User Selection in MIMO Interference Broadcast Channels

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Abstract

This report addresses the work related to user selection in Interference Alignment in Broadcast channels i.e. multi user multi cell scenario. For achieving Interference Alignment in Broadcast system, a closed form solution is proposed in [1] which is an extension of grouping algorithm [2]. These schemes support a small number of users simultaneously, therefore we have formulated a user scheduling scheme to select user subset from large number of users with the aim of maximizing the sum rate. The Brute-force search for optimal user subset is computationally exhaustive. We have proposed two suboptimal linear user selection algorithms with lower computational complexity than Brute-force search algorithm.

CONTENTS

List of Figures

I. Introduction

Multiple Input Multiple Output (MIMO) systems with multiple antennas at both receiver and transmitter have additional gain of multiplexing as compared to MISO (Multiple Input Single Output) and SIMO (Single Input Mutiple Output). In the scenario where we have more than one transmitter, inter-cell interference arises. It was proposed in [3] that maximum degrees of freedom (dof) in an Interference channel can be achieved using a technique called Interference Alignment (IA) and the maximum dof achieved are exactly half of the received signal space dimension. For single antenna systems symbol extension needs to be performed to increase the dimension of signal space. However, MIMO systems already have multiple antennas hence we need only to design the transmit precoding matrices to align the interference.

Achieving interference alignment in MIMO system is not straight forward and till now the closed form solution is known only for 3-transmitter system. With the aim of sum rate maximization the authors of [4] proposed modified precoding and receiver matrices using Zero-forcing and MMSE approach. The authors of [5] proposed two iterative algorithms to achieve IA for any number of transmitter-receiver pairs. The distributed algorithm for IA is based on Interference leakage power minimization which is the power of interference received at each receiver. The other algorithm aims at sum rate maximization by employing Signal to Interference-plus-noise ratio (SINR) maximization. Although these algorithms works for any number of transmitter-receiver pair but their convergence is a problem when this number grows large.

In an Interference Broadcast (IFBC) system, the base station (BS) in each cell supports multiple users. Therefore, we have inter-user interference as well as inter-cell interference at each receiver in each cell. In order to mitigate this interference some structured receiver matrices are to be designed. The authors of [2] proposed a closed form solution to achieve IA in IFBC system employing minimum number of transmit antennas using a approach called grouping in a 2-cell system. The users of the adjacent cell are grouped to reduce the dimension of interference. The authors of [1] extended the grouping scheme to any number of cells and proposed a general scheme.

The number of users supported by each BS in IFBC system is small, typically like 3 or 4. But in practical scenario, we have hundreds of users in each cell, therefore the BS needs to select the simultaneously supportable

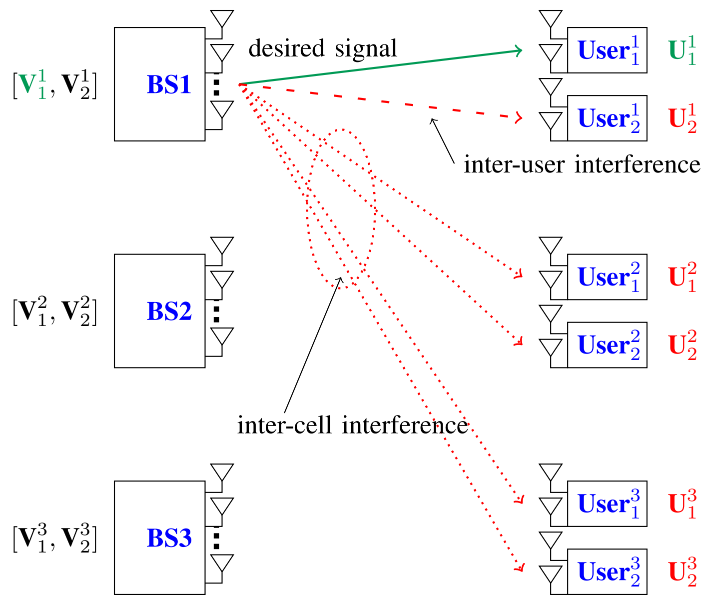

Fig. 1. MIMO IFBC system with $L = 3$ and $K = 2$ in each cell

users from the total users with some criteria. In this report we have formulated a user selection problem giving the maximum number of users than can be supported. The brute-force search algorithm can be employed to get the optimal user subset, but the computation complexity is exhaustive. Therefore, we have proposed two suboptimal linear user selection algorithms with much less computation complexity than brute-force search. The first algorithm selects the user using coordinate ascent approach giving maximum sum rate. The second algorithm utilizes the chordal distance [6] which is a measure of orthogonality between channel spaces' as a selection metric.

