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

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ABSTRACT
Conventional dual-hop scheme has used the same modulation method for the source and the relays. Given that the distances between the source and the relays are close, in other words, when the quality of the source-relays link is good, the usage of higher order modulation at the source improves total system throughput. However, in opposite case, bit error probability is increased through using higher order modulation. Therefore, we propose a relay scheme that uses hierarchical modulation at the source and adaptive modulation based on the channel state at the relays. Accordingly, the symbol error rate (SER) and throughput performances are improved by the proposed scheme.
Keywords: Dual-hop, Relay, Adaptive modulation, Channel state, Hierarchical modulation.

I. INTRODUCTION

In recent years, using relays in wireless networks has garneredsignificant interest. It is well known that due to shadowing,multipath fading, distance-dependent path losses and interference,the link quality between the source and destinationin a wireless network often degrades severely. In such a scenario,relays can be employed between the source and destination terminals for assisting the transmission of data from thesource to destination [1], [2]. In particular, source can cooperatewiththe relays to relay the replicas of the source signalto the destination thereby providing additional diversity and improvedsignal quality at the destination. In the literature, variousschemes of cooperative communications such as amplify-andforward(AF), decode-and-forward [2], coded-cooperation [3],and compress-and-forward [4] have been presented. In [5], theoutage and ergodic capacities have been analyzed for a three terminal network where one of the relays the messages ofanother terminals towards the third one.A multiple-input multiple-output (MIMO) relay network [6] iscomposed of source, relay, and destination terminals, each of which isequipped with multiple antennas. Network information theory hasshown that the use of multiple relay terminals in source and destination(S-D) communication makes the capacity of the S-D systemlogarithmically increase with the number of relay terminals.

A simple description of the dual-hop relaying protocol [7] is following. In the first hop, the source broadcasts to the relays. In the second hop, the relays simply transmit sources signals in separated channels or transmit them using a space-time code to the destination. Consequently, the reliability of the communications is improved whereas the throughput might go down since the transmission is performed by two times. Conventional dual-hop scheme has used the same modulation method for the source and the relays. Given that the distances between the source and the relays are close, in other words, when the quality of the source-relays link is good, the usage of higher order modulation at the source improves total system throughput. However, in opposite case, bit error probability is increased through using higher order modulation. Therefore, we propose a relay scheme that uses hierarchical modulation [7] at the source and adaptive modulation based on the channel state at the relays. Accordingly, the symbol error rate (SER) and throughput performances are improved by the proposed scheme.

II. SYSTEM MODEL

In this section, we consider a dual-hop relay system with 3 terminals which is made up of a source S, a relay R and a destination D. A source S and a relay R have a single antenna. We assume that communication takes place only over dual-hop links and there is no direct between S and D. The coefficient of the link between i-th antenna atS and j-th antenna at R is $g_{i,j}$ and $h_{i,j}$ is the coefficient of the link between i-th antenna atR and j-th antenna at D, where i, j = 1, 2. It is assumed that each channel goes through Rayleigh fading and the link coefficients $g_{i,j}$ and $h_{i,j}$are independent and identically distributed (i.i.d). Also, the channel state information (CSI) is known to R and D. We assume a half-duplex channel, for which all terminals cannot transmit and receive symbols at the same time over the same frequency band.

