World Academy of Science, Engineering and Technology
International Journal of Information and Communication Engineering
Vol:9, No:1, 2015

Coordinated Multi-Point Scheme Based On Channel State Information in MIMO-OFDM System

Su-Hyun Jung, Chang-Bin Ha, Hyoung-Kyu Song

***Abstract*—**Recently, increasing the quality of experience (QoE) is an important issue. Since performance degradation at cell edge extremely reduces the QoE, several techniques are defined at LTE/LTE-A standard to remove inter-cell interference (ICI). However, the conventional techniques have disadvantage because there is a trade-off between resource allocation and reliable communication. The proposed scheme reduces the ICI more efficiently by using channel state information (CSI) smartly. It is shown that the proposed scheme can reduce the ICI with fewer resources.

***Keywords*—**Adaptive beam forming, CoMP, LTE-A, ICI reduction.

I. Introduction

SINCE users of mobile devices are increasing exponentially, seamless multimedia services, even if user is moving, have been required persistently. However, service operators focused on high transmission rate at initial stage of long term evolution (LTE) system. There are some techniques which were used to increase the maximum speed in LTE system, i.e., orthogonal frequency-division multiplexing (OFDM), multiple input multiple output (MIMO), beam forming (BF) and so on [10], [16]-[19].

As time passes, service providers realized that it is not only important to increase transmission rate simply. And besides, demands for seamless services were elevated more and more. Especially, data throughput issues at the cell boundary prevent the seamless services because the data throughput is reduced extremely at the cell boundary.

Inter-cell interference coordination (ICIC) technique which applies constraints to radio resource management (RRM) block is defined at the LTE - Rel. 8 [1]-[3]. User equipments (UEs) which are located at the cell boundary use different frequency resources by using the ICIC technique. Consequently, high spectral efficiency is available.

However, the ICIC technique is not enough to reduce the inter-cell interference (ICI). Therefore, various techniques were added to reduce the performance degradation of the cell boundary at the LTE-A standard [11], [12]. Among these various techniques, enhanced ICIC (eICIC) technique and coordinated multi-point (CoMP) technique are important schemes to elevate throughput at cell edge.

The eICIC technique which is enhancement of the ICIC technique is defined at the LTE-A - Rel. 10 [4]-[6]. The eICIC technique is suitable to apply at heterogeneous network (HetNet) [13]-[15].

And the CoMP technique which provides the inter-cell cooperation is defined at the LTE-A - Rel. 11 [7]-[9]. Serving transmission point (TP) and adjacent TPs cooperate for transmission. Therefore, TP which is located at adjacent cell can transmit data to UE which is located at serving cell and the throughput at the cell edge can be increased, consequently. There are four different scenarios which are considering the CoMP technique. The CoMP scenario 1 and 2 consider the homogeneous network. And the CoMP scenario 3 and 4 consider the heterogeneous network. The scenario 3 and 4 are applied in this paper [12].

The remaining sections are organized as follows. Section II represents a system model which is used in this paper, Section III proposes a cooperative transmission scheme for improvement of performance at the cell edge, Section IV shows simulation results and Section V presents the conclusion of the proposed scheme.

II. System Model

A system model which is used in this paper is presented. Basically, MIMO-OFDM system is considered, since this paper is based on the LTE/LTE-A system.

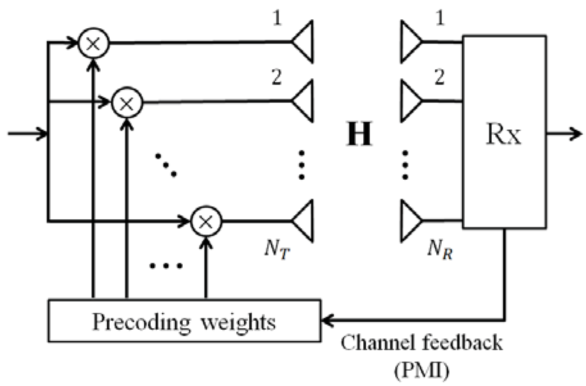

Fig. 1 Closed-loop MIMO transceiver using PMI

Fig. 1 shows the transceiver using the smart antenna technique. The number of transmitting antennas is N_T and the number of receiving antennas is N_R. A MIMO channel matrix is expressed as $\mathbf{H}$. And, the generating block for precoding weights vector $\boldsymbol{W}$ is represented in Fig. 1. The BF technique is applied to improve the signal to interference plus noise power ratio (SINR) in this paper. Precoding based on codebook is used in this system model. The selected precoding matrix indicator (PMI) in the codebook is transferred to transmitter and is used to generate the precoding weights vector, W. The received

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symbol vector Y is as follows,

$$\mathrm{Y} = \mathrm{H}W\mathrm{X} + \mathrm{N}\ , \quad (1)$$

where Y is a complex received symbol vector, H is a complex MIMO channel matrix, W is the precoding weight vector which is calculated by using the PMI, **X** is a transmitted complex OFDM symbol vector and **N** is an additive white complex Gaussian noise (AWGN) vector.

