A Low Complexity Configuration Selection Algorithm in IA-aided Uplink Coordinated Multipoint Systems

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***Abstract*— This work investigates the configuration selection in IA-aided UL CoMP systems which pursues the maximal achievable sum rate. The configuration is defined by the number of data streams transmitted in each user. Intuitively, the solution can be found by exhaustively calculating the achievable sum rate for all the possible configurations, and select the configuration leading to the maximal achievable sum rate. The exhaustive search method is infeasible due to its high complexity. Based on the characteristics of IA-aided UL CoMP systems, an algorithm is proposed to obtain the configuration with extremely low complexity, and the proposed approach achieves comparable performance as in exhaustive method.**

Keywords—CoMP; cooperative multipoint system; LTE-A; IA; MIMO; low complexity

I. INTRODUCTION

In wireless cellular networks, the growing demand on data rate brings great challenges. The spectrum is scarce and expensive for operators. As a result, high spectral efficiency is highly demanded. Transmissions of co-channel signals from neighboring cells cause interference and degrade the signal-to-interference-noise ratio (SINR), particularly when the users are located at the cell edge. To mitigate the effects of interference from neighboring cells, cooperative processing between the transmitters and the receivers has been investigated [1-2]. Besides, In emerging wireless standard such as Long-Term Evolution Advanced (LTE-A) aiming for the fourth generation mobile communication developed by Third Generation Partnership Project (3GPP), coordinated multipoint transmission and reception techniques (CoMP), based on the concept of cooperative processing, has been widely discussed [3-5].

Interference Alignment (IA) is a technique widely used in interference channel [6]. By aligning interference, the IA exploits the degree of freedoms (DoFs) for transmission of the desired signal, and improves the system sum rate in interference channel [6-8]. In addition to the interference channel, concepts of IA can also be used in CoMP systems to design practical IA-aided transceivers composed of precoders and a joint decoder in a CoMP system, and provide better performance than the conventional CoMP systems defined in LTE-A [9-10]. In those IA-aided transceiver design algorithms used in CoMP system, the design of precoders and decoders is based on the channel and the number of data streams transmitted by each user. Thus, the effect of IA is hugely affected by the number of data streams transmitted in the CoMP system and the characteristics of channel. If more data streams are transmitted, the transceiver has to utilize more DoFs to align interference, which simultaneously reduces DoFs used for desired data streams. On the other hand, transmitting more data streams provides potentially higher achievable sum rates if the interference can be properly mitigated. Thus, there is a trade-off in using DoFs for interference mitigation and data stream transmission. In this work, we consider all the possible combinations of number of data streams to be transmitted by each user as a feasible configuration set, where a single combination is denoted as a configuration. It can be seen that the selection of the configuration for the best sum rate is a challenging issue. Our goal is to choose a configuration that maximizes the achievable sum rate among all the possible configurations.

In this paper, a centralized IA-aidied uplink (UL) CoMP system in LTE-A [5] is considered. To achieve the maximal sum rate in IA-aided UL CoMP systems, a trivial method is the exhaustive method. The exhaustive method first computes the precoders and decoders for all the configurations based on certain IA-aided transceiver design algorithm, and then the achievable sum rates of all the configurations in IA-aided CoMP systems can be calculated. Finally, the configuration is selected as the one with the highest achievable sum rate. However, the complexity of exhaustive method is prohibitive for IA-aided UL CoMP systems. As a result, a low complexity algorithm is proposed in this paper. The proposed algorithm reduces complexities in two-fold. First, we explore the relations between channel and IA-aided transceiver design algorithm, and design a simple metric that can estimate the SINR for each data stream of all the configurations without explicitly computing the precoders and decoders. Then, the achievable sum rate can be calculated by the SINR for all the configurations. Second, the algorithm reduces the number of candidate configurations, and provides a linear increase in the

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number of candidates with respect to the number of transmit antennas. This property makes the proposed algorithm more practical compared with the exponential increase in the exhaustive method. Simulation results show that the proposed low complexity algorithm degrades within 5% in achievable sum rate compared with exhaustive method.

