Interference Cancellation Using Coordinated Beamforming in CoMP Transmission System

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Abstract: This paper is an overview of the key component in coordinated multipoint in the context of LTE-Advanced which includes architectures and approaches that can be employed. A system model is proposed to employ the cooperative communication in interference-limited scenario which may help to improve the cell-edge performance. Coordinated beamforming (CBF) has been studied in hope of mitigating the inter-cell interference experienced by cell-edge users. This paper provides analysis of coordinated beamforming in the multicell downlink.

Keywords: CoMP, LTE-A, CS/CB.

I. INTRODUCTION

In wireless cellular networks, the demand for high data rates and capacity has been raised. This leads to the insufficiency of spectrum; therefore an advanced technique is needed to cover a vast range of users with eminent performance. Third Generation Partnership Project (3GPP) has developed Long Term Evolution (LTE) as a 4G wireless broadband technology. LTE uses the orthogonal frequency multiple access technique OFDM which is an extension of W-CDMA. Orthogonal Frequency Division Multiple Access (OFDMA) and Single carrier-frequency division multiple access (SC-FDMA) are chosen multiple access schemes for downlink and uplink that gives a throughput of about 50Mbps and 100Mbps respectively. In comparison with other past technologies LTE increases spectral efficiency and minimizes latency [1].While using the OFDM techniques inter-cell interference takes place due to frequency reuse.

A standardization work has been carried out by 3GPP to extent LTE to LTE-Advanced (LTE-A).LTE-A can abate the inter-cell interference and intensify the cell-edge throughput. Cooperative transmission technique based networks are deployed in LTE-A to achieve requirements. The cooperative techniques are coordinated multi-point (CoMP) transmission/reception, enhanced inert-cell interference coordination (eICIC) and relay transmission.

This paper focus on the CoMP techniques as 3GPP has considered it as a tool to enhance coverage, cell-edge throughput and system performance. Section II provide the basic CoMP concepts and approaches, deployment architectures and section III gives the proposed system model for future mobile networks.

II. COORDINATED MULTIPOINT TRANSMISSION/RECEPTION

Coordinated Multipoint (CoMP) actually refers to a multiple geographically separated base stations (denoted as eNBs) which are dynamically coordinated to reduce inter-cell interference in the network. It is a network multiple-input multiple-output (MIMO) transmission technology. The primary intention is to get the inter-cell interference at the cell edge as useful data. Coordination between enhanced node Bs (eNBs) in the Uplink (UL) is referred as CoMP reception and in the Downlink (DL) is referred to as CoMP transmission [2]. Multiple antenna site locations with multiple transmit and receive antennas are used .The antennas used here perhaps belongs to same physical cell or not, but increases the received signal quality and reduce received interference. CoMP has two architectures for network deployment they are centralized and distributed as shown in the Fig. 1.

In a centralized approach, an optical fiber, with a basedband signal is used to connect multiple Remote Radio Equipments (RREs) to the central eNB. In the area covered by the coordinating eNBs, a central entity is required to collect channel information from all the UEs. The control of radio resources between the cells can be achieved by this entity, which is in charge of performing baseband signal processing and control. The control of high speed radio resources between cells is relatively easy and signalling delay and overhead between eNB are small with this approach. The increase in the processing load on the central eNB, due to the increase in number of RRE, requirement of high capacity optical fiber also increases which could be a drawback for this network configuration.

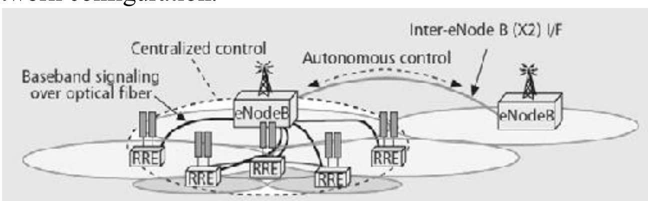

Fig. 1. CoMP Network configuration

Distributed architecture reduces the centralized approach in coordination. Channel information of coordinating sets and scheduler in all eNBs are available to all cooperating nodes. The major advantage of this architecture, is conventional systems need not undergo significant changes as it has the potential of reducing the infrastructure and signalling protocol cost associated with central processing unit.

