

# Improved Performance Scheme for Joint Transmission in Downlink Coordinated Multi-Point Transmission

Young-Su Ryu, Su-Hyun Jung, Myoung-Jin Kim, Hyoung-Kyu Song

**Abstract**—In this paper, improved performance scheme for joint transmission(JT) is proposed in downlink(DL) coordinated multi-point(CoMP) in case of the constraint transmission power. This scheme is that a serving transmission point(TP) requests the JT to an inter-TP and it selects a precoding technique according to the channel state information(CSI) from user equipment(UE). The simulation results show that the bit error rate(BER) and the throughput performances of the proposed scheme provide the high spectral efficiency and the reliable data at the cell edge.

**Keywords**—CoMP, joint transmission, minimum mean square error, zero-forcing, zero-forcing dirty paper coding.

## I. INTRODUCTION

AS the amount of wireless data usage has rapidly increased, economical wireless technology and the improved concepts of networks are required to provide the high throughput and reduce the system costs. The 4th generation(4G) of mobile communication system as known as Long term evolution(LTE) uses multiple input multiple output-orthogonal frequency division multiplexing(MIMO-OFDM) to get the high spectral efficiency [1], [2]. In addition, MIMO-OFDM system uses precoding techniques to cancel the interference among the multiple antennas. The theoretical throughput that the end user is able to get is extremely increased [3]. Since there are some fatal factors for the practical throughput, the end user wants to have the guaranteed quality of experience(QoE) rather than the high data rate.

Inter-cell interference is the one of degradation factors for the practical throughput. It decreases the throughput at the cell edge due to similar transmission power among the inter-cells [4]. In order to find a solution for the inter-cell interference problem, the inter-cell interference in LTE-Advanced is mitigated by using some techniques called CoMP [5], [6]. The CoMP gets rid of the inter-cell interference and it provides high throughput to the cell edge user. Multiple TPs in CoMP cooperate with each other and reduce the inter-cell interference.

Several CoMP techniques come up in LTE Release 11 [7]. The most promising technique is joint transmission. JT is that the multiple TPs send the same data to the UE. However, there are some trade-off problems. The UE is able to have

high reliability for the data but the wireless communication resource for the multiple TPs is increased.

In this paper, an improved performance scheme for JT is proposed in DL CoMP to improve the BER and throughput performances. The proposed scheme selects zero-forcing(ZF), minimum mean square error(MMSE), or ZF-dirty-paper coding(ZF-DPC) for the precoding technique.

## II. SYSTEM MODEL

### A. Downlink CoMP model

The DL CoMP system consists of multiple TPs and backhaul. The multiple TPs cooperate with each other and the backhaul is the intermediate link among the multiple TPs. The system assumes that the multiple TPs are connected with the ideal backhaul within intra-eNode B(eNB). The multiple TPs share the data and the CSI of UE through the backhaul. The ideal backhaul has no latency and infinite capacity. The DL CoMP system is comprised of heterogeneous networks with high power remote radio heads(RRHs) as a DL CoMP scenario 2 in LTE Release 11 [8]. In addition, this system considers single user-MIMO-OFDM(SU-MIMO-OFDM). The DL CoMP scenario 2 in LTE Release 11 is illustrated in Fig. 1.

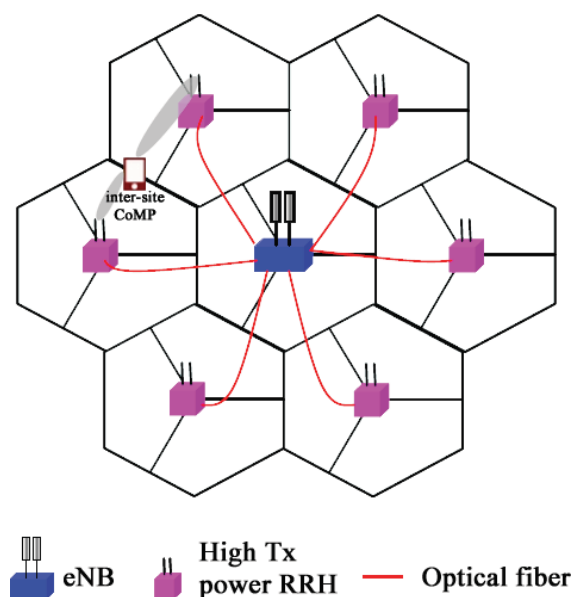


Fig. 1. DL CoMP scenario 2 in LTE Release 11

This system assumes that the transmission power of the multiple TPs is uniformly allocated and the average transmission power is limited as 1 W. Also, the system consists of 2x2 SU-MIMO. If a TP needs the JT and precoding techniques according to the CSI, the multiple TPs cooperate with each other through the ideal backhaul.