This paper is organized as follow. The centralized IA-aided UL CoMP system model is shown on section II. The explicit problem formulation and the proposed algorithm are presented on section III. In section IV, simulation results are provided. Finally, section V concludes this paper.

Notations: In this paper $\mathbf{I}_M$ is a $M \times M$ identity matrix; $(\cdot)^{-1}$, $(\cdot)^T$, $(\cdot)^H$, $\|\cdot\|_F$, and $\{\cdot\}_i^j$ represent matrix inverse, the matrix/vector transpose, conjugate matrix/vector transpose, Frobenius norm, and the ith column to jth column of a matrix, respectively. The rank$(\cdot)$ is the rank of a matrix. $\mathbf{X} = \mathrm{diag}(\mathbf{X}_1,\mathbf{X}_2,\ldots,\mathbf{X}_M)$ is a block diagonal matrix composed of $\mathbf{X}_1,\ldots,\mathbf{X}_M$ as diagonal elements.

II. System Model

A. *Uplink CoMP System Model*

The centralized UL CoMP system model in LTE-A is considered in this paper. Base stations (BSs) for different cells can operate at different transmission power levels and exchange full channel state information (CSI) and full data information to cooperatively receive and decode data. The practical scenarios are defined in [5] for CoMP scenario 3 and 4 where CSI and information is exchanged over dedicated fiber links.

As shown in Fig. 1, a UL CoMP system in LTE-A involves M BSs (M cells) each equipped with N_r antennas, and the lth cell has K_l user equipments (UEs). Every UE is equipped with N_t antennas. The transmitted signal vector for the kth user in the lth cell is described by $\mathbf{x}_l^k \in \mathbb{C}^{d_l^k \times 1}$. The corresponding precoding matrix is $\mathbf{V}_l^k \in \mathbb{C}^{N_t \times d_l^k}$, and d_l^k is the number of transmitted data streams of the kth user in the lth cell. The channel matrix between the mth BS and the kth user in the lth cell is denoted as $\mathbf{H}_{m,l}^k \in \mathbb{C}^{N_r \times N_t}$, whose elements is modeled as i.i.d. complex Gaussian random variables with distributions $CN(0,1)$ for serving links ($m = l$) and $CN(0,\varepsilon)$ for coordinating links ($m \neq l$) [1]. The received signal at mth BS is expressed as

$$\mathbf{y}_m = \sum_{l=1}^{M} \mathbf{H}_{m,l}\mathbf{V}_l\mathbf{x}_l + \mathbf{z}_m, \tag{1}$$

where the aggregated precoding matrix at the lth cell is denoted as $\mathbf{V}_l = \mathrm{diag}(\mathbf{V}_l^1, \mathbf{V}_l^2, \ldots, \mathbf{V}_l^{K_l}) \in \mathbb{C}^{N_t K_l \times d_l}$, where $d_l = \sum_{k=1}^{K_l} d_l^k$; the aggregated transmitted signal at the lth cell is described as $\mathbf{x}_l = \left[(\mathbf{x}_l^1)^T \quad (\mathbf{x}_l^2)^T \quad \ldots \quad (\mathbf{x}_l^{K_l})^T\right]^T \in \mathbb{C}^{d_l \times 1}$. The channel matrix between the mth BS and the lth cell is denoted as $\mathbf{H}_{m,l} = \left[\mathbf{H}_{m,l}^1 \quad \mathbf{H}_{m,l}^2 \quad \ldots \quad \mathbf{H}_{m,l}^{K_l}\right] \in \mathbb{C}^{N_r \times N_t K_l}$, and the noise vector at mth BS is denoted as $\mathbf{z}_m \in \mathbb{C}^{N_r}$ with each element being i.i.d. complex Gaussian distributed with distribution $CN(0,N_0)$. The total number of users in a cell is K. The total number of data streams to be transmitted is $d_T = \sum_{l=1}^{M} d_l$. The power restriction for each user is P_{UPW}, i.e., $\left\|\mathbf{V}_l^k \mathbf{x}_l^k\right\|_F \leq P_{UPW}$.

