

# A Cooperative Transmission Scheme Using Two Sources Based On OFDM System

Bit-Na Kwon, Dong-Hyun Ha, Hyoung-Kyu Song

**Abstract**—In wireless communication, space-time block code (STBC), cyclic delay diversity (CDD) and space-time cyclic delay diversity (STCDD) are used as the spatial diversity schemes and have been widely studied for the reliable communication. If these schemes are used, the communication system can obtain the improved performance. However, the quality of the system is degraded when the distance between a source and a destination is distant in wireless communication system. In this paper, the cooperative transmission scheme using two sources is proposed and improves the performance of the wireless communication system.

**Keywords**—OFDM, Cooperative communication, CDD, STBC, STCDD.

## I. INTRODUCTION

MULTIPLE-input multiple-output (MIMO) systems are used for high reliability and data rate in the wireless communication system [1]. In the MIMO system, orthogonal frequency division multiplexing (OFDM) can be used. The multiple carriers are used and the high-speed transmission of the data is possible in OFDM. The system combining these two schemes is called to the MIMO-OFDM system [2]. However, the implementation of multiple antennas at the terminal has the problems for the high cost and the limited size. The cooperative schemes have been widely studied in order to overcome the problems of the MIMO system [3]. Instead of the multiple antennas, the cooperative system uses the relays. The relays are located between a source and a destination and make the virtual MIMO system.

In the cooperative communication system, the spatial diversity schemes are applied for diversity gain. One of the spatial diversity schemes is space time block code (STBC), which has been proposed in [4]. The STBC scheme uses the code design of Alamouti and obtains full diversity gain and full rate. STBC can be applied to the cooperative system by using the relays. However, the cooperative STBC has a rate loss since the relays are used between the source and the destination. Among other spatial diversity schemes, cyclic delay diversity (CDD) is widely used and transmits cyclically delayed signals through different antennas [5]. The CDD scheme makes the random channel characteristics and can reduce the correlation between neighboring subcarriers. Space-time cyclic delay diversity (STCDD) is the spatial diversity scheme combining STBC with CDD. When three or more relays are used, two antennas transmit the STBC signal and other antennas transmit

the CDD signal in the STCDD scheme [6].

The additional processes are conducted in the system using the relays. In the first step, the source broadcasts the signals to the relays and the relays having the good channel state are selected. In the second step, the relays retransmit the signals to the destination. The amplify-and-forward (AF) or decode-and-forward (DF) relaying scheme is used at the relays [7]. In the AF scheme, the received signals are amplified by the amplification factor and retransmitted to the destination. In the DF scheme, the received signals are decoded at the relays and retransmitted to the destination after modulation.

Generally, if the distance between a source and a destination is distant, the quality of communication is degraded [8]. This problem can be solved by the relays since the distance between nodes is short.

In this paper, the transmission scheme for the user located in the cell boundary is proposed and the proposed scheme uses the cooperative scheme. The proposed scheme provides the improved performance and the performance of the system is evaluated by bit error rate (BER) and throughput.

This paper is organized as follows. Section II shows the system model and Section III shows the conventional scheme. The proposed scheme and the simulation results are shown in Sections IV and V respectively. In Section VI, the conclusion is shown.

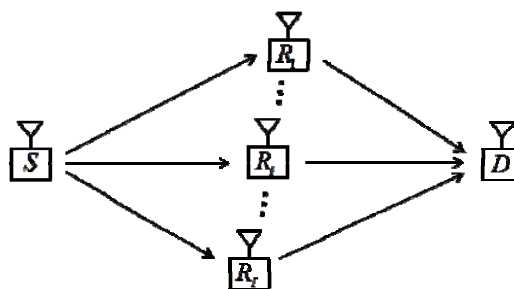


Fig. 1 The dual-hop cooperative system model

## II. SYSTEM MODEL

In this section, the cooperative system model is represented. The system is based on OFDM and the relay is used between the source and the destination. Since the relay is used, the destination is close to the source and the coverage of communication is expanded.