II. System Model

We consider a MIMO IFBC system with L number of cells each supporting K number of users. The BS in each cell has M transmit antennas and each user in each cell has N receive antennas. Fig. 1 illustrates the considered system for $L = 3$ and $K = 2$. It can be seen that each BS broadcasts signal to all the users present in the system generating inter-user interference and inter-cell interference. The matrix $\mathbf{H}_k^{i,j} \in \mathbb{C}^{N\times M}$ represents channel from BS j to user k in cell$-i$. The channel is assumed to be rayleigh fading i.e. each component is independently and identically (i.i.d.) distributed complex circular symmetric gaussian random variable with unity variance. The transmitted signal by the BS l is given by

$$\mathbf{x}^l = \sum_{k=1}^{K} \mathbf{x}_k^l = \sum_{k=1}^{K} \sum_{i=1}^{d_s} \mathbf{v}_{i,k}^l s_{i,k}^l = \sum_{k=1}^{K} \mathbf{V}_k^l \mathbf{s}_k^l \tag{1}$$

where d_s is the dof allocated to each user in each cell and $\mathbf{s}_k^l$ denotes the $d_s \times 1$ transmitted symbol vector for kth user. The $M \times d_s$ matrix $\mathbf{V}_k^l$ is precoding matrix for kth user in lth cell such that $||\mathbf{v}_{i,k}^l||^2 = 1$. The total power constraint at the lth BS is $E\left\{||\mathbf{x}^l||^2\right\} \leq P^l$. The received signal at the kth user in the lth cell is given by

$$\begin{aligned}\mathbf{y}_k^l &= \sum_{j=1}^{L}\mathbf{H}_k^{l,j}\sum_{i=1}^{K}\mathbf{x}_i^j \\ \mathbf{y}_k^l &= \mathbf{H}_k^{l,l}\mathbf{V}_k^l\mathbf{s}_k^l + \sum_{i=1,i\neq k}^{K}\mathbf{H}_i^{l,l}\mathbf{V}_i^l\mathbf{s}_i^l + \sum_{j=1,j\neq l}^{L}\sum_{i=1}^{K}\mathbf{H}_i^{l,j}\mathbf{V}_i^j\mathbf{s}_i^j + \mathbf{n}_k^l \end{aligned}\tag{2}$$

where the first term is the desired signal, second term is inter-user interference generated due to broadcast channel and third term is inter-cell interference due to interference channel. The receiver noise $\mathbf{n}_k^l$ is $N \times 1$ complex AWG with each entry having unit variance. Each receiver in the system decodes the desired signal by employing receiver beamforming as

$$\mathbf{U}_k^{l\,H}\mathbf{y}_k^l = \mathbf{U}_k^{l\,H}\mathbf{H}_k^{l,l}\mathbf{V}_k^l\mathbf{s}_k^l + \mathbf{U}_k^{l\,H}\sum_{i=1,i\neq k}^{K}\mathbf{H}_i^{l,l}\mathbf{V}_i^l\mathbf{s}_i^l + \mathbf{U}_k^{l\,H}\sum_{j=1,j\neq l}^{L}\sum_{i=1}^{K}\mathbf{H}_i^{l,j}\mathbf{V}_i^j\mathbf{s}_i^j + \tilde{\mathbf{n}}_k^l \tag{3}$$

where $\mathbf{U}_k^l$ is $N \times d_s$ receiver beamforming matrix and $\tilde{\mathbf{n}}_k^l$ is receiver noise after beamforming such that $\tilde{\mathbf{n}}_k^l = \mathbf{U}_k^{l\,H}\mathbf{n}_k^l$. In order for the user to decode the signal, the inter-user interference and inter-cell interference needs to be aligned. The dimensional requirements at the receiver can be written as

$$\begin{aligned}&\mathbf{U}_k^{l\,H}\mathbf{H}_k^{l,l}\mathbf{V}_i^l = 0, \quad \forall i = 1,...,K \neq k \\ &\mathbf{U}_k^{l\,H}\mathbf{H}_k^{l,j}\mathbf{V}_i^j = 0, \quad \forall i = 1,...,K \text{ and } \forall j = 1,...,L \neq l \\ &\text{rank}\left(\mathbf{U}_k^{l\,H}\mathbf{H}_k^{l,l}\mathbf{V}_k^l\right) = d_s \end{aligned}\tag{4}$$

We will assume that each user is allocated equal power by the BS and each symbol in transmitted vector $\mathbf{s}_k^l$ is i.i.d. gaussian such that $\mathbf{s}_{i,k}^l \in \mathcal{N}\left(0, P^l/Kd_s\right)$. The sum rate of the system with conditions in (4) holding is given by

$$C = \sum_{l=1}^{L}\sum_{k=1}^{K}\log_2\frac{|\mathbf{U}_k^{l\,H}\mathbf{U}_k^l + \frac{P^l}{Kd_s}\tilde{\mathbf{H}}_k^{l,l}\tilde{\mathbf{H}}_k^{l,l\,H}|}{|\mathbf{U}_k^{l\,H}\mathbf{U}_k^l|} \tag{5}$$

where $\tilde{\mathbf{H}}_k^{l,l} = \mathbf{U}_k^{l\,H}\mathbf{H}_k^{l,l}\mathbf{V}_k^l$.

