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Adaptive CoMP with Spatial Phase Coding for Interference Mitigation in the Heterogeneous Network

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Abstract: This paper proposes an adaptive coordinated multi point (CoMP) scheme using pre-coding in order to improve the reliability of wireless communication systems based on orthogonal frequency division multiplexing (OFDM). In the conventional scheme, the received signal to noise ratio (SNR) of the mobile is degraded due to the interference signal. Therefore, the bit error rate (BER) performance is degraded, as is, the reliability of the system, due to inter-cell interference (ICI). Therefore, the BER performance of the system is reduced and the transmitter must perform unnecessary re-transmission. The proposed scheme uses the CoMP scheme to improve reliability in a heterogeneous network (HetNet) system. Additionally, the proposed scheme uses the constructive spatial phase coding (SPC) scheme to mitigate the received SNR reduction due to the interference signal. Therefore, the proposed scheme can prevent performance degradation caused by the interference signal. When a mobile is located in the cell edge, the transmission signal is distorted by the transmitted signal from the adjacent cell. The proposed scheme can reduce the SNR of the interference signal by using the destructive SPC scheme. Therefore, this scheme can improve the reliability of the system. The simulation results show that the BER performance of the proposed scheme is better than that of the conventional scheme. As a result, the proposed scheme improves the reliability of systems by adaptively applying the CoMP and SPC schemes.

Keywords: cell edge; CoMP; HetNet; interference mitigation; OFDM; pre-coding; SPC

1. Introduction

Nowadays, wireless communication systems require a high spectral efficiency and high reliability. The orthogonal frequency division multiplexing (OFDM) technique was developed, because it is one of the schemes which use frequency efficiently within a limited bandwidth [1–3]. The OFDM technique is robust to the multi-path fading [1]. Therefore, the OFDM technique has been widely applied to various wireless communication systems [2,3].

In the wireless communication systems, the amount of required traffic and data are increased. In order to satisfy needs, additional network nodes (or transmitting/receiving base station) must generally be built. The system in which the additional network nodes are constructed is the heterogeneous network (HetNet) system [4–6]. By increasing the number of cells, the traffic per unit area can be increased without increasing the amount of traffic that must be supported per cell. The HetNet system is generally composed of a small cell, new access technologies, and various transmission power schemes of the base station. Also, arrangement of the small cell, such as the pico and femto cell, has advantage of expanding the capacity and cell coverage in the HetNet systems [5]. There are many issues of research on the HetNet. The energy efficiency, analysis of cell coverage and interference mitigation are subjects of research on the HetNet. Trestian, et al. propose a mechanism that can save energy when multimedia data in HetNet small cell environment are transmitted [7]. An algorithm for cell planning in HetNet to find the optimal number of cell sites subject to QoS requirements was proposed in [8]. Dhillon, et al proposes a tractable heterogeneous cellular network model through the cell coverage analysis [9]. In addition, a power allocation scheme for minimizing energy consumption in heterogeneous networks is proposed in [10,11]. In other words, the energy efficiency and cell coverage analysis are very important issues in HetNet system. Furthermore, the interference mitigation is a very important topic. Therefore, this paper focuses on interference mitigation.

However, the HetNet system can cause complex ICI scenarios, which are an important part of the HetNet system. In this paper, two representative scenarios are considered. The first scenario is the ICI by the signals transmitted from other mobiles in adjacent cell. When the mobile is located at the cell edge, the ICI occurs due to the signal transmitted from other mobiles to the other base station in the adjacent cell. The second scenario is the ICI by the signals transmitted from the base station in the adjacent cell. When the mobile is located in the cell edge, the ICI occurs due to the signal transmitted the base station of the adjacent cell to the other mobile. In the first scenario, because the interference signal is transmitted by the mobile in the adjacent cell, the power of the interference signal is lower than the interference signal transmitted by the base station. However, in the second scenario, because the interference signal is transmitted by the base station in the adjacent cell, the interference signal has high power. Therefore, it greatly affects the performance of the HetNet system. Owing to complex ICI scenarios, the reception performance of the mobile is reduced and consequently the reliability of the wireless communication system is reduced [12,13]. This paper proposes a scheme to mitigate the interference signal transmitted from the base station among the interference scenarios of the HetNet system.

In order to solve complicated ICI scenarios, this paper proposes a CoMP scheme in which the base station cooperates adaptively according to the location of the mobile. The CoMP scheme is a communication technique in which the base stations in adjacent cells cooperate with each other. In the proposed CoMP scheme, the mobile transmits feedback information (including the position, channel state information (CSI), etc.) to all base stations in adjacent cells. Then, the base stations apply the pre-coding scheme to the signals to be transmitted by using the received feedback information. As a result, the CoMP scheme proposed in this paper can improve the diversity gain of the mobile by using the signal with pre-coding scheme applying the feedback information [14–16].

The pre-coding scheme used in the proposed CoMP scheme is SPC. The SPC scheme is one of the pre-coding schemes. The SPC changes the channel relationship between the base station and the mobiles by using the CSI [17]. And then, the channel coefficients are increased by constructive superposition. In addition, the SPC changes the relationship of channels to destructive superposition. When a mobile user is located in the cell edge, the ICI is caused by the other signals transmitted from neighboring base station. If the mobile suffers from a transmitted signal from adjacent base station, the received signals have a large error and the performance degradation. But the interference signals can be suppressed through the destructive SPC scheme [18,19]. The schemes for interference mitigation using the relays are proposed in [18,19]. If a relay is used, an error propagation is present, and several pre-coding schemes must be performed to mitigate the interference. However, this paper proposes an interference mitigation scheme by performing only pre-coding without using the relay.

