Relay Selection Scheme Enhancing Reliability Based on MIMO-OFDM System

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***Abstract*—In this paper, a relay selection scheme is proposed in the Multiple-Input Multiple-Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) system. The conventional relay selection schemes in the wireless cooperative communication system have high implementation complexity and overhead. The proposed scheme is an adaptive relay selection scheme using Singular Value Decomposition (SVD) to select a relay with channel coefficients that maximize channel capacity. Proposed scheme uses combining factor with singular value in order to combine received signal. Simulation result shows that the proposed scheme improves the Bit Error Rate (BER) performance, compared with the conventional schemes. The proposed scheme with combining factors has enhanced BER performance than the conventional schemes.**

***Index Terms*—MIMO-OFDM, relay selection, DF, SVD, channel capacity, combining factor**

I. Introduction

Cooperative communication forms an antenna stream by sharing the antenna each User-Equipments (UEs). Each of the UEs operates as a relay and the signal transmitted by an antenna has diversity through multi-path [1]. Therefore, the transmitted signal obtains spatial diversity gain [2]. In addition, transmission reliability and cell coverage are improved. One of the relay schemes, an Amplify-and-Forward (AF) scheme is method of amplifying and transmitting the received signal at a relay. Also, AF scheme amplifies not only the received signal but the noise. On the other hand, a Decode-and-Forward (DF) scheme is method of decoding and re-encoding and transmitting the received signal at a relay [3]. Therefore, DF scheme has disadvantage of error propagation. The reliability of the received signal is affected by the channel state of the relay, in the AF or DF scheme. So relay selection scheme is an important issue in cooperative communications.

In this paper, cooperative communication is based on a Multiple-Input Multiple-Output (MIMO) system with for multiple antennas both source, relay, and destination, in order to increase the capacity without additional bandwidth.

Proposed scheme is compared with the conventional schemes in section V. One of the conventional schemes, random relay selection scheme is very simple since relay channel information is not considered. However, if the channel condition of the selected relay is poor, the reliability of the received signal is decreased. The other relay selection scheme uses amplitude of relay channels through Frobenius norm.

Proposed scheme uses a Singular Value Decomposition (SVD) to select the relays with channel coefficients that maximize the channel capacity. In addition, the proposed scheme combines the received signals using combining factor composed of the channel coefficients. Proposed scheme improves reliability with BER performance.

This paper is organized as follows. Section II presents the system model of proposed scheme. Section III describes a proposed scheme. Section IV demonstrates advantages of proposed scheme. Finally, section V concludes the paper.

II. System Model

Fig. 1 shows system model for proposed scheme with a single source node S, a single destination node D and K relays in cooperative communication based on MIMO Orthogonal Frequency Division Multiplexing (OFDM) system. Each node has N antennas. h_{sd} means channel between the source and destination and h_{sr} means channel between the source and relay. Also, h_{rd} means channel between the relay and destination. The cooperative communication scheme used in this paper is the DF scheme. Relay and destination use Zero Forcing (ZF) that is one of the linear detecting method in the MIMO system.

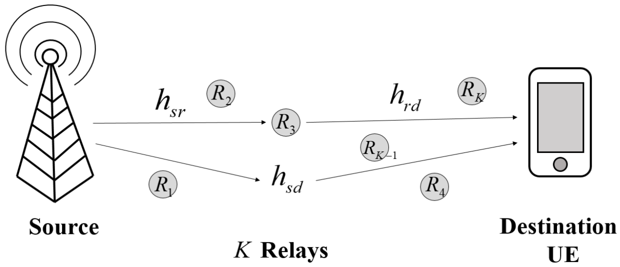

Figure 1. System model for proposed scheme.

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III. Conventional Scheme

Conventional schemes are explained in this section. In order to select the relay, there are two main method depending on the use of CSI. Methods using CSI include Best Harmonic Mean (BHM) and relay selection using the Frobenius norm.

A. Best Harmonic Mean (BHM)

BHM equation is as follows,

$$BHM = \frac{1}{(\left|\mathbf{H}_{SR_k}\right|^{-2} + \left|\mathbf{H}_{R_kD}\right|^{-2})}, \quad (1)$$

where $\mathbf{H}_{SR_k}$ denotes a channel amplitude between the source and K relays. Also $\mathbf{H}_{R_kD}$ denotes a channel amplitude between the K relays and destination. BHM is harmonic mean of the $\mathbf{H}_{SR_k}$ and $\mathbf{H}_{R_kD}$. Source selects a relay with largest harmonic mean.

