Power Efficient Cooperative Relay Systems for Multiuser MIMO

Soobum Cho, Sang Kyu Park, and Dong Geol Ryu

***Abstract*—This paper introduces a power efficient cooperative relay system with several antennas to achieve precoding gain and distinguish multiuser with one antenna. In a common relay transmission, the performance of decode-and-forward (DF) protocol is decreased when it uses higher modulation scheme. The proposed scheme not only increases a transmission data rate as one more bit per frame, but also reduces the maximum relay power consumption by a cooperative grouped relay scheme.**

***Index Terms*—Cooperative relay, precoding gain, decode-and-forward (DF), power consumption**

I. Introduction

A multiple input multiple output (MIMO) system has many benefits through multiple transmit and receive antennas such as multipath propagation conquest and interference cancelation. However, the MIMO system has physical problems when it is adapted at mobile devices, because many wireless mobile devices are limited by inherent size and hardware complexity. In order to overcome the limitations, a cooperative communication scheme has been proposed which allows single antenna mobile devices to achieve the advantages of MIMO system [1]. The cooperative communication is also called as virtual MIMO system in a manner to share their channel environments and multi-user MIMO (MU-MIMO) over 3GPP long term evolution (LTE) system. In LTE cellular communication systems, the maximum number of antennas is considered to four for a downlink that is recognized for cooperation scheme. So, we need a cooperation relay scheme between base station and mobile devices. A decode-and-forward (DF) scheme with several encoding methods is adapted on the cooperative relay systems.

In [2], the authors proposed a relaying scheme with maximum ratio combining (MRC) in a network for multiuser and distributed relays adapting DF scheme. A distributed cooperative relay for downlink multiuser system is presented in [3] that includes DF relays with zero-forcing (ZF) scheme and optimum precoding vector. The method derived for the optimum precoding vector is selected to achieve better bit error ratio (BER) performances than the advantage of precoding method. However, these schemes still have a degraded performance when higher modulation is adapted on its systems and all relays work for signal transmission. In [4], the author proposed the system which achieves power efficient and low complexity as a MIMO application using the portion of several equipped antennas. We extend this scheme to the version of relay system equipped with multiple antennas. In this paper, we propose power efficient transmission method for grouped cooperative relay with precoding vector and show the BER performances by simulation result.

This paper is organized as follows: In Section 2, we describe the system model. In Section 3, we explain the phase silence shift keying (PSSK) scheme for distributed relay transmission. In Section 4, we present the simulation results. Finally, we conclude in Section 5.

II. System Model

We consider a distributed relay system in which independent relays have all of the signals for multiuser. Since the system assumes that the channel is ideal between each of the relays and base station, received multiuser signals from the base station are perfectly decoded at the relays equipped R antennas. A single antenna is accommodated at the each of N users. It has diversity of $LR - L(N-1)$ where L denotes the number of relay. If the signals for multiuser are transmitted from each relay, the LR would be diversity, but this is contained unwanted signal for other users N-1. All users share the same frequency for communication with relays.

The base station transmits a signal at first hop and the distributed relays retransmit a signal at second hop. However, we focus on second hop, because the distributed relays receive the signals perfectly. The relays transmit multiuser signal $s_i, i \in 1,2$, to each user synchronously at the second hop. Fig. 1 shows the system model for two relays and user N=2.

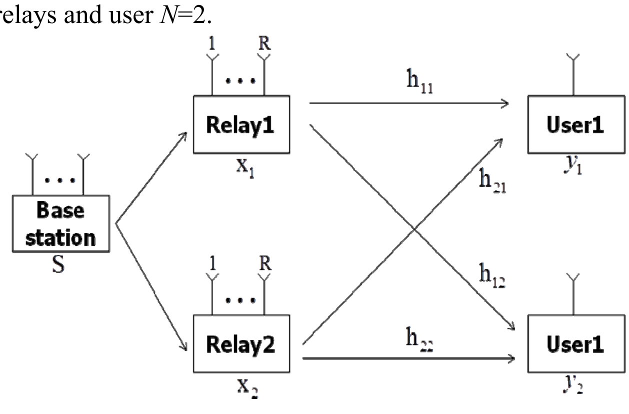

Fig. 1. Downlink cooperative relay transmission for multiuser system.

