A Two-Step Precoding Scheme for Multi-User Joint Transmission in Coordinated Multi-Point System

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***Abstract*—Joint transmission (JT) allows multiple base stations (BSs) to serve multiple users (UEs) in the same time and frequency resources, which will causes inter-user interference (IUI). Moreover, different signals from different BSs can't be executed coherent combination directly in non-coherent JT. In this paper, a two-step precoding scheme (TSPS) is proposed to solve these problems. Firstly, an alternating minimization algorithm over the precoders at BSs and the interference subspace matrixes at UEs based on interference alignment (IA) is applied, which can force interference at each UE into the subspace and make each UE observe the interference-free desired signals. Secondly, we use the phase adjustment (PHA) based on QR decomposition to implement the coherent combination of desired signals from different BSs. This paper proves the convergence of alternating minimization algorithm in TSPS. Furthermore, numerical results show TSPS can improve the system performance by the IUI suppression and the signal coherent combination.**

I. Introduction

Recent researches show multi-input multi-output (MIMO) technique can increase the throughput and peak spectral efficiency of a wireless communication system. However, cell edge UEs in the system usually suffer strong inter-cell interference (ICI) from adjacent cells, which causes the extreme performance loss. To solve this problem, coordinated multi-point (CoMP) transmission and reception is proposed [1]-[2]. In a CoMP system, all of cells are divided into multiple cooperation clusters, therefore, BSs in the same cluster can serve the original cell edge UEs cooperatively with sharing some information and improve the cell edge spectral efficiency and system transmission rate [3]-[4].

One of the CoMP transmission techniques is the joint transmission (JT) [5], which allows multiple BSs in a cluster transmitting signals to the same UEs in the same time and frequency resources,which transforms ICI to the desired signal. There are two categories of JT: coherent JT and non-coherent JT. In coherent JT, the channel state information (CSI) of all served UEs should be shared, so global precoding can be implemented. Coherent JT increases the information exchange overhead and the computational complexity of precoding. On the other hand, BSs can just utilize local CSI between itself and different UEs and carry out precoding independently, which is more simple than coherent JT. However, when multiple UEs are served, inter-user interference (IUI) will seriously affect the system performance in non-coherent JT. Furthermore, the desired signals from different BSs can't be executed coherent combination directly.

In order to overcome the drawback of non-coherent JT, in this paper, a two-step precoding scheme (TSPS) is proposed. Firstly, interference alignment (IA) [6]-[9] is utilized to suppress IUI. In the IA technique, partial degree of freedom of the system is used to construct a reduce-dimensional interference subspace of the received space to force interference at each UE into it. Unfortunately, closed-form solutions for IA with an arbitrary number of UEs are difficult to derive [9]-[10]. Hence, inspired by the scheme of IA in the MIMO interference channel [11]-[12], an algorithm alternating minimization algorithm is applied. In this algorithm, we minimize the Euclidean distance between the interference and the projection of that onto the interference subspaces, obtaining the first-step precoders (FSPs) and the receivers by iterative calculation. Secondly, the phase adjustment (PHA) based on QR decomposition [13] is adopted to jointly process the desired channels of UEs, FSPs and receivers got at the first step to combine signals coherently and obtain the final precoders (FPs). TSPS can be executed at each BS independently with some information exchange and that with an arbitrary number of antennas is proved to converge, while the coherently combination gain can be acquired by PHA.

The rest of the paper is organized as follows: the system model is described in Section II. In Section III, TPTS is provided. The convergence of TPTS is proved in Section IV. Section V discusses the simulation results, while Section VI concludes the paper. This paper uses the following notations: $\mathbf{A}$ is a matrix, $\mathbf{a}$ presents a vector, while a and A denote scalars; $\mathbf{A}^H$ is the conjugate transpose of $\mathbf{A}$, $\|\mathbf{A}\|_F$ is the Frobenius norm of $\mathbf{A}$, $[\mathbf{A}]_{rc}$ denotes the r row, c column element of $\mathbf{A}$, $\mathrm{rank}(\mathbf{A})$ represents the rank of $\mathbf{A}$, $|\mathbf{A}|$ denotes the determinant of $\mathbf{A}$, and $\mathrm{tr}(\mathbf{A})$ is the trace of $\mathbf{A}$; in addition, $\mathbf{I}_A$ is the $A \times A$ identity matrix, symbol "$\sim$" stands for obeying a kind of distribution, $\mathbb{E}$ denotes expectation, and $\mathcal{CN}(\mu, \mathbf{R})$ is the cyclic symmetric complex Gaussian distribution with mean μ and covariance matrix $\mathbf{R}$.