This paper is organized as follows. Section 2 shows the system model of the proposed scheme. Section 3 describes the constructive and destructive SPC principle. Section 4 explains proposed scheme for the CoMP with pre-coding to improve the reliability of the HetNet system. Section 5 shows the simulation results by comparing the conventional and the proposed scheme. Finally, Section 6 presents our conclusion.

2. System Model

2.1. OFDM System Model

This section describes the OFDM system. We consider an OFDM system with N_a active subcarriers and N-point inverse fast Fourier transform (IFFT). The samples of baseband OFDM symbol in the time domain can be expressed as follows,

$$x_i[n] = \frac{1}{\sqrt{N}} \sum_{k=0}^{N_a-1} X_i[k] e^{j2\pi nk/N_a},\ n = 0, 1, \ldots, N_a - 1, \tag{1}$$

where the $X_i[k]$ is an M-ary phase shift keying (MPSK) or M-ary quadrature amplitude modulation (MQAM) modulated symbol. The received signal after passing the channel and removing the guard interval is as follows,

$$y_l[n] = \sum_{k=0}^{N-1} H[k] X_l[k] e^{j2\pi kn/N} + w[n], \tag{2}$$

where the $H[k]$ is the channel coefficient and the $w[n]$ is the additive white Gaussian noise (AWGN) with zero-mean [5].

2.2. HetNet System Model

This section describes the system model of this paper. Figure 1 shows the proposed HetNet system. This system consists of one macro cell and three pico cells. All pico cells are located in the macro cell. The base station in the macro cell has two transmit/receive antennas, the base station in the pico cell and mobile have one transmit/receive antenna. This system can form a virtual multiple input single output (MISO) system using other base station antenna in the adjacent cells.

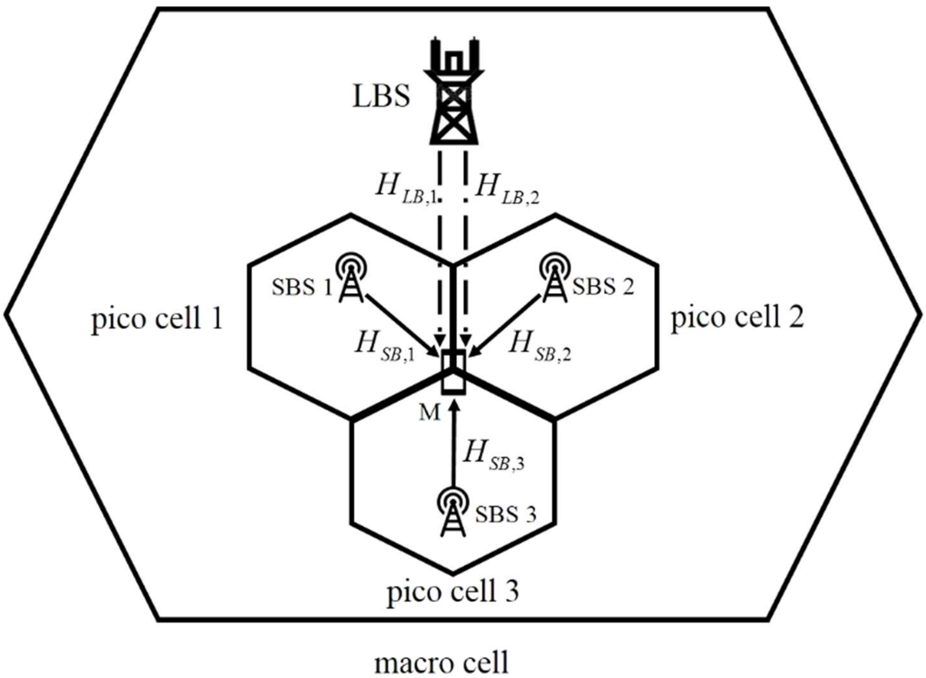

Figure 1. The system model for the proposed heterogeneous network.

In Figure 1, the LBS and SBS i ($i = 1, 2, 3$) represent the base stations in the macro and pico cells respectively. The $H_{LB,1}$ and $H_{LB,2}$ refer to the channel coefficients between the base station of the macro cell and mobile. The $H_{SB,1}$, $H_{SB,2}$ and $H_{SB,3}$ refer to the channel coefficients between the base station of the pico cells and mobile. The mobile transmits the channel state information (CSI) to the base stations. The CSI includes the position of the mobile and the phase information of the channel coefficient. The base stations modify the phase of the channel coefficient by applying the pre-coding scheme using the phase information of the channel coefficient included in the received CSI. Specifically, this paper uses the SPC scheme, which is one of the pre-coding techniques [17].

3. Spatial Phase Coding

This section explains the two types of the SPC scheme. The two types of the SPC scheme are described as the constructive and destructive. The constructive and destructive SPC schemey differ in the phase modification method and the pre-coding vectors used by these schemes. When the constructive SPC is applied, the magnitude of the superimposed channel coefficient is increased in the MISO system. Additionally, when the destructive SPC is applied, the magnitude of the superimposed channel coefficient is reduced in the MISO system. Therefore, the proposed CoMP scheme uses the constructive SPC to increase the SNR of the desired signal and the destructive SPC to reduce the SNR of the interference signal.

