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# Novel Beamforming and User Scheduling Algorithm for Inter-cell Interference Cancellation

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* *Short Paper*

***Abstract*:** Coordinated multi-point transmission is a candidate technique for next-generation cellular communications systems. We consider a system with multiple cells in which base stations coordinate with each other by sharing user channel state information, which mitigates inter-cell interference (ICI), especially for users located at the cell edge. We introduce a new user scheduling method that considers both ICI and intra-cell orthogonality. Due to the influence of ICI cancellation and the loss reduction of effective channel gain during the beamforming process, the proposed method improves the system sum rate, when compared to the conventional method, by an average of 0.55bps/Hz for different numbers of total users per cell.

***Keywords*:** CoMP, MU-MIMO, Orthogonality, Scheduling, Beamforming

## 1. Introduction

Recently, data traffic has increased due to the introduction of smart phones and tablet devices. Third-generation (3G) mobile communications systems can only support traffic growth to a certain extent. However, new technology and innovative developments are needed to satisfy capacity and performance requirements. Therefore, Long Term Evolution (LTE)-Advanced has attracted attention from researchers [1, 2]. One of the primary elements discussed in LTE-Advanced technology is coordinated multi-point transmission [3, 4], which can improve cell edge–user data transmission, as well as spectral efficiency, due to multiple input multiple output orthogonal frequency division multiplex (MIMO-OFDM). Downlink coordinated multi-point (CoMP) is divided into two groups: coordinated scheduling and beamforming (CoMP-CSB) and joint processing and transmission (CoMP-JPT).

As shown in Fig. 1, for CoMP-CSB, the collaborating base stations (BSs) share the channel state information (CSI) of all users in order to mitigate inter-cell interference (ICI), and a sub-frame is transmitted from one cell to a given user group.

As shown in Fig. 2, for CoMP-JPT, collaborating BSs share the CSI and data of all users in order to achieve full coordination of multiple cells and to jointly transmit to a given user group using the same time and frequency resources.

Although CoMP-JPT is associated with improved

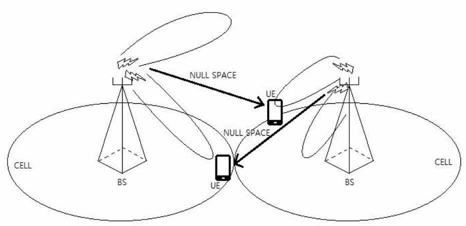


**Fig. 1. CoMP-CSB.**

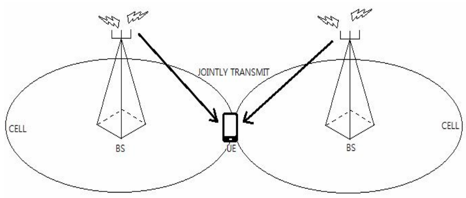


**Fig. 2. CoMP-JPT.**

performance, compared to CoMP-CSB, complexity and difficulty increase during implementation. Some research has been carried out for CoMP-JPT [5, 6], but in this paper, we consider CoMP-CSB due to its feasibility within practical systems. There are two factors (interference and orthogonality) that have direct effects on system performance, and therefore, we focus on how to balance the two.

## 2. System Model

We consider the downlink of cellular communications systems with $B$ multiple cells. Each cell has one BS equipped with $N_t$ transmission antennas, and $K$ single-antenna users located at the cell edge. The BSs exchange all users' CSI, including interference, through the backhaul network. Then the received signal of the $k^{th}$ user at the $b^{th}$ BS is written as

$$y_{b,k} = h_{b,k} w_{b,k} x_{b,k} + h_{b,k} \sum_{j \in S_b, j \neq k} w_{b,j} x_{b,j} + \sum_{\tilde{b} \neq b} h^1_{\tilde{b},k} \sum_{s \in S_{\tilde{b}}} w^1_{\tilde{b},s} x^1_{\tilde{b},s} + n_{b,k} \quad (1)$$

where $h_{b,k}$ is the channel vector of the $k^{th}$ user at the $b^{th}$ BS, which is independently and identically distributed (i.i.d.). $w_{b,k}$ and $x_{b,k}$ represent the precoding vector and the transmitted data, respectively. $n_{b,k}$ is the additive white Gaussian noise with zero mean and unit variance.

$h^1_{\tilde{b},k}$ is the interference channel of the $k^{th}$ user from the $\tilde{b}^{th}$ BS. Similarly, $w^1_{\tilde{b},s}$ and $x^1_{\tilde{b},s}$ are the precoding vector and the transmitted data, respectively, of the $\tilde{b}^{th}$ BS. $S_b$ represents the selected user group of the $b^{th}$ BS.

Therefore the main issue regarding this type of multiple-cell environment is how to eliminate or minimize the second and the third terms within Eq. (1).

## 3. Scheduling Method

In order to address the issue described above, we propose a new scheduling method, which is improved and enhanced [7].