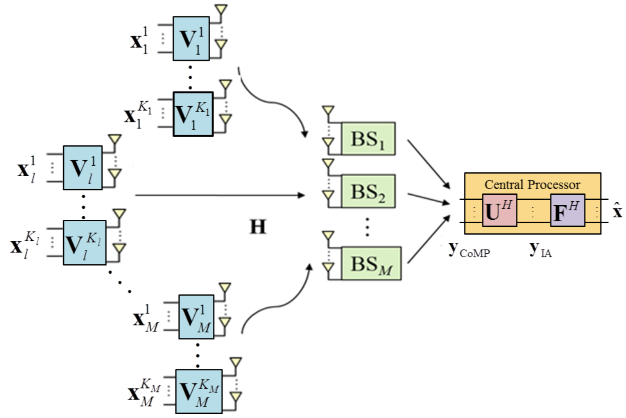

Fig. 1. Illustration of centralized IA aided UL CoMP system model.

In centralized UL CoMP, the cooperation is conducted on the central unit (CU). The collected received signal at CU is expressed by

$$\mathbf{y}_{\text{CoMP}} = \mathbf{HVx} + \mathbf{z}, \tag{2}$$

where $\mathbf{y}_{\text{CoMP}} = \left[\mathbf{y}_1^T \quad \mathbf{y}_2^T \quad \ldots \quad \mathbf{y}_M^T\right]^T \in \mathbb{C}^{d_T \times 1}$ is the aggregated received signal, and $\mathbf{V} = \mathrm{diag}(\mathbf{V}_1, \mathbf{V}_2, \ldots, \mathbf{V}_M) \in \mathbb{C}^{N_t K \times d_T}$ is the aggregated precoding matrix, where $K = \sum_{l=1}^{M} K_l$. The aggregated channel matrix is expressed as

$$\mathbf{H} = \left[\left[\mathbf{H}_{1,1},\ldots,\mathbf{H}_{1,M}\right]^T,\ldots,\left[\mathbf{H}_{M,1},\ldots,\mathbf{H}_{M,M}\right]^T\right]^T \in \mathbb{C}^{N_r M \times N_t K},$$

and aggregated noise vector is $\mathbf{z} = \left[\mathbf{z}_1,\ldots,\mathbf{z}_M\right] \in \mathbb{C}^{N_r M}$. The received signal processed through a decoder $\mathbf{U} \in \mathbb{C}^{N_r M \times d_T}$ yields

$$\mathbf{y}_{\text{IA}} = \mathbf{U}^H \mathbf{y}_{\text{CoMP}} = \mathbf{U}^H\mathbf{HVx} + \mathbf{U}^H\mathbf{z} = \mathbf{H}_{\text{eff}}\mathbf{x} + \mathbf{z}_{\text{eff}}, \tag{3}$$

where $\mathbf{H}_{\text{eff}} = \mathbf{U}^H\mathbf{HV} \in \mathbb{C}^{d_T \times d_T}$ is the effective channel consisting of precoders, decoder, and original channel matrix. Finally, the CU process the received signal $\mathbf{y}_{\text{IA}}$ as

$$\hat{\mathbf{x}} = \mathbf{F}^H\mathbf{y}_{\text{IA}} = \mathbf{F}^H\mathbf{H}_{\text{eff}}\mathbf{x} + \mathbf{F}^H\mathbf{z}_{\text{eff}}, \tag{4}$$

where $\hat{\mathbf{x}} \in \mathbb{C}^{d_T \times 1}$ is the estimated signal, and

$$\mathbf{F}^H = (\mathbf{H}_{\text{eff}}^H\mathbf{H}_{\text{eff}} + N_0\mathbf{I}_{d_T})^{-1}\mathbf{H}_{\text{eff}}^H \in \mathbb{C}^{d_T \times d_T} \tag{5}$$

is the minimum mean square error (MMSE) equalizing matrix. It should be noted that the total number of received antennas is assumed to be equal or greater than the total number of transmit antennas to make sure all the data streams in all the possible configurations can be successively separated using MMSE equalizing matrix in UL CoMP systems.