Downlink CoMP schemes has two categories, namely, coordinated scheduling/beamforming (CS/CB) and joint processing (JP) [3] as shown in Fig. 2. In CS/CB, all UEs are served by only one cell, therefore, user data is only available at the serving cell, but scheduling decisions are aligned across cooperating cell sites. In JP, multiple cell sites transmit simultaneously to a single UE in the cooperating cluster, therefore, user data needs to be available at several cell sites. The UEs combine coherently all received signals at symbol level.

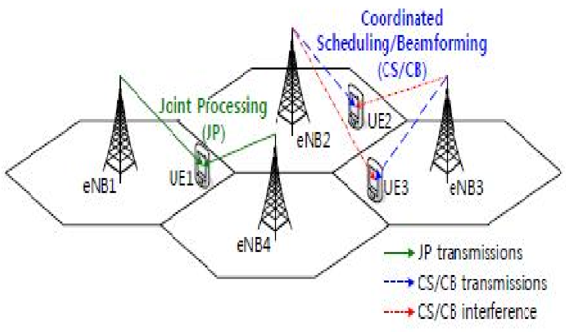

Fig. 2. CoMP architecture for CS/CB and JP transmissions.

Two different methods are being studied for the JP scheme: Joint transmission (JT) and dynamic cell selection (DCS)[4]. In JT data from several sites are transmitted at the same time by using the same time and frequency radio resources. For DCS cells can be opted in consideration of interference at any time

III. SYSTEM MODEL

In the paper, we will focus on multi user CoMP-CS/CB system. We adopt block diagonalization (BD) precoding transmission scheme, because we think it is a scheme with the greatest potential due to the fact that it has been used in most CoMP-related proposals submitted to 3GPP RAN1. The system model presented here concentrate only on downlink Scheme. The association of users to eNBs has been optimized. LTE-A physical layer configuration is used in this system. Beamforming will cancel the inter cell interference in cell and improve the system performance. BD is a method that uses the linear ZF techniques to create a block diagonal effective channel from the BSs to the users, such that each user receives its desired signal with minimal interference .This technique is widely considered in a full Channel State Information (CSI) case at the transmitter and when the power is evenly distributed between the users [7]. BD scheme eliminate the interference and derived the optimal power allocation based on the waterfilling technique.

BLOCK DIAGONALIZATION:

In this method only a block of diagonalization is enough to completely eliminate the multiuser interfence. BD precoding enables the system to transmit multiple data streams to each user while removing the inter-user interference. This precoding process can cancel the interference from other user signals. Gain of the CoMP systems depends much on the precoding scheme. When multiple receiver antennas are considered BD based precoding is utilized and reasonable precoding complexity and performance gain compared with unitary precoding and ZF-BF precoding method. Each UE connect with a primary eNB that has high receiver power. Multiple Input Multiple Output network has been considered with N_{Tx} transmitting antennas at each eNBs and N_{Rx} receiving antennas at each UE.

Received signal for a given user in case of multiple antennas with single output link is given by

$$a = \sum_{m \in L} i_m \sqrt{Q_m} b_m + \sum_{l \notin L} i_l \sqrt{Q_l} b_l + t$$

where L the set of base stations in the system that serve a given user, t is the additive white Gaussian noise with a σ_s standard deviation, *m* refers to transmitting antennas, *l* refers to cells not belong to K which indicates the interference signal to the given user in cell *m*, Q_m and Q_l are the average received power, i_m and i_l denote the channel matrix, x_n and x_k are the data matrices.

Throughput for the resulting block-diagonal system is represented as when m≠l

$$C_{BD} = \max_{I_m M_l = 0} \log_2 \left| Y + \frac{1}{\sigma_s^2} I_m M_m I_m^* M_m^* \right|$$

$$= \max_{I_m M_l = 0} \sum_{l=1}^{L} \log_2 \left| Y + \frac{1}{\sigma_s^2} I_l M_l I_l^* M_l^* \right| \leq C_s$$

where C_s represents the sum capacity of the system.

