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Improved Performance of Cooperative Scheme in the Cellular and Broadcasting System

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***Abstract*—**In the cooperative transmission scheme, both the cellular system and broadcasting system are composed. Two cellular base stations (CBSs) communicating with a user in the cell edge use cooperative transmission scheme in the conventional scheme. In the case that the distance between two CBSs and the user is distant, the conventional scheme does not guarantee the quality of the communication because the channel condition is bad. Therefore, if the distance between CBSs and a user is distant, the performance of the conventional scheme is decreased. Also, the bad channel condition has bad effects on the performance. The proposed scheme uses two relays to communicate well with CBSs when the channel condition between CBSs and the user is poor. Using the relay in the high attenuation environment can obtain both advantages of the high bit error rate (BER) and throughput performance.

***Keywords*—**Cooperative communications, diversity gain, OFDM, interworking system.

I. Introduction

IN order to obtain high transmission rate in wireless communication system, orthogonal frequency division multiplexing (OFDM) which is a method of encoding with multiple carrier frequencies is used [1]. The OFDM is a popular scheme because frequency efficiency is high and multi-path fading is sturdy. The multiple-input multiple-output (MIMO) scheme uses multiple transmit and receive antennas to obtain high data rate [2], [3]. The more the number of antennas increases, the better diversity and multiplexing gains are obtained [4]. However, the MIMO system has a lot of cost and is relatively difficult to produce. The size of the system and complexity of hardware are increased since multiple antennas are added to obtain diversity gain. So as to solve this problem of the MIMO system, the cooperative scheme which uses the relay between a source and a destination has been studied continuously [5], [6]. The cooperative scheme is a method that the source transmits the signal to the relay and the relay retransmits the signal to the destination. Since the signal is transmitted through the relay, the destination is in addition to receiving the same signal from both the source and the relay [7].

Both the broadcasting system and the cellular system are used in the interworking system [8]. The broadcasting system in [9] employs downlink while this system does not use the feedback information. In the case of the cellular system, the uplink and downlink are employed by using the feedback information [10]. However, the cell coverage of the broadcasting cell is much wider than the cell coverage of the cellular system [11]. The use of the interworking system has both advantages of the cellular system and the broadcasting system. The interworking system can reduce expenses since their bandwidth is shared with each other. As a result, it is clear that interworking system is helpful for a transmitter and a receiver.

In order to do reliable transmission, important elements like distance and the channel condition that influence on communication between a source and a destination are considered. The more the distance between a source and a destination is distant, the more the quality of the communication is poor by path loss. Therefore, two cellular base stations (CBSs) communicate with each other by adapting the cooperative transmission scheme. At that time, when the CBS is distant from the user, the channel condition is attenuated and the performance is decreased. In the proposed scheme, the performance of the poor channel condition can be overcome via the relay. According to the use of the relay, the proposed scheme has the better bit error rate (BER) performance than the conventional scheme [12].

This paper is composed as follows. A system model is presented in Section II and the proposed scheme is explained in Section III. Simulation results are shown in Section IV and Section V states some conclusions.

II. System Model

The proposed scheme consists of broadcasting base station (BBS), CBS1, CBS2, relays and the destination user. In addition, CBS is located in the BBS communication coverage and the position of the destination user is the corner of CBSs. By using one antenna, the base stations communicate with users by cooperative scheme. In this paper, the relays which are located in the attenuation environment are used to improve the quality of the communication and obtain the diversity gain [4]. Because of the relay, the destination user receives the same signal additionally. Therefore, the received signals are guaranteed even if the condition of the channel between CBSs and user is poor. Also, the system of the proposed scheme uses both broadcasting and cellular system. The interworking system is basis system for proposed scheme and base station shares information with other base station. In this paper, two CBSs composed of CBS1 and CBS2 transport the signal to the destination user which is located in the CBSs cell edge [13]. However, the system has potential problems that the channel condition between the CBSs and the user is poor and the distance between CBSs and the user is distant. Then, the

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performance is deteriorated in this system model. The proposed scheme assumes that the channel condition between CBSs and the user is poor compared with the channel condition between the base station and the user [14].

The signal from the base station is transmitted by passing through the Rayleigh fading channel. This transmitted signal also suffers complex Gaussian random noise added by receiver. The received signal vector $\mathbf{Z}$ is expressed as,

$$\mathbf{Z} = \mathbf{HX} + \mathbf{n},$$

where $\mathbf{Z}$ is the complex matrix passing the channel, $\mathbf{X}$ is the matrix form of the transmitted OFDM symbols and $\mathbf{n}$ means the additive white Gaussian noise (AWGN) vector having zero mean and σ^2 variance.