Step 1: Initialization $|S_b| = \varphi$

Step 2: Select the first user at each BS with maximum channel power.
(Share the selected user index through a backhaul network.)

$$h_{b,1} = \arg\max_{k \in K} \|h_{b,k}\| \quad (2)$$

$$|S_b| = |S_b| \cup h_{b,1} \quad (3)$$

Step 3: Adjacent BSs make $G_p$ (a parallel user group) for the $b^{th}$ BS.

$$G_p = \left\{ k \,\middle|\, \frac{\left|h^1_{\tilde{b},1} h^1_{\tilde{b},k}\right|}{\left\|h^1_{\tilde{b},1}\right\| \left\|h^1_{\tilde{b},k}\right\|} > \alpha, for\ k \in K \right\} \quad (4)$$

(Share the selected user index through a backhaul network.)

Apply threshold α to find users whose interference channels have high correlation (parallelization) with the first user's interference channel.

Step 4: Find $N_t - 1$ users for each BS.

$$h_{b,1} = U \Sigma V^H \text{ (singular value decomposition)} \quad (5)$$

$$h_{b,i} = \left\{ i \,\middle|\, \arg\max_{i \in G_P} \frac{|h_{b,i} v_i|}{\|h_{b,i}\| \|v_i\|}, for\ i \in [2, \cdots, N_t - 1] \right\} \quad (6)$$

$$|S_b| = |S_b| \cup h_{b,i} \quad (7)$$

When the users in $S_b$ are poorly conditioned, the effective channel gain is greatly reduced because of the loss due to inverting the channel in Step 5. Therefore, it is necessary to guarantee the selected users' orthogonality to ensure the optimality of zero-forcing beamforming [8]. The right singular matrix $V$ consists of orthonormal column vectors. $V_1$ corresponds to $h_{b,1}$, and $V_2$ ,..., $V_{N_t - 1}$ corresponds to the $2^{nd}$ to $(N_t - 1)^{th}$ users that are selected [9].

Step 5: Zero-forcing beamforming (ZFBF).

$$H_S = \left[ h^T_{b,1}, \cdots, h^T_{N_t - 1}, h^T_{\tilde{b},1} \right]^T \quad (8)$$

$$W_S = H^H_S \left( H_S H^H_S \right)^{-1} \quad (9)$$

For perfect cancellation of multi-user interference (MUI), we use ZFBF instead of directly using matrix $V$ .

## 4. Simulation Results

The performance of the proposed method was verified through extensive simulations in this section. Figs. 3 and 4 show comparisons of the sum rate among the proposed method, conventional method [7], and semi-orthogonal user selection (SUS) [10] with non-coordination. All of these methods are applied to water-filling power allocation.

The proposed method synthetically considers ICI, MUI, and orthogonalization, and improves system performance, as shown below. ICI should be particularly considered at the cell edge. However, orthogonality also directly and

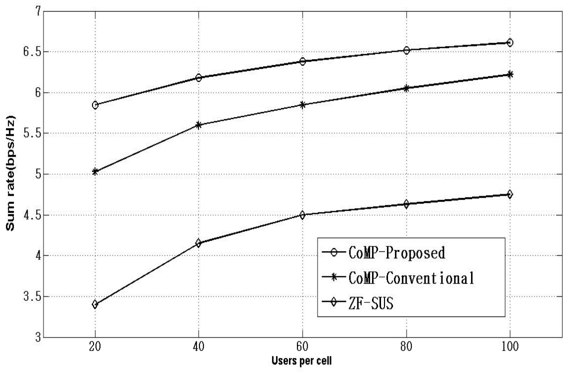


**Fig. 3. Sum-rate performance comparison of different strategies for various numbers of users.** $B = 2$, $N_t = 4$, $SNR = 10$, $\alpha = 0.5$.

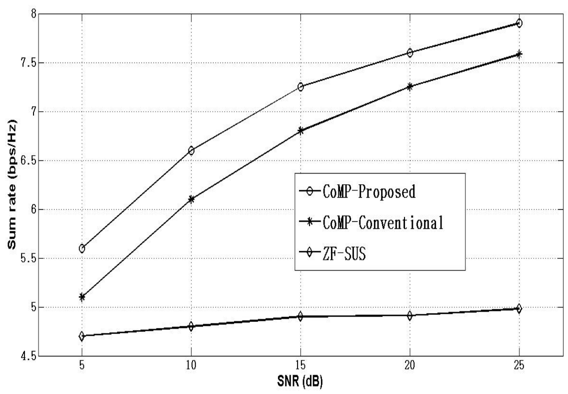


**Fig. 4. Sum-rate performance comparison of different strategies for various SNR values.** $B = 2$, $N_t = 4$, $K = 100$, $\alpha = 0.5$.

seriously affects the sum rate due to effective channel gain in the ZF process. Such situations are more significant to the first user of each cell whose interference from an adjacent cell is also canceled.

In general, advisable coordinating work between BSs can help to promote system performance. Conversely, ZF-SUS with non-coordination exhibits poor performance, even in high signal-to-noise ratio (SNR) conditions due to strong interference from adjacent cells, despite attaining orthogonality via the SUS algorithm.

In summary, maintaining good balance between interference and orthogonality is very important.

## 5. Conclusion

In this paper, we propose a new scheduling method in a CoMP-MU-MIMO environment in which BSs exchange user CSI for cooperation. The proposed method, which can significantly improve performance, compared to the conventional method, adopts a relatively simple method of creating a balance between ICI, MUI, and the orthogonality of selected user channels. The proposed method outperforms the system sum rate, when compared to the conventional method, by approximately 0.55bps/Hz using different SNRs.

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