II. System Model

Consider the multi-user non-coherent JT in a CoMP system illustrated in Fig. 1, where a cooperation cluster is constituted

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by M cells. In the cluster, each cell contains only one BS, and the ith BS employs M_i transmit antennas. The number of original cell edge UEs served in the cluster is N and UE k possesses N_k receive antennas. In addition, the number of spatial streams transmitted to UE k is L_k, and all of spatial streams satisfy $\sum_{k=1}^{N} L_k \leq M_i, \forall i$ apparently. In this paper, only IUI suppression in one cluster is investigated, that is to say, we don't meditate the interference between clusters. This paper adopts the block-fading channel model, where each link is constant during a frame transmission period, but changes independently between consecutive transmissions. Moreover, $\mathbf{s}_k$ denotes the transmitted signal vector intended for UE k. In this way, the received signal of UE k can be expressed as

$$\mathbf{y}_k = \mathbf{U}_k^H \left(\sum_{i=1}^{M} \mathbf{H}_{k,i} \mathbf{W}_{k,i} \mathbf{s}_k + \sum_{l \neq k, l=1}^{N} \sum_{i=1}^{M} \mathbf{H}_{k,i} \mathbf{W}_{l,i} \mathbf{s}_l + \mathbf{n}_k \right) \tag{1}$$

where $\mathbf{H}_{k,i}$ denotes the $N_k \times M_i$ channel matrix from BS i to UE k, $\mathbf{W}_{k,i}$ is the precoder between BS i and UE k which fulfills $\|\mathbf{W}_{k,i}\|_F^2 = L_k$, $\mathbf{n}_k$ represents the additive Gaussian noise with $\mathbf{n}_k \sim \mathcal{CN}(0, N_0 \mathbf{I}_{N_k})$ (N_0 is the noise power spectral density), and and $\mathbf{U}_k$ is receiver k. For the analysis in this paper, we assume the channels are each of full rank and uncorrelated, with perfect CSI at both BSs and UEs. Furthermore, the transmitted symbols are independent identically distributed (i.i.d.) such that $\mathbb{E}\left(\mathbf{s}_k \mathbf{s}_k^H\right) = \mathbf{I}_{L_k}, \forall k$, signals of different UEs are independent of each other as $\mathbb{E}\left(\mathbf{s}_k \mathbf{s}_l^H\right) = \mathbf{0}, \forall k \neq l$, and all transmitted signals are statistically independent from noise, i.e., $\mathbb{E}\left(\mathbf{s}_k \mathbf{n}_l^H\right) = \mathbf{0}$ for all $(k, l) \in \{1, \ldots, N\}$. Finally, we assume that the noises adding to different UEs are mutual independent, the signal and interference arrive synchronously at each UE and the transmit power is evenly allocated to all of the spatial streams.

This paper proposed TSPS, which can be expressed as

$$\mathbf{W}_{k,i} = \mathbf{W}_{k,i}^{(a)} \cdot \mathbf{W}_{k,i}^{(b)} \tag{2}$$

At the first step, IA technique is applied to suppress IUI [9]

$$\mathbf{U}_k^H \mathbf{H}_{k,i} \mathbf{W}_{l,i}^{(a)} = \mathbf{0} \tag{3}$$

$$\operatorname{rank}\left(\mathbf{U}_k^H \mathbf{H}_{k,i} \mathbf{W}_{k,i}^{(a)}\right) = L_k, \forall k, l \neq k, i \tag{4}$$

where $\mathbf{0}$ denotes the zero matrix. The closed-form solutions are difficult to obtain, so we adopt the alternating minimization algorithm to get FSPs and receivers. Then we adjust the phases of the desired signals from different BSs to acquire FPs and the coherent combination gain on the basis of the first step.

