The Study on the Adaptive Hybrid MIMO Cooperative Scheme in Wireless OFDM Systems

Hyun-Woo Jang and Hyoung-Kyu Song*

uT Communication Research Institute, Sejong University,
98 Gunja-Dong, Gwangjin-Gu, Seoul 143-747, Korea
songhk@sejong.ac.kr

Abstract

In this paper, a new adaptive hybrid multiple-input multiple-output (MIMO) cooperative scheme is proposed in wireless OFDM systems. The conventional hybrid MIMO cooperative scheme is inefficient in the relay because the relay does not use one antenna between two antennas for transmission to the destination. So the new hybrid MIMO cooperative scheme supplements inefficiency of the conventional scheme by using two antennas in the relay. Also the conventional scheme and the new hybrid MIMO cooperative scheme can be used adaptively according to the channel condition between source and relay. As a result, the adaptive scheme adaptively achieves proper diversity gain and symbol rate.

Keywords: *adaptive hybrid MIMO, OFDM, diversity gain, symbol rate*

1. Introduction

The MIMO systems have many advantages as high throughput and wider coverage [1]. Although the MIMO systems have the advantages, they cannot provide the advantages when transmitter or receiver cannot support multiple antennas due to size, cost or hardware limitations. To overcome the limitation, cooperative communication is very attractive in wireless communications because cooperative communication enables single antenna to realize a virtual multiple antenna transmitter by sharing their antennas. But cooperative communication has a disadvantage that the transmission rate is decreased for relaying in cooperation phase. So a hybrid MIMO cooperative communication system is proposed to compensate the disadvantage.

The conventional hybrid MIMO cooperative scheme achieves diversity gain and multiplexing gain by combining cooperation and MIMO [2]. But the conventional scheme wastes one antenna in a relay for transmission to the destination. To supplement the disadvantage of the conventional scheme, the new scheme which uses both two antennas in a relay is proposed. And its channel matrix can be composed of two space-time block codes (STBC) structure for more diversity gain. But the channel matrix causes a slight decrease of symbol rate.

To compensate the decrease of symbol rate, the conventional scheme and the new hybrid MIMO cooperative scheme are used adaptively according to channel condition between source and relay. Channel condition is estimated by using a cyclic redundancy check (CRC) in the relay. Therefore the adaptive scheme achieves the adequate symbol rate and bit error rate (BER) performance depending on channel condition.

* Corresponding Author

2. System Model

2.1. Cooperation Model

The relay model of the new hybrid MIMO cooperative scheme is similar to a considered relay model in [3], where the network is consist of one source, one relay and one destination. And the relaying strategy of the new hybrid MIMO cooperative scheme is decode-and-forward (DF). Figure 1 shows the system configuration which is used in the new hybrid MIMO cooperative scheme.

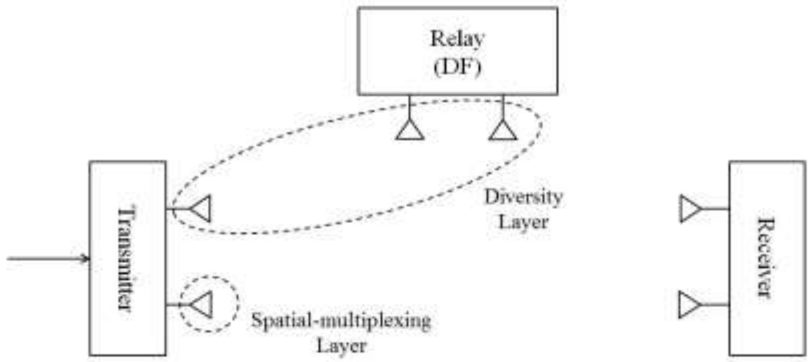

Figure 1. System Configuration of the New Hybrid MIMO Cooperative Scheme

The source transmits the symbols to the relay and the destination simultaneously at the first phase. At the second phase, the relay and the destination decode the received symbols from the source and the relay re-encodes the symbols. And the destination receives the symbols from the source and the relay at the third phase.