In second phase, the channel matrix $\mathbf{H}_k$ of k_{th} relay can be expressed as

$$\mathbf{H}_k = \begin{bmatrix} \mathrm{h}_{k1} \\ \mathrm{h}_{k2} \end{bmatrix} = \begin{bmatrix} h_{11}^{(k)} & h_{21}^{(k)} & \cdots & h_{R1}^{(k)} \\ h_{12}^{(k)} & h_{12}^{(k)} & \cdots & h_{R2}^{(k)} \end{bmatrix} \quad (1)$$

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where the elements $h_{ij,}\ i\in 1,2, j\in 1,2$, denote the channel between i_{th} relay and j_{th} user which is a Rayleigh flat fading, and h_{k1} is composed of the set $\{h_{11}^{(k)}, h_{21}^{(k)}, \cdots, h_{R1}^{(k)}\}$. The element $h_{R1}^{(k)}$ is the fading channel gain of R_{th} transmit antenna from the k_{th} relay. Each entry in the channel matrix is modeled as a statistically independent and identically distributed (i.i.d) zero-mean complex Gaussian variable with 1/2 variance.

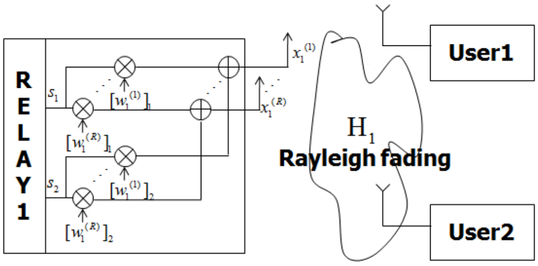


Fig. 2. Preceding process on the relay1.

We can describe the signals $\mathbf{S}=[s_1 \quad s_2]^{\mathrm{T}}$ for the user 1 and user 2 where $[\ ]^{\mathrm{T}}$ denotes matrix transposition. The user expects to receive the only own signal, therefore the relays have to multiply **S** with precoding process. The precoded signals $x_j, j\in 1,2$, can be express as

$$x_1 = \mathbf{W}_1\mathbf{S}, \quad x_2 = \mathbf{W}_2\mathbf{S} \tag{2}$$

where the precoding matrix $\mathbf{W}_j, j\in 1,2$, is consistent with precoding vectors depends on the each channel among j_{th} relays in the second hop. The precoding matrix can be achieved as

$$\mathbf{W}_j = \mathbf{H}_j^{+}(\mathbf{H}_j\mathbf{H}_j^{+})^{-1}$$
$$=\begin{bmatrix} w_1^{(j)} & w_2^{(j)} \end{bmatrix} = \begin{bmatrix} [w_j^{(1)}]_1 & [w_j^{(1)}]_2 \\ [w_j^{(2)}]_1 & [w_j^{(2)}]_2 \\ \vdots & \vdots \\ [w_j^{(R)}]_1 & [w_j^{(R)}]_2 \end{bmatrix} \tag{3}$$

where the notation $(\cdot)^{+}$ denotes matrix Hermitian operation. Through the calculated precoding matrices, each relay works same things on relay one. In Fig. 2, the precoded signal $x_i^{(R)}$ at the each R_{th} transmit and $[w_j^{(R)}]_i$ are demonstrated by the precoding component for R_{th} antenna in j_{th} relay which is dependent i_{th} user. The received signal y_i at the i_{th} user is represented as

$$y_i = h_{1i}\, x_1 + h_{2i}\, x_2 + n_i \tag{4}$$

where the variable n_i is additive white Gaussian noise (AWGN) of the i_{th} user with zero mean and σ^2 variance. In (4), we need to satisfy $h_{1k}\, w_j^{(1)} = h_{2k}\, w_j^{(2)} = 0, \quad k \neq j$, to cancel both interuser interference and the precoded signal from another relay.

If each relay makes precoding vector via the operation of relays to exchange channel information, the transmission is done perfectly to go through with it in spite of interuser interference. Thus the received signal at each user in the system under condition of (4) and $h_{1k}\, w_j^{(1)} = h_{2k}\, w_j^{(2)} = 0, \quad k \neq j$, is expressed as

$$y_j = s_j\left(h_{1j}\, w_1^{(1)} + h_{2j}\, w_1^{(2)}\right) + n_j \tag{5}$$

where n_j denotes AWGN for j_{th} user. In right side of $h_{1k}\, w_j^{(1)} = h_{2k}\, w_j^{(2)} = 0, \quad k \neq j$, the precoding term is always positive number.

III Power Efficient Transmission of Relay

The distributed and cooperative relay system model can achieve significantly higher performance than just one relay system and amplify-and-forward (AF) relay system. However, it suffers from performance reduction when a high order modulation is adapted. Thus we propose cooperative relay adapting a PSSK scheme in order to improve performances and reduce the half of power consumption. The PSSK scheme is a kind of phase shift keying (PSK), but the PSSK increases the symbol distance by a little increase bandwidth. Fig. 3 shows the constellations of the 8PSK symbols which are divided two orthogonal constellations in time domain.