### B. Channel model

The channel considers Rayleigh fading channel. This channel is independent and identically distributed random. The additive white Gaussian noise(AWGN) is added at the receiver. In addition, the channel considers the path-loss by the distance between the UE and the multiple TPs. The equation considering all of these factors can be denoted as follows:

$$\mathbf{Y} = \sqrt{P}\mathbf{H}\mathbf{X} + \mathbf{F} + \mathbf{N}, \quad (1)$$

where  $\mathbf{Y}$  is the received vector signal,  $P$  is root-mean-square power depending on the distance between a serving TP and an UE,  $\mathbf{H}$  is the channel vector,  $\mathbf{X}$  is the transmitted MIMO-OFDM signal vector,  $\mathbf{F}$  is the inter-cell interference vector caused by inter-TP and  $\mathbf{N}$  is a AWGN vector with zero mean and variance  $\sigma^2$ .

## III. CONVENTIONAL SCHEME

### A. Downlink CoMP transmission system

The DL CoMP refers dynamic coordination among the multiple TPs. DL CoMP consists of two main schemes. One is coordinated scheduling and beamforming(CS/CB) and the other is JP [8]. CS/CB is that the data for an UE is available at the only one point but the decisions of user scheduling and beamforming are made with the cooperating multiple TPs. The TPs are chosen semi-statically.

In JP, there are DPS and JT. TPs with JP share the data through the ideal backhaul. DPS chooses the one TP depending on CSI and makes the inter-TP mute. DPS is good at high resource efficiency of the TP, but UE with DPS has lower reliable received data than that with JT. For JT, the multiple TPs simultaneously transmit the same data to the UE. UE with JT has higher reliable received data than that with DPS, but TPs with JT has lower resource efficiency than that with DPS.

### B. Precoding

Precoding is a signal processing technique before transmission to get high spectral efficiency [9]. In MIMO-OFDM, the precoding exploits the multiple antennas to achieve low interference introduced from multiple antennas. However, precoding techniques has a tradeoff between the throughput performance and the system complexity. The common linear precoding is ZF which is the inverse of the channel. ZF precoding is appropriate to the high signal-to-noise-ratio(SNR) and the environment in many users [10]. The ZF precoding vector,  $\mathbf{W}_{ZF}$ , is expressed as follows:

$$\mathbf{W}_{ZF} = \mathbf{H}^H(\mathbf{H}\mathbf{H}^H)^{-1}, \quad (2)$$

where  $(\cdot)^{-1}$  is the transformation of inverse matrix and  $(\cdot)^H$  is Hermitian matrix. The point of ZF precoding is that it is the most common and the simplest method, but it does not consider the noise.

Minimum mean square error(MMSE) precoding is a nonlinear precoding scheme [11]. It decreases the noise factors based on minimizing the mean square error(MSE) between the transmitted symbol and the received symbol. The MMSE precoding vector,  $\mathbf{W}_{MMSE}$ , is as follows:

$$\mathbf{W}_{MMSE} = \mathbf{H}^H(\mathbf{H}\mathbf{H}^H + \sigma^2\mathbf{I})^{-1}, \quad (3)$$

where the identity matrix is denoted by  $\mathbf{I}$  and  $\sigma^2$  is the variance of the noise.