3.1. Constructive Spatial Phase Coding

This section describes the constructive SPC scheme. The transmitter uses the pre-coding vector to modify the phase of the channel coefficients. The pre-coding vector is determined by the phase relationship between the channel coefficients and depends on the feedback information. The receiver obtains feedback information through the channel estimation and transmits it to the transmitter. According to the number of feedback bits, the constructive SPC scheme is divided into constructive 1- and 2-bit feedback SPCs. The pre-coding vector C_1^S of the constructive 1-bit feedback SPC is as follows,

$$C_1^S = \left\{ \begin{array}{lll} 1, & 0 < |\alpha| \leq \pi/2 & \text{(State 1)} \\ e^{-j\pi}, & \pi/2 < |\alpha| \leq \pi & \text{(State 2)} \end{array} \right\}. \tag{3}$$

The α is the phase difference between the two channel coefficients. If the state of α is the State 1, the phase of the channel coefficient is not modified. On the other hand, if the state of α is the State 2, the phase of the channel coefficient is flipped by the C_1^S in this State 2 [17]. The pre-coding vector C_2^S of the constructive 2-bit feedback SPC is as follows,

$$C_2^S = \left\{ \begin{array}{ccc} 1, & \left(\begin{array}{c} 0 < |\alpha| \leq \pi/4 \\ 7\pi/4 < |\alpha| \leq 2\pi \end{array} \right) & \text{(State 1)} \\ e^{-j\pi/2}, & \pi/4 < |\alpha| \leq 3\pi/4 & \text{(State 2)} \\ e^{-j\pi}, & 3\pi/4 < |\alpha| \leq 5\pi/4 & \text{(State 3)} \\ e^{j\pi/2}, & 5\pi/4 < |\alpha| \leq 7\pi/4 & \text{(State 4)} \end{array} \right\}. \tag{4}$$

If the state of α is 1, the phase is not modified. On the other hand, if the state of α is not 1, the phase is modified to each state [20]. The transmitter multiplies the transmission signal by the pre-coding vectors C_1^S, C_2^S, and transmits the signal. Therefore, the phase of the channel coefficients experienced by the OFDM sub-carriers is selectively flipped. When the signals are transmitted by multiplying the pre-coding vectors C_1^S, C_2^S, the SNR of the received signal can be improved because the amplitude of the superimposed channel coefficient can be increased.

Figure 2 shows the constructive 1-bit and 2-bit feedback SPCs. The H_1 and H_2 refer to channel coefficients. The H_c refers to a superimposed channel coefficient that the constructive 1-bit or 2-bit feedback SPC is not applied. The $H_2 \cdot C_1^S$ and $H_2 \cdot C_2^S$ are the channel coefficients whose phase is modified by the pre-coding vectors. The H_S refers to the superimposed channel coefficient that the constructive 1-bit or 2-bit feedback SPC is applied. As shown in Figure 2, the H_S that the constructive SPC is applied is larger than the H_c that the constructive SPC is not applied [17]. So, the mobile can receive a signal having a high signal-to-noise ratio (SNR) when constructive SPC is applied. And, when the constructive 2-bit SPC scheme is applied, the magnitude of the superimposed channel coefficient can be effectively increased as compared with the constructive 1-bit SPC scheme. One of the pre-coding schemes that uses feedback information is the maximum ratio transmission (MRT) scheme [5]. The MRT scheme is an optimal pre-coding scheme which uses full feedback information. Although the scheme has a slightly better performance than the SPC, it has a very high implementation complexity. The pre-coding coefficient of MRT is as follows,

$$\mathbf{C}_n = \left(H_n^{(1)*}, H_n^{(2)*}, \ldots, H_n^{(m)*}\right)^T. \tag{5}$$

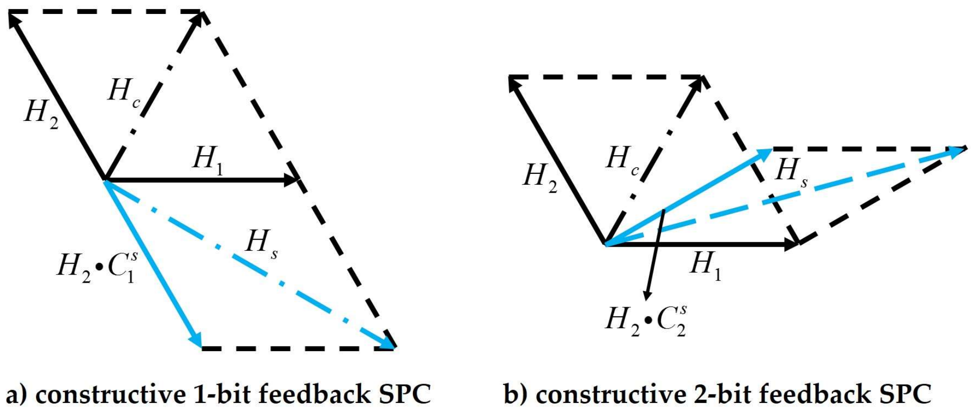

Figure 2. Constructive 1-bit and 2-bit feedback SPC.

The full channel information about $H_n^{(m)*}$ must be estimated at the receiver. Thus, the MRT requires the most complex estimation with highest overhead of all pre-coding schemes. Moreover, the MRT requires full feedback of amplitude and phase of each channel. Therefore, the MRT requires a large amount of feedback information [17].

As such, the proposed method uses the SPC scheme with simple implementation and high performance by using limited feedback information. In addition, the implementation complexity and performance of the constructive 2-bit SPC scheme are higher than those of the 1-bit SPC scheme and lower than those of the MRT scheme. Therefore, this paper uses the constructive 2-bit SPC scheme considering both implementation complexity and performance.

