Signal Relaying Method for High Data Rate in the MIMO System

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***Abstract*— This paper deals with an efficient relaying method that guarantees a high data rate in a multi-antenna based wireless communication system. In order to solve the data rate reduction problem that occurs during signal relay using a half-duplex relay node in a wireless communication system, a relaying method using the multiple input multiple output (MIMO) signal detection is proposed. The proposed method considers the space time block code (STBC) based two-way relay technique to improve a data rate. At this time, the inter relay interference (IRI) is generated between each relay nodes. The IRI component can be removed using the MIMO signal detection method based on channel alignment. Using the computer simulation, it is demonstrated that the throughput performance of the proposed method is improved compared to the conventional method.**

Keywords—MIMO system, relay communication, MIMO signal detection.

I. INTRODUCTION

Fifth generation (5G) new radio (NR) standard presented by the 3rd generation partnership project (3GPP) is announced a major improvement of the long term evolution-advance (LTE-A) standard, where the main focus is on enhanced mobile broadband, ultra-reliable and low latency communications, and massive machine-type communications. To achieve these goals, 3GPP has introduced a unified network architecture, with a new physical layer design that supports mmWaves, large frequency bandwidths, and new techniques such as massive multiple-input and multiple-output (MIMO), and beamforming [1][2]. However, a major bottleneck for propagation at mmWave frequencies is the high free space attenuation, especially for the non-line-of-sight (NLOS) paths. This makes radio frequency planning very difficult for long distance communications due to the high path loss at mmWave frequencies, and communication coverage can severely be reduced [3]. Relay communication is a representative communication technology capable of increasing the coverage of a wireless communication network [4][5]. Also, relay communication can be effectively used with multiple input multiple output (MIMO) communication technique for high data rate and communication coverage enhance [6]. The relay node can be divided into a full-duplex based relay node capable of simultaneously transmit and receive signals and a half-duplex based relay node that cannot perform signal transmission and reception. In a mobile communication network, half-duplex relay communication may be considered. As the number of hops increases, the maximum achievable data throughput of this half-duplex relay node decreases linearly. To solve this issue, many studies have been performed, and one solution is to apply a two-way relay technique [7]. Two-way relay technique is possible to ensure wasted time resources and to solve the problem of reducing the transmission data rate, by reducing idle time in a half-duplex relay communication system. This two-way relay technique is a good method to solve the transmission data rate reduction problem by reducing the transmission in idle time. However, since this method uses two relay nodes, inter relay interference (IRI) occurs between each relay nodes that degrades the performance of the relay communication system. In this paper, the channel alignment based QR decomposition-M (QRD-M) method is used to detect the MIMO signals in the relay system [8]. And in the two-way relay system, the channel alignment based signal detection scheme can significantly improve the error performance by obtaining a higher post signal to interference plus noise ratio (SINR) compared to the signal detection technique that does not perform the channel alignment.

The rest of this paper is structured as follows. Next chapter explains the proposed signal relaying method for high data rate. Chapter III shows simulation results and chapter VI concludes this paper.

II. PROPOSED METHOD

This chapter introduces an efficient relaying method with MIMO signal processing in the wireless communication system using the half-duplex relay node. The proposed method uses space time block code (STBC) which is one of the diversity transmission modes for high reliability in the two-way relay communication.

TABLE I. THE SIGNAL TRANSMISSION TABLE OF THE CONVENTIONAL METHOD

	S		R	
	Tx_1	Tx_2	Tx_1	Tx_2
$t_{1,1}$	x_1	x_2		
$t_{1,2}$	$-x_2^*$	x_1^*		
$t_{2,1}$			$\hat{x}_1$	$\hat{x}_2$
$t_{2,2}$			$-\hat{x}_2^*$	x_1^*

TABLE II. THE SIGNAL TRANSMISSION TABLE OF THE PROPOSED METHOD

	S		R_1		R_2	
	Tx_1	Tx_2	Tx_1	Tx_2	Tx_1	Tx_2
$t_{1,1}$	x_1	x_2				
$t_{1,2}$	$-x_2^*$	x_1^*				
$t_{2,1}$	x_3	x_4	$\hat{x}_1$	$\hat{x}_2$		
$t_{2,2}$	$-x_4^*$	x_3^*	$-\hat{x}_2^*$	x_1^*		

Table I represents a signal transmission table of the conventional method in which total time slots are designated as 4. S means the transmitter, and R is the relay node. Tx_1 and Tx_2 mean the MIMO transmit antenna index 1 and 2, respectively. As shown in table I, x_1 and x_2 in the signal transmission step of the conventional method are transmitted from S to R using STBC at $t_{1,1}$ and $t_{1,2}$, respectively. And then, the decoded signals $\hat{x}_1$ and $\hat{x}_2$ are transmitted from R to the receiver using STBC at $t_{2,1}$ and $t_{2,2}$, respectively.

Table II shows a signal transmission step of the proposed method in which total time slots are 4. R_1 is the node 1 and R_2 means the repeat 2. From the table 2, we can see that x_1 and x_2 in signal transmission step of the proposed method are transmitted from S to R_1 using STBC at $t_{1,1}$ and $t_{1,2}$, respectively. However, x_3 and x_4 are transmitted from S to R_2 using STBC at $t_{2,1}$ and $t_{2,2}$, respectively. At the same time, the decoded signals $\hat{x}_1$ and $\hat{x}_2$ are transmitted from R1 to the receiver using STBC, and these decoded signals are also propagated to R_2. And then, IRI component between each nodes is generated. A same signal transmission step is performed in an every time slots. In the conventional method of Table 1, a wasted time slot is occurred because a signal cannot be transmitted and received at the same time, but the proposed scheme of Table 2 can be transmitted a signal without wasting the time slot. The maximum data rate of the conventional and the proposed method is $2n/4n$ and $(4n-2)/4n$, respectively. At here, the proposed method has the advantage of having the same data rate as a system to which relay communication is not applied, as the number of time slots is increased.

