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Cooperative Scheme Using Adjacent Base Stations in Wireless Communication

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Abstract—In a wireless communication system, the failure of base station can result in a communication disruption in the cell. This paper proposes a way to deal with the failure of base station in a wireless communication system based on OFDM. Cooperative communication of the adjacent base stations can be a solution of the problem. High performance is obtained by the configuration of transmission signals which is applied CDD scheme in the cooperative communication. The Cooperative scheme can be a effective solution in case of the particular situation.

Keywords—Base station, CDD, OFDM, Diversity gain, MIMO.

I. Introduction

THE MIMO-OFDM system provides diversity gain. OFDM is a multi-carrier modulation technique where data symbols modulate a parallel collection of regularly spaced the sub-carrier. The sub-carrier has the minimum frequency separation to maintain orthogonality. OFDM is commonly used for high data rate in wireless communication and has been used in various wireless communication systems. The orthogonal frequency division multiplexing (OFDM can be extended to a multiple input multiple output (MIMO) system in order to obtain high performance. The MIMO-OFDM system obtains the high data rate or the high reliability without the use of additional bandwidth and power consumption in wireless communication. Therefore, MIMO-OFDM system has been widely used in wireless communication system [1]. However, the use of the multiple antennas has the problems for the limited size, high cost and hardware limitations. In order to overcome these problems, the cooperative communication has recently been researched. The cooperative communication scheme can provide the high reliability by using the transmit diversity schemes in MIMO system. The cooperative communication has been considered as an alternative way to achieve spatial diversity in case the terminals can not use the multiple antennas. Therefore, the cooperative communication can provide the high performance by using only the minimum antennas in wireless communication One of the typical MIMO multiplexing schemes is vertical Bell laboratories layered space time (V-BLAST). The V-BLAST is an effective MIMO-OFDM system which provides spatial multiplexing gain and reception diversity gain. For this reason, a lot of detection algorithms compared with V-BLAST have been proposed for the MIMO-OFDM systems. Among those detection algorithms for V-BLAST, the linear detection schemes are popular way to detect the received signals with low complexity. However, the linear detection schemes have the worse performance among MIMO detection schemes for noise enhancement. The ordered successive interference cancellation (OSIC) and the decision feedback equalization (DFE) detection scheme has better performance than linear detection. Because the detection of the first signal determines the overall system performance, the accurate detection of the first signal is very important to obtain high performance in DFE scheme [2]-[4]. In this paper, an efficient DFE using a cyclic delay diversity (CDD) scheme is proposed in the MIMO-OFDM system. The proposed scheme obtains high performance by the accurate detection of the first signal. In this paper, a cooperative scheme between adjacent base stations is proposed in the MIMO-OFDM system. The proposed scheme is an alternative to cope with communication disruption in the cell where a problem occurs at particular base station [5], [6].

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II. System Model

Fundamentally, each of the base stations is connected to the backbone network. The system model can be divided into two cases. In both cases, the base station has four antennas and the MS has two antennas. Also, the received signals are estimated at the MS by DFE detection scheme. The one is a conventional transmission system that works without any problem in the all cell. Fig. 1 shows the conventional transmission system. The conventional transmission system has 4x2 MIMO-OFDM system. The other is a cooperative transmission system to be applied when a problem occurs in a particular base station. The proposed cooperative transmission system is presented in Fig. 2. Adjacent base stations which are in the cell 1 and cell 3 are switched to cooperation mode in case that a problem occurs in the base station. Each of adjacent base stations uses two antennas among their four antennas for cooperation mode. And the adjacent base stations communicate 2x2 MIMO-OFDM system with the MS in the cell 1 and cell 3 by using the remaining two antennas. In the cell 2 where a problem occurs, the communication can be available by the proposed cooperative system using the antennas of the adjacent base stations.

III. DFE Scheme of V-BLAST System

V-BLAST is used to detect the multiple received signals in the MIMO-OFDM system. In V-BLAST with the DFE scheme, the multiple received signals are detected by sequential detection scheme using QR decomposition.