3.2. Destructive Spatial Phase Coding

This section describes the destructive SPC scheme. In the destructive SPC scheme, the two different channels are destructively superimposed. So, the magnitude of superimposed channel coefficient is decreased. The destructive SPC modifies the phase of the channel coefficient by using the pre-coding vector different from pre-coding vector of the constructive SPC. The pre-coding vectors C_1^d, C_2^d of the destructive 1-bit and 2-bit feedback SPC are as follows,

$$C_1^d = \left\{ \begin{array}{lll} e^{-j\pi}, & 0 < |\alpha| \le \pi/2 & \text{(State 1)} \\ 1, & \pi/2 < |\alpha| \le \pi & \text{(State 2)} \end{array} \right\}, \tag{6}$$

$$C_2^d = \left\{ \begin{array}{lll} e^{-j\pi}, & \begin{pmatrix} 0 < |\alpha| \le \pi/4 \\ 7\pi/4 < |\alpha| \le 2\pi \end{pmatrix} & \text{(State 1)} \\ e^{j\pi/2}, & \pi/4 < |\alpha| \le 3\pi/4 & \text{(State 2)} \\ 1, & 3\pi/4 < |\alpha| \le 5\pi/4 & \text{(State 3)} \\ e^{-j\pi/2}, & 5\pi/4 < |\alpha| \le 7\pi/4 & \text{(State 4)} \end{array} \right\}. \tag{7}$$

Figure 3 shows the destructive 1-bit and 2-bit SPCs. The transmitter multiplies the transmission signal by the pre-coding vectors C_1^d, C_2^d, and then transmits the signal. When the signals are transmitted by multiplying the pre-coding vectors C_1^d, C_2^d, the SNR of the received signal can be decreased because the amplitude of the superimposed channel coefficient can be decreased [18,19]. Therefore, the destructive SPC scheme can reduce the magnitude of the superimposed channel coefficient and the SNR of the interference signals. The MRT scheme using full feedback information can remove the phase of the channel experienced by the interference signal. Therefore, the distortion of the received signal due to the interference signal can be significantly reduced. As described above, the MRT scheme uses the full feedback information, and the implementation complexity is very high. This paper uses the destructive SPC scheme which uses a small number of feedback information and can efficiently mitigate the interference signal. Additionally, the destructive 2-bit feedback SPC can reduce the superimposed channel coefficient H_s^d more efficiently than the destructive 1-bit feedback SPC [18,19]. Therefore, this paper focuses upon the destructive 2-bit feedback SPC scheme.

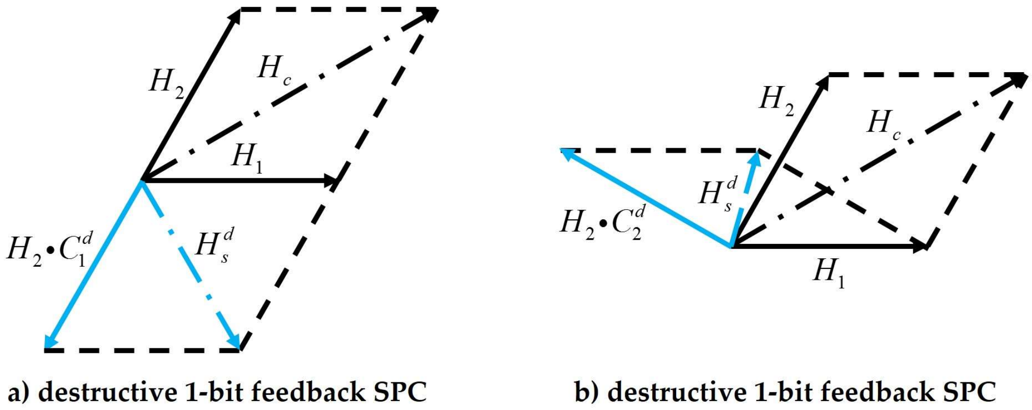

Figure 3. Destructive 1-bit and 2-bit feedback SPC.

4. Proposed Scheme

In this section, the CoMP scheme using the SPC in base station is introduced for the HetNet system. In the CoMP scheme proposed in this paper, all base stations in the cells transmit signals by applying the constructive and destructive SPC adaptively according to the location of the mobile. There are three cases according to the location of the mobile. In case 1, location of the mobile is the center of the pico cell 1. In case 2, location of the mobile is between the pico cells 1 and 2. Finally, in case 3, the mobile is located among the three pico cells. Figures 4–6 show cases 1, 2 and 3 respectively.

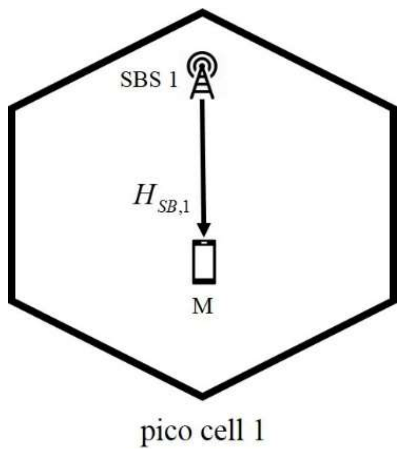

Figure 4. The case 1 of the proposed scenario.

