperative communication makes use of the broadcast nature of wireless communication to improve the reliability of the data transmitted between two users. It utilizes intermediate nodes as relays to produce diversity in a point-to-point communication link. This diversity produced by the relays allows an increase in capacity, speed and performance. The aim of this paper is to exploit the characteristics of the cooperative communication associated to LDPC codes using three distinct channels. The amount of data retransmitted by the relay is variable. The cooperative coding schemes are analyzed on different combinations of fading levels for the channels. The results show that even using a very simple way to combine the codewords that reach the destination before the iterative decoding process it is possible to achieve significant performance gains.**

***Index Terms*—Cooperative coding, Coded Cooperation, LDPC.**

I. Introduction

The basic idea of cooperative communication is to allow mobile devices to share their antennas creating a multiple-input-multiple-output (MIMO) system. The cooperative communication generates spatial diversity by using retransmission of a signal from distinct locations, obtaining different independent fading versions of the signal at the receiver. Fig. 1 shows a cooperative communication scheme that utilizes two users and a destination. Each user transmits its data and can act as a relay. The cooperation among users increases the spectral efficiency due to diversity and a possible increase in channel coding rate [1], [2], [3], [4].

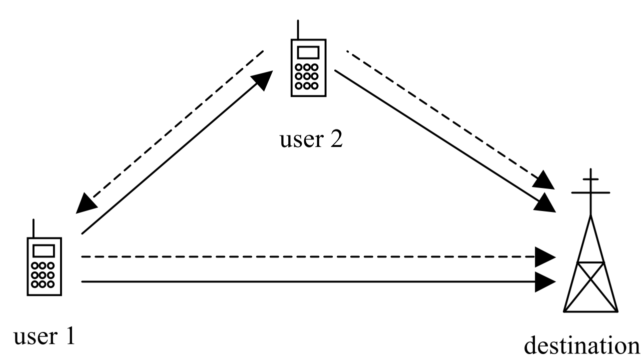

Fig. 1 Cooperative communication scheme

The above scheme can be simplified without loss of generality as presented in fig. 2. The source (user 1) broadcasts the data to the relay (user 2) and the destination. The relay receives the data that can be somehow manipulated (encoded, equalized, amplified, etc.) and retransmits them to the destination. At the destination the data coming from two distinct sources (user 1 and relay) are used to obtain the best estimative of the transmitted information [1], [2], [3].

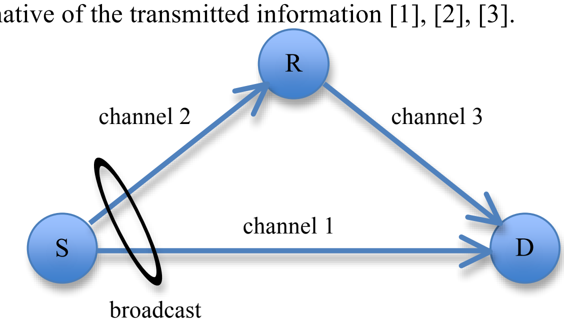

Fig. 2 Cooperative communication scheme

There exist basically three cooperative schemes among users: detect-and-forward, amplify-and-forward and coded cooperation. In the detect-and-forward method the relay attempts to detect the partner's data and retransmit them to the destination. Both data sent by the source (S) and relay (R) are detected by the destination (D) that makes a final decision on the transmitted information. In the amplify-and-forward method the relay receives a noisy version of the signal transmitted by the source and amplifies and retransmits it to the destination. The destination combines the information sent by the source and relay, and makes a final decision on the transmitted information. In the coded cooperation scheme there is an integration of cooperation and channel coding. The source encodes the information bits and broadcasts a codeword to the destination and relay. The relay decodes the received sequence and re-encodes its information portion. The new codeword is transmitted to the destination. At the destination both codewords are used to obtain the best estimate of original information. This paper will focus on this third scheme.

II. Cooperative Coding

The relay and source represented in fig. 2 are users of the cooperation system therefore their functions in the coded cooperation scheme can be interchanged. Moreover, each user can perform both operations as source and relay at the same time.

The data transmission of the source and relay are based on frames of length n bits. Each frame is divided into two sub-frames of length n_1 and n_2 bits, respectively. If a user (relay) cooperates it allows the other user (source) to utilize its sub-frame or its whole frame. It will depend on the strategy of cooperation adopted by the system. Therefore cooperative coding is very flexible and can be used virtually with any channel coding scenario [1].