The channel matrix for all users other than user *k* is shown as

$$\tilde{I}_k = \left[I_1^T \ldots, I_{K-1}^T, I_{K+1}^T \ldots, I_k^T \right]^T$$

$\tilde{I}_k M_k = 0$ is a beamforming vector. The singular value decomposition has been applied and represented as

$$\tilde{I}_k = \bigcup_k \begin{bmatrix} \sum_k & 0 \\ 0 & 0 \end{bmatrix} \left[V_k^{(1)} \quad V_k^{(0)} \right]^H$$

where $\sum_k$ is the diagonal matrix with all non-negative singular values and $V_k^{(1)}$, $V_k^{(0)}$ consists of the singular vectors corresponding to zero and non-zero singular values respectively.

Block diagonalization precoding matrix is given as below

$$M_k = \left[V_1^{(0)} V_1^{(1)} \quad V_2^{(0)} V_2^{(1)} \quad \ldots\ldots \quad V_k^{(0)} V_k^{(1)} \right]$$

Zero-forcing beamforming [8] has been designed as the follows.The eNodeB selects the two UEs, the concatenated quantized channel vectors are $I_k = \left[I_1^T I_2^T \right]^T$. Then the ZF matrix is

$$M_k = I_k^H \left[I_k I_k^H \right]^{-1} \mathrm{diag}(p)^{1/2}$$

$$= G_k \mathrm{diag}(p)^{1/2}$$

where $p_k = (p_1 p_2)^T$ is the vector of power normalization coefficients. For equal power allocation

$$p_k = \frac{p_t}{2} \frac{1}{\|g_k\|^2}$$

where g_k denotes the k-th column of G_k .We assume a perfect channel state information (CSI) known at receiver side and coherent detection is used. The received SINR is given by

$$\gamma(L) = \frac{\sum_{m \in L} |I_m|^2 Q_m}{\sum_{l \notin L} |I_l|^2 Q_l + \sigma_s^2}$$

For the cooperative transmission with multiple inputs and multiple outputs link, received signal for the particular user at eNodeB *n* can be expressed as

$$a = I_m C_m \sqrt{\frac{q_m}{N_{Tx}}} b_m + \sum_{l \neq m} I_l C_l \sqrt{\frac{q_l}{N_{Tx}}} b_l + t$$

Where I_m and I_l are the channel matrices, C_m and C_l are the precoding matrices which contains the precoders c_i assigned for each of the users in the cell and q_m/N_{Tx} is the particular allocated power.

IV. RESULT

In this section, we evaluate the proposed block diagonalization (BD) algorithm .The performance of CoMP-coordinated beamforming has shown in Fig. 3. The parameters are set as N_{Tx} = 4, N_{Rx} =4, K = 4 are simulated.

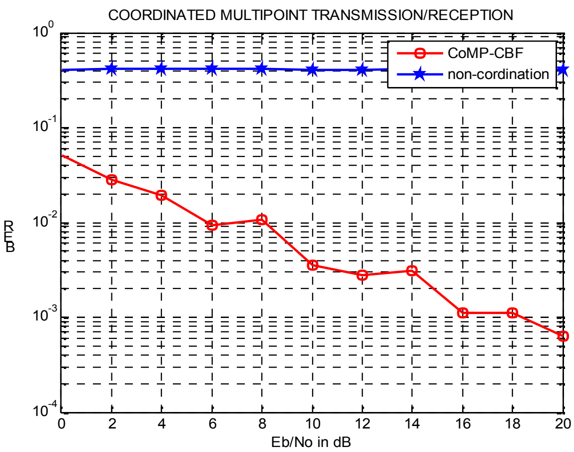

Fig. 3. Performance of the CoMP- CBF

V. CONCLUSION

In this paper, the basic concept of coordinated multipoint transmission and reception in the context of LTE-Advanced has been discussed. There are some limitations and advantages of each transmission schemes and deployment architectures. The proposed system model gives the simulation results of coordinated beamforming.

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