2.2. Channel Model

The channel is assumed as a quasi-static block fading Rayleigh channel. The assumption is caused by using the orthogonal frequency division multiplexing (OFDM) system. The OFDM system can convert a frequency selective fading channel into a parallel flat-fading channel by inverse fast Fourier transform (IFFT) and fast Fourier transform. At time k, the received symbols in the frequency domain can be presented as follows:

$$Y[\mathrm{k}] = H[\mathrm{k}]X[\mathrm{k}] + N[\mathrm{k}], \tag{1}$$

where $X[\mathrm{k}]$ means the transmitted symbols, $H[\mathrm{k}]$ means the frequency response of the channel that is generated independently and $N[\mathrm{k}]$ means the complex-Gaussian noise that is zero mean and $N_0/2$ variance.

3. Conventional Scheme

The conventional scheme is composed of diversity layer which achieve better BER performance and spatial-multiplexing layer which achieve higher symbol rate. So the conventional scheme has diversity gain by using the Alamouti space-time code (STC) [4] and spatial-multiplexing gain by using Vertical-Bell Laboratories Layered Space-Time (V-BLAST) [5]. The transmission protocol of the conventional scheme is shown in Table 1.

In the Table 1, $(\cdot)^*$ means complex conjugate. The relaying strategy is decode-and-forward (DF) protocol and it is assumed that received symbols are decoded correctly in a relay.

Table 1. Transmission Protocol for the Conventional Scheme

Transmitting node	Transmitted symbols per time slot			
Source	x_1, x_3	x_2, x_4	$-x_2^*$, x_5	x_1^*, x_6
Relay	0	0	x_1	x_2
Time slot	T = 1	T = 2	T = 3	T = 4

Then, in the destination, the received symbols are presented as follows:

$$\begin{bmatrix} Y_{1,1} \\ Y_{2,1}^* \\ Y_{3,1} \\ Y_{4,1}^* \\ Y_{1,2} \\ Y_{2,2}^* \\ Y_{3,2} \\ Y_{4,2}^* \end{bmatrix} = \begin{bmatrix} H_{1,1} & 0 & H_{3,1} & 0 & 0 & 0 \\ 0 & H_{1,1}^* & 0 & H_{3,1}^* & 0 & 0 \\ H_{2,1} & -H_{1,1} & 0 & 0 & H_{3,1} & 0 \\ H_{1,1}^* & H_{2,1}^* & 0 & 0 & 0 & H_{3,1}^* \\ H_{1,2} & 0 & H_{3,2} & 0 & 0 & 0 \\ 0 & H_{1,2}^* & 0 & H_{3,2}^* & 0 & 0 \\ H_{2,2} & -H_{1,2} & 0 & 0 & H_{3,2} & 0 \\ H_{1,2}^* & H_{2,2}^* & 0 & 0 & 0 & H_{3,2}^* \end{bmatrix} \begin{bmatrix} X_1 \\ X_2^* \\ X_3 \\ X_4^* \\ X_5 \\ X_6^* \end{bmatrix} + \begin{bmatrix} N_{1,1} \\ N_{2,1}^* \\ N_{3,1} \\ N_{4,1}^* \\ N_{1,2} \\ N_{2,2}^* \\ N_{3,2} \\ N_{4,2}^* \end{bmatrix}, \quad (2)$$

where $\{Y_{2,1}, Y_{4,1}, Y_{2,2}, Y_{4,2}\}$ which is the received symbols at second and fourth time is taken the complex conjugate to make the above matrix.

The detection is performed by using successive interference cancellation (SIC) algorithm in the destination. First, x_1 and x_2 are detected by using the minimum mean-square error (MMSE) criterion of the diversity layer [6]. Next, their interference over the remaining symbols is canceled. And the MMSE detection is performed again to recover $\{x_3, x_4, x_5, x_6\}$ by the channel of the spatial-multiplexing layer.