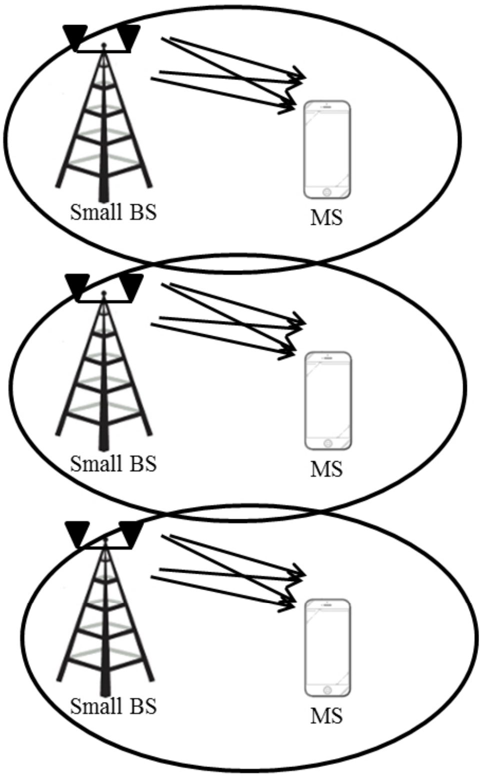

Fig. 1 Conventional transmission system

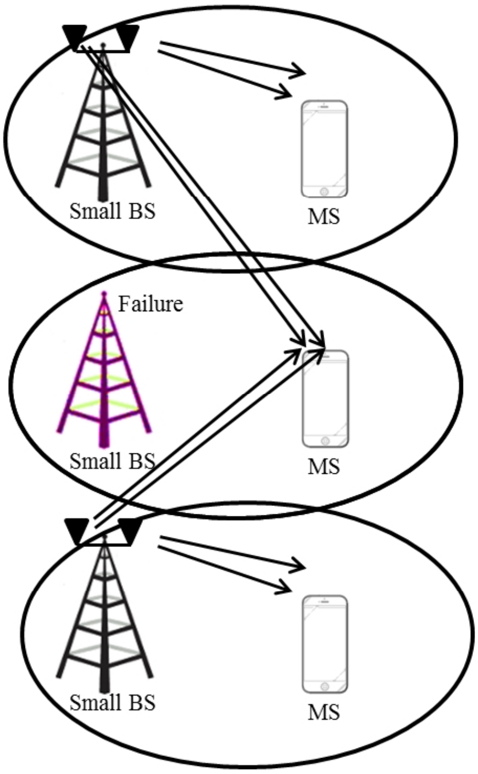

Fig. 2 Proposed cooperative transmission system

Detection method is as:

$$\mathbf{G}_{\text{MMSE}} = (\mathbf{H}^H\mathbf{H} + \sigma^2\mathbf{I}_M)^{-1}\mathbf{H}^H. \tag{1}$$

The minimum mean square error (MMSE) detector leads to the filter G matrix, where I_M is $M \times M$ identity matrix. So, the channel matrix $\underline{\mathbf{H}}$ is can be expressed as:

$$\underline{\mathbf{H}} = \begin{bmatrix} \mathbf{H} \\ \sigma\mathbf{I}_M \end{bmatrix}. \tag{2}$$

The DFE scheme which is based on QR decomposition avoids the calculation of the pseudo-inverse matrix in every layer. In this QR decomposition, $||\mathbf{G}||^2$ is calculated and sorted from the smallest to the largest value. $\mathbf{H}_{sort}$ is also made by the way that the columns of channel coefficient $\mathbf{H}$ is sorted equally with $||\mathbf{G}||^2$. Sorted $\mathbf{H}_{sort}$ is decomposed to Q and R through QR decomposition.

$$\mathbf{G}_{\text{MMSE}} = (\underline{\mathbf{H}}^H\underline{\mathbf{H}}^{-1})\underline{\mathbf{H}}^H. \tag{3}$$

The matrix $\mathbf{Q}$ is an orthogonal matrix satisfied with $\mathbf{Q}^H\mathbf{Q} = \mathbf{I}$ and $\mathbf{R}$ is an upper triangular matrix. $M \times 1$ vector that $\mathbf{Q}$ ingredient is removed can be gained by using $\mathbf{Q}^H$,

$$\mathbf{Z} = \mathbf{Q}^H\mathbf{Y} = \mathbf{R}\mathbf{X} + \eta, \tag{4}$$

$$\begin{bmatrix} z_1 \\ z_2 \\ \vdots \\ z_M \end{bmatrix} = \begin{bmatrix} r_{1,1} & r_{1,2} \cdots & r_{1,M} \\ 0 & r_{2,2} \cdots & r_{2,M} \\ \vdots & \vdots \quad \ddots & \vdots \\ 0 & 0 \quad \cdots & r_{M,M} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_M \end{bmatrix} + \begin{bmatrix} \eta_1 \\ \eta_2 \\ \vdots \\ \eta_M \end{bmatrix}, \tag{5}$$

where $\mathbf{Z} = [z_1 z_2 \ldots z_M]^T$ and $\eta = \mathbf{Q}^H\mathbf{W}$. Based on such matrix, the first detected signal is expressed by removing channel ingredient of signal which would be first detected,

