Improved Cooperative Scheme by Extending Cell Coverage in Broadcasting System

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ABSTRACT: *In the wireless communication system, an improved cooperative scheme using extra relays for the broadcasting system is proposed. In order to do reliable transmission, cyclic delay diversity (CDD) and space-time cyclic delay (STCDD) are used in the proposed scheme. In the broadcasting system, bit error rate (BER) performance and throughput performance are degraded if the destination user is located in the edge of the broadcasting base station (BBS) cell coverage. The conventional scheme employs two CBSs and relays. However, if the destination user differs from a cellular base station (CBS), communication performance is decreased. Therefore, the cooperative scheme using two BBSs and extra relays is proposed to improve the performance and guarantee the quality of the communication. The simulation result implies that the proposed scheme can obtain high performance for the destination user in the BBS edge.*

Keywords: Wireless Communications, CDD, Diversity Gain, STBC, Reliable Transmission.

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1. Introduction

In wireless communication, both high data rate and high reliability are demanded. Since multiple-input multiple-output (MIMO) can achieve high data rate and reliability, MIMO is useful in communication system. The transmitted signals allocate to orthogonal sub-carriers in orthogonal frequency division multiplexing (OFDM) system. The system which combines MIMO and OFDM is named for MIMO-OFDM system. Although MIMO system can obtain multiplexing gain and diversity gain, the hardware implementation is very hard in accordance with the number of antennas. So, the MIMO system has the problems of high cost and the size limitation. In order to resolve the problems of MIMO system, cooperative transmission scheme has been studied. In the cooperative transmission scheme, relay is used between a base station and a destination through independent paths. As a result, virtual MIMO system is constructed by the relays with single antenna.

Due to the cooperative transmission scheme, the diversity gain is obtained and the reliable transmission between a base station and a destination is guaranteed. One of the cooperative transmission schemes, space-time block code (STBC) uses spatially separated signals during two time slots. Since STBC uses Alamouti code design, full diversity gain is obtained and the performance is improved. Cyclic delay diversity (CDD) scheme of the cooperative transmission scheme transmits cyclically delayed signals to a destination with random channel characteristics. In CDD scheme, the correlation between subcarriers can be reduced and reliable communication is available.

The broadcasting and cellular system are adapted in the proposed scheme. In the broadcasting system, receivers do not have to connect for algorithm and subcarrier transmission at subcarrier is effective way. On the other hand, the cellular system exists in uplink and downlink between a base station and a destination. Also, design of multiple access for uplink and down link is needed and a base station is connected with a destination. So, the coverage of the cellular system is small compared with the broadcasting system.

The communication quality is influenced by the transmission distance between a base station and a destination in wireless communication. If the destination user is located in the edge of cell coverage, the performance is degraded. In order to improve the performance, improved cooperative scheme using two base stations and extra relays is proposed. The proposed scheme is employed in accordance with the location of a destination user since the cell edge user causes bad performance.

The remaining sections are arranged as follows. Section 2 shows the overall system model used in this paper and Section 3 explains the conventional scheme. Section 4 represents the proposed scheme for performance improvement and Section 5 describes the simulation results for conventional scheme and proposed scheme. In Section 6, the conclusion of the proposed scheme is demonstrated.

2. System Model

In this paper, the cooperative transmission scheme using relays is used to obtain diversity gain and extend cell coverage. Also, the OFDM system is based on this paper. In Fig. 1, the system model of the cooperative transmission scheme is shown. The source communicates with a destination with extra relays. When extra relays are used, the transmission distance between a source and a destination is short and the performance degradation according to the path loss can be reduced. In general, the received signal power becomes weak and communication quality is not guaranteed if a destination is far from the base station.

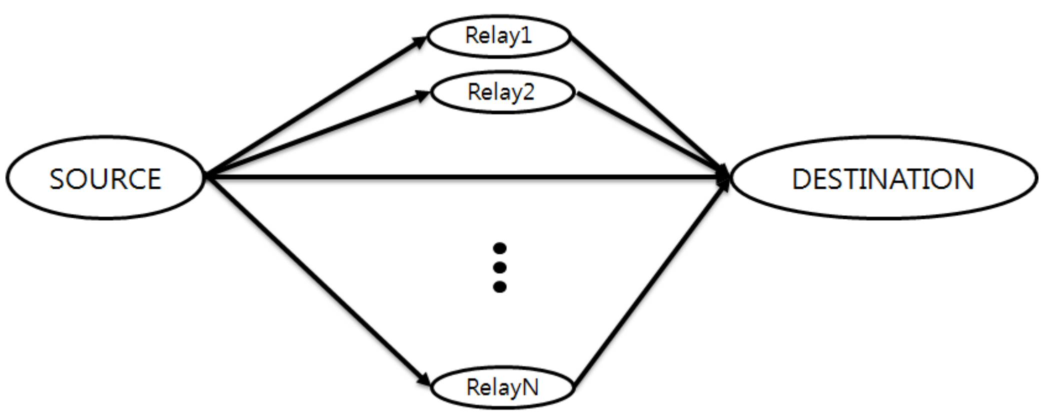

Figure 1. System model of the cooperative transmission scheme

The system assumes that the transmitted signals from BBS and CBS suffer Rayleigh fading channel which has stable characteristics. Also, complex Gaussian random noise is added. The received signal vector **Y** is expressed as follows,