III. Proposed Cooperative Scheme

In the conventional transmission scheme, the cooperative scheme is used for reliable transmission between CBSs and the user which is located in the cell edge of CBS1 and CBS2. The transmitted signal from the base station is not guaranteed well according to the path loss, if the receiver is far from the transmitter [15]. The reduced power of the transmitted signal is expressed as,

$$L_p(d) \propto \left(\frac{d}{d_{ref}} \right)^n ,$$

where the path loss L_p is related to the d which means the distance between transmitter and the receiver. Also, d_{ref} signifies the reference distance like the location from a base station and n is the space range. Through the upper equation, the distance between CBSs and the user has influence on the path loss in wireless communication. Therefore, the quality of the received signal is degraded and the conventional scheme can't reliable transmission if the distance between the transmitter and the receiver is distant. In the conventional scheme, the cooperative scheme is used between CBS1 and CBS2. However, the performance can be deteriorated if the channel condition between the user and CBSs is poor. In order to overcome this problem, the use of the extra relay is proposed.

For reliable communication, the proposed scheme suggests the extra relays in the attenuation channel influenced by the path loss. Such as the conventional scheme, the proposed scheme uses one BBS and two CBSs. In addition, it is supposed that the channel condition between both CBS1 and CBS2 and user is poor in this paper. But, in order to improve the performance of the transmission, the extra relays are used in the proposed scheme in the attenuation channel between CBSs and the user. Since the assumption of the proposed scheme is the use of the relay in the CBSs communicating with user, the proposed scheme can obtain reliable transmission. The signal which is transmitted from the base station can suffer the serious distortion, if the condition of the channel which CBSs communicate with the user is bad. Therefore, by using the extra relays in the attenuation environment, the quality of the signals which is received from CBS1 and CBS2 can be guaranteed in the proposed scheme. The proposed scheme can receive the more accurate signals than the conventional scheme because of the extra relay in the degraded environment. Since the relay selects the best channel condition, the distance between CBSs and the user is reduced in the proposed scheme even if the user is located in the cell edge of CBS1 and CBS2.

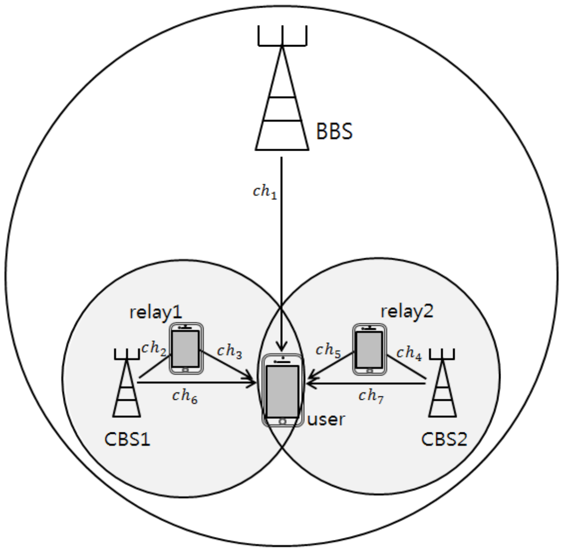

Fig. 1 Transmission model of the proposed scheme

The system model of the proposed scheme which uses the extra relay in the bad channel condition is shown in Fig. 1. In the proposed scheme, since the transmitted signals are passed through the BBS, CBS1 and CBS2 the destination user can receive the more reliable signal than the conventional scheme. The proposed scheme supposes that the received signals from CBS1 and CBS2 suffer the channel attenuation. Also, in order to obtain high performance in the attenuation environment, the channels between CBSs and the user located in the cell of the CBS1 and CBS2 use the relay [13].

TABLE I
Transmission System of the Proposed Scheme by Using the Extra Relays

Time Slot	Broadcasting Station	Cellular Station1	Cellular Station2
t	x_1	x_2	x_2
t+T	x_2	x_1	x_1

The cooperative transmission scheme is used in BBS, CBS1 and CBS2 according to Table I including two time slots presented in this paper. In the cooperative scheme, high reliable communication is provided by receiving several signals which are transmitted from the base station. Since the user receives the signals through the BBS, CBS1, CBS2 and extra relays, the proposed scheme can obtain the advantages of both diversity gain and multiplexing gain. The received signals are represented by the polynomial form as,

$$z_{t1} = x_1 ch_1 + x_2 ch_6 + x_2 ch_7,$$
$$z_{t2} = x_2 ch_1 + x_1 ch_3 + x_1 ch_5,$$

where z_{ti} is the i th time index signal which is received through BBS and CBSs without AWGN. Also, x_i expresses the signal of the i th time index and ch_i means the channel passed by the signals.