B. Interference Alignment in Uplink CoMP Systems

To efficiently utilize the available DoFs to mitigate interference, IA techniques are introduced into centralized UL CoMP systems for designing transceivers. The basic idea of IA is to align interference onto a lower dimensional subspace, and thus each receiver can adopt more DoFs to better decode the desired signal. The design criteria of IA in UL CoMP systems for the kth user $\forall k \in \{1, 2, ..., K\}$ can be described as [9]:

$$\begin{aligned} &\left(\bar{\mathbf{U}}_k\right)^H \bar{\mathbf{H}}_l \bar{\mathbf{V}}_l = \mathbf{0}_{\bar{d}_k \times \bar{d}_l},\ \forall l \neq k, \\ &\text{rank}\left(\left(\bar{\mathbf{U}}_k\right)^H \bar{\mathbf{H}}_k \bar{\mathbf{V}}_k\right) = \bar{d}_k,\ \forall k \end{aligned} \quad (6)$$

where $\bar{\mathbf{H}}_k = \{\mathbf{H}\}_{(k-1)N_t}^{kN_t}$, $\bar{\mathbf{U}}_k = \{\mathbf{U}\}_{\bar{d}_{k,1}}^{\bar{d}_{k,\bar{d}_k}}$, and $\bar{\mathbf{V}}_k$ is the precoding matrix of the kth user. The location index of decoding vector corresponding to dth layer belonging to the kth user within $\mathbf{U}$ is denoted as $\bar{d}_{k,d} = \sum_{i=1}^{k-1} \bar{d}_i + d$.

In IA aided UL CoMP systems, the CU attempts to design decoder and precoder for each user with the goal to fulfill the constraints in (6). By adopting the iterative IA algorithms [10-11], the decoder and precoders for each user can be found. The corresponding achievable sum rate after the MMSE equalizing matrix in IA-aided UL CoMP systems is defined as

$$R_{\text{sum}} = \sum_{d=1}^{d_T} \left[\log_2(1 + \text{SINR}_d)\right], \quad (7)$$

where SINR_d is the SINR measured at the output of equalizer corresponding to each layer which is expressed as

$$SINR_d = \frac{(\mathbf{F}^d)^H \mathbf{H}_{\text{eff}}^d (\mathbf{H}_{\text{eff}}^d)^H (\mathbf{F}^d)^H}{(\mathbf{F}^d)^H \left(\sum_{l \neq d} \mathbf{H}_{\text{eff}}^l (\mathbf{H}_{\text{eff}}^l)^H + N_0 \mathbf{U}^H \mathbf{U}\right) \mathbf{F}^d}. \quad (8)$$

III. PROPOSED LOW COMPLEXITY ALGORITHM

In this section, the problem is formulated using an optimization form. Two different proposed methods to reduce complexity from two different aspects are described, respectively. Finally, the proposed algorithm consisting of the two methods is summarized.

A. Problem Formulation

The achievable sum rate for the qth configuration can be formulated as

$$C_{\theta_q} = \sum_{d=1}^{d_T^{(q)}} \log(1 + \text{SINR}_d^{(q)}) = \sum_{k=1}^{K} \sum_{j=1}^{d_k^{(q)}} \log(1 + \text{SINR}_{kj}^{(q)}), \quad (9)$$

where $\theta_q \subset \Theta$, and Θ is a set containing all possible configurations; $d_T^{(q)}$, $d_k^{(q)}$ are the total transmitted data streams, and transmitted data streams of the kth user for the qth configuration, respectively; and $\text{SINR}_{kj}^{(q)}$ is the SINR for the jth layer of the kth user with the qth configuration. Thus, the optimization problem can be formulated as

$$\arg\max_{\theta_q} \sum_{k=1}^{K} \sum_{j=1}^{d_k^{(q)}} \log(1 + \text{SINR}_{kj}^{(q)}). \quad (10)$$

The intuitive method to solve this optimization problem is using exhaustive method, and the SINR of each data stream is calculated after designing the decoder and precoders. However, the exhaustive method induces high complexities. Therefore, we proposed an algorithm to provide a near optimal solution with low complexity.