It is assumed that the source broadcasts k information bits in a codeword $\mathbf{c}$ of length n bits, then the coding rate is $r = k/n$. Therefore the source does not cooperate in the system. The codeword reaches both destination and relay by distinct channels. At the relay, the noise-corrupted codeword is detected, decoded, re-encoded in a codeword $\mathbf{c_1}$ of length n_1 bits ($n_1 \leq n$) using a convenient encoding process and transmitted to the destination. The length n_1 of $\mathbf{c_1}$ is related to the level of cooperation provided by the relay. If the relay is not transmitting data, then its whole frame is available for cooperation with the source, i.e., $n_1 = n$.

The encoding process at the relay does not need to be the same of the source. The destination receives the noise-corrupted version of both codewords $\mathbf{c}$ and $\mathbf{c_1}$ and uses them to best estimate the k information bits sent by the source.

Fig. 3 shows the performance, in terms of bit error rate (BER) per energy per bit to unilateral noise power spectral density ratio (E_b/N_0), of a cooperative coding scheme using a binary (4512, 2256) LDPC code [4]. Its parity check matrix $\mathbf{H}$ has row weight $w_r = 6$ and column weight $w_c = 3$. The source encodes $k = 2256$ information bits into a codeword of length $n = 4512$ bits. This codeword is modulated using a 2-PSK modulator and broadcasted to destination and relay. The source-destination and source-relay channels are supposed to be independent additive white Gaussian noise (AWGN). The relay demodulates the received sequence, iterative decodes it to estimate the original k information bits and re-encodes this estimate using the same LDPC code. Two situations are analysed: a complete cooperation by the relay processing and sending a full-length codeword ($n_1 = n$) to the destination; and partial cooperation where the relay uses only one sub-frame sending therefore only half codeword ($n_1 = n_2 = n/2$). The performance curve for the straight encoded source-destination transmission is also drawn as reference for performance comparisons. The destination receives the noise-corrupted sequences $\mathbf{r}$ and $\mathbf{r}_1$, related to the codewords $\mathbf{c}$ and $\mathbf{c}_1$, respectively. The received symbols of $\mathbf{r}$ and $\mathbf{r}_1$ are firstly compared based on their reliabilities and then only the more reliable symbol in each position is kept in a unique received sequence. This final sequence is then sent to the iterative decoder to obtain the best estimate of the information sequence transmitted by the source. The decoder is based on the belief propagation algorithm. In this figure, all three channels have no fading. Notice that for $BER = 10^{-4}$ the coded cooperation produces a gain of 0.9 dB and 0.7 dB for full or half codeword transmitted by the relay, respectively.

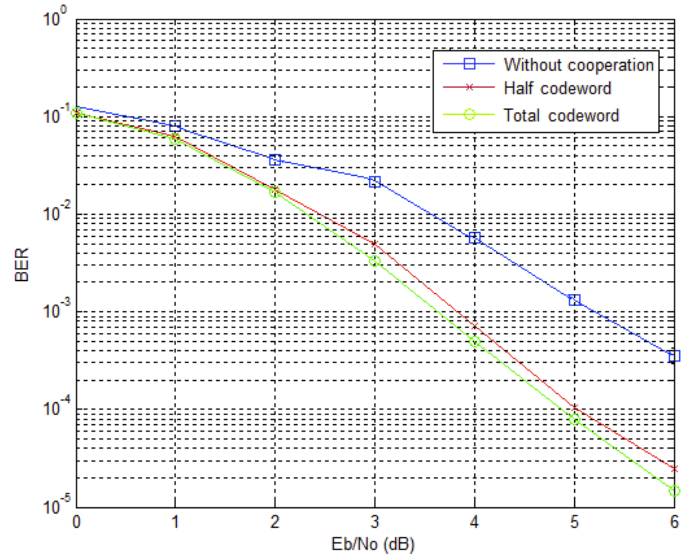

Fig. 3 Cooperative coding using a (4512, 2256) LDPC code with the three channels having no fading.