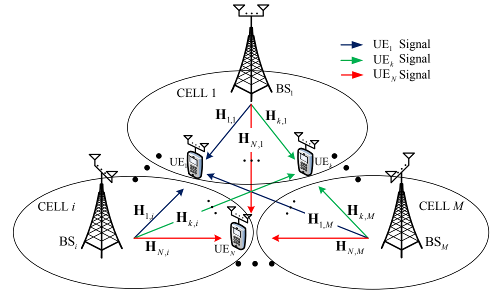


Fig. 1. A cluster with M BSs and N served UEs in a CoMP system.

III. The Proposed Scheme-TSPS

This section introduces TSPS, which is feasible without any assumption on number of BSs (UEs), antenna distribution, or stream allocation.

A. The First Step-IA

So as to suppress IUI, the optimization objective is given as follows [11]-[12]

$$\min_{\substack{\mathbf{W}_{l,i}^{(a)H} \mathbf{W}_{l,i}^{(a)} = \mathbf{I}, \forall l,i \\ \mathbf{C}_k^H \mathbf{C}_k = \mathbf{I}, \forall k}} \sum_{k=1}^{N} \sum_{\substack{l=1 \\ l \neq k}}^{N} \sum_{i=1}^{M} \left\| \mathbf{H}_{k,i} \mathbf{W}_{l,i}^{(a)} - \mathbf{C}_k \mathbf{C}_k^H \mathbf{H}_{k,i} \mathbf{W}_{l,i}^{(a)} \right\|_F^2 \tag{5}$$

where $\mathbf{C}_k$ is the orthogonal basis matrix of the kth interference subspace. That is to say, we minimize the overall Euclidean distance between the interferences and their projection onto the corresponding subspaces. It can be seen that deriving the closed-form solutions to (5) for an arbitrary number of UEs is difficult due to the interdependence of each precoder and interference subspace, thus we utilize the alternating minimization approach. By alternating minimization, FSPs and orthogonal basis matrixes are optimized respectively. When we calculate one precoder or orthogonal basis matrix, all of others are held fixed. Alternating is carried out between the variables of the objective function, until the predetermined convergence condition is reached. Thus the alternating minimization process takes the following form:

1) : Initialize all of FSPs arbitrarily.

2) : Consider the optimization of orthogonal basis matrixes. Applying the properties of matrix analysis [14], the optimization objective can be rewritten as equation (6). The solution to (6) on the columns of $\mathbf{C}_k$ is the $N_k - L_k$ dominant eigenvectors of $\sum_{l=1, l \neq k}^{N} \sum_{i=1}^{M} \mathbf{H}_{k,i} \mathbf{W}_{l,i}^{(a)} \left(\mathbf{H}_{k,i} \mathbf{W}_{l,i}^{(a)}\right)^H, \forall k$.

$$\mathbf{C}_k^{opt} = \arg \max_{\mathbf{C}_k^H \mathbf{C}_k = \mathbf{I}, \forall k} \operatorname{tr} \left(\mathbf{C}_k^H \left(\sum_{l=1, l \neq k}^{N} \sum_{i=1}^{M} \left(\mathbf{H}_{k,i} \mathbf{W}_{l,i}^{(a)} \left(\mathbf{H}_{k,i} \mathbf{W}_{l,i}^{(a)} \right)^H \right) \right) \mathbf{C}_k \right) \tag{6}$$

$$\mathbf{W}_{l,i}^{(a)opt} = \arg \min_{\mathbf{W}_{l,i}^{(a)H} \mathbf{W}_{l,i}^{(a)} = \mathbf{I}, \forall l,i} \operatorname{tr} \left(\mathbf{W}_{l,i}^{(a)H} \left(\sum_{k=1, k \neq l}^{N} \mathbf{H}_{k,i}^H \left(\mathbf{I}_{N_k} - \mathbf{C}_k \mathbf{C}_k^H \right) \mathbf{H}_{k,i} \right) \mathbf{W}_{l,i}^{(a)} \right) \tag{7}$$

3) : Similar to (6), the optimization objective is modified as equation as equation (7). The L_l least dominant eigenvectors of $\sum_{k=1,k\neq l}^{N} \mathbf{H}_{k,i}^H \left(\mathbf{I}_{N_k} - \mathbf{C}_k\mathbf{C}_k^H\right)\mathbf{H}_{k,i}$ are taken as the solution on the columns of $\mathbf{W}_{l,i}^{(a)}, \forall l, i$.