B. Proposed metric for calculation of achievable sum rate

Due to the high complexity in calculating the exact transceiver before calculating the achievable sum rate of a configuration, we propose a metric to predict the SINR without actually finding the transceiver. Since the focus is on the interference-limited case, the derivation of the algorithm assumes to be approximated in high SNR regime. However, it should be noted that from the simulation results, this algorithm works well in low SNR regime as well. For the high SNR case, the MMSE equalizing matrix would become a zero-forcing equalizing matrix, expressed as

$$\mathbf{F}^H = \left(\mathbf{H}_{\text{eff}}^H \mathbf{H}_{\text{eff}} + N_0 \mathbf{I}_{d_T}\right)^{-1} \mathbf{H}_{\text{eff}}^H \approx \left(\mathbf{H}_{\text{eff}}^H \mathbf{H}_{\text{eff}}\right)^{-1} \mathbf{H}_{\text{eff}}^H. \quad (11)$$

From equation (4) and (11), the received signal can be represented as

$$\hat{\mathbf{x}} = \mathbf{x} + \left(\mathbf{H}_{\text{eff}}^H \mathbf{H}_{\text{eff}}\right)^{-1} \mathbf{H}_{\text{eff}}^H \mathbf{z}_{\text{eff}} = \mathbf{x} + \mathbf{n}, \quad (12)$$

where $\mathbf{n} = \left(\mathbf{H}_{\text{eff}}^H \mathbf{H}_{\text{eff}}\right)^{-1} \mathbf{H}_{\text{eff}}^H \mathbf{z}_{\text{eff}}$. The equation (12) implies that the SINR for the estimated signal is related to the covariance of the noise $\mathbf{n}$, and the covariance of noise can be described as

$$\mathbf{C}_{\mathbf{n}} = \left(\mathbf{H}_{\text{eff}}^H \mathbf{H}_{\text{eff}}\right)^{-1} \mathbf{H}_{\text{eff}}^H \mathbf{H}_{\text{eff}} \left(\mathbf{H}_{\text{eff}}^H \mathbf{H}_{\text{eff}}\right)^{-1} = \left(\mathbf{H}_{\text{eff}}^H \mathbf{H}_{\text{eff}}\right)^{-1}. \quad (13)$$

By assuming that the interference is perfectly aligned by IA algorithms, the covariance of the noise becomes

$$\mathbf{C}_{\mathbf{n}} = \left[\text{diag}\left(\bar{\mathbf{H}}_{1,\text{eff}}^H \bar{\mathbf{H}}_{1,\text{eff}}, \bar{\mathbf{H}}_{2,\text{eff}}^H \bar{\mathbf{H}}_{2,\text{eff}}, ..., \bar{\mathbf{H}}_{K,\text{eff}}^H \bar{\mathbf{H}}_{K,\text{eff}}\right)\right]^{-1}, \quad (14)$$

where $\bar{\mathbf{H}}_{k,\text{eff}} = \mathbf{U}^H \bar{\mathbf{H}}_k \mathbf{V}_k$. Again, due to perfect interference alignment, the diagonal term of covariance of noise becomes

$$\bar{\mathbf{H}}_{k,\text{eff}}^H \bar{\mathbf{H}}_{k,\text{eff}} = \left(\left(\bar{\mathbf{U}}_k\right)^H \bar{\mathbf{H}}_k \bar{\mathbf{V}}_k\right)^H \left(\bar{\mathbf{U}}_k\right)^H \bar{\mathbf{H}}_k \bar{\mathbf{V}}_k. \quad (15)$$

This means that the noise power with respect to the kth user is only related to the channel for the kth user to transmit signal, the preocder for the kth user, and the part of decoder that belongs to the kth user. Therefore, the major impact factors of SINR for different configurations of the transmitted data streams of the kth user are the number of DoFs used for decoding desired signal and the power constraint for each user. Thus, a metric to calculate SINR for the jth layer of the kth user with the qth configurations is represented as

TABLE I

PROPOSED ALGORITHM OF CONFIGURATION SELECTION

Initial stage:

1. Set the reference configuration θ_r.
2. Compute the SINR, and achievable sum rate for the reference configuration using original IA-aided algorithms to design the decoder and precoders.
3. Set selected configuration $\theta_s = \theta_r$.