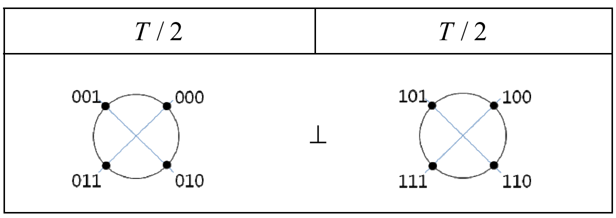
Although each relay uses the separated set of symbol constellation, we need to detect whether the transmitted signal has been arrived at the first half slot or not. At first, we have to know how to derive a received signal form under condition which impose the same signal to noise ratio (SNR) at all users. It can be expressed as a matrix form by

$$\begin{aligned} y &= \mathbf{H}_1\mathbf{W}_1\mathbf{S} + \mathbf{H}_2\mathbf{W}_2\mathbf{S} + n \\ &= \begin{bmatrix} \mathbf{H}_1 & \mathbf{H}_2 \end{bmatrix} \begin{bmatrix} \mathbf{W}_1 \\ \mathbf{W}_2 \end{bmatrix} \mathbf{S} + n \end{aligned} \tag{6}$$

where received signal vector y is scaled as N by 1, in 2 by 1 case, and the n is denoted AWGN vector at all users with same scale of y . If let the y_1' represent the signal of user1 at the first half slot and the y_1'' denotes the one another, we can select a slot which is used for transmission by

$$\arg\max\left\{E_1\{y'\}, E_1\{y''\}\right\} \tag{7}$$

where $E\{\cdot\}$ represents a expectation. In (7), the process of choosing any slot is very simple and suitable for the distributed relay system with precoding scheme, because the distributed relaying signal gains achieved by the precoded signals are focused on just one user.



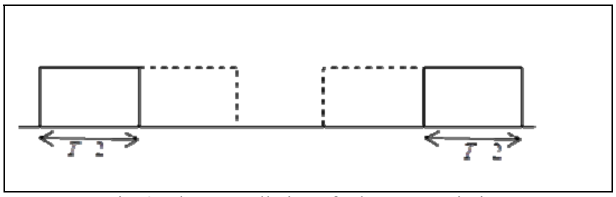


Fig. 3. The constellation of relays transmission.

IV Simulation and Discussion

In this section, simulation results are shown for both conventional schemes and the proposed scheme. The simulations are preformed under 8PSK modulation which provides three bits per a channel. All the relays have the multipath channel of different links which are statically independent. However, the relay system is able to cooperate with another relays and they can exchange channel state information (CSI). If the distributed relays have other CSIs, the relays work for multiuser without interferences which are come from other users and relays.

Fig. 4 shows simulation results as the BER performances of different schemes and users for ZF, MMSE precoding and *N*=2. Fig. 4 shows the results as point of view non-cooperation. The distributed relay system with ZF has a low performance when the number of users is increased. 1 dB to 1.5dB gains are achieved when the MMSE precoding is adapted to its system, because adapted precoding is robust for the situation of existing interferences. It has 5dB gain at case of two users as compared with conventional distributed relay system using ZF precoding.

Fig. 5 shows the results with non-cooperation, when the distributed relays have the other CSIs via the cooperation. We compare the two schemes which have better performances than the distributed relay system adapting conventional ZF and MMSE schemes. The simulation results show the higher performances than the non-cooperation relay system. The proposed method achieves about 2dB gain at the case of two users as compared to the PSSK scheme. The BER performance of ZF precoding is the lowest one of them. The results adapting MMSE and PSSK have a better performance than the ZF that uses a half slot to transmit for saving half power. The PSSK schemes have one disadvantage which is bandwidth increase, so we get the advantage of that scheme and solve the included problem by proposed scheme.

V Conclusion

In this paper, we have proposed cooperative transmission in distributed relay system to improve BER performance and save the half of total power at each relay. The proposed scheme is demonstrated via the simulation of BER performance over Rayleigh flat fading channel.

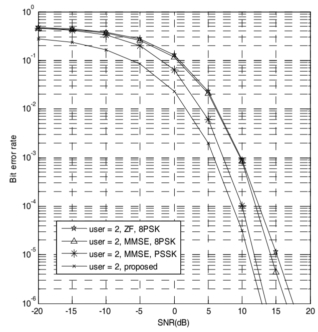


Fig. 4. The comparison of the BER performances without CSI.

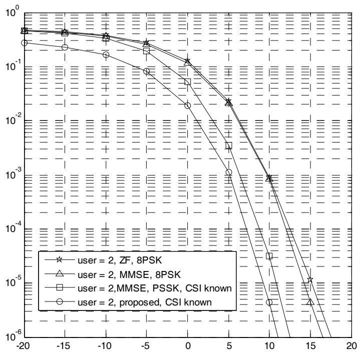


Fig. 5: The comparison of the BER performances when CSI is known at each relays.

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