DPC is a non-linear precoding scheme by canceling the known interference before transmission [12]. However, DPC can be hardly implemented to this system. Therefore, the intuitive suboptimal DPC precoding scheme is needed [13]. One of the suboptimal DPC precoding schemes is ZF-DPC. It exploits LQ decomposition of the channel information. The LQ decomposition of the 2x2 MIMO-OFDM channel can be expressed as follows:

$$\mathbf{H} = \mathbf{L}\mathbf{Q} = \begin{bmatrix} l_{11} & 0 \\ l_{21} & l_{22} \end{bmatrix} \begin{bmatrix} q_1 \\ q_2 \end{bmatrix}, \quad (4)$$

where  $\mathbf{L}$  denotes a lower triangular matrix and  $\mathbf{Q}$  denotes a unitary matrix. The ZF-DPC precoding is able to cancel the interference among multiple antennas using LQ decomposition. This precoding vector,  $\mathbf{W}_{ZF-DPC}$ , is as follows:

$$\mathbf{W}_{ZF-DPC} = \mathbf{Q}^H \begin{bmatrix} 1 & 0 \\ -\frac{l_{21}}{l_{22}} & 1 \end{bmatrix}. \quad (5)$$

## IV. IMPROVED PERFORMANCE SCHEME FOR JOINT TRANSMISSION

The conventional JT CoMP scheme provides high spectral efficiency at the cell edge when the multiple TPs have high transmission power. If the multiple TPs have the constraint of transmission power, the performance of JT at the cell edge

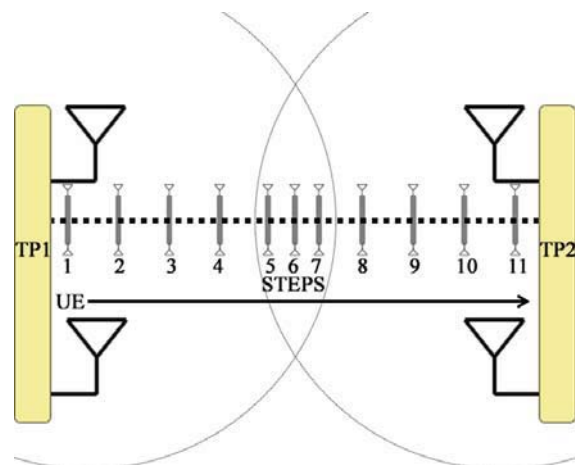


Fig. 2. The scenario of moving steps for the proposed scheme

is reduced remarkably. Therefore, this section proposes an improved performance scheme for JT in DL CoMP system when the multiple TPs have the constraint of transmission power. This proposed scheme provides high spectral efficiency at the cell edge and economical usage of the system resource by selecting the one of precoding techniques depending on the CSI.

In this paper, eleven moving steps are considered for the scenario of the proposed scheme. The scenario is illustrated in Fig. 2. The multiple TPs select the one precoding technique within ZF, MMSE, and ZF-DPC precoding techniques. Since the signal from the inter-TP can hardly reach, ZF precoding technique is appropriate. Therefore, ZF precoding is optimal for the low complexity of the system at the steps of 1, 2, 10, and 11. MMSE precoding technique is chosen at the steps of 3, 4, 8, and 9. ZF-DPC precoding technique is adapted at the steps of 5, 6, and 7 where the signals from multiple TPs are very weak. The complexity of the system is high at the steps of 5, 6, and 7, but JT with ZF-DPC provides high reliability of data to UE.