Search stage:

1. Set $n = 1$.
2. Calculate SINR for every data streams of configuration θ_i, i=1,2, …,N_t corresponding to $\mathrm{SINR}_{kj}^{(i)} = \mathrm{SINR}_k^{\mathrm{ref}} \cdot \frac{1}{d_k^{(i)}} \cdot \frac{MN_r + 1 - d_T^{(i)}}{MN_r + 1 - K}$, where the data streams to be transmitted for θ_i is set according to $\begin{cases} d_l^{(i)} = d_l^{(s)}, & l \neq n \\ d_l^{(i)} = i, & l = n \end{cases}$.
3. Compute the sum rate for θ_i, i=1,2,…,N_t using equation (9), and find $\hat{i} = \arg\max_{i=1,\ldots,N_t} C_{\theta_i}$.
4. Set $\theta_s = \theta_{\hat{i}}$ and $n = n$+1.
5. Go back to step 2 until $n = K$.
6. Output the selected configuration θ_s.

$$\mathrm{SINR}_{kj}^{(q)} = \frac{MN_r - d_T^{(q)} + 1}{d_k^{(q)}} \sigma^2, \qquad (16)$$

where σ is a constant. The nominator accounts for the number of DoFs used for decoding desired signal. The insight of nominator is that the gain of SINR is larger if the total number of DoFs used for better decoding the desired data stream is larger, and the maximum gain is equal to the total number of receive antennas which corresponds to the case where only a single data stream is transmitted. The denominator is due to the power shared by other data streams belonging to the same user, which means that only fractional power can be guaranteed by each data stream.

The remaining unknown in (16) is the constant. Thus, a reference configuration is necessary for deriving this constant. Therefore, the explicit transceiver design process has to be done at least once. From the process, the SINR of the reference configuration can be found, and the constant can be calculated using (16). After deriving the constant, the SINR for each data streams of all possible configurations can be calculated. Then, the achievable sum rate can be calculated for each configuration using (9). Intuitively, the reference configuration is set to be the case where each user transmits a single data stream. This reference configuration is also used in our algorithm and simulations.

C. *Proposed search strategy*

Although the complexity for calculating the achievable sum rate is reduced, the number of configurations to be searched increases exponentially with respect to the number of transmit antennas, This exponential increase is still too complicated as the transmit antenna number is large. Thus, a heuristic search strategy is proposed to further reduce the complexity. In this strategy, the initial search configuration is set to be the configuration where each user transmits a single data stream. After the initial setup, the number of data streams transmitted by the first user is altered, and the achievable sum rate is calculated for every possible numbers using the algorithm in Section III-B. We then select that number that maximizes the achievable sum rate as the number of data streams transmitted by the first user. The same process applies to the second user, and so on. After conducting this process on all the users once, the configuration is then decided. Since the process is conducted once for each user, the increase in the number of possible configurations remains linear as the number of transmit antennas increase.

The proposed metric converts the difficult sum rate computing process via exact transceiver design process into an easy metric calculation, and the proposed search strategy renders the number of candidate configurations to increase linearly instead of exponentially. As a result, by combining these two methods, an algorithm is proposed which is expected to have extreme low complexity compared with exhaustive method. The detailed algorithm is summarized in Table I. It is important to note that, while the proposed metric and strategy are theoretically suboptimal, the proposed algorithm is empirically near-optimal as observed in the simulation results. The empirical near-optimality of the proposed algorithm is due to the large differences of achievable sum rates among configurations with high and low achievable sum rates as well as the small differences of achievable sum rates among the configurations with best and high achievable sum rates. Therefore the system provides resilience in tolerating the incorrect configuration selections to a certain degree.