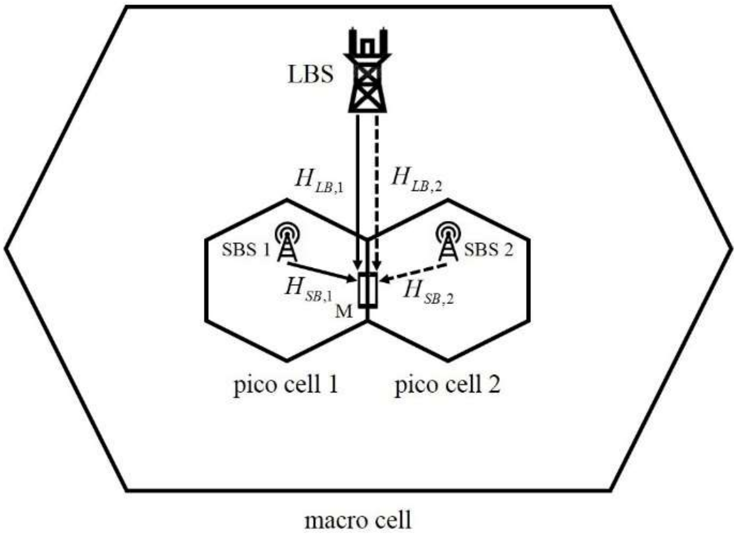

Figure 5. Case 2 in the proposed scenario.

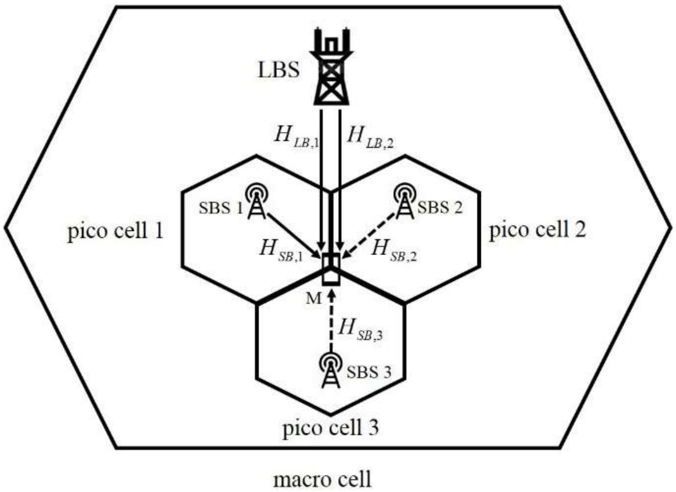

Figure 6. Case 3 in the proposed scenario.

Case 1: Figure 4 shows case 1, in which the mobile is located in the center of the pico cell. In this case, the base station transmits the signal to the mobile through the conventional communications system. The base station transmits the signal to the mobile by using the single input single output (SISO) OFDM technique. The mobile receives one signal transmitted from the base station, as follows,

$$Y_{Case\,1} = H_{SB,1}S_1 + N. \tag{8}$$

The $H_{SB,1}$ is the channel coefficient between the base station of the pico cell 1 and the mobile, S_1 is the transmitted OFDM symbol, and N is the AWGN.

Case 2: Figure 5 shows case 2, in which that the mobile is located between the pico cells 1 2. When the mobile is located between the the two cells, it receives a signal which is distorted by the interference signal transmitted from the base station of the pico cell 2. The received signal is as follows,

$$Y_{ICI,1} = \underbrace{H_{SB,1}S_1}_{a1} + \underbrace{H_{SB,2}S_2}_{b1} + N. \tag{9}$$

S_2 is the signal transmitted from the base station of pico cell 2. $H_{SB,2}$ is the channel coefficient between the base station of the pico cell 2 and the mobile. $a1$ refers to the desired signal. Because $b1$ is not a desired signal, it is regarded as noise by the mobile. The Equation (9) describes a received signal when the mobile is located within the intersection of two pico cells. When the number of the pico cells is increased, the received signal is as follows,

$$Y_{ICI,1} = \underbrace{H_{SB,1}S_1}_{a1} + \underbrace{\left[\sum_{i=1}^{N} H_{SB,i}\right] \cdot S_2}_{b1} + N. \tag{10}$$

In Equation (10), i means the index of the pico cell and N denotes the number of the pico cells.

In case 2, the proposed CoMP scheme forms the virtual MISO system in cooperation with the base station of the macro cell for improving diversity gain of the mobile and interference mitigation. One of the base station antennas of the macro cell transmits the signal using the constructive 2-bit feedback SPC scheme, in order to improve the diversity gain of the mobile by raising the SNR of the desired signal. Additionally, the other antenna transmits the signal with the destructive 2-bit feedback SPC scheme in order to mitigate the effects of interference by reducing the SNR of the interference signal. After the constructive and destructive SPC scheme are applied, the received signal is as follows,

$$\begin{aligned} Y_{Case2} &= H_{SB,1}S_1 + H_{LB,1} \cdot C_2^s S_1 + H_{SB,2}S_2 + H_{LB,2} \cdot C_2^d S_2 + N \\ &= \underbrace{(H_{SB,1} + H_{LB,1} \cdot C_2^s)S_1}_{a2} + \underbrace{\left(H_{SB,2} + H_{LB,2} \cdot C_2^d\right)S_2}_{b2} + N. \end{aligned} \tag{11}$$

In this case, the pre-coding vectors of C_2^s and C_2^d facilitate that the channel coefficient is either constructively and destructively superimposed, respectively. $a2$ can be larger than $a1$ and $b2$ can be smaller than $b1$. Therefore, the SNR of the desired signal is increased, and the SNR of the interference signal is reduced. As such, the diversity gain of the mobile is improved and interference is mitigated. When the number of pico cells and base station antennas in the macro cell is increased, the received signal is as follows,

$$Y_{Case2} = \underbrace{\left(H_{SB,1} + \sum_{k=1}^{M}\left[H_{LB,k} \cdot C_2^S\right]\right) \cdot S_1}_{a2} + \underbrace{\left(\sum_{i=2}^{N}\left[H_{SB,i} + H_{LB,i} \cdot C_2^d\right]\right) \cdot S_2}_{b2} + N. \tag{12}$$

In Equation (12), the k means the index of the base station antenna in the macro cell.