Grouping Scheme

In order to decode the desired signal correctly the conditions in (4) must hold. Therefore we can say

$$\mathbf{U}_k^l \in [\mathbf{H}_k^{l,l}\mathbf{V}_i^l \quad \mathbf{H}_k^{l,j}\mathbf{V}_m^j]^{\perp} \quad \forall i \neq k \text{ and } \forall j \neq l, m = 1,...,K \tag{6}$$

or equivalently we can write these conditions to determine $\mathbf{V}_k^l$ as

$$\mathbf{V}_k^l \in null([(\mathbf{U}_i^{l\,H}\mathbf{H}_k^{l,l})^H \quad (\mathbf{U}_m^{n\,H}\mathbf{H}_k^{l,n})^H \quad (\mathbf{U}_m^{j\,H}\mathbf{H}_k^{l,j})^H]^H) \quad \forall i \neq k, j \neq l, n \text{ and } m = 1,...,K \tag{7}$$

TABLE I

CAPACITY BASED USER SELECTION ALGORITHM

1) **Initialization**: Define $\Gamma^l = \{1, ..., K_T\}$ for each $1 \leq l \leq L$, initialize the user subsets as $\mathcal{S}^l = \underset{K}{\text{arglist}} \max_{j \in \Gamma^l} ||\mathbf{H}_j^{l,l}||_F$ for each $1 \leq l \leq L$ such that $\mathcal{S}^l = \{s_1^l, ..., s_K^l\}; C = 0$. Perform the grouping and compute the initial value of receiver processing matrices $\mathbf{U}_k^l, \forall k \in \mathcal{S}^l$ and $\forall l$

2) for $l = 1 : L$
   for $k = 1 : K$
      For every $j \in \Gamma^l$,
      i) define $\mathcal{S}_{k,j}^{l\,temp} = \{\mathcal{S}^l | s_k^l = j\}$.
      ii) Compute the temporary receiver processing matrix for users in $\mathcal{S}_{k,j}^{l\,temp}$ using grouping method as $\mathbf{U}_j^{l\,temp}$.
      iii) Using the $\mathbf{U}_j^{l\,temp}$ and $\mathbf{U}_i^m, i \in \mathcal{S}^m\ \forall m \neq l$ compute transmit processing matrices $\mathbf{V}_i^m, i \in \mathcal{S}^m$ $\forall m \neq l$ and $i \in \mathcal{S}_{k,j}^{l\,temp}$, for $m = l$.
      iv) Using computed values of receive and transmit matrices compute C_j using (5) for the selected users.
      $p = \arg\max_{j \in \Gamma^l} C_j$
      if $C_p > C$,
         $\mathcal{S}^l = \mathcal{S}_{k,j}^{l\,temp}$;
         $\Gamma^l = \Gamma^l - \{p\}$;
      end-if
   end-for
end-for

where n is cyclic next cell index of k, for e.g. if $l = 1, n = 2$ and $l = L, n = 1$. Now if we group the next cell matrices together then the dimension of column space of composite matrix in (7) reduces, which in turn reduces the minimum number of transmit antennas required. This is what is known as Grouping scheme introduced in [2] and extended in [1]. The minimum number of transmit and receive antennas required to satisfy grouping scheme and (7) are given in [1] as

$$\begin{aligned} M &\geq [K(L-1)+1] \times d_s \\ N &\geq [(K-1)(L-1)+1] \times d_s \end{aligned} \tag{8}$$

III. User Scheduling

In our considered system we have L cells supporting K users in each cell such that each BS has M antennas and each receiver has N antennas. For given values of M, N and L, the maximum number of users that can be supported simultaneously by the BS are such that they satisfy (8) and hence can be written as

$$K = \min\left\{ \left\lfloor \frac{1}{L-1}[\frac{M}{d_s} - 1] \right\rfloor, 1 + \left\lfloor \frac{1}{L-1}[\frac{N}{d_s} - 1] \right\rfloor \right\} \tag{9}$$

where $\lfloor x \rfloor$ is floor operation. Therefore, the K defined above is the maximum number of users than can be supported by a MIMO IFBC system. Using this value of K we will formulate user selection algorithms.