When the signal of R_1 at $t_{2,1}$ and $t_{2,2}$ is transmitted, the received signal $y=\left[y_{1,t_{2,1}}\ \ y_{2,t_{2,1}}\ \ y_{3,t_{2,2}}^*\ \ y_{4,t_{2,2}}^*\right]^T$ at R_2 with the IRI component can be expressed as

$$\begin{bmatrix} y_{1,t_{2,1}} \\ y_{2,t_{2,1}} \\ y_{3,t_{2,2}}^* \\ y_{4,t_{2,2}}^* \end{bmatrix} = \begin{bmatrix} h_{11,R_1,R_2} & h_{12,R_1,R_2} & h_{11,SR_2} & h_{12,SR_2} \\ h_{21,R_1,R_2} & h_{22,R_1,R_2} & h_{21,SR_2} & h_{22,SR_2} \\ h_{12,R_1,R_2}^* & -h_{11,R_1,R_2}^* & h_{12,SR_2}^* & -h_{11,SR_2}^* \\ h_{22,R_1,R_2}^* & -h_{21,R_1,R_2}^* & h_{22,SR_2}^* & -h_{21,SR_2}^* \end{bmatrix} \begin{bmatrix} \hat{x}_1 \\ \hat{x}_2 \\ x_3 \\ x_4 \end{bmatrix}. \quad (1)$$

where $(\cdot)^T$ means transpose operator and it is assumed that there is no noise in (1). h_{ij,SR_2} means a channel coefficient between the j-th transmit antenna of S and the i-th receive antenna of R_2. Also, h_{ij,R_1R_2} is a channel coefficient between the j-th transmit antenna of R_1 and the i-th receive antenna of R_2 and it is channel coefficient corresponding to the IRI value. x_3 and x_4 are the desired component in the R_2. $\hat{x}_1$ and $\hat{x}_2$ are the IRI value. In (1), IRI component can be separated by detecting x_3 and x_4 using the MIMO signal detecting technique. In this paper, the QRD-M scheme of [2] is used for MIMO signal detection. QRD-M scheme decides the order of signal detection based on channel alignment. In general, since the IRI component is dominant over the desired component, the post SINR can be maximized by removing the IRI through the channel alignment.

III. SIMULATION RESULT

The performance of the proposed signal relaying method is evaluated by the computer simulation. The cyclic prefix-orthogonal frequency division multiplexing (CP-OFDM) based wireless communication system is considered in the computer simulation. And then, the throughput performance is measured to evaluate the performance of the proposed method. Fast Fourier transform (FFT) size is used 512, and CP size is 64 for simulation. Modulation is 16-quadrature amplitude modulation (QAM). Also, 10 multipath based frequency selective Rayleigh channel is used. Figure 1 shows the throughput performance of the conventional method with table I and the proposed method. The throughput performance is normalized with maximum throughput value which does not use relay node. N/T in the proposed method of figure 1 means the number of N data reached to the receiver among the used total number of T time slot. The performance of the proposed method is divided into zero-forcing (ZF) method without channel alignment and QRD-M method with channel alignment to remove the IRI component. QRD-M based the proposed method has an improved throughput performance compared to the conventional method. Since the QRD-M scheme performs the signal detection based on channel alignment, the probability that the IRI component is removed firstly is high, and as the transmit power increases, the post SINR increases, so it has similar error performance with the conventional method. From the simulation results, we can see that the proposed signal relaying method can be effectively used in the wireless communication system.

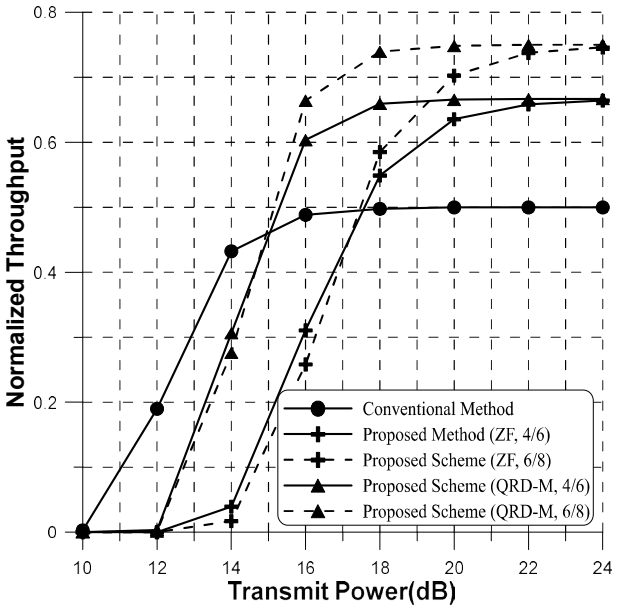

Figure 1. The normalized throughput performance of the conventional and proposed method

IV. Conclusion

To improve the data rate and reliability in the relay communication system, it is necessary to perform relay method using the QRD-M based MIMO signal processing. The MIMO signal detection structure that removes the IRI component using the two-way relay method is proposed in this paper. The proposed method obtains the maximized post SINR by separating the IRI component using the channel alignment-based signal detection technique. By computer simulation result, it is demonstrated that the proposed method has improved the throughput performance compared to the conventional method. However, since the number of required antennas also increases linearly, which has a disadvantage of requiring a large amount of computation, additional research on a dimensional reduction based MIMO signal detection technique rather than simply a low multiplication computation is required.

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