III. Proposed Scheme

In this section, a cooperative transmission scheme is proposed to improve bit error rate (BER) performance. There is a scenario for explaining the communication process which is assumed in this paper.

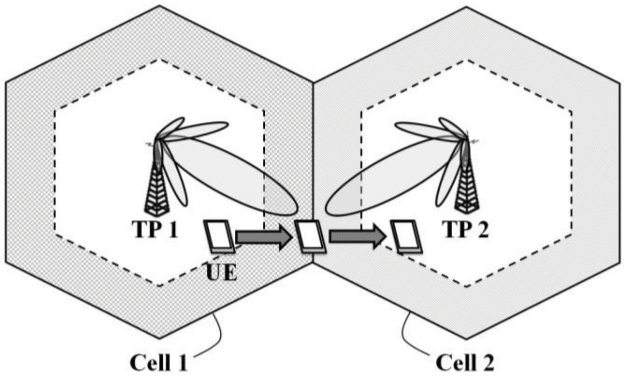

Fig. 2 The process for handover

Fig. 2 shows TP 1, TP 2, cell 1, cell 2 and a moving UE which is destination of downlink (DL) communication. The UE is moving from the cell 1 to the cell 2. There are 3-stages of movement for the UE. At the stage 1, the UE is located at the cell 1. At the stage 2, the UE is located at the cell edge. Finally, at the stage 3, the UE is located at the cell 2. The stage 1 and the stage 3 have no problem for transmission. However, the problem is occurred at the stage 2 since the UE undergoes the ICI problem. Therefore, a new transmission scheme is proposed in this paper.

The adaptive CoMP scheme based on CSI is applied to remove the ICI. The proposed scheme uses the CSI to compute the threshold. The SINR which is used to indicate the channel state is calculated as follows,

$$SINR_i = 10 \times log_{10}\ \frac{P_S}{P_N + P_I}\ , \quad (2)$$

where P_S is the power of the received signal, P_N is the power of the noise vector and P_I is the power of the interference. At the stage 2, P_I becomes large, and then the total SINR value becomes low. And then, $SINR_i$ means the SINR between the UE and the *i*-th TP, i.e., TP *i*.

The proposed scheme defines a threshold T to decide the transmission method adaptively. The threshold is decided by service operators. If the T is decided as a large value, the transmission of the service can be more robust. And if the T is decided as a small value, the speed of the service can be more improved. If $SINR_1 - SINR_2$ is larger than the T, it means that the state is in the stage 1 or the stage 3. In this state, spatial multiplexing (SM) mode is applied to improve the data rate. This process means that the SM transmission is applied, if the channel state is good. On the other hand, if $SINR_1 - SINR_2$ is smaller than the T, it means that the state is in the stage 2. In the stage 2, because the UE undergoes the ICI problem, special technique is applied. The TPs cooperate for the simultaneous transmission. And the BF technique is applied to provide the robust transmission. If the channel condition from TP to a user is bad, the cooperative transmission is applied.

The block diagram for the proposed scheme is represented in Fig. 3.

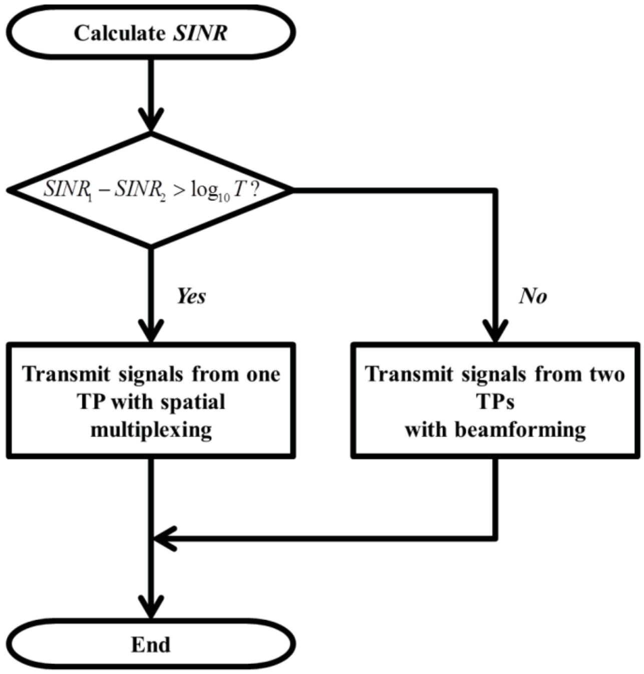

Fig. 3 The block diagram for the proposed scheme

The block diagram shows two transmission modes. If $SINR_1 - SINR_2$ is larger than the threshold T, the state is in the stage 1 or the stage 3. In this state, the one TP transmit signals with SM. This process means that the SM transmission is applied, if the channel state is good. On the other hand, if $SINR_1 - SINR_2$ is smaller than the threshold T, the state is in the stage 2. In the stage 2, because the UE undergoes the ICI problem, the two TPs transmit same signal by using beamforming technique. If the UE is stage 1 or 3, the SM mode is applied to improve the data rate. On the other hand, if the UE is stage 2, the CoMP mode is applied to improve the performance.