$$\mathbf{Y} = \mathbf{HX} + \mathbf{N} \tag{1}$$

where the vector of received signals **Y** denotes the complex matrix suffered Rayleigh channel and **X** means the matrix of OFDM symbols transmitted from BBS and CBS. Also, **H** is the complex matrix of the channel and **N** denotes the noise for additive white complex-Gaussian noise (AWGN) vector. AWGN noise vector has zero mean and σ^2 variance.

3. Conventional Cooperative Scheme

In this paper, the conventional scheme is formed from two CBSs, two relays and one destination user. The CBSs, relays and destination user are belonged to the coverage of BBS. Since the BBS and CBS are connected with back bone system, BBS shares the information of signal with CBS. Also, two CBSs communicate with each other by cooperative scheme. In Fig. 2, the conventional cooperative scheme is shown. Fig. 2 is composed with a base station CBS_i, a relay R_i and USER as a destination user. The user receives the two signals through two paths of relays at the same time. Table 1 indicates the transmission symbol sequences of the conventional scheme. The OFDM symbols x_1 and x_2 are transmitted to extra relays and $\tilde{x}_i$ means a symbol retransmitted from extra relays with decode and forward (DF) scheme at the i th time.

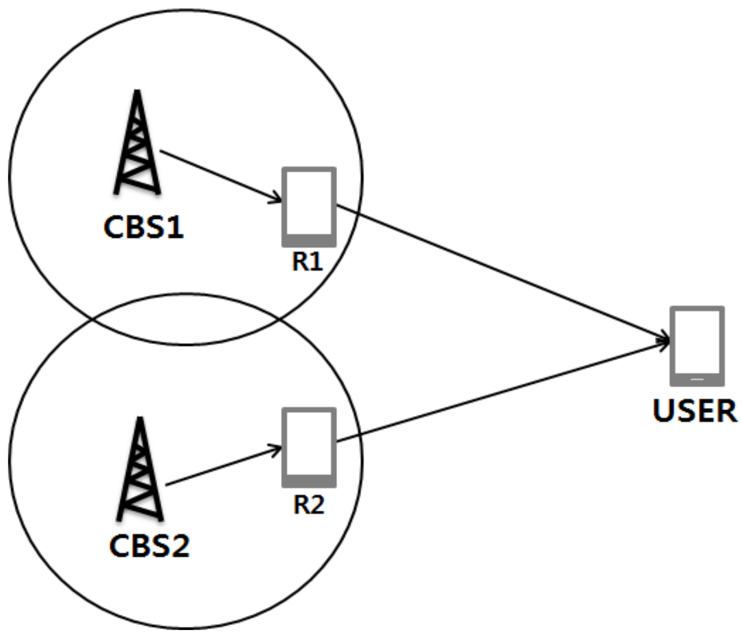

Figure 2. Transmission model of the conventional cooperative scheme

Time Slots	R1	R2
T_1	$\tilde{x}_1$	$\tilde{x}_2$
T_2	$\tilde{x}_2$	$\tilde{x}_1$

Table 1. Transmission system of the conventional scheme

In order to improve communication performance and obtain diversity gain, relay is used to transmit short distance. Thus, the user can receive two signals from two relays through independent short transmission distance. As a result, reliable communication is available since extra relays transmit the signal at the same time. However, the system performance is degraded when a user is distant from both BBS and CBS. The distance between a base station and a user is denoted as the attenuated rage of the transmitted signals. So, if the attenuation rate is large, the system performance is degraded and the quality of the communication is not guaranteed.

4. Proposed Cooperative Scheme

The conventional scheme cannot improve the system performance when a user is distant from a base station. Since the power of transmitted signal is reduced according to the transmission distance, the quality of the conventional transmission scheme is not guaranteed.

