A Cooperative Communication Technique for Improved Transmission Rate in OFDMA-Based System

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Abstract. In orthogonal frequency division multiple access system, it is proposed that each user shares their allocated sub-channels instead of using the MIMO system to improve the transmission rate. In this paper, the performance of cooperative transmission scheme is evaluated in fading channel.

Keywords: cooperation, improved rate, OFDMA, STBC

1 Introduction

The users share their antennas each other to achieve high reliability or high data rate like multiple input multiple output(MIMO) system. But cooperative communications have a disadvantage that the transmission rate is decreased for relaying in cooperation phase. Recently, the transmission scheme is proposed to achieve 3/4 transmission rate [8]. However, the performance is sensitive to error of first phase. In this paper, the performance of transmission scheme is evaluated when the symbols of the first phase are not decoded perfectly in the base station.

2 Structure of Cooperative Transmission

In this section, the structure of Space-Time Block Code (STBC) is introduced in Decode-and-Forward (DF) cooperative communication for two users. It is assumed that the user with the best inter-user channel condition is already selected by the base station (BS) using the received signal to noise ratio (SNR) value. The inter-user channel condition means the relative difference of received signal's SNR value between the direct channel and the inter-user channel [8].

The basic transmission structure of the proposed scheme is described through the following equations.

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$$\text{User } i = \begin{pmatrix} \overbrace{\mathbf{X}^i(1)}^{\text{user } i \text{ subchannel}} & \overbrace{null}^{\text{user } j \text{ subchannel}} \\ \mathbf{X}^i(2) & \left(\mathbf{X}^j(1)\right)^* \\ \mathbf{X}^i(3) & \left(\mathbf{X}^j(2)\right)^* \\ \mathbf{X}^i(1) & \left(\mathbf{X}^j(3)\right)^* \end{pmatrix}, \tag{1}$$

$$\text{User } j = \begin{pmatrix} \overbrace{null}^{\text{user } i \text{ subchannel}} & \overbrace{\mathbf{X}^j(1)}^{\text{user } j \text{ subchannel}} \\ \left(\mathbf{X}^i(1)\right)^* & \mathbf{X}^j(2) \\ \left(\mathbf{X}^i(2)\right)^* & \mathbf{X}^j(3) \\ \left(\mathbf{X}^i(3)\right)^* & \mathbf{X}^j(1) \end{pmatrix}, \tag{2}$$

where the row and column are the time slot and user's subchannel respectively, and $(\cdot)^*$ means "conjugate". In Eqs. (1) and (2), $\mathbf{X}^p$, $\mathbf{R}^p$, and $\mathbf{H}^p_{\{1,2,\text{ic}\}}$ are the vector notations for $\{X^p(1), \cdots, X^p(k), \cdots, X^p(K_p)\}$, $\{R^p(1), \cdots, R^p(k), \cdots, R^p(K_p)\}$, and $\{H^p_{\{1,2,\text{ic}\}}(1), \cdots, H^p_{\{1,2,\text{ic}\}}(k), \cdots, H^p_{\{1,2,\text{ic}\}}(K_p)\}$.

In the first phase, the user i and j broadcast the first symbol. After the first phase, each user decodes the symbols from each other user and reconstruct symbols for DF according to Eqs. (1) and (2). The next symbols are transmitted through own subchannel and the reconstructed symbols are transmitted through the other user's subchannel. The BS receives the superposition signals from user i and j at each phase.

In this paper, it is considered that decoding process takes only user i since the received signals of the user i and j are decoded by same process. So, at the BS, the received signals for the user i in the frequency domain can be expressed as follows,

$$\mathbf{R}^i(1) = \mathbf{H}^i_1\mathbf{X}^i(1) + \mathbf{W}(1), \tag{3}$$

$$\mathbf{R}^i(2) = \mathbf{H}^i_1\mathbf{X}^i(2) + \mathbf{H}^i_2\mathbf{X}^i_{DF}(1) + \mathbf{W}(2), \tag{4}$$

$$\mathbf{R}^i(3) = \mathbf{H}^i_1\mathbf{X}^i(3) + \mathbf{H}^i_2\mathbf{X}^i_{DF}(2) + \mathbf{W}(3), \tag{5}$$

$$\mathbf{R}^i(4) = \mathbf{H}^i_1\mathbf{X}^i(1) + \mathbf{H}^i_2\mathbf{X}^i_{DF}(3) + \mathbf{W}(4), \tag{6}$$

where $\mathbf{X}^i_{DF}(\cdot)$ is the decoded and re-constructed symbols form subcarrier of the user j and $\mathbf{X}^i_{DF}(\cdot) = (\mathbf{X}^i(\cdot))^*$.

The received signals of the user i can be decoded by the following combining rules.

$$\hat{\mathbf{X}}^i(1) = \text{demodulation}(\mathbf{R}^i(1)). \tag{7}$$

$$\begin{aligned} \mathbf{X}^i(1) &\approx \hat{\mathbf{X}}^i(1) \\ \mathbf{H}^i_1 &\approx \hat{\mathbf{H}}^i_1 \\ \mathbf{H}^i_2 &\approx \hat{\mathbf{H}}^i_2, \end{aligned} \tag{8}$$

where $\hat{\mathbf{X}}^i(1)$ is the demodulated symbol, and $\hat{\mathbf{H}}^i_1$ and $\hat{\mathbf{H}}^i_2$ are estimated channels. $\hat{\mathbf{X}}^i(1)$ and estimated channel are approximated to Eq. (8) assuming that $\mathbf{R}^i(1)$ is demodulated perfectly and the channel is estimated perfectly.

