Adaptive Transmission Scheme Based on Channel State in Dual-Hop System

Seung-Jun Yu, Yong-Jun Kim, Jung-In Baik, Hyoung-Kyu Song

Abstract—In this paper, a dual-hop relay based on channel state is studied. In the conventional relay scheme, a relay uses the same modulation method without reference to channel state. But, a relay uses an adaptive modulation method with reference to channel state. If the channel state is poor, a relay eliminates latter 2 bits and uses Quadrature Phase Shift Keying (QPSK) modulation. If channel state is good, a relay modulates the received symbols with 16-QAM symbols by using 4 bits. The performance of the proposed scheme for Symbol Error Rate (SER) and throughput is analyzed.

Keywords—Adaptive transmission, channel state, dual-hop, hierarchical modulation, relay.

I. INTRODUCTION

MULTIPLE input multiple output orthogonal frequency division multiplexing (MIMO-OFDM) systems can provide a significant improvement of data rate even under conditions of interference [1]. By using a relay node in MIMO-OFDM system, the network reliability and coverage can be considerably improved [2], [3]. In dual-hop relay system, a relay can assist communication between a source and a destination by equipping with multiple antennas. The relay node can either amplify-and-forward (AF) or decode-and-forward (DF) the symbols [4]-[6].

Conventional relay scheme uses the same modulation method in a relay, even if the channel state changes. Therefore, the conventional relay scheme obtains low performance for poor channel state. In this paper, an adaptive transmission scheme based on channel state is proposed in dual-hop relay system. The proposed scheme uses an adaptive modulation method according to channel state between a source and a relay. Simulation results show that the proposed scheme performs higher SER and throughput performance that that of conventional scheme for poor channel state.

This paper is organized as follows. In Section II, a dual-hop relay system is shown and hierarchical modulation is shown. In Section III, the proposed scheme based on channel state in dual-hop relay system is explained. In Section IV, simulation results are given. Lastly, Section V makes a conclusion.

II. SYSTEM MODEL

A. Dual-Hop Relay System

In this section, a dual-hop relay system is considered. A dual-hop relay system is composed of one source (S) with two antennas; one relay (R) with two antennas and one destination (D) with two antennas. The channel coefficient between i-th antenna at S and j-th antenna at R is $h_{i,j}$, and the channel coefficient between i-th antenna at R and j-th antenna at D is $g_{i,j}$, where $i, j = 1, 2$. Channel state information (CSI) is assumed to be frequency flat Rayleigh fading and is known to R and D.

B. Hierarchical Modulation

In Fig. 2, hierarchical modulation [7] with Gray code mapping is considered. Various standards including Digital Video Broadcasting (DVB) support hierarchical modulation. Hierarchical modulation transmits two streams over the same radio frequency (RF) channel. In the hierarchical modulation, the two most significant bits convey high-priority data that are mapped with QPSK. The two least significant bits are used to convey low-priority data that are mapped with QPSK.

III. PROPOSED SCHEME

In this section, the proposed scheme in dual-hop relay system is described. The proposed scheme adaptively transmits the modulated symbols according to the channel state in a relay. In order to transmit the modulated symbols adaptively, a relay calculates the channel state taking advantage of condition number of channel. The condition number of channel measures the amount of channel distortion. The condition number of channel is denoted as,

$$C_P(\mathbf{H}) = \|\mathbf{H}\|_P \cdot \|\mathbf{H}^{-1}\|_P, \qquad (1)$$

where

$$\|\mathbf{H}\|_P = \left(\sum_{i=1}^{n} h_i^P\right)^{\frac{1}{P}}. \qquad (2)$$

The parameter p is matrix norm. The condition number of channel is determined in accordance with the parameter p. Due to complexity, the proposed scheme sets the parameter as 1-norm.

If the channel state is good, numerical value of the condition number is small, whereas the numerical value of the condition number is large if the channel state is poor. To determine the channel state, a threshold value η of the condition number is established. A threshold value η is calculated by averaging frequency channel values. Therefore, the threshold value η is as

$$\eta = \frac{1}{N_F} \sum_{i=1}^{N_F} C^i(\mathbf{H}), \qquad (3)$$

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where, $C^i(\mathbf{H})$ is the i-th frequency channel value of channel $\mathbf{H}$.

The proposed scheme adaptively transmits the modulated symbols according to the condition number of channel. In the proposed scheme, hierarchical 16-QAM which can be regarded as the combination of two QPSK modulations is used. In the

