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Packet error rate performance of multi-stage cooperative relaying: Outdoor measurement

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Abstract: The packet error rate (PER) performance of space-time block code based multi-hop cooperative relaying is studied. In the case of multiple relays at each hop, a unique feature of the end-to-end PER performance can be observed up to 3rd hop. In this letter, an outdoor measurement campaign is conducted to verify this PER performance. In addition, a cooperative relaying scheme with received data sharing among relays is also examined. It is experimentally shown that PER at the 3rd hop is better than that of the 1st hop.

Keywords: multi-hop transmission, cooperative relaying, space-time block code, packet error rate, collaborative relaying, measurement campaign

Classification: Wireless Communication Technologies

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1 Introduction

Multi-hop cooperative relaying has been widely studied [1]. Implementation and experimental results of cooperative relaying are reported in several papers [2, 3, 4]. Space-time code is useful for signal-level (i.e., PHY-layer) cooperation [5], and its implementation issues are investigated in [3]. However, to the best of the authors' knowledge, the error rate performance of signal-level cooperation is not well verified in actual environments.

A multi-stage concept with multiple intermediate relays at each stage is suggested in [6]. It is pointed out in [7, 8] that the multi-stage concept has a unique advantage over a simple relaying with a single intermediate relay at each hop. The theoretical analysis in [8] reveals that the end-to-end packet error rate (PER) performance can be kept almost constant, or even improved, as the number of hops is increased. This unique feature in the end-to-end PER with the number of hops is demonstrated both theoretically and experimentally [9]. In the case of two relays in each stage, this improvement can be observed up to 3rd hop in most cases [8].

These studies assume independently and identically distributed (i.i.d.) Rayleigh fading for all channels, which is the best condition for signal-level cooperation. Experimental verification of this unique feature by an actual outdoor measurement

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campaign is limited to 2-hop scenarios [10, 11]. Then, a question arises: How about the end-to-end error performance of multi-stage cooperative relaying at the 3rd hop in actual environments (i.e., not i.i.d.), which is exactly the focus of this letter [12].

The PER performance can be further improved when relays at each stage can communicate with each other [13]. Experimental verification using a fading emulator is reported in [13]. This cooperative relaying scheme with data sharing is also examined together with a cooperative relaying scheme without data sharing.

2 Multi-stage cooperative relaying

The system model is shown in Fig. 1(a). The experimental equipment employed in this letter is a multi-stage cooperative relaying system with two relay stations at each stage. In a cooperative relaying scheme without data sharing, two relays (S1-A and S1-B, S2-A and S2-B) independently transmit a space-time block coded packet carrying the received data bits if no error is found by cyclic redundancy check (CRC). In a cooperative relaying scheme with data sharing, the packets received correctly are shared in two relay (S1-B and S1-C, S2-B and S2-C) through a data link. Therefore, the probability of transmitting space-time block coded packets from two relays is improved.

When propagation channels are independently distributed, the performance of multi-stage cooperative relaying is improved by received data sharing among relays. However, the distances between the relays are close so that the relays can communicate together; the diversity gain may be degraded due to correlations between propagation channels. Therefore, employing distant relays without data sharing may be more efficient than employing nearby relays with data sharing. In this letter, the effect of the received data sharing in multi-stage cooperative relaying is also examined via field experiments.

3 Experimental system and setup

The experimental system consists of eight software-defined radio (SDR) based wireless stations. The carrier frequency is 5.11 GHz. Built-in global positioning system (GPS) receivers are employed for timing and frequency synchronization.

3.1 Signaling format

The frame structure is shown in Fig. 1(b). In this signaling format, 100 packets are packed into one block so that the transmit/receive switching frequency is reduced for stable operation of SDR. Two cooperative relaying schemes are switched packet by packet. This enables quasi-simultaneous measurements of PERs of two schemes. The packet consists of 8-symbol training sequence, 50-symbol data symbols, and 8-symbol CRC symbols [12]. Two orthogonal training sequences and Alamouti's space-time block codes are assigned uniquely for two relay stations of each scheme. The modulation scheme is 100 k symbols/s QPSK except for the training sequence. The data bits are drawn from a pseudo-random sequence.