A. Optimal Scheduling

We have seen that for given transmit and receive antennas and other configurations of MIMO IFBC system, the maximum number of users that can be supported simultaneously is given by (9). Now, if we have a total of K_T users in each cell in our system, then the BS is required to select the user subset such that the sum rate is maximized. The optimal user subset in each cell is found as

$$\mathcal{R}_{opt} = \max_{\mathcal{S}^l \subset \Gamma^l, |\mathcal{S}^l| \leq K, \forall l=1,\ldots,L} C(\mathcal{S}^1, \mathcal{S}^2, ..., \mathcal{S}^L) \tag{10}$$

where $\Gamma^l = \{1, ..., K_T\}$ and $\mathcal{S}^l$ is the user subset selected by BS$-l$ subject to a cardinality constraint. The total number of searches to be made to determine optimal user subsets are $\binom{K_T}{K}^L$ which increases exponentially and is impractical for large values of K_T, for e.g. if $K_T = 50, K = 2, L = 3$ then number of searches to be made are 1.838×10^8 which is quite large even for a small value of K_T. To save from this we have proposed two linear suboptimal user selection algorithms.

B. C-algorithm

Initialize the user subset by selecting the users in each cell with maximum channel energy given by $||\mathbf{H}_k^{l,l}||^F$, where $\underset{K}{\text{arglist}}$ give arguments of K users. After initializing user subsets compute the receiver processing matrices for each user in selected subset in each cell. We will use coordinate ascent approach [7] to update the user subsets. In coordinate ascent approach a user index in a cell is varied keeping all the users fixed in selected user subsets. The notation $\mathcal{S}_{k,j}^{l\,temp}$ denotes replacing the kth user in $\mathcal{S}^l$ by j. Using this temporary user subset we will compute precoding matrices according to (7) and hence compute sum rate of the system using (5). The users giving maximum sum rate for the system will be selected and the algorithm terminates.

C. Chordal distance based algorithm

While the c-algorithm is linear as compared to exponential brute-force search, the complexity of search can further be reduced if we develop some deep thought into what is going on while computing receiver and transmitter matrices. We know that null space of matrix $\mathbf{A}$ is the orthogonal space of $\mathbf{A}^H$. Therefore, if we use reciprocal channel model [5], [8] to our considered MIMO IFBC system, the dof achieved will be same, but $\mathbf{U}$ will now become precoding matrix and $\mathbf{V}$ will become receiver beamforming matrix. The reciprocal system for our considered case is shown in Fig. 2. The receiver at reciprocal system compute $\mathbf{V}_k^l$ to project the desired signal to orthogonal space of interference (7).

Let us consider a toy example in which the interference and desired signal are $2-D$ vectors, then the processing at the receiver can be looked upon as shown in Fig. 3. As we can see that more the desired signal is close to orthogonal of interference more is the magnitude of projected signal i.e. desired signal after receiver processing. Therefore, we must select the users whose received desired signal is close to orthogonal to interference received. For selecting the users employing orthogonality constraint we will use chordal distance [6] as selection metric.

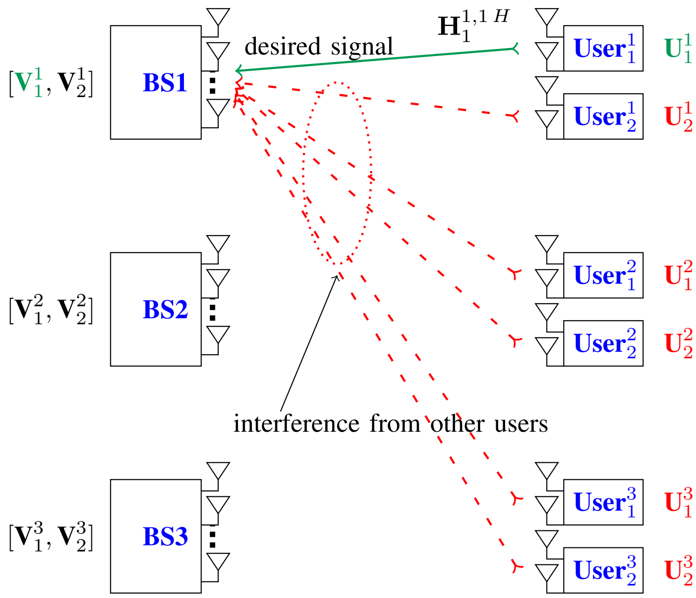

Fig. 2. Reciprocal system of MIMO IFBC system with $L = 3$ and $K = 2$ in each cell