4. New hybrid MIMO Cooperative Scheme and Adaptive Scheme

In the new hybrid MIMO cooperative scheme, both two antennas are used in a relay for reception and transmission. To improve BER performance, the transmission protocol of the new hybrid MIMO cooperative scheme is different from the conventional scheme. The transmission protocol is composed of two STBC structures and it is shown in the Table 2.

Table 2. Transmission Protocol for the New Hybrid MIMO Cooperative Scheme

Transmitting node	Transmitted symbols per time slot		
Source	x_1, x_3	x_2, x_4	$-x_1$, $-x_3$
Relay	0	x_1^*, x_3^*	x_2^*, x_4^*
Time slot	T = 1	T = 2	T = 3

Then, in the destination, the received symbols are presented as follows:

$$\begin{bmatrix} Y_{1,1} \\ Y_{2,1}^* \\ Y_{3,1} \\ Y_{1,2} \\ Y_{2,2}^* \\ Y_{3,2} \end{bmatrix} = \begin{bmatrix} H_{1,1} & 0 & H_{4,1} & 0 \\ H_{2,1}^* & H_{1,1}^* & H_{3,1}^* & H_{4,1}^* \\ -H_{1,1} & H_{2,1} & -H_{4,1} & H_{3,1} \\ H_{1,2} & 0 & H_{4,2} & 0 \\ H_{2,2}^* & H_{1,2}^* & H_{3,2}^* & H_{4,2}^* \\ -H_{1,2} & H_{2,2} & -H_{4,2} & H_{3,2} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2^* \\ X_3 \\ X_4^* \end{bmatrix} + \begin{bmatrix} N_{1,1} \\ N_{2,1}^* \\ N_{3,1} \\ N_{1,2} \\ N_{2,2}^* \\ N_{3,2} \end{bmatrix}. \quad (3)$$

The detection is performed similarly to the conventional scheme. But the complexity of the detection is lower than the conventional scheme. The detection is performed at a time because the new hybrid MIMO cooperative scheme's transmission protocol is composed of two STBC structures.

The new hybrid MIMO cooperative scheme's BER performance is better than conventional scheme but its symbol rate is 4/3 symbols per channel use. It is lower than conventional scheme having a symbol rate of 6/4 symbols per channel use. To supplement a decrease of a symbol rate, the adaptive scheme is used.

The adaptive scheme uses a CRC in a relay to estimate channel condition between source and relay. If a CRC is zero, it is assumed that channel condition is good and the conventional scheme is used. Otherwise, the new hybrid MIMO cooperative scheme is used. Then, the adaptive scheme can be used adaptively according to channel condition between source and relay. As a result, the adaptive scheme properly achieves a higher symbol rate than the new hybrid MIMO cooperative scheme and a better BER performance than the conventional scheme.