Case 3: Figure 6 shows the case 3 that the mobile located within the intersection of three pico cells. When the mobile is located within the intersection of the three pico cells, the mobile receives the signal distorted by the interference signal transmitted from the base station of the pico cell 2 and pico cell 3. The received signal is as follows,

$$\begin{aligned} Y_{ICI,2} &= H_{SB,1}S_1 + H_{SB,2}S_2 + H_{SB,3}S_2 + N \\ &= \underbrace{H_{SB,1}S_1}_{a3} + \underbrace{(H_{SB,2} + H_{SB,3})S_2}_{b3} + N. \end{aligned} \tag{13}$$

The S_2 is the interference signal transmitted from the base station of pico cells 2 and 3. $H_{SB,3}$ is the channel coefficient between the base station of the pico cell 3 and the mobile. $a3$ denotes the desired signal. Because $b3$ is not a desired signal, it is regarded as noise by the mobile. When the number of the pico cells is increased, the received signal is as follows,

$$Y_{ICI,2} = \underbrace{H_{SB,1}S_1}_{a3} + \underbrace{\left[\sum_{i=2}^{N} H_{SB,i}\right]\cdot S_2}_{b3} + N. \quad (14)$$

In case 3, the proposed CoMP scheme forms the virtual MISO system in cooperation with the base stations of the macro cell for improving diversity gain of the mobile. The base station of the macro cell transmits the signal with the constructive 2-bit feedback SPC scheme, in order to improve the diversity gain of the mobile by raising the SNR of the desired signal. Additionally, the base stations of pico cells 2 and 3 transmit the signal with the destructive 2-bit feedback SPC scheme in order to mitigate the effect of the interference, by reducing the SNR of the interference signal. After the constructive and destructive SPC scheme are applied, the received signal is as follows,

$$\begin{aligned} Y_{Case3} &= H_{SB,1}S_1 + H_{LB,1}\cdot C_2^s S_1 + H_{LB,2}\cdot C_2^s S_1 + H_{SB,2}S_2 + H_{SB,3}\cdot C_2^d S_2 + N \\ &= \underbrace{(H_{SB,1} + H_{LB,1}\cdot C_2^s + H_{LB,2}\cdot C_2^s)S_1}_{a4} + \underbrace{\left(H_{SB,2} + H_{SB,3}\cdot C_2^d\right)S_2}_{b4} + N. \end{aligned} \quad (15)$$

In this case, the pre-coding vectors C_2^s and C_2^d facilitate that the signal is constructively and destructively superimposed respectively. $a4$ can be larger than $a3$ and $b4$ can be smaller than $b3$. Therefore, the SNR of the desired signal is increased, and the SNR of the interference signal is reduced. When the number of pico cells and base station antennas in the macro cell is increased, the received signal is as follows,

$$Y_{Case3} = \underbrace{\left(H_{SB,1} + \sum_{k=1}^{M}\left[H_{LB,k}\cdot C_2^S\right]\right)\cdot S_1}_{a4} + \underbrace{\left(H_{SB,2} + \sum_{i=3}^{N}\left[H_{SB,i}\cdot C_2^d\right]\right)\cdot S_2}_{b4} + N. \quad (16)$$

Also, the schemes in [18,19] mitigate the interference but exhibit several disadvantages. These schemes use the relay; as such, a complicated relay selection scheme is needed. Because the schemes apply the pre-coding not only to the base station but also to the relay, a large number of feedback bits are required. The schemes in [18,19] can mitigate the interference only when the channel conditions between the base station and relay are good. Additionally, the interference mitigation methods of [18,19] can reduce the transmission rate due to the use of the relay, but the interference mitigation scheme proposed in this paper cannot reduce the transmission rate. As a result, the proposed CoMP scheme can increase the diversity gain of the mobile, without reducing the transmission rate, and can efficiently mitigate interference.

The proposed CoMP scheme uses constructive and destructive SPC schemes adaptively, according to the location of the mobile. This CoMP scheme improves the diversity gain of the mobile by increasing the SNR of the desired signal through the constructive 2-bit feedback SPC scheme. Additionally, when the mobile is located in the cell edge and is affected by the interference, the effect of the interference is mitigated by reducing the SNR of the interference signal using the destructive 2-bit feedback SPC scheme. Therefore, the proposed CoMP scheme improves the reliability of the HetNet system by improving the reception performance of the mobile.

5. Simulation Results

In this section, 2-bit feedback SPC is compared to 1-bit feedback SPC. The proposed CoMP scheme is compared to the conventional scheme. The simulation results are based on the OFDM system. The simulation parameters are as follows: the number of carriers is 256 and the length of the cyclic prefix (CP) is 64. The modulation order is quadrature phase shift keying (QPSK). All channels are the Rayleigh fading channels of 7-multi paths. The conventional coding is applied with the code rate of 1/2 and constraint length of 3. The path loss is applied to the signal according to distance between the base station and mobile [5]. Figure 7 shows the BER performance of the constructive SPC and MRT (full-bit SPC) scheme. The constructive 2-bit SPC scheme has higher BER performance than the constructive 1-bit SPC scheme in all SNR environments. In addition, the constructive 2-bit SPC scheme achieves a BER performance similar to that of the MRT scheme with only 2-bit feedback information. Therefore, the proposed CoMP scheme uses the constructive 2-bit SPC scheme to improve the diversity gain of the mobile and reduce implementation complexity.