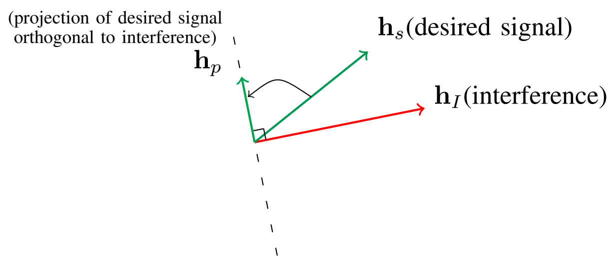

Fig. 3. Receiver processing in reciprocal system

1) Chordal distance: Let us go through the notations and matrices required to compute the chordal distance. For a matrix $\mathbf{A}$ whose columns spans the range of matrix, the generator matrix $\mathbf{A}_G$ is defined as matrix whose columns are orthonormal basis of the range space of $\mathbf{A}$. The generator matrix can be computed by applying Gram-Schmidt Orthogonalization (GSO) to the columns of $\mathbf{A}$. The projection matrix to the range space of $\mathbf{A}$ then becomes $\mathbf{A}_G\mathbf{A}_G^H$. The chordal distance between two subspaces is then given by

$$d_c\left(\mathbf{A}, \mathbf{B}\right) = \frac{1}{\sqrt{2}}||\mathbf{A}_G\mathbf{A}_G^H - \mathbf{B}_G\mathbf{B}_G^H||_F \tag{11}$$

IV. Complexity Analysis

In this section we will provide the analytical complexity analysis of the brute-force search algorithm and two proposed algorithms. The flop count is used as measure of complexity, where a flop is defined as a real floating point operation [9]. A real addition, multiplication, division is counted as one flop. Hence for complex addition we will have 2 flops, complex multiplication will involve 6 flops. Before calculating the total flop count of the algorithms let us see flops count of some operations [10] used frequently. We will assume that $K << K_T$.

- **Frobenius Norm**, $||\mathbf{H}_k^{i,j}||_F$ takes $4MN$ flops.
- **GSO** of channel matrix $\mathbf{H}_k^{i,k}$ requires $8N^2M - 2MN$ flops.
- The **SVD** operation of $\mathbf{H}_k^{i,k}$ requires approximately $24NM^2 + 48N^2M + 54N^3$ flops.

A. C-algorithm

The total flops required for making initial search requires $L \times K_T$ frobenius norm computations, hence flops required are $L \times K_T \times 4MN$. The flops required for computing receiver processing matrix in each cell are f_U. The authors of [1] proposed a decoupled technique to compute receiver matrices using intersection of subspaces which greatly improves over other method for $K \geq 3$. Therefore, for $K \leq 3$ we will use flop count of the regular method in [1], which can be calculated as. Let us call the flop count of computing SVD of a $N \times M$ matrix as

$$\mathcal{F}(N, M) = 24NM^2 + 48N^2M + 54N^3$$

The computation of receiver matrix in each cell involves SVD computation of $KM \times M + (K-1)N$ matrix [1]. Hence $f_U = \mathcal{F}(KM, M + (K-1)N)$ for $K \leq 3$. For $K \geq 3$ we will use the decoupled approach which involves SVD computation of matrices, column dimension of which reduces with each subspace intersection operation.

$$f_U = K \times \mathcal{F}(M, M+N) + \sum_{i=1}^{\lceil \log_2 K \rceil} \frac{K}{2^i} \mathcal{F}(M, 2^{i-1}N - s_i M) + K \times 8(2^{i-1}N - s_i M)^2 (2^i N - s_{i+1} M) \quad (12)$$

where $s_1 = 0, s_i = 2s_{i-1} + 1$. For computing the precoding matrices $\mathbf{V}_k^l$, the SVD of a $M \times K(L-1)d_s$ needs to be computed for $L \times K$ times requiring a total of $L \times K \times \mathcal{F}(M, K(L-1)d_s)$ flops. In order to compute the sum rate C_p the flops required are $K \times L \times (8MNd_s + 8M^2d_s + 8N^2d_s)$ and we have ignored the flops required to compute the determinant since the size of the matrix would be $d_s \times d_s$ which is small compared to M and N. Therefore, the total flops required for c-algorithm are

$$\begin{aligned} \psi_c &\leq K_T L \times 4MN + L \times f_U + \{KL \times \mathcal{F}(M, K(L-1)d_s) \\ &\quad + f_U + KL \times (8MNd_s + 8M^2d_s + 8N^2d_s)\} \times (K_T - K + 1)L \\ &\approx \begin{cases} \mathcal{O}\left(K_T K^3 M^2 N L\right) & \text{if } K \leq 3 \\ \mathcal{O}\left(K_T K M^3 L\right) & \text{if } K \geq 3 \end{cases} \end{aligned} \quad (13)$$