The signal x_i which is transmitted from the base station communicates with the destination user through the noise of the channel. Therefore, the use of the extra relays can improve the performance in terms of the received signal. The signal which is received in the destination user suffers the noise n_k that is formulated by the form of the matrix as,

$$\begin{bmatrix} z_{t1} \\ z_{t2} \end{bmatrix} = \begin{bmatrix} ch_1 & ch_6 + ch_7 \\ ch_3 + ch_5 & ch_1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix}.$$

The signals which are transmitted from CBS1 and CBS2 use the decode and forward (DF) process by the relay of the cooperative transmission scheme.

As a result, the destination user receives the signals from several routes and the minimum mean square error (MMSE) detects these signals [16]. The form of the MMSE matrix is represented as,

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

where $\mathbf{H}^H$ is a form the self-adjoint matrix that is composed of a complex square matrix with own conjugate transpose, $\mathbf{I}$ means a form of the unit matrix and σ^2 is noise variance.

IV. Simulation Results

In this section, simulation result indicates the better BER of the proposed scheme than the conventional scheme. It is supposed that the proposed scheme uses the extra relays in the attenuation environment and the base station communicates with CBS1 and CBS2 by sharing the base station channel information. Since the performance can be decreased in accordance with the channel condition between CBSs and the user, the proposed scheme using relays is proposed. The base station transmits the signals coded with the 1/2 code rate of a convolutional code and the signals pass through the interleaver which spreads the burst error. In addition, the signals from the base station are transmitted by modulating with 16 quadrature amplitude modulation (16QAM). The transmitted signals suffer the Rayleigh fading channel model with the 7 path length and the transmission power is distributed uniformly.

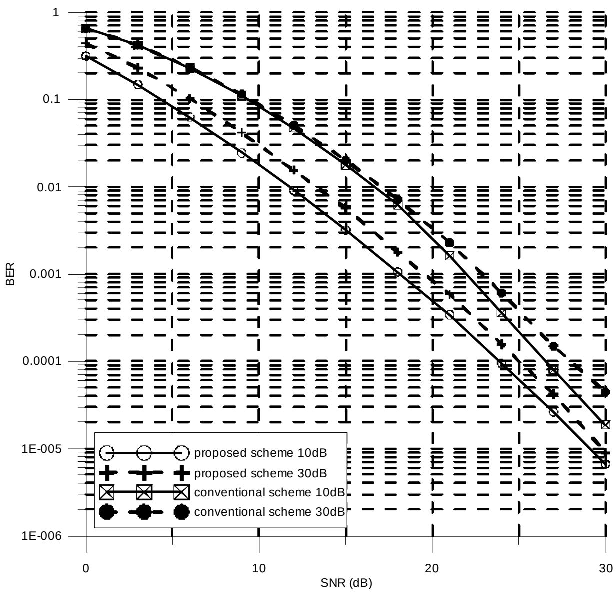

Fig. 2 BER performance of the conventional scheme and the proposed scheme in the degradation environment

Fig. 2 shows the BER of the proposed scheme and the conventional scheme. This simulation offers the equivalent environment to obtain accurate BER. In order to compare with each case, the proposed scheme sets two cases of 10 and 30 decibels that are the ratio of the signals according to the channel condition. Therefore, it is represented that the channel condition is attenuated if the measurement value of the decibel is high. In the case of the SNR with 30 decibel, the BER performance of the proposed scheme is about 10^{-5}. It means that the transmitted signal is received well and the quality of communication is guaranteed. Therefore, the proposed scheme is better than the conventional scheme, since the proposed scheme can achieve the high BER performance compared with the conventional scheme in the attenuation environment.

V. Conclusion

In order to achieve high performance in the poor channel condition, the use of the relay is proposed in this paper. The interworking system with an extra relays in the cell edge of CBSs can guarantee the quality of the communication. If the channel condition is bad and the path loss is large, the signal from the base station suffers the attenuation. Therefore, the use of the relay by the cooperative scheme is used for reliable communication in the proposed scheme. In the proposed scheme which achieves diversity gain, the BER performance and throughput are improved by using the extra relays of the good channel condition. The extra relays can reduce the distance between CBSs and the destination user by considering the degradation of the channel condition. The simulation results indicate the better performance of the proposed scheme than the conventional scheme. Therefore, the proposed scheme can obtain the high performance by using the relay in the attenuation environment although the channel condition between CBSs and the destination user is bad. As a result, when the channel condition is poor and the distance between CBSs and the destination user is distant, the proposed scheme is more effective transmission scheme in the cellular and broadcasting system.

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