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Relay selection in cooperative communication systems over continuous time-varying fading channel

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Abstract In this paper, we study relay selection under outdated channel state information (CSI) in a decode-and-forward (DF) cooperative system. Unlike previous researches on cooperative communication under outdated CSI, we consider that the channel varies continuously over time, i.e., the channel not only changes between relay selection and data transmission but also changes during data transmission. Thus the level of accuracy of the CSI used in relay selection degrades with data transmission. We first evaluate the packet error rate (PER) of the cooperative system under continuous time-varying fading channel, and find that the PER performance deteriorates more seriously under continuous time-varying fading channel than when the channel is assumed to be constant during data transmission. Then, we propose a repeated relay selection (RRS) strategy to improve the PER performance, in which the forwarded data is divided into multiple segments and relay is reselected before the transmission of each segment based on the updated CSI. Finally, we propose a combined relay selection (CRS) strategy which takes advantage of three different relay selection strategies to further mitigate the impact of outdated CSI.

1. Introduction

Air traffic is increasing significantly due to the increase of unmanned aerial vehicle (UAV) and small general aviation aircraft. The expected growth in air traffic will lead to the increment in data transmission of aeronautical communication. The high-rate and high-reliability data transmission in wireless channel is needed for future aeronautical communication. Fading in wireless channel tremendously affects the performance of wireless communications. In aeronautical communication, wireless fading is severe since channel coefficients of

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aeronautical link change frequently. Thus it is imperative to mitigate the impact of wireless impairment in order to improve the performance of aeronautical communication.

Cooperative communication has been shown as a promising approach to combat wireless impairments by exploiting spatial diversity without the need of multiple antennas at one node.[1,2] In a cooperative communication system, intermediate nodes are utilized as relays to forward data from source to destination over independent wireless channels by two manners, i.e., the one way relaying and the two way relaying. No matter which manner is chosen, relay selection that instructs a subset of relays in the cooperative system to forward data has been considered as an effective method to improve the performance of cooperative communication.[3–7] When the nodes in cooperative system have multiple antennas, antenna selection, which has similar influence on the system performance as relay selection, is also investigated.[8]

Most of the literature dealing with relay selection assumes that the channel state information (CSI) used in the selection procedure is the same as that actually experienced by the data transmitted (i.e., ideal CSI). However, from a practical point of view, the channel varies over time and a time gap exists between relay selection and data transmission, and thus the CSI used in the selection procedure is not consistent with actual one during data transmission. In other words, the CSI used in relay selection is an outdated version of that during data transmission. As a result, the selected relays may not actually be the best for data transmission. Recently, the impact of outdated CSI on the performance of cooperative communication is investigated.[9–13] It is found that the outdated CSI results in serious performance degradation. Some relay selection strategies have been proposed to improve the performance of cooperative communication under outdated CSI.[14–19] Relay is selected based on channel prediction.[14–17] The relay with the maximal predicted channel strength[14,15] or the minimal predicted outage probability[16,17] is selected to forward data. Multiple relays are selected based on the outdated channel strength.[18] An outage-optimal relay strategy is proposed based on the optimization of the transmitting power of the relays to minimize the conditional outage probability.[19]

All the above research work implicitly or explicitly assumed a block fading channel where the CSI varies between relay selection and data transmission but maintain constant during data transmission. However, the duration of data transmission is comparable with or even larger than the gap between the relay selection and data transmission. Thus the channel variation during data transmission should be considered in cooperative communication system under outdated CSI, especially for the scenario of aeronautical communication. The correlation between the CSI used in relay selection and that experienced by the data transmitted decreases as the data is being transmitted. In other words, the level of accuracy of the CSI used in relay selection degrades with data transmission. To the best of our knowledge, this issue has not been addressed by the previous researches.

In this paper, we study relay selection under continuous time-varying fading channels in a decode-and-forward (DF) cooperative communication system. The channel not only changes between relay selection and data transmission but also changes during data transmission. We first evaluate the packet error rate (PER) performance of a cooperative system under continuous time-varying fading channel through simulation. It is found that the PER performance of cooperative system deteriorates more seriously under continuous time-varying fading channel than under block fading channel. Then, to improve the PER performance, we propose a repeated relay selection (RRS) strategy, which is a simple but effective approach. The forwarded data is divided into multiple segments. Before the transmission of each segment, the CSI is updated and relay is reselected based on the updated CSI. Finally, to further mitigate the impact of outdated CSI on the PER performance, we propose a combined relay selection (CRS) strategy which takes advantage of three different kinds of the existing relay selection strategies, i.e., the relay selection strategy based on channel prediction, the multiple relay selection strategy and the repeated relay selection strategy.

2. System model

We consider a DF cooperative system consisting of one source (S), one destination (D), and K half-duplex relays, where each node is equipped with only one antenna. The direct link between the source and the destination does not exist, as a result of high shadowing between them. The source wants to transmit a data packet containing N_b bits to the destination. The cyclic redundancy check (CRC) bits are included in the transmitted bits for error detection of data reception, but no error correction code (ECC) bit is included. Through modulation with constellation size b (i.e., b bits per symbol), the bit sequence with length N_b is mapped to a symbol sequence with length $N = N_b/b$ for each packet.

2.1. DF cooperative scheme

The relays in the system assist the source to transmit the data packet to the destination (Fig. 1). The cooperation period is divided into three phases.

Data Phase 1: the source S broadcasts the data packet and each relay in the system listens. After receiving the data packet, all relays decode it. With CRC bits, each node knows whether the data packet is decoded correctly or not. The relays that have decoded data correctly (or called decodable relays) are the candidates for data forwarding.

Relay Selection Phase: some of the decodable relays are selected to forward the received data packet based on the channel states between relays and the destination D.

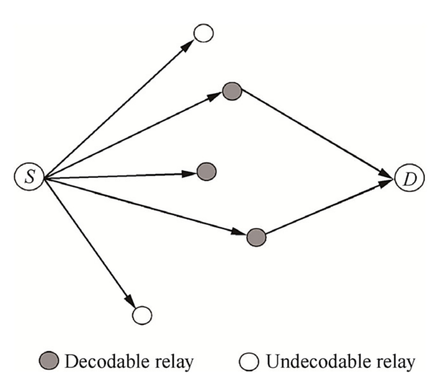

Fig. 1 System model of DF cooperative communication.