B. Brute-force search based algorithm

The flop count for brute-force search algorithm can be written as

TABLE II
CHORDAL DISTANCE BASED USER SELECTION ALGORITHM

1) **Initialization**: Define $\Gamma^l = \{1, ..., K_T\}$ for each $1 \le l \le L$, initialize the user subsets as $\mathcal{S}^l = \underset{K}{\text{arglist}} \max_{j \in \Gamma^l} ||\mathbf{H}_j^{l,l}||_F$ for each $1 \le l \le L$ such that $\mathcal{S}^l = \{s_1^l, ..., s_K^l\}; C = 0$. Perform the grouping and compute the initial values of receiver processing matrices $\mathbf{U}_k^l, \forall k$ and $\forall l$

2) for $l = 1 : L$
   for $k = 1 : K$
      For every $j \in \Gamma^l$,
      i) define $\mathcal{S}_{k,j}^{l\,temp} = \{\mathcal{S}^l | s_k^l = j\}$.
      ii) Compute the temporary receiver processing matrix for users in $\mathcal{S}_{k,j}^{l\,temp}$ using grouping method as $\mathbf{U}_j^{l\,temp}$.
      iii) Compute generator matrix for desired signal as $\mathbf{A}_G = [\mathbf{H}_j^{l,l\,H}\mathbf{U}_j^l]_o$ and for interference as
         $\mathbf{B}_G = [\mathbf{H}^{l,l\,H}_{t(t \in \mathcal{S}_{k,j}^{l\,temp} \neq j)} \mathbf{U}^l_{t(t \in \mathcal{S}_{k,j}^{l\,temp} \neq j)} \quad \mathbf{H}^{m,m(m=1,...,L,\neq l)\,H}_{j(j \in \mathcal{S}^m)} \mathbf{U}^{m(m=1,...,L,\neq l)}_{j(j \in \mathcal{S}^m)}]_o$
      $p = \arg\max_{j \in \Gamma^l} ||\mathbf{A}_G\mathbf{A}_G^H - \mathbf{B}_G\mathbf{B}_G^H||_F$
      Compute the sum rate as C_p
      if $C_p > C$,
         $\mathcal{S}^l = \mathcal{S}_{k,j}^{l\,temp}$;
         $\Gamma^l = \Gamma^l - \{p\}$;
      end-if
   end-for
end-for

$$\begin{aligned}
\psi_{opt} &\le \left(\binom{K_t}{K}\right)^L \times \{KL \times \mathcal{F}(M, K(L-1)d_s) + \\
&\qquad KL \times (8MNd_s + 8M^2d_s + 8N^2d_s) + f_U\} \\
&\approx \mathcal{O}\left(K_T^{KL} K^{-KL-\frac{L}{2}+1} M^3 L\right) \qquad (14)
\end{aligned}$$

where we have used the stirling's approximation [11] to the factorial and approximated the binomial coefficient as

$$\binom{K_T}{K} \approx K_T^K K^{-K-\frac{1}{2}}$$

C. Chordal distance based algorithm

The flops required for initializing are $LK_T \times (4MN)$ for computing frobenius norm and $L \times f_U$ for computing receiver matrices. The computation of chordal distance involves computation of $\mathbf{A}_G$ and $\mathbf{B}_G$ requiring $8M^2d - 2Md$ and $8M^2(K(L-1)d_s) - 2M(K(L-1)d_s)$ flops respectively. For matrix product $\mathbf{A}_G\mathbf{A}_G^H$ and $\mathbf{B}_G\mathbf{B}_G^H$ flops required are $8Md_s^2$ and $8M(K(L-1)d_s)^2$. The computation of distance metric $||\mathbf{A}_G\mathbf{A}_G^H - \mathbf{B}_G\mathbf{B}_G^H||_F$ requires $8M^3$ flops. The total flops for chordal distance based algorithm are

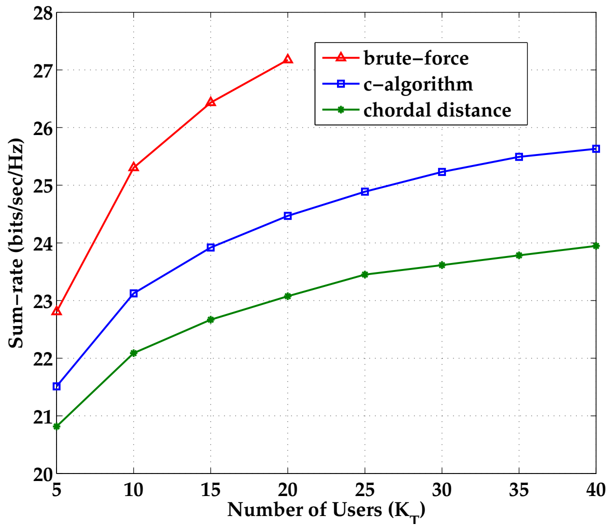

Fig. 4. Sum rate versus total number of users when $M = 6, N = 4, K = 2, L = 2$ for SNR = 10 dB.