BHM has highest performance reliability among other relay selection schemes. However, BHM has very high complexity since source needs all channel information [4]. Therefore, BHM is difficult to use in the actual system.

B. Frobenius Norm scheme

Relay selection scheme using the Frobenius norm selects relay with the largest value of the channel amplitude as follows,

$$Frobenius\,norm = max(\frac{\sum_{i=1}^{k}\mathbf{H}_{R_iD}^2}{k}), \quad (2)$$

where $\mathbf{H}_{R_kD}$ denotes a channel amplitude between the k relays and destination. Equation (2) means the maximum value of the average of the Frobenius norm between each relay and destination

In this paper, scheme using Frobenius norm considers only Frobenius norm of $\mathbf{H}_{R_kD}$ since the transmitted signal is assumed to be perfectly detected at the relay.

After selecting a relay in cooperative communication, received signals are combined to improve the reliability.

IV. Proposed Scheme

When each antenna transmits with the same power, the channel capacity based on MIMO system are as follows,

$$C = \log_2 \det(\mathbf{I} + \frac{P_t}{N_0 N}\mathbf{H}\mathbf{H}^H), \quad (3)$$

where $\mathbf{I}$ means eigen-matrix and $\mathbf{H}$ means a superimposed channel $\mathbf{H_E}$ of $\mathbf{H_{SD}}$ and $\mathbf{H_{RD}}$ in the MIMO system [5]. P_t is a transmitted signal power, N is a number of transmission antenna and N_0 refers to noise power.

In order to maximize mutual information, two relations can be chosen by [6],

$$\mathbf{H}\mathbf{H}^H = \mathbf{Q}\boldsymbol{\Lambda}\mathbf{Q}^H, \quad (4)$$

$$\det(\mathbf{I}_m + \mathbf{AB}) = \det(\mathbf{I}_n + \mathbf{BA}). \quad (5)$$

Equation (4) means eigen-decomposition. $\mathbf{Q}$ is a square matrix the i -th column is the eigenvector of $\mathbf{HH^H}$ and $\boldsymbol{\Lambda}$ is diagonal matrix the i -th element is the i -th eigenvalue. Equation (5) is satisfied in the case of when $\left(\mathbf{A} \in \mathbb{C}^{m*n}, \mathbf{B} \in \mathbb{C}^{n*m}\right)$. Equation (3) is simply summarized through two relations.

$$C = \log_2 \prod_N (1 + \rho\sigma_N{}^2), \quad (6)$$

In (6), index ρ means $\frac{P_t}{N_0 N}$ and $\sigma_N{}^2$ refers to square of channel coefficients of $\mathbf{HH}^H$ at each antenna stream [7]. In order to maximize the channel capacity according to (6), $1+\rho\sigma_N{}^2$ has maximum value. Finally, (6) simply is described as follows,

$$\Lambda_K = \prod_N (1 + \sigma_N{}^2), \quad (7)$$

where Λ_k means multiplying coefficients of h_e which is described as superimposed channel of each relay h_{rd} and h_{sd}. Equation (7) should be the maximum value to maximize the channel capacity. Therefore, SVD is used to determine the channel coefficients maximizing the channel capacity. The singular values of each superimposed channel obtained through SVD are applied to (7). In other words, singular values denote the channel coefficients. The relay with the largest Λ_K is selected. As a result, selected relay has best superimposed channel conditions.

Also, channel coefficients are utilized to combine the received signals through h_{R_kD} and h_{SD} as follows,

$$\frac{\sigma_{sd}}{\sigma_{sd} + \sigma_{rd}}\hat{\mathbf{X}}_{sd} + \frac{\sigma_{rd}}{\sigma_{sd} + \sigma_{rd}}\hat{\mathbf{X}}_{rd}, \quad (8)$$

where σ_{sd} is channel coefficients of h_{sd} and σ_{rd} is channel coefficients of h_{r_kd}. $\hat{\mathbf{X}}$ denotes received signals estimated by the ZF scheme. $\hat{\mathbf{X}}_{sd}$ and $\hat{\mathbf{X}}_{rd}$ are the estimated received signals between h_{sd} and h_{r_kd}, respectively. Each channel coefficient is divided by sum of σ_{sd} and σ_{rd}. That is weight of the received signals. Therefore, the signal received through the regular channel condition has a high weight [8]. On the other hand, the signal received through the non-regular channel condition has a low weight. Combining factors are designed to improve received signal reliability of the received signal by considering channel condition.