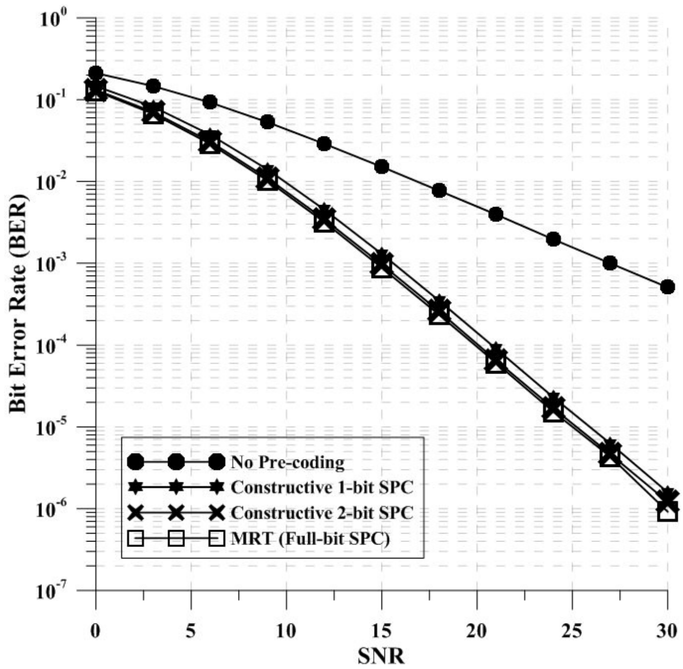

Figure 7. BER performance of the constructive SPC and MRT schemes.

Figure 8 shows the BER performance when the interference is mitigated by the destructive SPC and MRT (full-bit SPC) schemes. The destructive 2-bit SPC scheme mitigates interference better than the 1-bit destructive SPC scheme. And, the destructive 2-bit SPC scheme has lower performance than the MRT scheme. However, in the MRT scheme, the implementation complexity is high because all feedback information on the channel phase experienced by the interference signal is used. Therefore, the proposed CoMP scheme uses the destructive 2-bit SPC scheme to mitigate the interference signal.

Figure 9 shows the BER performance of the proposed and conventional schemes. In this figure, −3, −6 and −12 dB mean the power in proportion to ICI compared with the signal power. The conventional system refers to the system without interference mitigation, and the conventional scheme refers to the scheme proposed in [18,19]. When the mobile is located between two adjacent pico cells (case 2), the proposed and conventional schemes improve the diversity gain and mitigate the interference by applying the constructive and destructive SPC schemes. However, because the conventional schemes use a relay base station or relay mobile, system performance is reduced by propagating errors to the receiver. The proposed scheme does not use a relay base station or relay mobile and the pre-coding is applied directly in the base station in the pico cell, so there is no performance degradation due to error propagation.

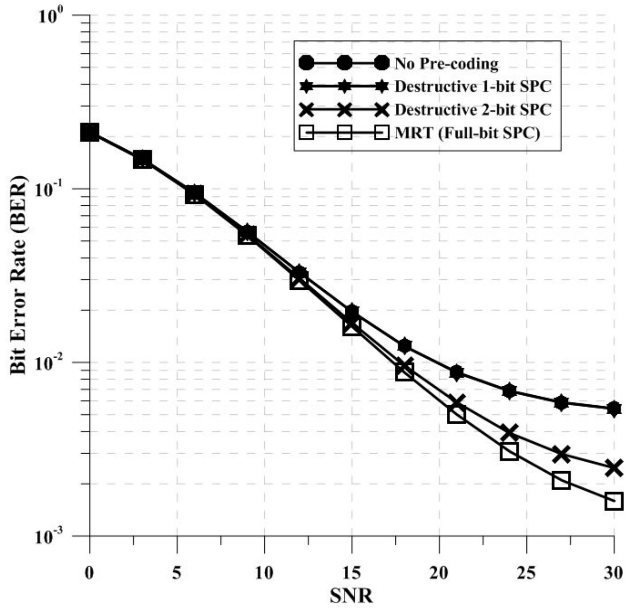

Figure 8. BER performance of the destructive SPC and MRT schemes.

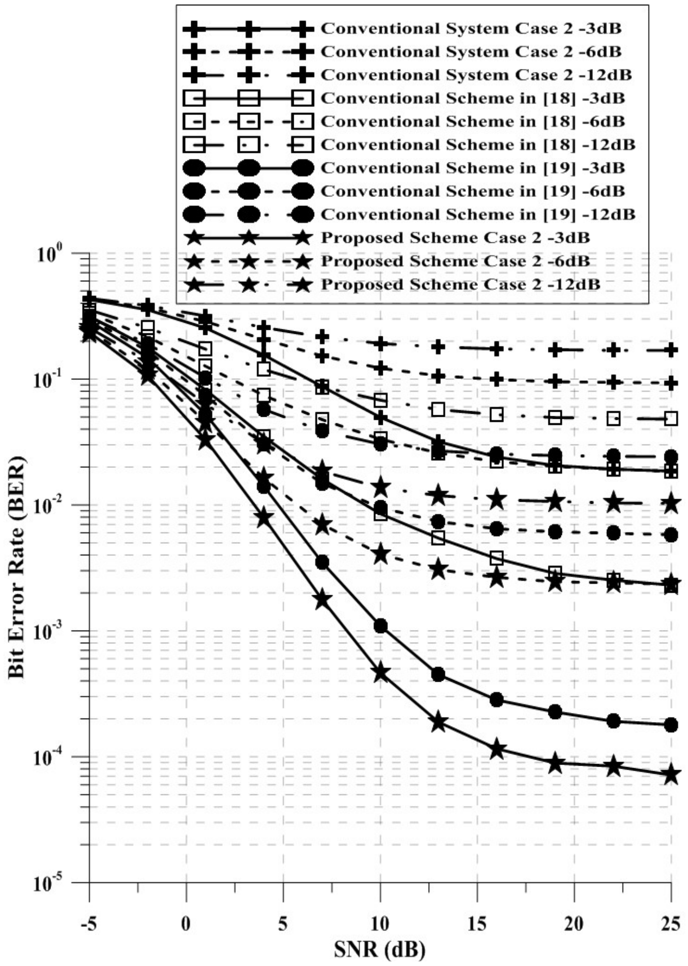

Figure 9. BER performance of the proposed and conventional schemes according to the mobile's location.