For pulse shaping, eight times oversampling and a root roll-off Nyquist filter with a roll-off factor of 0.4 is employed at the transmitter. At the receiver side, oversampled signals are utilized only for finding the symbol timing. The symbol

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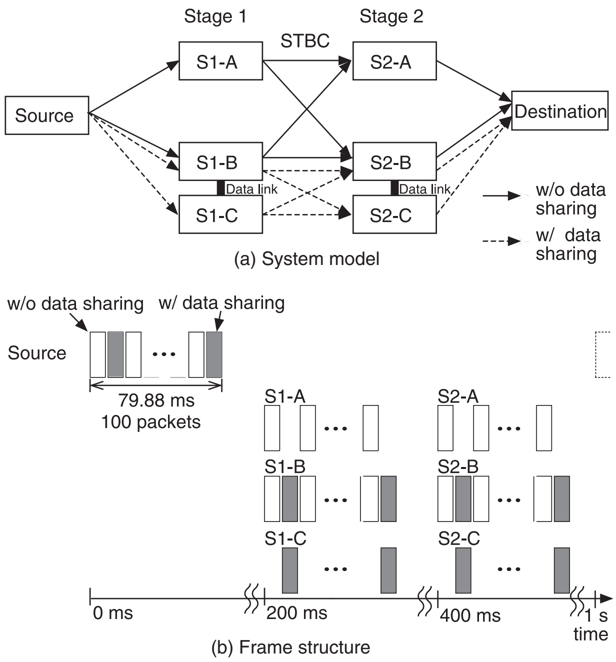

Fig. 1. System model and frame structure.

timing is estimated by a simple correlation technique using the training sequence, and the channel state information is also acquired. Note that these processes are performed for each packet independently.

3.2 Measurement setup

The locations of eight wireless stations are shown in Fig. 2. As can be seen, distances between a pair (transmit/receive) of wireless stations are 19 m except for two *cross* links (S1-A to S2-B,C and S1-B,C to S2-A). Antenna separation (i.e., between S1-B and S1-C, and also between S2-B and S2-C) for the cooperative relaying scheme with data sharing is 16 cm. For all wireless stations, omni-direc-

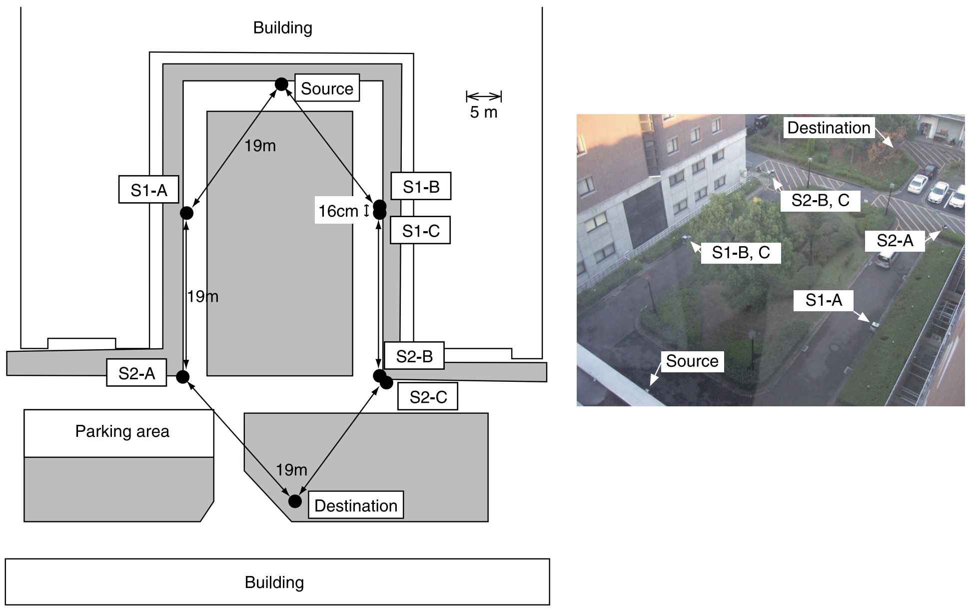

Fig. 2. Measurement campaign scenario.

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tional antennas with 3 dBi gain are fixed at 0.9 m above the ground. The transmit power is −1 dBm.