Fig. 4 shows performance curves BER versus E_b/N_0 of a cooperative coding scheme using the same (4512, 2256) LDPC code presented above. In this case, channel 1 and 3 have no fading while in channel 2 the E_b/N_0 is kept 3 dB below them. Notice that the coded cooperation produces a lost in E_b/N_0 for full or half codeword transmitted by the relay. Therefore, there is no advantage in cooperate when channel 2 has a higher level of fading than the other two. This poor performance can be explained by the fact that the estimate of the information obtained by the relay has some uncorrectable errors that are re-encoded and transmitted to the destination causing more errors.

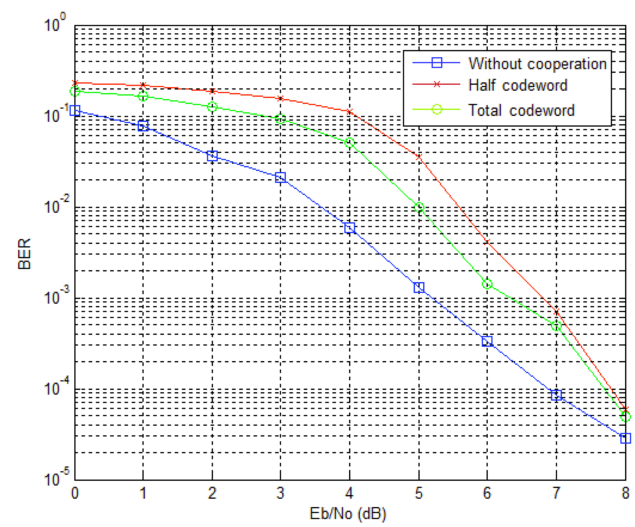

Fig. 4 Cooperative coding using a (4512, 2256) LDPC code with channel 2 fading 3 dB below the other two channels.

Finally, fig. 5 shows performance curves BER versus E_b/N_0 of a cooperative coding scheme using the same (4512, 2256)

LDPC code. In this case, channel 2 and 3 have no fading while in channel 1 the E_b/N_0 is kept 3 dB below them. Notice that the coded cooperation produces a gain of 5.25 dB and 4.75 dB for full or half codeword transmitted by the relay, respectively. When the direct channel suffers the highest level of fading, the coded cooperation has an awesome performance.

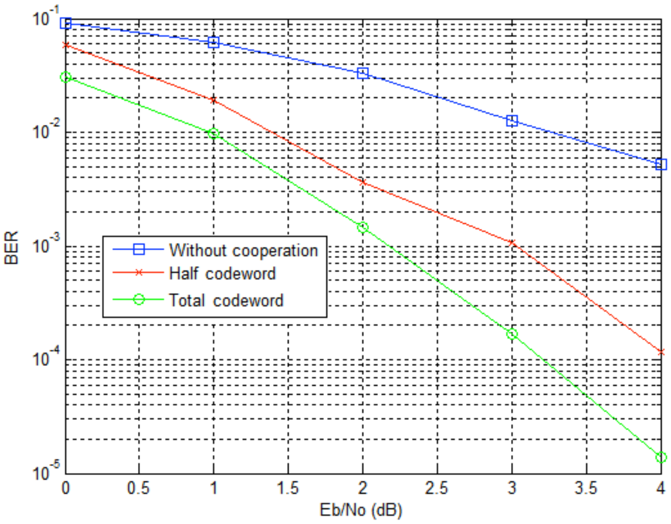

Fig. 5 Cooperative coding using a (4512, 2256) LDPC code with channel 1 fading 3 dB below the other two channels.

III. Conclusion

The preliminary results presented in this paper have shown that even using a very simple way to combine the codewords that reach the destination, it is possible to achieve significant improvements in *BER* performance. The binary (4512, 2256) LDPC code utilized in the simulations has the parity check matrix **H** as described in the standard IEEE 802.16e [6]. Generally cooperative communications make use of a multiple access schemes (CDMA, OFDMA, TDMA) to transmit data between users and base station. For convenience and simplicity, it was considered a 2-PSK modulation to convey the data on the channels.

These promising results show that there is a wide range of possibilities to be exploit to improve the performance in cooperative communications, such that, the use of quasi-cyclic LDPC codes based on latim square that can allowed coding rates more flexible [6] and a more efficient decoding process that makes use simultaneously of the reliabilities of codewords from both channels.

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