symbol quality, most significant bits (MSBs) errors tend to be degradative compared with any least significant bits (LSBs) errors in voice and video signals. Let us consider 4 bits with 2 MSBs and LSBs [8].
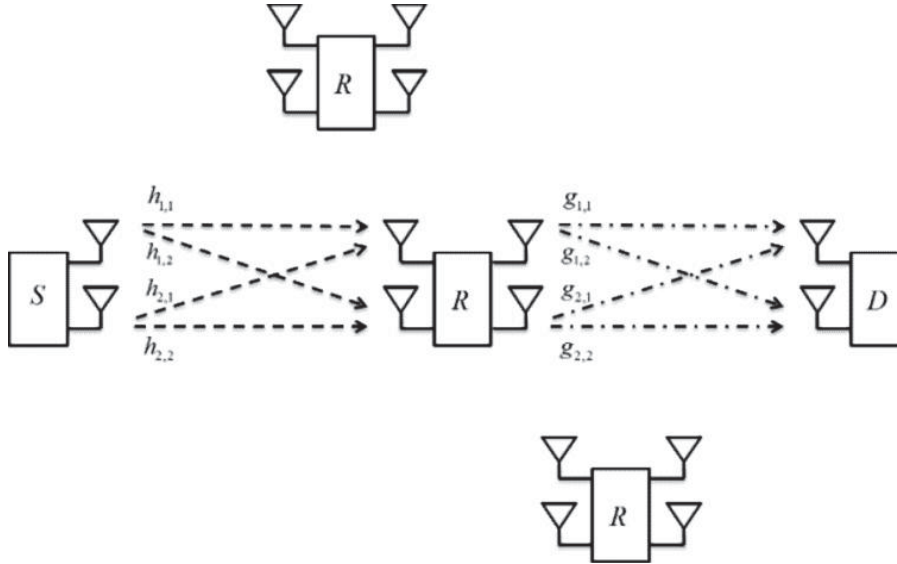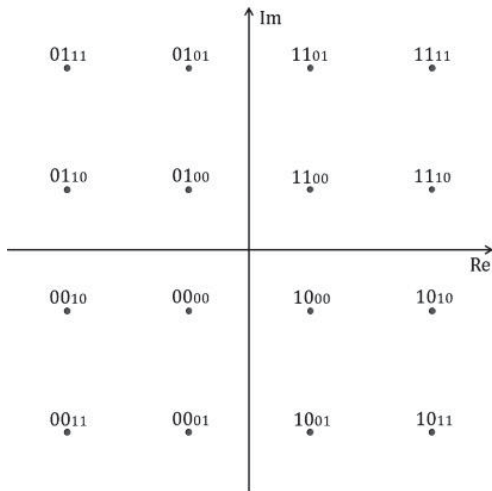

Fig. 1 Dual-hop relay system

Fig. 2 Hierarchical modulation

If the value of the condition number is large, a relay gets rid of the latter 2 bits and transmits QRSK modulated symbols to a destination. If the value of the condition number is small, a relay transmits 16-QAM modulated symbols to a destination.

For easier understanding of the proposed scheme, the proposed scheme is explained according to time slots. At first time slot, a source transmits hierarchical 16-QAM modulated symbols X_{12} and X_{34} to a relay. The received symbols at a relay are represented as:

$$\begin{bmatrix} R_1 \\ R_2 \end{bmatrix} = \begin{bmatrix} H_{1,1} & H_{2,1} \\ H_{1,2} & H_{2,2} \end{bmatrix} \begin{bmatrix} X_{12} \\ X_{34} \end{bmatrix} + \begin{bmatrix} N_{R_1} \\ N_{R_2} \end{bmatrix}, \tag{4}$$

where R_i denotes the received symbol at the i-th antenna in a relay, $H_{i,j}$ denotes the frequency responses of channel between i-th antenna at a source and j-th antenna at a relay, and N_{Ri} is a complex Gaussian random variable with zero mean and variance σ^2.

A relay demodulates received symbols with a 16-QAM demodulator. And then, a relay modulates adaptively symbols in accordance with the condition number of channel. If the value of condition number is large, a relay gets rid of latter 2 bits and modulates former 2 bits to QPSK symbol. In this case, the modulated symbols are as,

$$D = \begin{pmatrix} X_1 \\ X_3 \end{pmatrix}. \tag{5}$$

If the value of condition number is small, a relay modulates all 4 bits to 16-QAM symbol. In this case, the modulated symbols are as,

$$D = \begin{pmatrix} X_{12} \\ X_{34} \end{pmatrix}. \tag{6}$$

At second time slot, a relay transmits modulated symbols to a destination. And then, a destination receives adaptively

modulated symbols from a relay.

In case of a large condition number value, the received symbols in the frequency domain is as

$$\begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} G_{1,1} & G_{2,1} \\ G_{1,2} & G_{2,2} \end{bmatrix} \begin{bmatrix} X_1 \\ X_3 \end{bmatrix} + \begin{bmatrix} N_{Y_1} \\ N_{Y_2} \end{bmatrix}, \qquad (7)$$

where Y_i denotes the received symbol at i-th destination antenna, $G_{i,j}$ is the frequency response of channel between i-th antenna at a relay and j-th antenna at a destination, and N is a complex Gaussian random variable with zero mean and variance σ^2.

In cased of small condition number value, the received symbols in the frequency domain can is as

$$\begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} G_{1,1} & G_{2,1} \\ G_{1,2} & G_{2,2} \end{bmatrix} \begin{bmatrix} X_{12} \\ X_{34} \end{bmatrix} + \begin{bmatrix} N_{Y_1} \\ N_{Y_2} \end{bmatrix}. \qquad (8)$$

Finally, the destination reconstructs the original signals with minimum mean square error (MMSE) detection.