The basic cooperative system model is shown in Fig. 1. The relaying system like Fig. 1 is called to the dual-hop system and only one relay connects the source with the destination. In this paper,  $S$  denotes the source,  $R_i$  denotes the relay and  $D$  denotes

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the destination.  $i \in \{1, 2, \dots, I\}$  and means the index of the relay.

The source  $S$  transmits the signal to the relay  $R_i$  and  $R_i$  retransmits the signal to the destination  $D$ . In this case, the signals are processed by the DF relaying scheme at the relay  $R_i$ . Generally, if the destination is distant from the source, the power of the received signal is weak and the quality of the communication is degraded. These problems can be solved since the distance among the nodes is short by the relay.

This system assumes that the channel is a Rayleigh channel and has the quasi-static characteristic. At the receiver, additive white Gaussian noise (AWGN) is added. The received signal can be simply expressed as follows,

$$y = hx + n, \tag{1}$$

where  $y$  is a received signal,  $h$  is a channel,  $x$  is a transmitted OFDM symbol and  $n$  is a noise. The noise is AWGN with zero mean and  $\sigma^2$  variance.

### III. CONVENTIONAL SCHEME

In this section, the conventional cooperative scheme is explained. It is assumed that the source  $S$ , the destination  $D$ , the first relay  $R_1$  and the second relay  $R_2$  are used in the system. This system obtains the diversity gain by using the two relays and the dual-hop relaying system is applied.

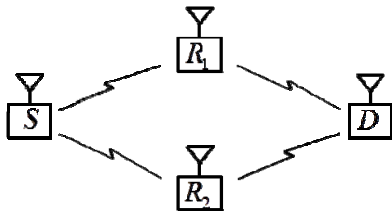


Fig. 2 The conventional cooperative system using two relays

Fig. 2 represents the conventional transmission system. It is confirmed that the two relays cooperate with each other for the diversity gain. The source  $S$  transmits the signal to the relays and the relays retransmit the signal to the destination  $D$  by DF. In this case, the STBC scheme can be applied in order to obtain the improved performance. The source  $S$  broadcasts the OFDM symbol  $x_1$  and  $x_2$  to the relay  $R_1$  and  $R_2$ . The received signals at the relays are designed according to the Alamouti's code design and this code design can be expressed as follows [4],

$$\mathbf{x} = \begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix}, \tag{2}$$

where  $\mathbf{x}$  is the matrix of the transmission symbols at the relays and  $(\cdot)^*$  means the conjugation of  $(\cdot)$ . The column elements of  $\mathbf{x}$  represent the transmitted symbols in each relay and the row elements represent the transmitted symbols in each time slot.

Finally, the OFDM symbols are transmitted to the destination  $D$ . In the destination  $D$ , the received signal is demodulated after the compensation of the channel and the OFDM symbols are estimated at the receiver.

### IV. PROPOSED TRANSMISSION SCHEME

The proposed transmission scheme is represented in this section. Two sources  $S_1$  and  $S_2$ , three relays  $R_{11}$ ,  $R_{21}$  and  $R_{22}$  and the destination  $D$  are used in the proposed system. The proposed scheme uses two sources while the conventional scheme uses only one source and it is possible by the relaying scheme in the proposed system.

In the conventional scheme, the dual-hop relaying system is used. The conventional system cannot use other source located in the distant place because of the limitation for the distance. However, we propose the scheme using the three-hop relaying system in order to use other source. In the three-hop relaying system, two relays are located between the source and the destination in series.

The dual-hop relaying system and the three-hop relaying system are used in the proposed scheme.  $d_{dual-hop}$  means the distance between nodes when the dual-hop system is used. And  $d_{three-hop}$  means the distance between nodes when the three-hop system is used. It is confirmed that  $d_{three-hop}$  is shorter than  $d_{dual-hop}$ . Since the quality of the communication is good when each node is close, it is expected that the three-hop system is better than the dual-hop system. At this point, it is assumed that the relays having the good channel state are selected. If the total distance between the source and the destination is assumed to be  $d$ ,  $d_{dual-hop}$  and  $d_{three-hop}$  are expressed as follows,

$$d_{dual-hop} = \frac{d}{2}, d_{three-hop} = \frac{d}{3}. \tag{3}$$

In the wireless communication system, path loss occurs in proportion to the distance. Therefore, the three-hop system has two-thirds of path loss compared with the two-hop system according to (3).