III. PROPOSED SCHEME

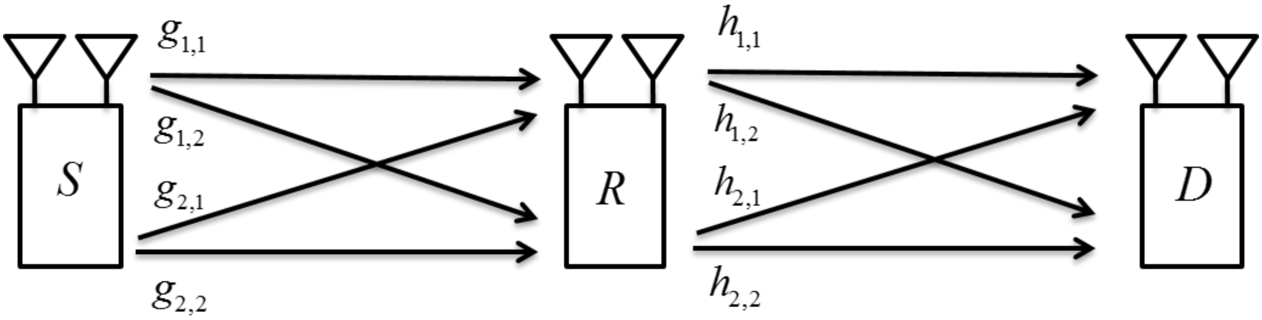

Fig 1: Dual-Hop Relay System

In this section, we propose an adaptive relay scheme based on channel statein dual-hop relay system. The proposed relay scheme provides high throughput in good channel condition and maintain SER performance in bad channel condition. In order to adaptively transmit signals in a relay, the post SNR is calculated.To know the channel state for each subcarrier, post-signal-to-noise ratio (Post SNR) which can be determined by the channel state is used. The post SNR value for k-th subcarrier (ρ_i) is represented as follows,

$$\rho_i = \frac{\left\| X\ (k) \right\|^2}{\sigma_n^2 \left\| \mathbf{G}_i (k) \right\|^2}, \quad (1)$$

where $\|X(k)\|^2$ means transmit power of subcarrier, σ_n^2 denotes noise power and $G_i(k)$ is the i-th row of the Moore-Penrose pseudo-inverse matrix. The noise considered by the minimum mean square error (MMSE) method which can be expressed as,

$$\mathbf{G}_{MMSE} = \mathbf{H}^H (\mathbf{H}\mathbf{H}^H + \sigma_n^2 / \sigma_x^2 \mathbf{I}_{N_R})^{-1}, \quad (2)$$

where I is identity matrix and the σ_x^2 denotes the power for the transmit signal. In Eq. (1), because the transmit signal power is 1, transmit power little impacts on the post SNR. Most impact on the post SNR power value is obtained by a Moore-Penrose pseudo-inverse matrix.

If the $\|G(k)\|^2$ value is large, the post SNR is to be small and the channel state is determined to poor state. And vice versa, if the $\|G(k)\|^2$ value is small, the channel state is determined good state.

The proposed scheme uses hierarchical 16-QAM, which can be regarded as the combination of two QPSK modulations. The former 2 bits choose a position of large quadrant and the latter 2 bits determine a position of the small quadrant within the former 2 bits selected position. We name them hierarchical modulation class 1 (HM class 1) and class 2 (HM class 2), respectively. In conventional use of hierarchical 16-QAM, these distinctive classes enable a QPSK or a 16-QAM demodulator according to the channel quality. In contrast to that, we use hierarchical 16-QAM to let a relay always demodulate with a 16-QAM demodulator.

If the $\|G(k)\|^2$ value is large,a relay discard the latter 2 bits. In voice and video signals, any most significant bits (MSBs) errors cause significantly more degradation in the symbol quality as compared to errors in the least significant bits (LSBs). Let us consider 4 bits data with 2 MSBs and LSBs. In hierarchical 16-QAM, groups of 2 MSBs are mapped to HM class 1 and groups of 2 LSBs are mapped to HM class 2, respectively. Hence, a very small performance drop is caused by omitting the latter 2 bits. For easier understanding of the proposed scheme, a simple relay example which considers a relay with 2 antennas is provided. The proposed scheme may be operated using following steps. A source broadcasts hierarchically 16-QAM modulated symbols X_{12} and X_{34} to a relay. The received symbols at a relay in frequency domain are represented as

$$\begin{aligned} Y_{R_1} &= G_{1,1} X_{12} + G_{2,1} X_{34} + N_{R_1}, \\ Y_{R_2} &= G_{1,2} X_{12} + G_{2,2} X_{34} + N_{R_2}, \end{aligned} \quad (3)$$

where the subscript R_i stands at the i-thantennain a relay, $G_{i,j}$ represents the frequency responses of link between i-th antenna atS and j-th antenna at R and N is a complex Gaussian random variable with zero mean and variance σ^2.