$$\hat{X}_M = Q[Z_M / r_{M,M}] = Q[(r_{M,M}X_M + \eta_M)/r_{M,M}]. \tag{6}$$

After the first detection step, extra signals can be detected as:

$$\begin{gathered} \hat{X}_{M-1} = Q[Z_{M-1} - r_{M-1,M} \cdot \hat{X}_M \big/ r_{M-1,M-1}] \\ \hat{X}_{M-2} = Q[\{Z_{M-2} - (r_{M-2,M} \cdot \hat{X}_M + r_{M-2,M-1} \cdot \hat{X}_{M-1})\} \big/ r_{M-2,M-2}] \\ \vdots \\ \hat{X}_m = Q[(Z_m - \sum_{i=m-1}^{M} r_{m,i} \cdot \hat{X}_i) \big/ r_{m,m}] \\ \vdots \\ \hat{X}_1 = Q[(Z_m - \sum_{i=m-1}^{M} r_{1,i} \cdot \hat{X}_i) \big/ r_{1,1}]. \end{gathered} \tag{7}$$

The DFE scheme sequentially detects signals. The first detected signal affects generally from next detected signal to the final detected signal. Also, the DFE scheme is not necessary to calculate the inverse matrix of the channel repeatedly. Therefore, the DFE scheme based on the QR decomposition has characteristic that complexity is very low.

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TABLE I
PROPOSED CONFIGURATION OF TRANSMISSION SIGNAL

Time slot	BS 1	BS 2		BS 3
	$Tx\,1$	$Tx\,1$	$Tx\,3$	$Tx\,1$
$T=1$	S_1	-	-	$S_{1,\delta}$
$T=2$	S_2	-	-	$S_{2,\delta}$
$T=3$	S_3	-	-	$S_{3,\delta}$
⋮	⋮	-	-	⋮
$T=n$	S_4	-	-	$S_{4,\delta}$

IV. PROPOSED HYBRID DETECTION SCHEME

This paper proposes a cooperative scheme for dealing with a failure occurring in the base station. The purpose of the proposed scheme is to maintain communication environment in the cell by using the cooperation of the adjacent base stations. The proposed scheme can be expressed as cooperative scheme which obtains diversity gain. Also, the proposed scheme takes advantage of the DFE characteristic that the accurate detection of the first signal affects the overall system performance. By using a particular configuration of the transmission signals from the adjacent base stations, the communication environment is maintained more reliably in the cell where the problem occurs.

The proposed configuration of transmission signals uses the cyclic delay diversity (CDD) scheme in order to obtain the improved diversity gain. The proposed configuration of transmission signals applying the CDD scheme is presented in Table I. Table I shows only the antennas used for the cooperation mode. In each time slot, the signal is transmitted by Tx_1 from adjacent base stations. S_n is transmitted from BS 1 to MS which is in the cell 2. Also, S_{n,δ_1} is transmitted from BS 3 to the MS. In this case, the signals applying the CDD scheme provides a diversity gain to the MS as a diversity node. In the CDD scheme, the cyclically delayed symbols give only an effect on the destination as multi-path. δ_l is defined as the cyclic delay length of the l-th antenna in BS 3. The optimal cyclic delay can be obtained as,

$$\Delta_{opt}^{\mathrm{A}} = \frac{M}{|\mathrm{A}|} \tag{8}$$

where A is the cardinal number of the modulation alphabet and M is the number of carriers [4]. This means that the difference of both shifts is determined from specific modulation.

The received signals at the MS are shown in Table II. $G_{1,i}$ and $H_{1,i}$ are the channels that connect the signals from BS 1 to the i-th antenna of the MS. Also, $H_{2,i}$ and $H_{3,i}$ denote the channels that connect the signals from the BS 3 to the i-th antenna of the MS. The noise at the i-th antenna of the destination at time n is represented by $N_{n,i}$. The received symbols in the frequency domain are expressed as,

$$Y_{n,i} = S_{n-1}H_{1,i} + S_{n-1,\delta_1}H_{2,i} + N_{n,i}, \tag{9}$$

The non-delayed signal and the CDD signal in the frequency domain are expressed as,

$$s(n) = \frac{1}{\sqrt{M}} \cdot \sum_{k=0}^{M-1} S(k) \cdot e^{j\frac{2\pi}{M}kn}, \tag{10}$$

$$s_{\delta_{cyc}}(n) = \frac{1}{\sqrt{M}} \cdot \sum_{k=0}^{M-1} e^{-j\frac{2\pi}{M}k\cdot\delta_{cyc}} \cdot S(k) \cdot e^{j\frac{2\pi}{M}kn}, \tag{11}$$

where M denotes the number of carriers. As mentioned earlier, the cyclically delayed symbols give only an effect on the destination as multi-path. Therefore, (8) can be expressed as,

$$Y_{n,i} = S_{n-1}(H_{1,i} + H_{2,i} \cdot e^{-j\frac{2\pi}{M}k\cdot\delta_1}) + N_{n,i}, \tag{12}$$