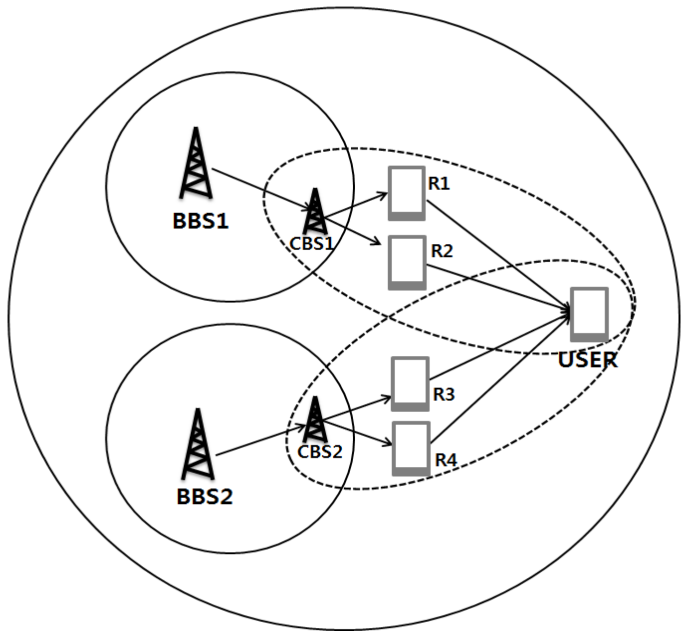

Figure 3. Transmission model of the proposed cooperative scheme

With two BBSs, two CBSs and four relays in the Fig. 3, the proposed scheme obtains higher performance than the conventional scheme when a user is located in the edge of a CBS. The BBS and CBS transmit the signal to a user in CBS coverage and extra relays are used to extend the communication coverage. In the proposed scheme, transmitted signals suffer low attenuation rate by the channel condition. Due to the attenuation, the conventional scheme is difficult to apply in one BBS system since the signal power is decreased. Therefore, the proposed scheme employs two BBS to improve the performance by cooperating between BBS1 and BBS2. A user in Fig. 3 finally receives four signals from BBS1 and BBS2 through four relays and both multiplexing and diversity gain can be obtained.

Time Slots	Relayl	Relay2	Relay3	Relay4
T_1	x_1	x_2	x_1	x_2
T_2	x_2	$-x_1^*$	$x_{1,\delta}$	$x_{2,\delta}$

Table 2. Transmission system of the proposed scheme with STBC and CDD scheme

In Table 2, the transmission system of the proposed scheme with STBC and CDD scheme is described. The OFDM symbols x_1 and x_2 are transmitted at two time slots. To improve the received signal quality, STBC and CDD scheme are used in proposed scheme. The STBC scheme transmits the separated signals spatially and temporally. The CDD scheme uses cyclically delayed signal to transmit a user. The signal of x_i* means the conjugated signal applying STBC scheme and the signal of $x_{i,\delta}$ is the cyclically delayed signal applying CDD scheme. According to the Table 2, the transmitted signals from four extra relays are expressed as follows,

$$
\begin{aligned}
y_1 &= x_1 h_1 + x_2 h_2 + x_1 h_3 + x_2 h_4, \\
y_2 &= -x_2^* h_1 + x_1^* h_2 + x_{1,\delta} h_3 + x_{2,\delta} h_4,
\end{aligned} \tag{2}
$$

where y_i is the received signal at the i th time, x_i means the transmitted signal from relay1, relay2, relay3 and relay4 which are located between CBSs and a user. And the channel h_i suffers when the signals are transmitted to a user.

The equation (2) is represented as

$$
\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} h_1 + h_3 & h_2 + h_4 \\ h_2 + h_3 & h_1 + h_4 \end{bmatrix} \begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix}. \tag{3}
$$

The received signals are finally detected by MMSE scheme. A matrix of MMSE is written as follows,

$$
\mathbf{G}_{mmse} = \left(\mathbf{H}^H \mathbf{H} + \sigma^2 \mathbf{I} \right)^{-1} \mathbf{H}^H, \tag{4}
$$

where $\mathbf{H}^H$ is Hermitian matrix, **I** means a unit matrix form and σ^2 denotes noise variance.

5. Simulation Results

In this section, the performance results of BER and throughput for the conventional scheme and the proposed scheme are described. For the fair evaluation, the simulation parameters are used equally in the conventional and proposed scheme. The fast Fourier transform size is 256 and cyclic prefix is 64. Also, the signal is modulated by binary phase shift keying (BPSK) and coded with 1/2 convolutional code. Finally, the signal suffers from Rayleigh fading channel of 7 paths and the received signal is detected by the MMSE scheme.

Fig. 4 represents the BER performance and Fig. 5 shows the throughput performance for the proposed and conventional scheme when a user is distant from BBSs. The system performances are represented by the signal to noise ratio (SNR) and attenuated rate. When the attenuation rate is 30dB, the degradation of system performance is very large by the path loss. In all attenuation rates, the proposed scheme has good performance compared with the conventional scheme. Since the proposed scheme applies the STBC and CDD scheme, the BER and throughput performances are high when the user is far from the base station. Therefore, the proposed scheme is the improved cooperative scheme since the proposed scheme can obtain better performance than the conventional scheme.