4) : Repeat steps 2 and 3 until the difference between the objective function values after two consecutive iterations are no more than δ (δ is a predetermined constant) or the maximum number of iterations is reached. Afterwards, the receiver k is acquired as

$$\mathbf{U}_k = \mathbf{I}_{N_k} - \mathbf{C}_k\mathbf{C}_k^H, \forall k \tag{8}$$

Thus the results approximately satisfies (3) and (4). It can be seen that each BS designs their FSPs only with their local CSI independently. In addition, each user's receiver can be obtained at its serving BS with partial CSI exchange (namely the products of channels and FSPs at step 2 of the alternating minimization process).

B. The Second Step-PHA

The first step based on IA doesn't make full use of the desired channels. Hence, at this step we jointly process the desired channels, FSPs and receivers by QR decomposition, which can be expressed as

$$\left(\mathbf{U}_k^H\mathbf{H}_{k,i}\mathbf{W}_{k,i}^{(a)}\right)^H = \mathbf{Q}_{k,i}\mathbf{R}_{k,i}, \forall k, i \tag{9}$$

where $\mathbf{Q}_{k,i}$ is a $L_k \times L_k$ unitary matrix while $\mathbf{R}_{k,i}$ is a upper triangular matrix, whose expression is

$$\mathbf{R}_{k,i} = \begin{bmatrix} r_{1,1}^{(k,i)} & \cdots & r_{1,L_k}^{(k,i)} & \cdots\cdots & r_{1,N_k}^{(k,i)} \\ \vdots & \ddots & \vdots & & \vdots \\ 0 & \cdots & r_{L_k,L_k}^{(k,i)} & \cdots\cdots & r_{L_k,N_k}^{(k,i)} \end{bmatrix} \tag{10}$$

The diagonal elements (from $r_{1,1}^{(k,i)}$ to $r_{L_k,L_k}^{(k,i)}$) are real and the absolute value of these stand for the channel gain. In order to implement the coherent combination, the phase adjustment matrix is introduced as[13]

$$\mathbf{P}_{k,i} = \begin{bmatrix} \frac{r_{1,1}^{(k,i)}}{\left|r_{1,1}^{(k,i)}\right|} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \frac{r_{L_k,L_k}^{(k,i)}}{\left|r_{L_k,L_k}^{(k,i)}\right|} \end{bmatrix} \tag{11}$$

So the second-step precoder (SSP) $\mathbf{W}_{k,i}^{(b)}$ can be written as $\mathbf{W}_{k,i}^{(b)} = \mathbf{Q}_{k,i}\mathbf{P}_{k,i}$. Then the equivalent channel of UE k is

$$\mathbf{H}_k = \sum_{i=1}^{M}\mathbf{H}_{k,i}\mathbf{W}_{k,i} = \sum_{i=1}^{M}\mathbf{H}_{k,i}\mathbf{W}_{k,i}^{(a)}\cdot\mathbf{W}_{k,i}^{(b)} \tag{12}$$

In this case, the received signal can be written as

$$\mathbf{y}_k = \mathbf{U}_k^H\left(\mathbf{H}_k\mathbf{s}_k + \sum_{l=1,l\neq k}^{N}\sum_{i=1}^{M}\mathbf{H}_{k,i}\mathbf{W}_{l,i}^{(a)}\cdot\mathbf{W}_{l,i}^{(b)}\mathbf{s}_l + \mathbf{n}_k\right) \tag{13}$$

where the interference is suppressed, and the desired signal is transformed into

$$\mathbf{U}_k^H\mathbf{H}_k\mathbf{s}_k = \sum_{i=1}^{M}\mathbf{R}_{k,i}^H\mathbf{P}_{k,i}\mathbf{s}_k = \begin{bmatrix} \sum_{i=1}^{M}\left|r_{1,1}^{(k,i)}\right| s_k^{(1)} \\ \sum_{i=1}^{M} r_{1,2}^{(k,i)}[\mathbf{P}_{k,i}]_{11}s_k^{(1)} + \sum_{i=1}^{M}\left|r_{2,2}^{(k,i)}\right| s_k^{(2)} \\ \vdots \\ \sum_{i=1}^{M}\sum_{j=1}^{L_k-1} r_{j,L_k}^{(k,i)}[\mathbf{P}_{k,i}]_{jj}s_k^{(j)} + \sum_{i=1}^{M}\left|r_{L_k,L_k}^{(k,i)}\right| s_k^{(L_k)} \\ \sum_{i=1}^{M}\sum_{j=1}^{L_k} r_{j,L_k+1}^{(k,i)}[\mathbf{P}_{k,i}]_{jj}s_k^{(j)} \\ \vdots \\ \sum_{i=1}^{M}\sum_{j=1}^{L_k} r_{j,N_k}^{(k,i)}[\mathbf{P}_{k,i}]_{jj}s_k^{(j)} \end{bmatrix} \tag{14}$$