Table 1. Simulation parameters of proposed scheme.

Parameters	Value
Size of FFT	256
Cooperation users	2
Subcarriers in subchannel	128
Length of cyclic prefix	32
Channel H_1, H_2	Rayleigh fading multipath 8
Channel H_{ic}	Rayleigh fading channel multipath 8 with dB gain

In order to restore the signal, the α_1, α_2, β_1, and β_2 are derived as follows [8],

$$\begin{aligned}
&\alpha_1 \equiv \mathbf{H}_1^i \mathbf{X}^i(2) + \mathbf{W}(2), \\
&\alpha_2 \equiv \left|\mathbf{H}_2^i\right|^2 \mathbf{X}^i(2) + \mathbf{H}_2^i \left(\mathbf{W}(3)\right)^* - \left(\mathbf{H}_1^i\right)^* \mathbf{W}(4), \\
&\beta_1 \equiv \mathbf{H}_2^i \left(\mathbf{X}^i(3)\right)^* + \mathbf{W}(4), \\
&\beta_2 \equiv \left|\mathbf{H}_1^i\right|^2 \mathbf{X}^i(3) + \left(\mathbf{H}_1^i\right)^* \mathbf{W}(3) - \mathbf{H}_2^i \left(\mathbf{W}(2)\right)^* .
\end{aligned} \tag{9}$$

$\tilde{\mathbf{X}}^i(2)$ and $\tilde{\mathbf{X}}^i(3)$ are derived as follows [8],

$$\begin{aligned}
\tilde{\mathbf{X}}^i(2) &= \left(\left|\mathbf{H}_1^i\right|^2 + \left|\mathbf{H}_2^i\right|^2\right) \mathbf{X}^i(2) + \eta_2, \\
\tilde{\mathbf{X}}^i(3) &= \left(\left|\mathbf{H}_1^i\right|^2 + \left|\mathbf{H}_2^i\right|^2\right) \mathbf{X}^i(3) + \eta_3,
\end{aligned} \tag{10}$$

where η_2 and η_3 are the following noise elements, respectively.

$$\begin{aligned}
\eta_2 &= \left(\mathbf{H}_1^i\right)^* \mathbf{W}(2) + \mathbf{H}_2^i \left(\mathbf{W}(3)\right)^* - \left(\mathbf{H}_1^i\right)^* \mathbf{W}(4), \\
\eta_3 &= -\mathbf{H}_2^i \left(\mathbf{W}(2)\right)^* + \left(\mathbf{H}_1^i\right)^* \mathbf{W}(3) + \mathbf{H}_2^i \left(\mathbf{W}(4)\right)^* .
\end{aligned} \tag{11}$$

In Eq. (10), the DF cooperative communication using modified STBC structure can get the channel diversity $\left(\left|\mathbf{H}_1^i\right|^2 + \left|\mathbf{H}_2^i\right|^2\right)$ and the transmission rate 3/4 [8].

3 Simulation Results and Discussion

In this section, the error performance of the transmission scheme is shown. OFDMA symbol is modulated by QPSK without channel coding. For performance evaluation in fading channel, Rayleigh fading channel is used. The channel model has an independent and identically distributed (i.i.d.) characteristic. The number of multi-user is 2 in this simulation. The simulation parameters are shown in the Table 1.

Fig. (1) shows the BER performance of the proposed scheme, and the basic OFDMA system at the inter-user channels SNR 3[dB]. The BER performance is worse when the symbols of the first phase $X(1)$ are not decoded perfectly in the base station. The performance is sensitive to error of first phase because

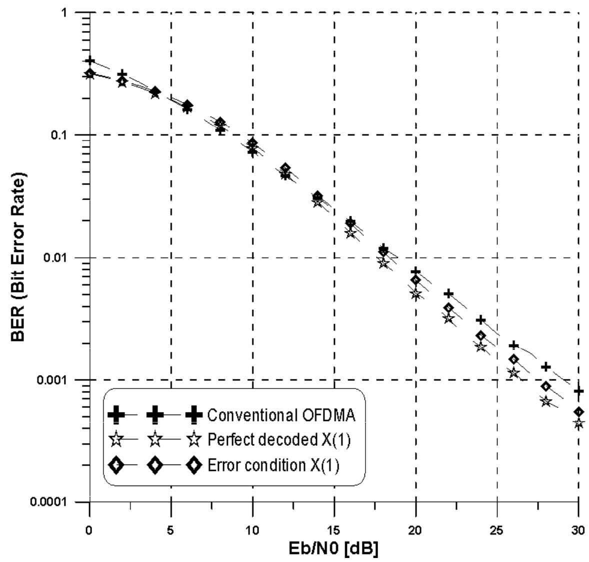

Fig. 1. BER performance of proposed scheme compared with OFDMA system according to relative condition of inter-user channel (3[dB]) and error condition of $X(1)$.

the second and the third symbol is decoded by using the first symbol $X(1)$. To get the effective performace, the decoding process of proposed scheme must be modified.

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