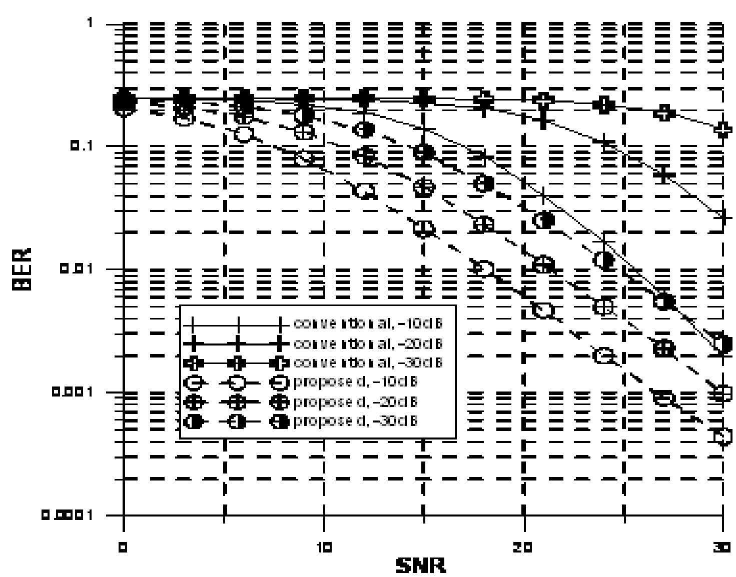

Figure 4. BER performance of the conventional and proposed scheme

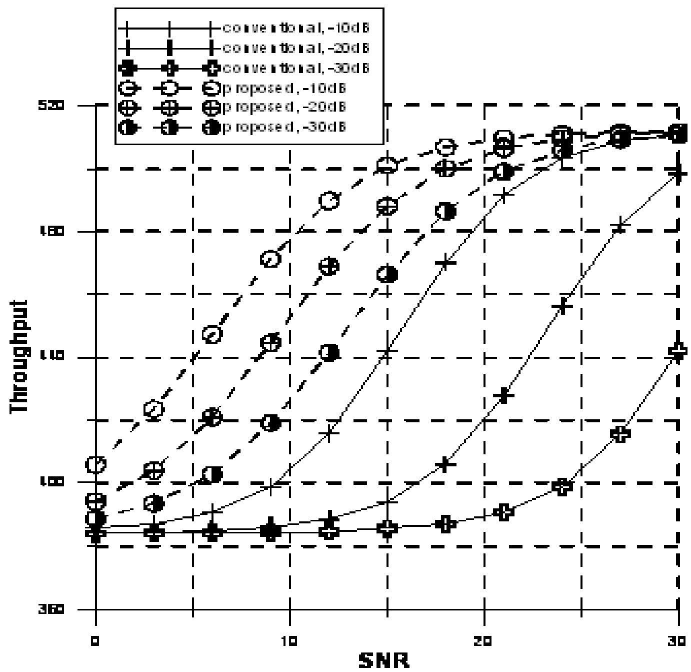

Figure 5. Throughput performance of the conventional and proposed scheme

6. Conclusion

For performance improvement, the cooperative transmission scheme using BBSs and relays is proposed. In the proposed scheme, STBC and CDD can be applied since the four relays are used between BBSs and a user. Since the relays can reduce the transmission distance and the effect of attenuated rate through short path, the performance of the proposed scheme is improved and obtains high BER and throughput performances. Therefore, the proposed scheme can reliable transmission compared with the conventional scheme. Also, the simulation results are proved that the proposed scheme obtains better performances than the conventional scheme when a user is distant from BBS. As a result, the proposed scheme is more effective way in high attenuation environment.

7. Acknowledgements

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References

[1] Lee, E. H., Song H. K. (2013). An Improved Transmission Rate in Cooperative Communication Based on OFDMA Systems. *IEICE: Trans. & Fundamentals*, E96-A (7) 1667-1670.

[2] Alamouti, S.M.(1998). A Simple Transmit Diversity Technique for Wireless Communications. *IEEE, J. Sel. Areas Commun,* 16 (8) 1451-1458.

[3] Bosserty, M., Huebnery, A., Schuehleiny, F., Haasz, H. & Costaz, E.(2002) On Cyclic Delay Diversity in OFDM Based Transmission Schemes. *Germany, Hamburg: 7th International OFDM-Workshop*

[4] Wel, D., Deng, L., Rui, Y., Wang, F.(2012) Cooperative Transmission with Broadcasting and Communication. *Romania, Bucharest: 4th International Conference,* 541-544.

[5] Kim, K. R., Ha, D. H., Song H. K. (2015) Performance Improvement Technique with Cooperative Relay in Cellular System. *IEICE: Trans. & Fundamentals,* E96-A (6), 1339-1342.