The received symbols in the frequency domain are expressed again as,

$$Y_{n,i} = S_{n-1}H_i + N_{n,1}, \tag{13}$$

where H_i are the channels under the influence of the two paths from the CDD scheme. In this system, the received signals are detected by DFE detection scheme. The accurate detection of the first signal affects the overall system performance. The proposed scheme is intended to strengthen the DFE properties by using CDD scheme. H_1 is the largest columns of channel coefficient. Therefore, S_{n-1} is detected as the first detected signal. And next time, S_n is detected. The system obtains diversity gain by using the proposed scheme. As a result, the proposed scheme provides a reliable communication in the cell 2 where the problem occurs.

V. SIMULATION RESULTS AND DISCUSSIONS

In this section, the BER performance of the proposed scheme is evaluated. In this simulation, the number of carriers is 256 and the cyclic prefix (CP) length is 64. The channel model is a Rayleigh fading channel model and the number of channel paths is 7. The cyclic delay length δ_1 is considered to 64. The convolutional coding is applied with the constraint length of 3 and the code rate of $\frac{1}{2}$. The proposed scheme has the simulation result in case of cooperative scheme using adjacent base stations. And the comparison subject is the conventional system which has any problems. In Fig. 3, The proposed cooperation scheme doesn't reach the performance of the conventional scheme. However, the proposed cooperation scheme obtains a relatively good performance by strengthening the DFE properties through CDD scheme. According to the simulation results, the proposed scheme can obtain the improved BER performance effectively.

TABLE II
THE RECEIVED SIGNALS AT THE MS

Time slot	MS	
	$Tx\,1$	$Tx\,2$
$T=1$	0	0
$T=2$	$Y_{2,1}=S_1H_{1,1}$ $+S_{1,\delta_1}H_{2,1}+N$	$Y_{2,2}=S_1H_{1,2}$ $+S_{2,\delta_1}H_{2,2}+N$
$T=3$	$Y_{3,1}=S_2H_{1,1}$ $+S_{2,\delta_1}H_{2,1}+N$	$Y_{3,2}=S_2H_{1,2}$ $+S_{2,\delta_1}H_{2,2}+N$
⋮	⋮	⋮
$T=n$	$Y_{n,1}=S_{n-1}H_{1,1}$ $+S_{n-1,\delta_1}H_{2,1}+N$	$Y_{n,2}=S_{n-1}H_{1,2}$ $+S_{n-1,\delta_1}H_{2,2}+N$

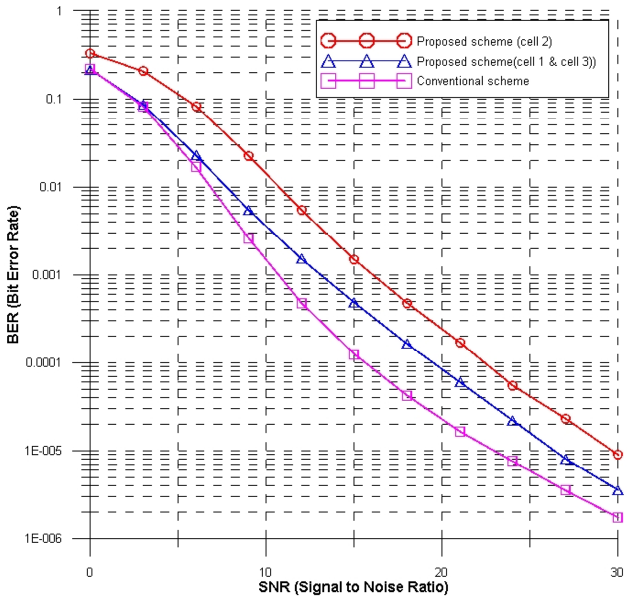

Fig. 3 BER performance of the proposed detection scheme compared to conventional scheme and 4x2 transmission system

VI. Conclusion

In this paper, the cooperation scheme using adjacent base station antennas is proposed in order to prevent a communication disruption. The one of the adjacent base stations transmits the rare signal. The other adjacent base stations transmits the cyclically delayed signals in order to provides diversity gain. The configuration of cooperative transmission signals reinforces the DFE properties. Therefore, the proposed cooperation scheme can achieves a high performance even though the attenuation is high. As a results, the proposed cooperation scheme ensures a sufficient communication environment by using the cooperation of the adjacent base stations in case that a problem occurs in a particular base station.

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