V. Simulation Result

In this section, proposed scheme is compared with the conventional schemes. Table I shows the simulation parameters used in this paper.

TABLE I. SIMULATION PARAMETERS

The number of relays	16
The number of antenna	4
The number of sub-carriers	128
Length of the CP	32
Modulation	16-QAM
Channel	7-path Rayleigh fading
Detection scheme	ZF

System model uses DF scheme and number of relay candidates is 16. Also, each node has 4 multi antennas. The number of sub-carriers is 128 and length of the Cyclic Prefix (CP) is 32. The modulation is 16-Quadrature Amplitude Modulation (16-QAM). The channels have 7-path Rayleigh channel. Distance rate means each node has randomly different distance range within 0.25 – 0.5 assuming that the distance from the source to the destination is 1.

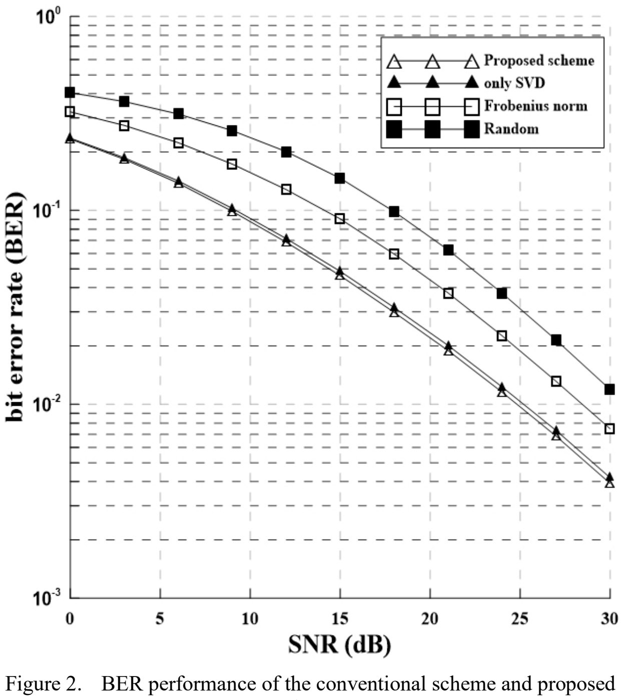

Figure 2. BER performance of the conventional scheme and proposed scheme.

Fig. 2 shows that proposed scheme has improved Bit Error Rate (BER) performance than conventional schemes. Random relay selection scheme shows the lowest BER performance. Since random relay selection scheme does not consider CSI it can select the relay with poor channel condition. Although relay selection scheme using the Frobenius norm uses CSI, this scheme does not consider superimposed channel h_e. For this reason, relay selection scheme using Frobenius norm degraded than proposed scheme in BER performance. The proposed scheme shows the highest BER performance in Fig. 2. The proposed scheme with combining factors has enhanced BER performance than scheme only using SVD (no combining factors).

VI. Conclusion

This paper proposes relay selection scheme based on MIMO-OFDM system. Proposed scheme uses SVD to select relays with channel coefficients that maximize channel capacity. Also proposed scheme uses combining factor of superimposed channel coefficients in order to improve received signal reliability. The proposed scheme enhances the system transmission rate and enables reliable cooperative communication. The simulation result shows that the proposed scheme has the improved BER performance compared to the conventional schemes. However, the proposed scheme still performs a large amount of computation. Future work is to reduce the complexity of the proposed scheme.

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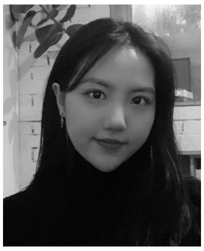

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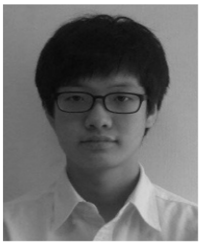

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