An Improved Relay Selection Scheme for FD-MIMO based System

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***Abstract*— This paper proposes an improved relay selection method in full dimension-multiple input multiple output (FD-MIMO) system. The conventional best harmonic mean (BHM) relay selection scheme was studied as an optimal method for relay selection. However, instantaneous power based the BHM method has a degradation of error performance in the channel environment where rank is not obtained. To solve this problem, this paper uses the instantaneous condition number of 3D channel environment which is defined by 3rd generation partnership project (3GPP) and 2-dimension transmit array. The proposed scheme has better error performance than the conventional scheme in a wireless channel environment with poor rank by selecting a relay through the harmonic mean of the instantaneous condition number of the wireless channel. Through the computer simulation, it is shown that the proposed relay selection scheme is efficient for the FD-MIMO system which has poor rank channel environment.**

Keywords*— *FD-MIMO system, relay communication, relay selection

I. Introduction

The fifth generation (5G) new radio (NR) system has a flexible frame structure to consider various service scenarios by subcarrier spacing [1]. This 5G NR specification was announced, and signal processing technologies using full dimension-multiple input multiple output (FD-MIMO) have been studied to achieve high key performance indicator (KPI) [2]-[5]. There is a relay communication technology as a field that is being studied together in relation to the MIMO technology. The relay communication is one of the representative communication technologies for expanding the coverage of wireless communication. One of the various problems in relay communication is which relay node is selected. And depending on which relay node is selected from the candidate relay node on the wireless channel, the reliability of wireless communication is affected. The conventional best harmonic mean (BHM) scheme is known to have a good error performance by selecting the relay node with the largest value by measuring the instantaneous power of all wireless channels between the transmitter and the relay node, and between the relay node and the receiver [6]. Since the distance between antennas is reduced compared to the existing cellular communication environment in the FD-MIMO system using a high frequency band such as mmWave band, it becomes difficult to obtain a scattering environment when using a two-dimensional transmit antenna array. Therefore, it is necessary to study a relay node selection scheme that can be applied in an environment that is difficult to ensure MIMO rank. This paper proposes a relay node selection scheme based on the instantaneous condition number of wireless channel to ensure high error performance and coverage in a mobile communication radio channel environment where high rank is not obtained. Using the 2-norm operation of a channel matrix to obtain a condition number leads to high complexity. Therefore, the proposed scheme uses 1-norm operation.

The rest of this paper is structured as follows. Next chapter presents the proposed relay selection scheme. Chapter III presents simulation results and conclusion is given in chapter VI.

II. Proposed Scheme

This chapter presents an efficient relay selection scheme using instantaneous condition number of wireless channel.

When there are N_R candidate group repeaters within a cell, the $n-$th relay node is selected through the BHM technique as follows.

$$n = \underset{m=1,2,\ldots,N_R}{\arg\max} \sum_{k=0}^{N_D} \frac{1}{\left\| H_{SR}^{m,k} \right\|^{-2} + \left\| H_{RD}^{m,k} \right\|^{-2}} \tag{1}$$

where N_D is the total number of subcarriers used when generating cyclic prefix orthogonal frequency division multiplexing (CP-OFDM) based frames, $H_{SR}^{m,k}$ and $H_{SR}^{m,k}$ mean wireless channel matrices between transmitters and relay node and receivers, respectively. Since the conventional BHM scheme selects the relay node based on the instantaneous power of the MIMO channel matrix, the error performance decreases as the channel correlation increases. The antenna spacing is a parameter related to the correlation of the wireless channel. In this paper, to solve the problem of the conventional scheme, a relay node is selected based on the instantaneous conditions of the wireless channel as follows

$$n = \underset{m=1,2,\ldots,N_R}{\arg\min} \sum_{k=0}^{N_D} \frac{1}{C\left(H_{SR}^{m,k}\right)^{-1} + C\left(H_{RD}^{m,k}\right)^{-1}} \tag{2}$$

where $C(\cdot)$ means instantaneous condition number, and is calculated using the 2-norm value as follows

$$C\left(H_{SR}^{m,k}\right) = \left\|H_{SR}^{m,k}\right\| \left\|\left(H_{SR}^{m,k}\right)^{-1}\right\|, \tag{3}$$

and

$$C\left(H_{RD}^{m,k}\right) = \left\|H_{RD}^{m,k}\right\| \left\|\left(H_{RD}^{m,k}\right)^{-1}\right\|. \tag{4}$$