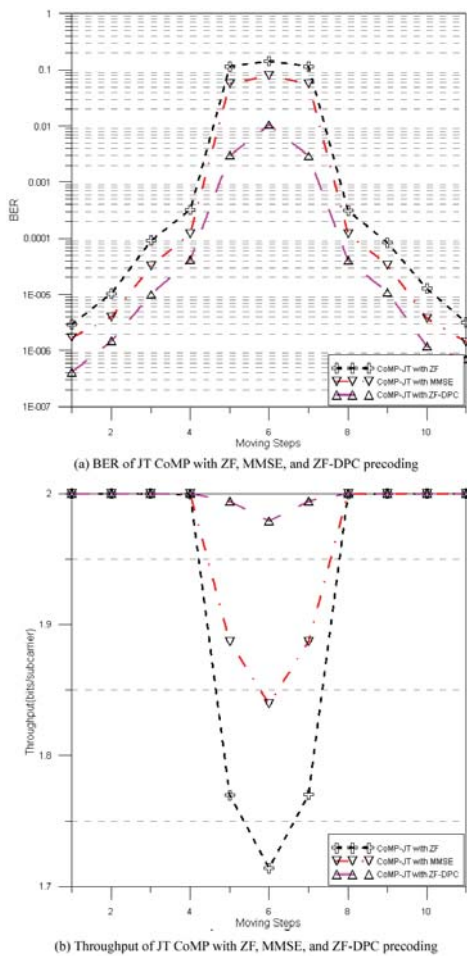


Fig. 3. BER and throughput of JT CoMP with ZF, MMSE, and ZF-DPC precoding

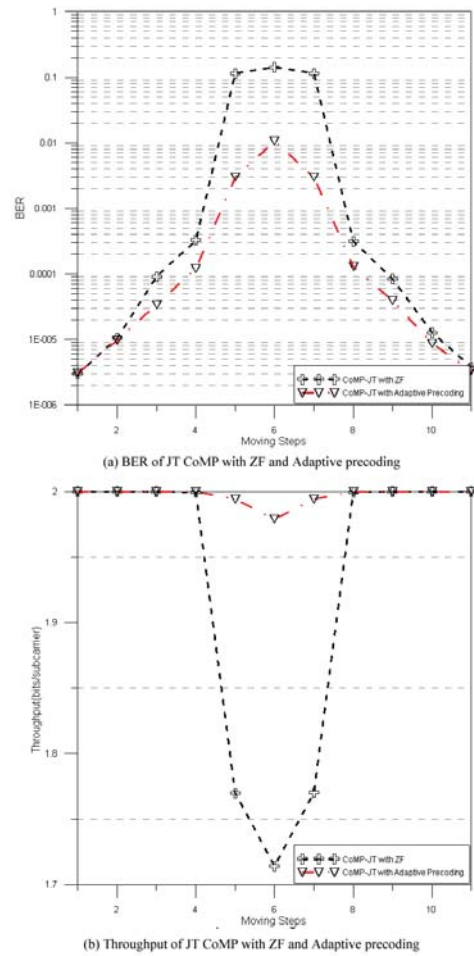


Fig. 4. BER and throughput of JT CoMP with ZF and Adaptive precoding

## V. SIMULATION RESULTS

In this section, the simulation results of the proposed scheme according to the scenario are presented. The transmitted signals are modulated with quadrature phase shift keying(QPSK) with the convolutional code rate by 1/2. The signals experience Rayleigh channel with path length 7. The transmission power of the multiple TPs is uniformly allocated and the average transmission power is limited as 1 W.  $2 \times 2$  MIMO-OFDM system is considered and uses 64-subcarriers. BER and throughput are considered for the measurement of the proposed scheme performances. The throughput, bits per subcarrier, can be calculated as follows:

$$\frac{N_{bits} \times (1 - P_e)}{N_{symbols} \times N_{FFT}} \quad (\text{bits/subcarrier}), \quad (6)$$

where  $N_{bits}$  is the number of transmitted data bits,  $P_e$  is a BER,  $N_{symbols}$  is the number of the OFDM data symbols, and  $N_{FFT}$  is the number of subcarriers.

Fig. 3(a) and 3(b) show the BER and throughput of JP CoMP with three precoding techniques. Fig. 4(a) and 4(b) refer the BER and throughput of JT CoMP with ZF and adaptive precoding. The BER and throughput performances describe

that the proposed scheme provides high spectral efficiency remarkably.

## VI. CONCLUSION

This paper proposes an improved performance scheme JT in DL CoMP transmission to provide high spectral efficiency to UE at the cell edge. From the proposed scheme, it can be expected that UE is able to achieve high spectral efficiency and reliable data with the economical usage of system resource.

## ACKNOWLEDGMENT

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Science, ICT and future Planning(No. 2013R1A2A2A01067708) and the MSIP(Ministry of Science, ICT and Future Planning), Korea, under the C-ITRC(Convergence Information Technology Research Center) (IITP-2015-H8601-15-1008) supervised by the IITP(Institute for Information & communications Technology Promotion).