4 Experimental results

Fig. 3 shows the measured PER performance and the received signal power at the destination. The PER performance is averaged over 50 packets in this figure. As can be seen in Fig. 3(a) and (b), the received signal amplitude from two corresponding transmitters apparently follows different distributions in both the cases of

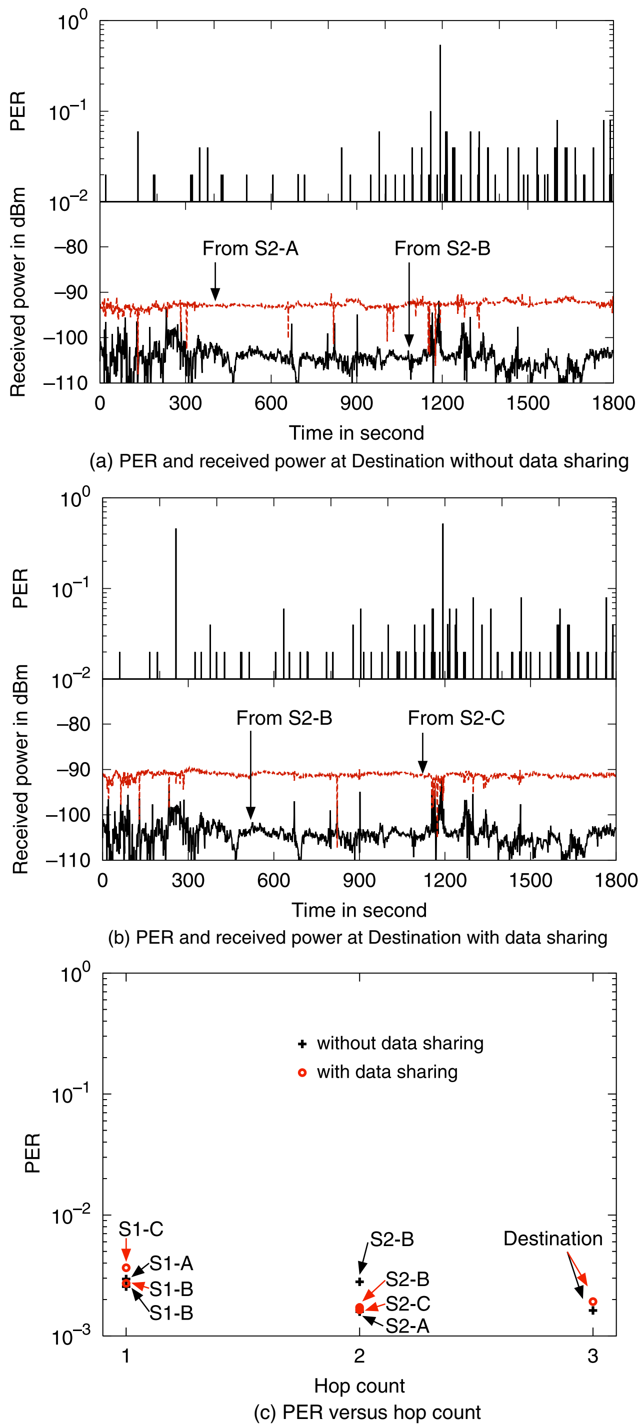

Fig. 3. Measured PER of two cooperative relaying schemes.

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(a) without data sharing and (b) with data sharing. This is due to multipath fading and shadowing by trees and plants.

Fig. 3(c) shows the average PER versus the hop count. This PER is averaged over 90,000 (30 minutes observation) packets for each scheme. The average PERs improve on the whole as the number of hops increases. It can be seen that PERs at the 3rd hop are better than those of the 1st hop, and almost comparable to those of the 2nd hop. This is the major feature of multi-stage cooperative relaying. However, we cannot give a detailed discussion of the measured PERs due to the nature of outdoor field experiments.

5 Conclusion

This letter presented the field experimental results of two cooperative relaying schemes. Due to the nature of outdoor field experiments, the difference of the PER performance between two schemes cannot be observed clearly. However, it is shown that multi-stage cooperative relaying can keep the end-to-end PER at the 3rd hop below that of the 1st hop and comparable to that of the 2nd hop. Therefore, the major feature of multi-stage cooperative relaying is observed in an actual environment, where the propagation channels are not i.i.d. but follow different distributions.

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