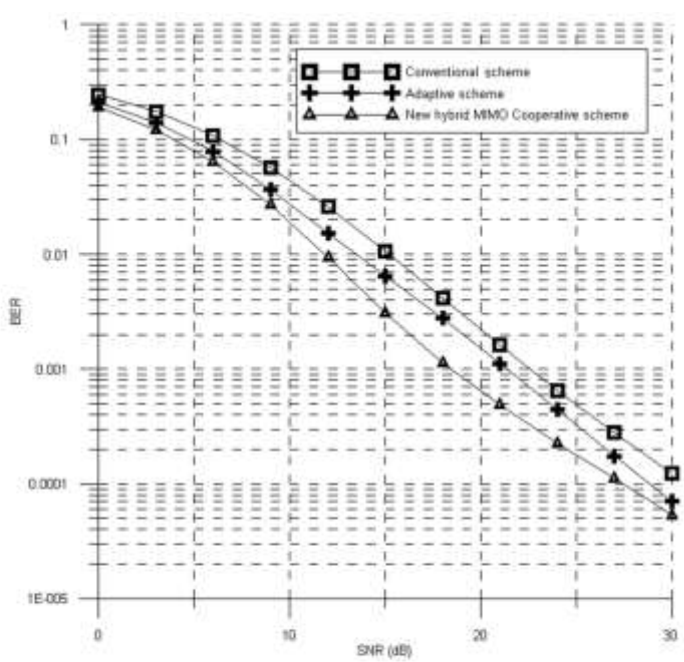

Figure 2. BER Performance of the Schemes

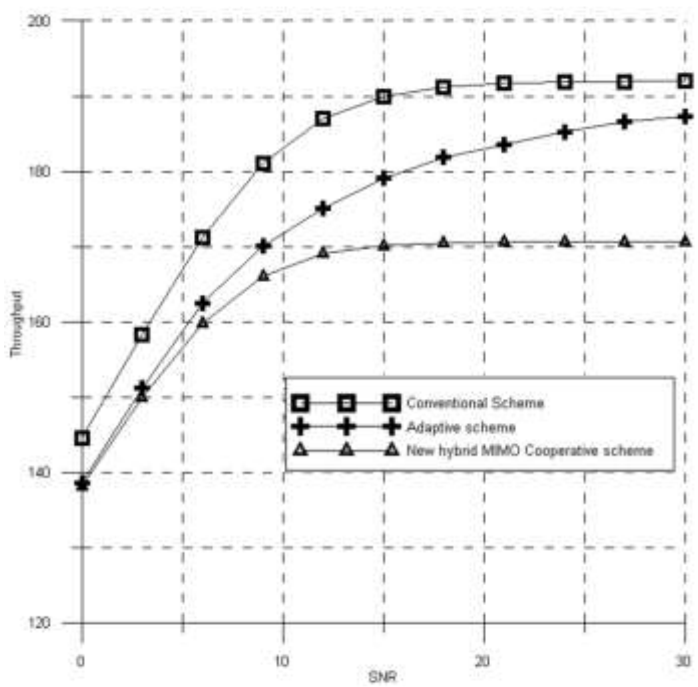

Figure 3. Throughput Performance of the Schemes

5. Simulation Results

The computer simulations are performed to compare the performance of the schemes. These simulations are performed over 7-path Rayleigh fading channel. Figure 2 presents BER performance of the schemes using QPSK modulation without channel coding. It is observed that BER performance of the new hybrid MIMO cooperative scheme is better than the conventional scheme. But Figure 3 shows that throughput performance of the new hybrid MIMO cooperative scheme is worse than the conventional scheme. Also, the adaptive scheme has intermediate performance of the other schemes.

6. Conclusion

In this paper, the new hybrid MIMO cooperative scheme is proposed to supplement a disadvantage of the conventional scheme. But the new hybrid MIMO cooperative scheme has lower symbol rate. So the adaptive scheme is used to supplement the two disadvantages of the other schemes. As a result, the adaptive scheme has proper BER performance and throughput according to the channel state.

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Authors

Hyun-Woo Jang was born in Seoul, Korea in 1986. He received the B.S. degree in Information & Communication Engineering, Sejong University, Seoul, Korea, in 2011. He is working toward to M.S. degree in the Department of Information & Communication Engineering, Sejong University, Korea. His research interests are in the areas of wireless communication system design, MIMO signal processing, cooperative communication.

Hyoung-Kyu Song was born in ChungCheong-Bukdo, Korea on 14th May 1967. He received B.S., M.S., and Ph.D. degrees in Electronic Engineering from Yeonsei University, Korea in 1990, 1992, and 1996, respectively. From 1996 to 2000 he had been Managerial Engineer in Korea Electronics Technology Institute (KETI). Since 2000 he has been a Professor of the Department of Information & Communication Engineering, Sejong University, Korea. His research interests include digital and data communications, information theory, and their applications with an emphasis on mobile communications.