A relay demodulates symbols with a 16-QAM demodulator and uses an adaptive modulation method according to the channel state. If the measured pose SNR is large at a relay, a relay modulates 4 bits with a 16-QAM modulator. If the measured pose SNR is small at a relay,a relay discard latter 2 bits. And then, a relay modulates former 2 bits with a QPSK modulator. Modulated symbols are implemented by using IFFT of size N_F in a relay. The code design of the relay which has a large post SNR is

$$M = \begin{pmatrix} X_{12} \\ X_{34} \end{pmatrix}, \quad (4)$$

The code design of the relay which has a small post SNR is

$$M = \begin{pmatrix} X_1 \\ X_3 \end{pmatrix}, \quad (5)$$

At second time slot, the destination receives adaptive modulated symbols from a relay. In cased of a large post SNR, the received symbols in the frequency domain can be expressed as

$$Y_{D_1} = H_{1,1} X_{12} + H_{2,1} X_{34} + N_{R_1}, \quad Y_{D_2} = H_{1,2} X_{12} + H_{2,2} X_{34} + N_{R_2}, \qquad (6)$$

whereD$_n$ is an index of the n-th destination antenna, $H_{i,j}$is the channel frequency response of link between i-th antenna at R and j-th antenna at D, and N is a complex Gaussian random variable with zero mean and variance σ^2.
In cased of a small post SNR, the received symbols in the frequency domain can be expressed as

$$Y_{D_1} = H_{1,1} X_1 + H_{2,1} X_3 + N_{R_1}, \quad Y_{D_2} = H_{1,2} X_1 + H_{2,2} X_3 + N_{R_2}, \qquad (6)$$

Finally, we can reconstruct the original signal with simple V-BLAST detection algorithm in a destination. The linear scheme with MMSES is used. The MMSE Moore-Penrose pseudo-inverse matrix is as

$$\mathbf{G}_{MMSE} = \mathbf{H}^H (\mathbf{H}\mathbf{H}^H + \sigma_n^2 / \sigma_x^2 \mathbf{I}_{N_R})^{-1}, \quad (7)$$

where $(\cdot)^H$ is the conjugate transpose operation. Finally, the estimated symbols are as

$$\begin{bmatrix} \hat{X}_{12} \\ \hat{X}_{34} \end{bmatrix} = \mathbf{G}_{MMSE} \begin{bmatrix} Y_{D1} \\ Y_{D2} \end{bmatrix}. \quad (8)$$

IV. SIMUATION RESULTS

In the relay model, we consider perfect synchronization and complete equalization. Moreover, the total power of the transmitting terminals is the same as the transmit power of a single hop transmission for pair comparison and all terminals have the same noise characteristics. Simulations are accomplished with following parameters. The fast Fourier transform (FFT) size is 128 and the cyclic prefix (CP) length is 32. For simulations, a source, a relay and a destination terminal are used over 8-path Rayleigh fading channel. Fig. 2 shows the SER performance of the proposed scheme. In the simulation, depending on the channel state, a relay adaptively transmitsmodulated symbols. Consequently, the proposed scheme shows higher SER performance than that of the conventional scheme.

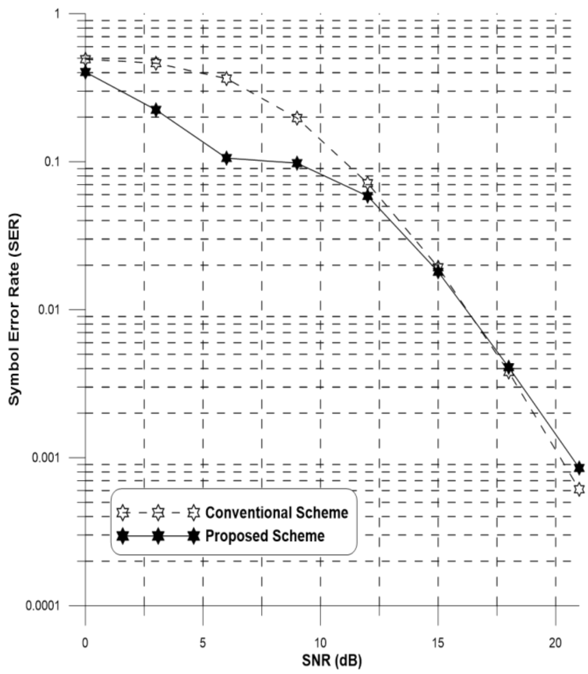

Fig 2: The SER performance of theproposedscheme

V. CONCLUSION

In this paper, we propose an adaptive relay scheme based on channel state in dual-hop system. The simulation result has shown that the SER performance of the proposed scheme is improved by using an adaptive modulation. In particular, the proposed scheme guarantees reliable transmission for low SNR.

VI. ACKNOWLEDGMENTS

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