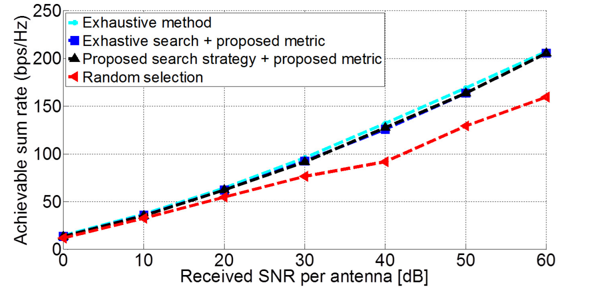

Fig. 2. The achievable sum rates of various configuration selection schemes with $\varepsilon = 0.4$, $N_t = 4$, $N_r = 4$, $K = 3$, and $M = 3$.

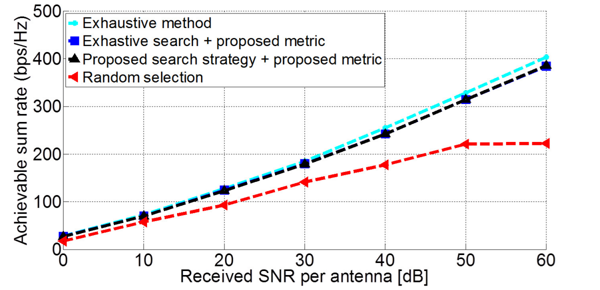

Fig. 3. The achievable sum rates of various configuration selection schemes with $\varepsilon = 0.4$, $N_t = 8$, $N_r = 8$, $K = 3$, and $M = 3$.

IV. Simulation Results

In this section, we evaluate the proposed metric and search strategy. The performance of "Exhaustive method", "Exhaustive search + proposed metric", and "Proposed search strategy + proposed metric" are compared. Besides, a random selection method that randomly selects the configuration is used for comparison. The channel matrices are set by $\varepsilon = 0.4$ for Fig. 2 and Fig. 3, and $\varepsilon = 0.9$ for Fig. 4 and Fig. 5 to evaluate the performance in a more severe interference-limited environment. The transceiver design algorithm used here is the maximum SINR algorithm [10]. A typical scenario in 3GPP recommendation [5] is used with different number of antennas. The number of transmit antennas, the number of received antennas, the number of UEs, and the number of BSs are N_t, N_r, K, M, respectively.

Fig. 2 shows the performance comparison of different algorithms. The parameters are set as $N_t = 4$, $N_r = 4$, $K = 3$, $M = 3$. As Fig. 2 shows, the proposed metric can predict the achievable sum rate closely as if the transceiver is actually designed. Although it is not shown here, the performance degradation is within 5% compared to exhaustive method. Besides, the proposed strategy can have almost identical performance as exhaustive search strategy. Thus, the proposed search strategy combining with the metric can have comparable performance with exhaustive search, and have much lower complexities. Also, if we randomly select the configurations, the performance is degraded substantially as can be seen in Fig. 2. For Fig. 3, the parameters are set as $N_t = 8$, $N_r = 8$, $K = 3$, $M = 3$. The results show that the similar conclusion as in Fig. 2 can be observed. In Fig. 4 and Fig. 5, the parameters are set to be the almost the same as Fig. 2 and Fig. 3, respectively. The only difference is that $\varepsilon = 0.9$ to evaluate the performance in a situation where interference is much severe. The same conclusions can be achieved as in Fig.2 and Fig. 3. The proposed algorithm can have almost the same performance as exhaustive search method in a situation with more severe interference. It is noted that the achievable sum rate of Fig. 4 and Fig. 5 can be larger than the achievable sum rate of Fig. 2 and Fig. 3, respectively. This is due to that the stronger coordinated link can potentially provide larger achievable sum rate for CoMP system.

In summary, the simulation results show that the proposed algorithm can effectively select the configuration that maximizes the achievable sum rate; the complexity of the proposed approach is much lower than the exhaustive method.

V. Conclusions

In this paper, we propose a low complexity algorithm to select the configuration that maximizes UL CoMP IA-aided system. This algorithm consists of two parts. First, a metric to predict the achievable sum rate for each configuration is proposed. The metric can substantially reduce the computation efforts for computing achievable sum rate. Second, a search strategy to reduce the number of candidate configurations is proposed, and the simulation results show that the proposed search strategy can have the similar performance as in exhaustive search strategy. Finally, the simulation results show that the proposed algorithm has similar performance as in exhaustive method.