IV. Simulation Results

In this section, BER performance of the proposed scheme is presented. The transmitted signals are modulated by the OFDM modulation. The number of subcarrier is 64 and signals are mapped by the quadrature phase shift keying (QPSK). The

Rayleigh fading channel is considered as MIMO channel and the path length is 7. The zero-forcing (ZF) and minimum mean square error (MMSE) techniques are considered for BF or MIMO equalization. Two-transmit antennas and two-receive antennas are considered.

Fig. 4 shows the BER performance for the several transmission schemes. If the channel condition between a TP and a UE is bad, i.e., SINR is low, the CoMP transmission scheme is applied. If the CoMP scheme is applied, the BF transmission is used also. This scheme obtains a 3 dB gain than SM scheme at a BER of 10^{-3}.

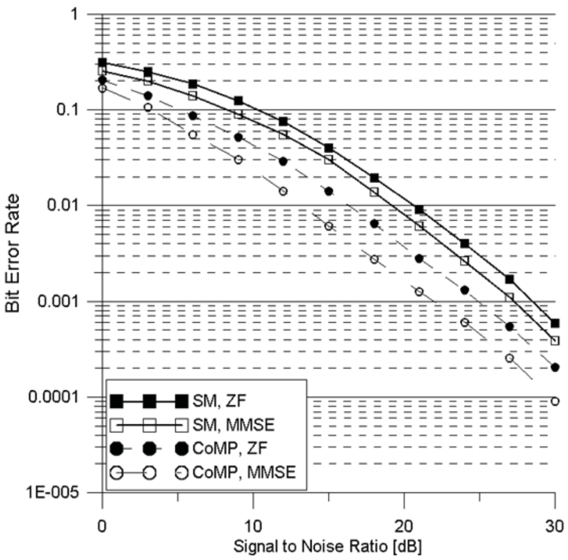

Fig. 4 The BER performance for the four schemes

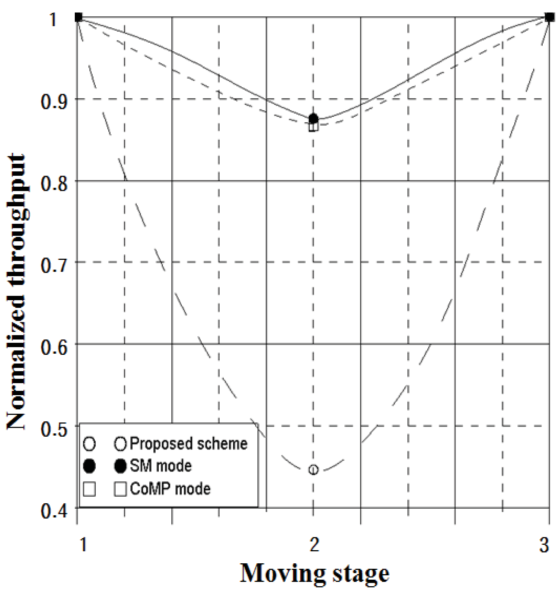

Fig. 5 The normalized throughput for three transmission schemes

Fig. 5 shows the normalized throughput for the three moving stage. The proposed scheme has almost same throughput with the CoMP mode. However, if the CoMP mode is applied, the usage of resource is increased. The usage rate of resource is expressed in Table I.

This means that the proposed scheme can use the resource more efficiently. If the UE is in the stage 2, the performance of cell edge is increased by using the CoMP scheme and the total throughput of cell is increased.

TABLE I
RATIO OF RESOURCE UTILIZATION

	SM	CoMP	Proposed scheme
Resource utilization rate	1	2	4/3

V. CONCLUSION

The proposed scheme applies the SM scheme and CoMP scheme adaptively in order to provide more robust transmission in LTE-A system. By using the proposed scheme, the data rate is increased at the center of the cell and the performance at the cell edge is improved. The proposed scheme uses much less resources than the conventional CoMP scheme and has almost same performance with the conventional CoMP scheme. And, since the SM scheme is applied at the center of cell, the total data rate of cell can be improved. Consequently, the proposed scheme improves the total cell throughput by using less resource.

ACKNOWLEDGMENT

This work was supported by the IT R&D program of MOTIE/KEIT [10041686, Cooperative Control Communication/Security Technology and SoC Development for Autonomous and Safe Driving System] and the MSIP (Ministry of Science, ICT and Future Planning), Korea, under the C-ITRC (Convergence Information Technology Research Center) support program (NIPA-2014-H0401-14-1007) supervised by the NIPA(National IT Industry Promotion Agency).

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