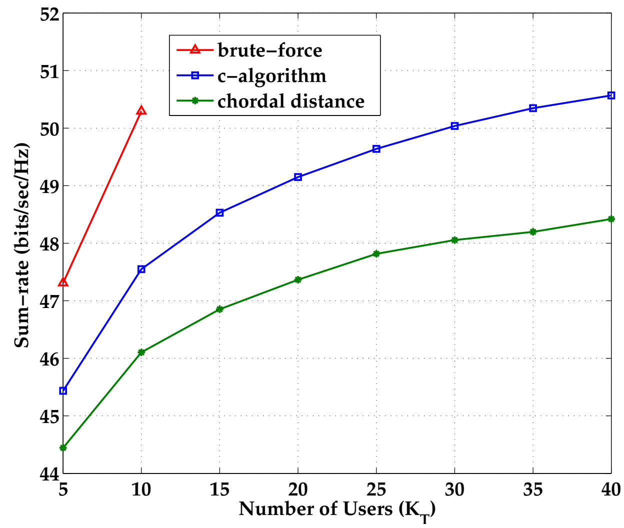

Fig. 5. Sum rate versus total number of users when $M = 6, N = 4, K = 2, L = 2$ for SNR = 20 dB.

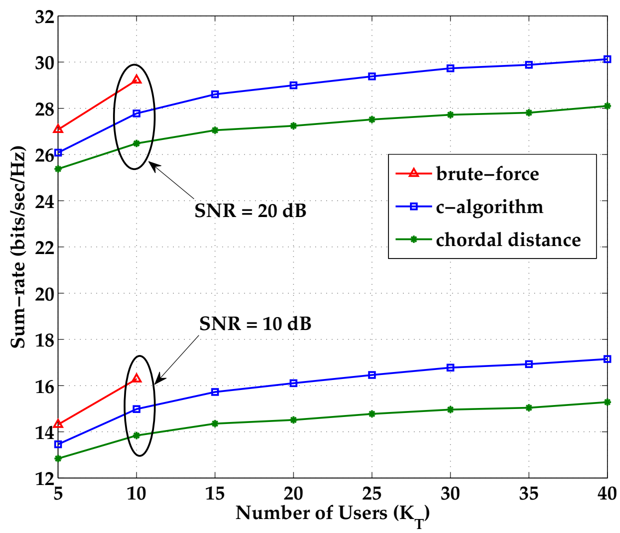

Fig. 6. Sum rate versus total number of users when $M = 3, N = 2, K = 2, L = 2$.

$$\begin{aligned} \psi_{cho} &\leq K_T L \times 4MN + L \times f_U + \{f_U + 8Md_s^2 + 8M^2 d_s \\ &\quad +8M^2(K(L-1)d_s)^2 - 2Md_s - 2M(K(L-1)d_s) + 8M^3\} \\ &\quad \times (K_T - K + 1)L \\ &\approx \mathcal{O}\left(K_T K L M^3\right) \end{aligned} \tag{15}$$

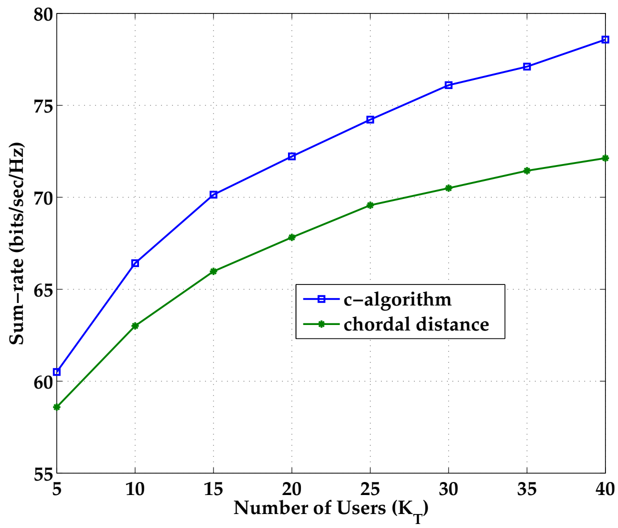

Fig. 7. Sum rate versus total number of users when $M = 10, N = 6, K = 2, L = 3$ for SNR = 10 dB.