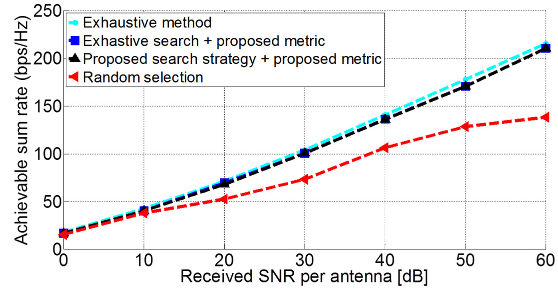

Fig. 4. The achievable sum rates of various configuration selection schemes with $\varepsilon = 0.9$, $N_t = 4$, $N_r = 4$, $K = 3$, and $M = 3$.

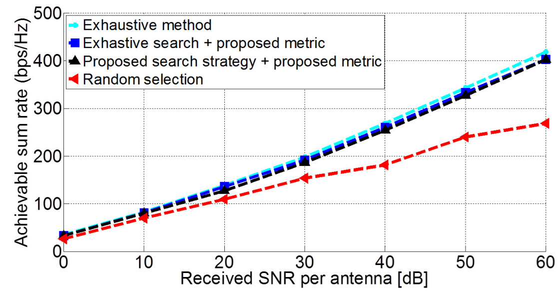

Fig. 5. The achievable sum rates of various configuration selection schemes with $\varepsilon = 0.9$, $N_t = 8$, $N_r = 8$, $K = 3$, and $M = 3$.

References

[1] D. Gesbert, and et. al., "Muiticell MIMO cooperative networks: A new look at interference," *IEEE JSAC*, vol. 28, no. 9, pp. 1380-1408, Dec. 2010.

[2] I. Hwang, C. B. Chae, J. Lee, and R. W. Heath, Jr., "Multicell cooperative systems with multiple receive antennas," *IEEE Mag. Wireless Commun.*, vol. 20, no. 1, pp. 50-58, Feb. 2013.

[3] M. Sawahashi, Y. Kishiyama, A. Morimoto, D. Nishikawa, and M. Tanno, "Coordianted multipoint transmission.reception techniques for LTE-Advanced," *IEEE Mag. Wireless Commun.*, vol. 17, no. 3, pp. 36-34, Jun. 2010.

[4] R. Irmer, and et. al., "Coordinated multipoint: Concepts, performance, and field trial results," *IEEE Mag. Commun.*, vol. 49, no. 2, pp. 102-111, Feb. 2011.

[5] 3GPP TR 36.819, "Coordinated multi-point operation for LTE physical layer aspects (Release 11)," Dec. 2011.

[6] V. R. Cadambe and S. A. Jarfar, "Interference alignment and degrees of freedom of *K*-user interference channel," *IEEE Trans. Inf. Theory*, vol. 56, no. 1, pp. 3425-3441, Aug. 2008.

[7] I. Santamaria, O. Gonzalez, R. W. Heath, Jr. and S. W. Peters. "Maximum sum-rate interference alignment algorithms for MIMO channels," *in Proc. IEEE GLOBECOM*, pp. 1-6, Dec. 2010.

[8] K. Gomadam, V. R. Cadambe, and S. A. Jarfar, "A distributed numerical approach to interference alignment and applications to wireless interference networks," *IEEE Trans. Inf. Theory*, vol. 57, no. 6, pp. 3309-3321, Jun. 2011.

[9] W. L. Chen, I H. Huang, and T. S. Lee, "Mixed criteria interference alignment-aided transceiver design in uplink coordinated multipoint systems," *in Proc. IEEE ISPACS*, pp. 810-815, Nov. 2012.

[10] C. J. Huang, W. C. Chang, and T. S. Lee, "Codebook based interference alignment in uplink coordinated multipoint systems," *in Proc. IEEE ISPACS*, pp. 816-821, Nov. 2012.