In case of the conventional system case 2, the BER 10^{-2} is not satisfied in all SNR environments regardless of the ratio of interference signal to the desired signal. In the conventional scheme in [18], when the interference signal has the lowest power, it satisfies BER 10^{-2} at approximately SNR 9 dB. However, the remaining case of the conventional scheme in [19] does not satisfy the BER performance in all SNR environments. On the other hand, the proposed scheme satisfies BER 10^{-2} at approximately 3, 7 and 18 dBs. Therefore, the proposed scheme has better BER performance than the conventional schemes.

Figure 10 shows the BER performance when there are no interference signals (case 1) and the mobile is located between three pico cells (case 3). In case 1, because there are no interference signals, the proposed scheme has the same BER performance as that of conventional systems. In case 3, because the interference signal is transmitted from the other two base stations, the conventional scheme has low BER performance. The proposed scheme applies both constructive and destructive SPC schemes, to improve the diversity gain of the mobile, and to mitigate interference signals. Case 2 in the conventional scheme does not satisfy the BER 10^{-2} in all SNR environments. On the other hand, the proposed scheme increases the SNR of the desired signal and mitigates the interference through pre-coding scheme. So, the proposed scheme satisfies high BER performance in a low SNR environment. As a result, the proposed scheme can improve the performance and reliability of the HetNet systems by effectively mitigating interference signals even if the mobile is located between three adjacent pico cells.

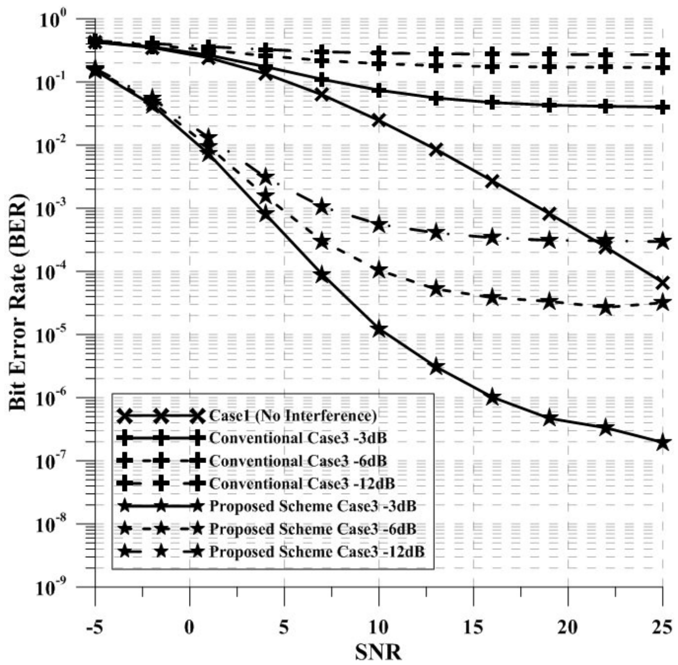

Figure 10. BER performance of the proposed scheme and conventional system according to the mobile's location.

As shown in the simulation results, the proposed scheme has higher BER performance than the conventional scheme. The proposed scheme can effectively mitigate the interference by using the pre-coding in the HetNet system without the relay base station or relay mobile. As a result, the proposed scheme can improve the performance and reliability of the HetNet system.

6. Conclusions

This paper proposes the CoMP scheme with the pre-coding scheme in order to improve reliability and mitigate the interference in the HetNet system based on OFDM. The proposed CoMP scheme improves diversity gain, and mitigates the interference signal by adaptively using the constructive and destructive SPC scheme according to the mobile's location. Therefore, the SNR of the desired signal is increased, and the SNR of the interference signal is reduced, thereby the reception performance of the mobile is improved. In addition, because the proposed CoMP scheme does not use a relay, interference can be mitigated without additional transmission rate reduction, security problems, or error propagations. However, in order to mitigate interference, the proposed scheme requires pre-coding vectors according to the channel relationship between mobile and base station.

Several topics serve as background research for the HetNet system. Such research includes energy efficiency and optimization issues. Energy-efficiency for real-time vehicular cloud services, allocation of virtual elements (VEs) for minimizing the energy consumption and routing algorithm for energy-limited heterogeneous fog-supported wireless sensor networks are proposed in [21–23] respectively. The analysis of robust optimization under multi-band uncertainty is included in [24]. In addition, [25] proposes a hybrid system based on genetic neural computing (GNC). Because the GNC is a hot topic, it can be considered as a research issue of the HetNet system. Therefore, we plan to study more efficient interference mitigation schemes through the joint transmission (JT) scheme—which is one of the CoMP types—, beamforming scheme, and power allocation for energy efficiency. The simulation results show that the BER performance of the proposed scheme is better than that of conventional schemes. As a result, the proposed CoMP scheme can improve the reliability of the HetNet system.

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