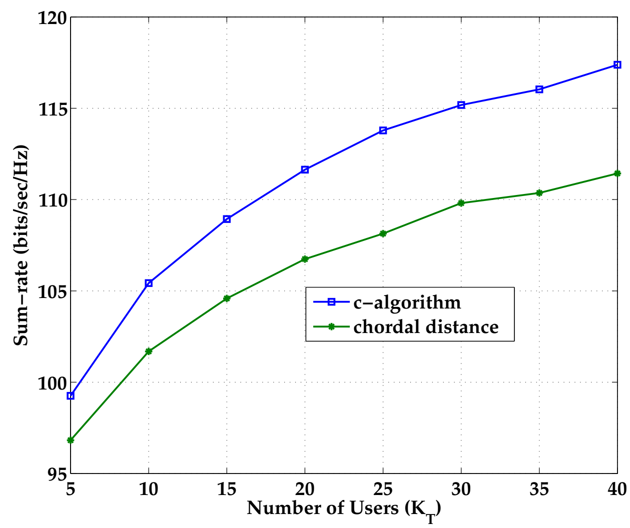

Fig. 8. Sum rate versus total number of users when $M = 10, N = 6, K = 2, L = 3$ for SNR = 20 dB.

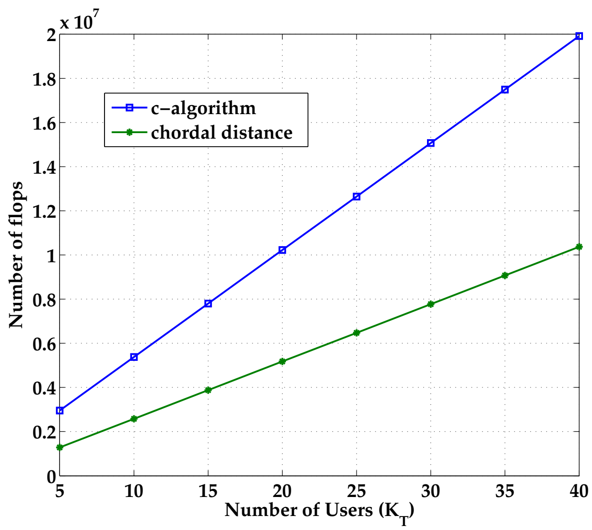

Fig. 9. Number of flops versus total number of users when $M = 6, N = 4, K = 2, L = 2$.

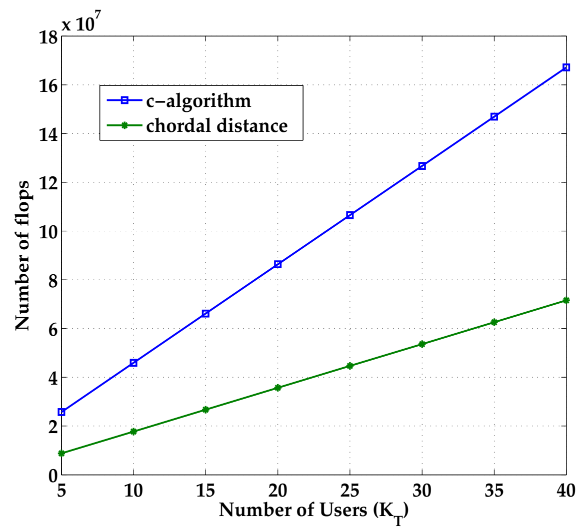

Fig. 10. Number of flops versus total number of users when $M = 10, N = 6, K = 2, L = 3$.

V. Simulation Results

In this section the sum rate plots and flop count plot is provided to compare the algorithms based on their sum rate performance and computational complexity.

Fig. 4 presents the sum rate versus total number of users (K_T) when $(M, N) = (6, 4)$ at SNR $= 10$ dB. As we can see from the plot that the sum rate achieved by the c-algorithm is close to the optimal sum rate. The chordal distance algorithm also achieves sum rate close to that of c-algorithm.

Fig. 5 shows the sum rate performance for the same MIMO IFBC system at SNR $= 20$ dB.

Fig. 7 and Fig. 8 show the sum rate plots when $(M, N) = (10, 6), L = 3$ at SNR $= 10$ dB and SNR $= 20$ dB.

The conclusions made from the plots are similar to previous system setting.

In Fig. 6 we have shown sum rate plot for the discussed algorithms when $(M, N) = (3, 2)$ at various SNR's.

In Fig. 9 the number of flops are plotted versus total number of users (K_T) when $(M, N) = (6, 4)$. It can be seen that the flop count linearly increase with K_T for both c-algorithm and chordal distance based algorithm. The chordal distance algorithm takes roughly half number of flops than c-algorithm. Similar conclusions can be made from Fig. 10 where we have changed the system setting to $(M, N) = (10, 6)$.

VI. Conclusions

In this work we have formulated user selection scheme for MIMO IFBC system where grouping method is used to design the receiver and transmitter matrices. In order to save from exponentially growing brute-force search two suboptimal linear complexity algorithms are proposed. Simulation results show that the sum rate achieved by these algorithms is close to optimal solution. The chordal distance based algorithm has further reduced complexity as compared to c-algorithm. The user selection is vital while applying the IFBC schemes in practical scenario like cellular networks, Wifi access points etc.

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