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Asynchronous diversity receiving scheme and analysis on cooperative relay networks

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Abstract

The transmission antennas of cooperative systems are spatially distributed on multiple nodes, so the received signal can be asynchronous due to propagation delays. A receiving scheme for cooperative relay networks is proposed, multiple asynchronous signals are reconstructed at the receiver by forward and backward interference cancellation, which can obtain gains of cooperative transmission diversity with obvious delay and with no requiring timing synchronization or orthogonal channelization between relays. Analysis and simulation show that the bit error rate (BER) of the proposed scheme is similar to Alamouti code, and the scheme has the diversity order of orthogonal transmission scheme accompanied by minimal BER losses. It is demonstrated that the performance can be further improved by adding an error correcting code (ECC).

Keywords relay networks, asynchronous communications, cooperative diversity, interference cancellation

1 Introduction

The attenuation in a wireless channel may vary due to time-variant fading in wireless networks. Thus, diversity is used in the receiver to increase the chances of a successful transmission. Taking advantage of multiple-antenna spatial diversity, in the wireless cooperative networks, the single-antenna nodes coordinate with each other and form a virtual antenna array. The cooperative relay networks make use of the broadcast nature of wireless network allowing simultaneous transmission to relay nodes, and then the relay nodes retransmit the signal towards destination. Such a multi-hop transmission with cooperative diversity may favor a better reception in each receiver along the path. Thus, the range, rate or autonomy is got improved [1].

In the previously proposed cooperative diversity schemes, it was assumed that coordination among the relay nodes accounts for accurate symbol-level timing synchronization at the destination. However, unlike the multiple-antenna systems where the antennas are collocated at the same device, the antennas in cooperative relay networks are spatially distributed on different nodes, so the received signal can be asynchronous dues to the propagation delays.

Delay-tolerant space-time codes (DT-STBCs) were proposed in Refs. [2–3]. The delay-tolerant codes can provide full diversity and coding gains only if in the existed delay between the received signals within a certain range. Recently, some new delay-tolerant STBCs is proposed Refs. [4–5]. However, as in Ref. [4], the new codes preserve the full diversity only if the relative delays are in a delay tolerance interval. The author of Ref. [5] proposed a bounded delay-tolerant time interleave reversal Alamouti code (BDT-TIR AC) with the maximum likelihood (ML) decoder. Because the longer the delay is the larger the dimension of the STBC is, the complexity of decoding becomes higher. There should be a trade-off between the acceptable delays and the signal processing complexity. Such trade-off is not permissible in practice networks.

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The author of Ref. [6] treated asynchronous as benefits rather than obstacles to the transmission with drawback of a higher processing complexity. Recently, the zigzag interference cancellation proposed in Ref. [7] to deal with the problem of hidden terminals in multiple-access networks [8–9], is expanded to asynchronous cooperative receiving scheme. However, this method divides the information into two messages and transmitted once more, resulting in lower transmission efficiency.

An asynchronous diversity receiving scheme is proposed based on the forward and backward interference cancellation for cooperative relay networks, making contributions to developing realizable solutions for providing cooperative diversity in wireless networks as follows:

1) Discuss a transmission set-up with cooperative relays, which does not require any space-time coding and are optimally combined to provide diversity.

2) Provide cooperative diversity for a delay, and a less complex decoding relative to ML decoders.

3) Derive BER for this asynchronous cooperative scheme which can be further improved by adding an ECC, and so a diversity order of two can be achieved is proved.

4) Compare the performance of the new scheme with Alamouti code and the orthogonal transmission scheme.

5) Compare the BER and the out probability with the zigzag interference cancellation proposed in Ref. [7].

2 System model

For simplicity without loss of generality, we consider a scenario consisting of one source S, two relays (R_1 and R_2), and one destination D (as shown in Fig. 1), where all nodes are equipped with a single antenna, and the time division duplex is used. It is assumed that, due to distance, the direct link between the source and the destination is broken.

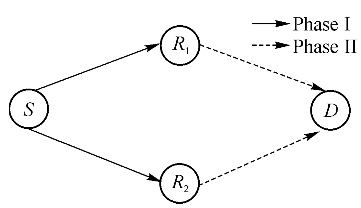

Fig. 1 Considered cooperative scenario: diamond channel model

For simulations, the authors assume that all channel fading obey slow fading Rayleigh distribution, even then the analysis is valid for any channel distribution. The authors also assume that all noises are additive white Gaussian noises (AWGN) with variance σ_0^2. A uniform power distribution is considered, where all transmitters (the source and the two relays) transmit with the same power *P*. Without loss of generality, the transmit power $P = 1$ W. Here, the destination is assumed with perfect channel state information (CSI), i.e. perfect knowledge of the channel gain and the channel delay.

The fading coefficient of the $S \rightarrow R_z$ link is denoted by h_{sz}, and the fading coefficient of the $R_z \rightarrow D$ link is denoted by h_{zd}. The channels coefficients can thus be considered as constant during the transmission of one frame and then switched to an independent random value in the next frame. We consider an amplify-and-forward (AF) strategy to reduce the complexity of the relay, with the amplifying factor denoted by β_z. For simplicity of notation, the product of the two channels is defined by $h_z = h_{sz}\beta_z h_{zd}$, $z \in \{1, 2\}$. The amplifying factor β_z is chosen to optimize transmission performance while respecting the power constraint: $\beta_z = 1\Big/\sqrt{\delta^2 + |h_{sz}|^2}$ [10]. A binary phase shift keying (BPSK) modulation is used here. Let $x[k]$ be the transmitted *k*th symbol and the destination received signals $x_1[k]$ and $x_2[k]$ are transmitted by R_1 and R_2 with a relative delay Δ. The transmission is divided into two phases: the source *S* broadcasts the messages to the relays R_1 and R_2. Relays R_1 and R_2 transmit the message to destination *D* thereafter.

3 Proposed schemes

The proposed asynchronous diversity receiving scheme is based on the forward and backward interference cancellation, in which the decoding is done twice, from the front and back (as shown in Fig. 2) respectively. Plain packets represent the decoded signals, dashed packets represent the removed signals. The forward interference cancellation process is analyzed only for the backward process is similar. Since the chunk 1 of x_1 is interference-free, the destination can decode it using the standard decoder. Then the destination subtracts chunk 1 from the next chunk. Similarly, chunk 2 of x_1 is interference-free, which can also be decoded by the standard decoder and so on. The process is repeated until x_1 is fully decoded. After the forward and backward