IV. SIMULATION RESULTS

In the simulation, a dual-hop relay system considers perfect synchronization and completes equalization. Simulations are accomplished with the following parameters. The fast Fourier transform (FFT) size is 128 and the cyclic prefix (CP) length is 32. The channel model is 8-path Rayleigh fading channel model. Fig. 3 shows the SER performance of the conventional scheme and the proposed scheme. Unlike the conventional scheme, the proposed scheme adaptively transmits the modulated symbols depending on the channel state in a relay. Consequently, the proposed scheme shows higher SER performance than that of the conventional scheme for low Signal-to-noise ratio (SNR). Fig. 4 shows the throughput performance of the conventional cooperative scheme and the proposed scheme. In the simulation, the throughput performance is calculated as,

$$T = (1 - E) \times R, \qquad (9)$$

where T is throughput, E is bit error rate, R is transmission bits, respectively. The throughput performance of the proposed scheme outperforms that of the conventional scheme because of the use of hierarchical modulation.
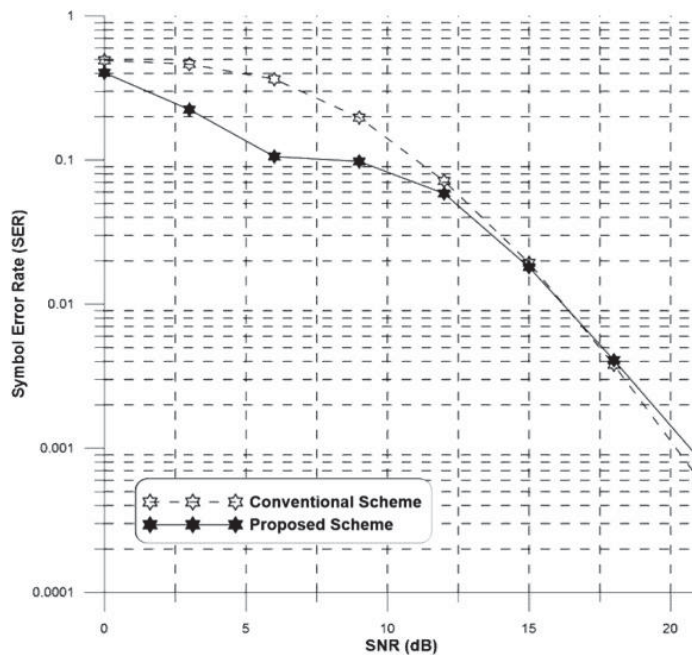

Fig. 3 The SER performance of conventional schemes and proposed scheme

V. CONCLUSION

In this paper, an adaptive transmission scheme based on channel state is proposed in dual-hop relay system. The proposed scheme adaptively transmits modulated symbols according to the channel state in a relay. The simulation results have shown that the performance of the proposed scheme are improved according to the channel state. In particular, the proposed scheme reliably transmits symbols for low SNR.
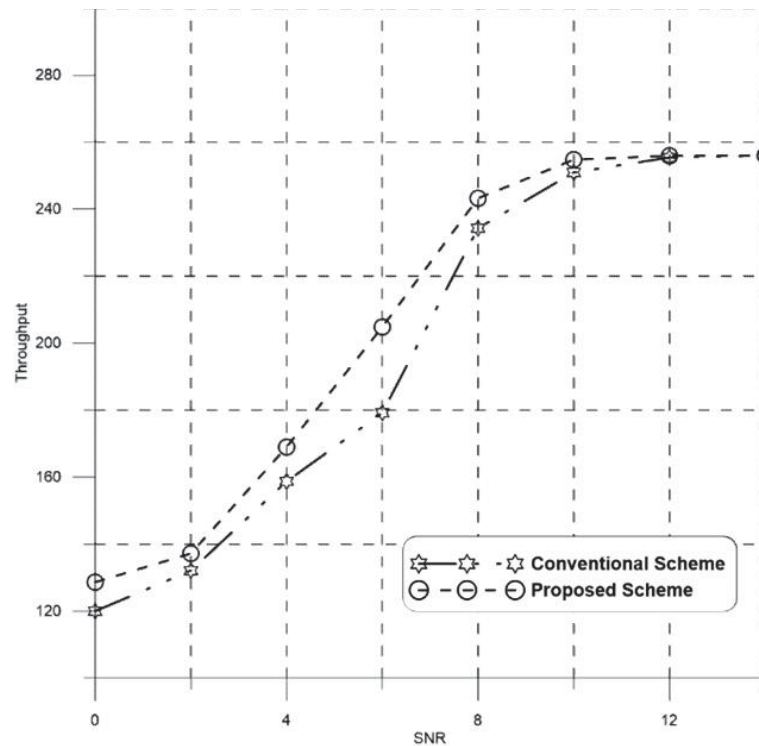
Fig. 4 Throughput performance of conventional schemes and proposed scheme

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