In (4), since matrix decomposition is required to obtain the 2-norm value, the 1-norm operation is considered in this paper. Figure 1 shows the instantaneous condition number of channel based on 1-norm and 2-norm depending on the antenna spacing using the 2D transmission antenna array. At here, λ means the wavelength of the signal. From the figure 1, it can be seen that there is a difference in absolute values, but the relative dominance does not change. In addition, it is shown that the condition number of the channel matrix decreases because independence between channels is ensured as the transmission antennas spacing increases. The transmitter selects the relay node based on the condition number of the channel as shown in (2), and then transmits a signal to the selected relay node using a zero-forcing (ZF) digital beamforming technique. When the number of transmission antennas is N_t and the number of reception antennas of the relay node is N_r ($N_t \geq N_r$), the received signal y_R of the relay node is expressed as

$$y_R = \frac{1}{\sqrt{F_{SR}}} H_{SR} W_{SR} x + n_R \tag{5}$$

where assuming that the number of different transmission data streams is N_r, H_{SR} is the $N_t \times N_r$ complex channel matrix between transmitter and relay node, W_{SR} is $N_r \times N_t$ size ZF beamforming matrix, x is $N_r \times 1$ modulated digital symbol, n_R is additive white Gaussian noise (AWGN), and F_{SR} means a normalization constant. Elements of H_{SR}, x, and n_R are zero-mean standard normal distribution with unit variance. The ZF beamforming matrix W_{SR} and the power normalization constant F_{SR} are expressed as

$$\begin{aligned} W_{SR} &= H_{SR}^H \left(H_{SR} H_{SR}^H\right)^{-1}, \\ F_{SR} &= \left\|W_{SR}\right\|_F^2 = \operatorname{tr}\left(W_{SR} W_{SR}^H\right) \end{aligned} \tag{6}$$

where $\|\cdot\|_F$ means the Frobenius norm. The relay node uses a decode and forward (DF) scheme for forwarding the decoded signal to the receiver.

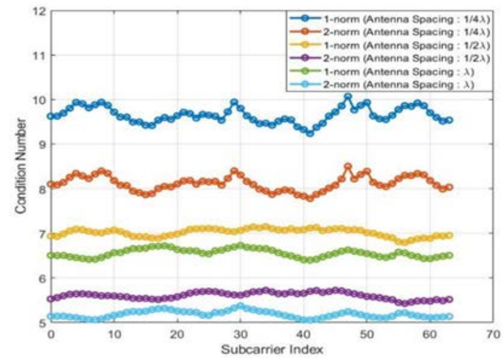

Fig. 1. The condition number of channels according to antenna spacing

III. Simulation Results

The performance of the proposed relay node selection scheme is evaluated in the computer simulation. This paper evaluates the performance of the proposed scheme using Monte-Carlo simulations. The system in a 2-hop environment with 100 relay node candidates is considered for the performance evaluation of the proposed scheme. 16-quadrature amplitude modulation (QAM), 64-QAM modulation method, and $N_D = 256$ are used. The number of transmitter and receiver antenna is considered as $N_t = 4$ and $N_r = 2$, respectively. Also, the transmission antenna is applied to size of 2×2 squared array antenna using the 2D array. The transmission antenna spacing of the proposed scheme and the conventional BHM scheme is selected from among $\lambda/8$, $\lambda/4$, and $\lambda/2$ randomly. Considering 8 multi-paths, the frequency selective Rician fading channel is used based on the 3D channel model provided by 3GPP, and the K-factor of the Rician channel is set to 10. Figure 2 presents the bit error rate (BER) performance of the proposed and the conventional BHM scheme versus transmission power when the 16-QAM and 64-QAM modulations are used. The conventional BHM scheme depends only on the instantaneous power of the channel when relay node is selected, and it can cause the incorrect relay node selection in the channel environment where correlation exists. Since this causes error propagation to the receiver, performance degradation occurs compared to the proposed relay node selection scheme. From the simulation results, the proposed relay node selection scheme can be effectively used in the FD-MIMO system.

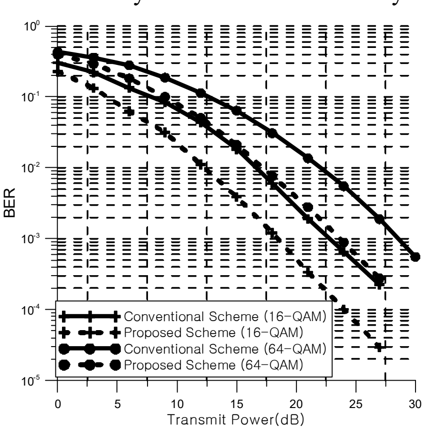

Fig. 2. BER performance of the conventional and proposed scheme when modulation is 16-QAM and 64-QAM

IV. Conclusion

In this paper, the relay selection method is proposed for the FD-MIMO based relay communication system. The proposed scheme considers the transmit antenna array and directivity of the FD-MIMO system. Also, the proposed scheme selects the relay based on the instantaneous condition number of the wireless channel to cope with the high correlation value between antennas. The simulation result shows that the proposed scheme based on the instantaneous condition number of the wireless channel has less error performance degradation compared to the conventional BHM method in an environment where it is difficult to secure rank of MIMO channel. The future study will focus on reducing the amount of feedback data related to channel information for the relay selection.

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