## REFERENCES

- [1] J.-H. Lee and J.-K. Han, "MIMO Technologies in 3GPP LTE and LTE-advanced," EURASIP Journal on Wireless Commun. and Networking, 2009.
- [2] J.-K. Ahn, H.-W. Jang and H.-K. Song, "An Improved Low Complexity Detection Scheme in MIMO-OFDM Systems," IEICE Trans. on Inform. and Systems, vol.E97-D no.5, pp. 1336-1339, May 2014.
- [3] M. Chandrasekaran and S. Subramanian, "Performance of Precoding Techniques in LTE," IEEE Recent Trends in Inform. Technology (ICRITIT), pp.367-371, Apr. 2012.
- [4] M. Rahmanm and H. Yanikomeroglu, "Enhancing Cell-edge Performance: A Downlink Dynamic Interference Avoidance Scheme with Inter-cell Coordination," IEEE Trans. Wireless Commun., vol.9, no.4, pp. 1414-1425, Apr., 2010.
- [5] J.-H. Lee, Y.-S. Kim, H.-J. Lee, B. L. Ng, D. Mazzares, J. H. Liu, W. M. Xiao, and Y. X. Zhou, "Coordinated Multipoint Transmission and Reception in LTE-Advanced Systems," IEEE Commun. Mag., vol.50, no.11, pp.44-50, Nov. 2012.
- [6] A. H. Muqaibel and A. N. Jadallah, "Parctical Performance Evaluation of Coordinated Multi-point(CoMP) Networks," IEEE GCC Conf. and Exhibition, pp. 1-6, Feb, 2015.
- [7] 3GPP TR 36.814 V9.0.0, "Further Advancement for E-UTRA Physical Layer Aspects," Mar. 2010.
- [8] 3GPP TR 36.819 V11.2.0, "Coordinated multi-point operation for LTE physical lyaer aspects," Sept. 2013.
- [9] M. Vu and A. Paulraj, "MIMO wireless linear precoding," IEEE Signal Processing Mag., vol.24, no.5, pp.86-105, Sept. 2007.
- [10] A. Wiesel, Y. C. Eldar, and S. Shamai, "Zero-forcing precoding and generalized inverses," IEEE Trans. Signal Processing, vol.56, no.9, pp.4409-4418, Aug. 2008.
- [11] V. Gardašević, R. R. Müller, B. M. Zaidel, G. E. Øien, and L. Lundheim, "On the spectral efficiency of MMSE vector precoding," IEEE Wireless Commun. and Networking Conf., pp. 1805-1810, Mar. 2011.
- [12] B. Saradka, S. Bhashyam, and A. Thangaraj, "A dirty paper coding scheme for the multiple input multiple output broadcast channel," IEEE National Conf. Commun.(NCC), pp.1-5, Feb. 2012.
- [13] G. Gaire and S. Shamai, "On the achievable throughput of a multiantenna Gaussian broadcast channel," IEEE Trans. Inform. Theory, vol.20, pp. 279-280, Mar. 1974.

**Young-Su Ryu** received the B.S. degree in Information & Communication Engineering, Sejong University, Seoul, Korea, in 2015. He is working toward to M.S. degree in the Department of Information & Communication Engineering, Sejong, University, Seoul, Korea. His research interests are digital broadcasting and cooperative communication.

**Su-Hyun Jung** received the B.S. degree in Information & Communication Engineering, Sejong University, Seoul, Korea, in 2014. She is working toward to M.S. degree in the Department of Information and Communications Engineering, Sejong University, Seoul, Korea. Her research interests are in the areas of wireless communication system design and transmission technique for MIMO antenna.

**Myoung-Jin Kim** received the B.S. degree in Information & Communication Engineering, Sejong University, Seoul, Korea, in 2015. He is working toward to M.S. degree in the Department of information and communications engineering, Sejong University, Seoul, Korea. His research interests are in the areas of wireless communication system design and cooperative communication.

**Hyoung-Kyu Song** received B.S., M.S., and Ph.D. degrees in electronic engineering from Yonsei University, Seoul, Korea, in 1990, 1992, and 1996, respectively. From 1996 to 2000 he had been managerial engineer in Korea Electronics Technology Institute (KETI), Korea. Since 2000, he has been a professor of the Department of information and communications engineering, Sejong University, Seoul, Korea. His research interests include digital and data communications, information theory and their applications with an emphasis on mobile communications.