Fig. 3 shows the transmission scenario for the proposed scheme. In the proposed system, the destination can receive the signals from both two sources  $S_1$  and  $S_2$  since the two relays  $R_{21}$  and  $R_{22}$  are used and the three-hop relaying scheme is applied between the source  $S_2$  and the destination  $D$ .

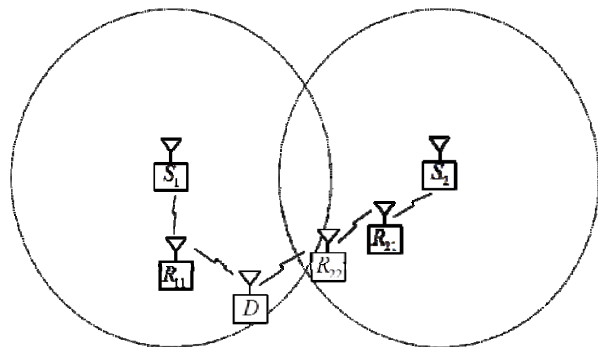


Fig. 3 The proposed transmission scenario using two sources

TABLE I  
TRANSMISSION SEQUENCE FOR THE PROPOSED SCHEME IN EACH NODE

Time Slot	$S_1$	$R_{11}$	$S_2$	$R_{21}$	$R_{22}$
$t_1$	$x_1$		$x_1$		
$t_2$	$x_2$		$x_2$	$x_1$	
$t_3$		$x_2$		$x_2$	$x_1$
$t_4$		$x_1^*$			$-x_2^*$

In this transmission system, it is assumed that the sources share their information with each other and it means the cooperative communication among the sources.

The transmitted symbol at each node is represented in Table I. It is assumed that the direct signal from  $S_1$  and  $D$  is not considered in the proposed system.  $R_{11}$  receives  $x_1$  and  $x_2$  from  $S_1$  and transmits  $x_2$  and  $x_1^*$  to  $D$ .  $S_2$  cooperating with  $S_1$  transmits the same symbol  $x_1$  and  $x_2$  to  $R_{21}$  and  $R_{21}$  retransmits  $x_1$  and  $-x_2^*$  to  $D$ . The received signal in the destination is equal to the STBC code design. In the proposed scheme, the signal from  $S_2$  is used as the information signal since the sources share their information with each other. The received signals at the destination are expressed as follows,

$$\begin{aligned} y_1 &= h_{11}x_2 + h_{22}x_1 + n_1, \\ y_2 &= h_{11}x_1^* - h_{22}x_2^* + n_2, \end{aligned} \quad (4)$$

where  $y_i$  is the received signal,  $h_{mn}$  is the channel between  $R_{mn}$  and  $D$ ,  $x_i$  is the transmitted OFDM symbol,  $n_i$  is AWGN and  $i$  of  $y_i$ ,  $x_i$  and  $n_i$  is the index of each component. Since the received signal is equal to STBC, the transmitted symbols can be estimated by the detection scheme of STBC [4].

## V. SIMULATION RESULTS

In this section, the simulation results are represented. The simulations assume that the sources and the relays share their information with each other and the channel is estimated perfectly. Also, the power allocation is uniform. The simulations are accomplished with following parameters. The fast Fourier transform size is 256 and the cyclic prefix size is 64. The signals experience a 14-path Rayleigh fading channel. Fig. 4 shows the BER performance of the conventional and proposed scheme. It is confirmed that the BER performance of the proposed scheme is better than the conventional scheme. The throughput performance of the conventional and proposed scheme is shown in Fig. 5. The proposed scheme has the good throughput performance compared with the conventional scheme. Figs. 4 and 5 show that the proposed scheme is better than the conventional scheme.

## VI. CONCLUSION

In this paper, the improved transmission scheme is proposed. The proposed scheme uses two sources for the user located in the cell boundary and obtains the good performance. The Alamouti's code is applied to the transmission symbol. The proposed scheme has the same code design with the conventional scheme. However, the improved performance can be obtained because the three-hop relaying system is used and the distance between nodes is short. Therefore, the proposed

scheme provides the reliable communication.

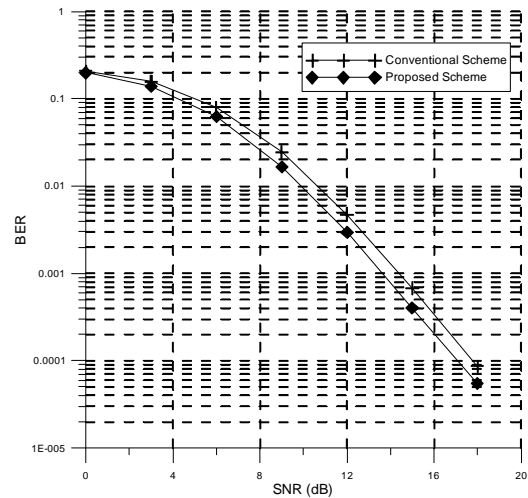


Fig. 4 The BER performance of the conventional and proposed scheme

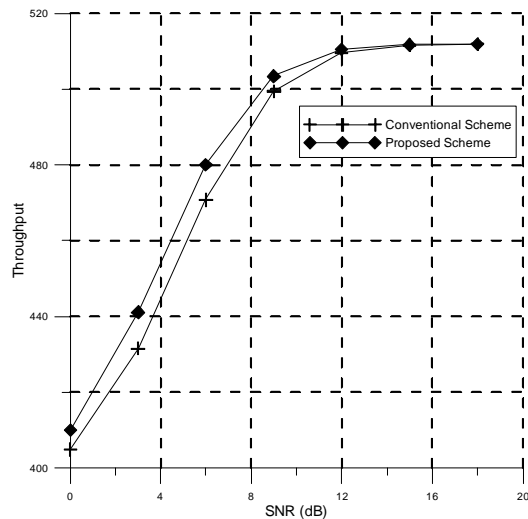


Fig. 5 The throughput performance of the conventional and proposed scheme

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## REFERENCES

- [1] E.-H. Lee and H.-K. Song, An improved transmission rate in cooperative communication based on OFDMA system, *IEICE Trans. Fundamentals*, vol. E96-A, no. 7, pp.1667-1670, 2013.

- [2] H. Sampath, S. Talwar, J. Tellado, V. Erceg and A. Paulraj, A fourth-generation MIMO-OFDM broadband wireless system: design, performance, and field trial results, *IEEE Commun. Mag.*, vol. 40, no. 9, pp. 143-149, Sep. 2002.
- [3] J.-H. Kim and H.-K. Song, Performance improvement of cooperative MB-OFDM system based coming home network, *IEEE Trans. Consum. Electron.*, vol.53, no.2, pp.442-447, May 2007.
- [4] S. M. Alamouti, A simple transmitter diversity scheme for wireless communications, *IEEE Trans. Wireless Commun.*, vol. 16, no. 8, pp. 1451-1458, Oct. 1998.
- [5] M. Bossert, A. Huebner, F. Schuehleiny, H. Haasz, and E. Costaz, On cyclic delay diversity in OFDM based transmission schemes, *Proc. of the 7th International OFDM-Workshop*, Sep. 2002.
- [6] J.-H. Song, J.-H. Kim, and H.-K. Song, Space-time cyclic delay diversity encoded cooperative transmissions for multiple relays, *IEICE Trans. Commun.*, vol. E92-B, no. 6, pp.2320-2323, 2009.
- [7] J. Boyer, D. Falconer, and H. Yanikomeroglu, Multihop diversity in wireless relaying channels, *IEEE Trans. Commun.*, vol.52, no.10, pp.1820-1830, Oct. 2006.
- [8] H.-J. Shin, H.-W. Jang and H.-K. Song, An advanced cooperative scheme in the broadcasting and cellular system, *IEICE Inf. & Syst.*, vol. E97-D, no. 6, June 2014.

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