The first L_k rows of the generated vector in (14) contain the information for the coherent combination, so we take these and apply the successive interference cancellation (SIC) technique to extract data streams. It is seen that PHA doesn't need extra information interaction at the second precoding step.

IV. Analysis for Convergence

It is known that from Section III, the key for TSPS is the convergence of the alternating minimization based on IA. Therefore, the following lemma is given to prove the convergence immediately [15].

Lemma 1: The alternating minimization algorithm of TSPS based on (5), (6) and (7) is convergence.

Proof: Let $\mathbf{W}_{l,i}^{(a)}(n-1), \forall l, i$ and $\mathbf{C}_k(n-1), \forall k$ denote the FSP and the orthogonal basis matrix after $n-1$ iterations respectively. Then the value of objective function is

$$I(n-1) = \sum_{k=1}^{N}\sum_{\substack{l=1\\l\neq k}}^{N}\sum_{i=1}^{M} p_{k,l,i}(n-1) \tag{15}$$

where $p_{k,l,i}(n-1)$ is expressed as equation (16).

Now the nth iteration is started. Firstly, because of the orthogonal basis matrixes of different interference subspaces are mutually independent, so without loss of generality we only analyze one of them via (6), that is

$$\mathbf{C}_k(n) = \arg\max_{\mathbf{C}_k^H\mathbf{C}_k=\mathbf{I},\forall k} a_k(n) \tag{17}$$

where $a_k(n)$ is set as equation (18). Put the updated orthogonal basis matrixes into the objective function, we can get

$$\sum_{k=1}^{N}\sum_{\substack{l=1\\l\neq k}}^{N}\sum_{i=1}^{M}\hat{p}_{k,l,i}(n-1) \leq \sum_{k=1}^{N}\sum_{\substack{l=1\\l\neq k}}^{N}\sum_{i=1}^{M} p_{k,l,i}(n-1) \tag{19}$$

where $\hat{p}_{k,l,i}(n-1)$ can be written as equation (20).

Secondly, similar to the analysis for the orthogonal basis matrixes, only one FSP need to be analyzed via (7) since the independence between them, which can be expressed as

$$\mathbf{W}_{l,i}^{(a)}(n) = \arg \min_{\mathbf{W}_{l.i}^{(a)H}\mathbf{W}_{l,i}^{(a)}=\mathbf{I},\forall l,i} b_{l,i}(n) \tag{21}$$

where $b_{l,i}(n)$ is represented as equation (22). We calculate the value of the objective function with the updated FSPs as

$$\sum_{i=1}^{M}\sum_{l=1}^{N}\sum_{k=1,k\neq l}^{N} p_{k,l,i}(n) \leq \sum_{i=1}^{M}\sum_{l=1}^{N}\sum_{k=1,k\neq l}^{N} \hat{p}_{k,l,i}(n-1) \tag{23}$$

where the structure of $p_{k,l,i}(n)$ is similar as $p_{k,l,i}(n-1)$. Therefore, after one iteration, the following relationship can be established such as

$$I(n) \leq I(n-1) \tag{24}$$

Equation (24) indicates the value of the objective function during iteration is monotonous and no increasing. Furthermore, according to the property of the Frobenius norm, we have

$$p_{k,l,i}(n) \geq 0, \forall k \neq l, i, n \tag{25}$$

Hence, the alternating minimization algorithm in TSPS based on (5), (6) and (7) is convergence. ■

In addition, when the system degree of freedom is enough for arranging the interference (i.e., the number of streams is less than the system degree of freedom), this algorithm should converge fast to a close to zero solution, which means IUI can be effectively suppressed.

V. Simulation results

This section presents simulation results. In order to observe the effects of step 1 and 2 in TSPS, we observe the precoding performance by only executing the first step and implementing both the two steps respectively. All of the results are evaluated by Rayleigh channels each element of which satisfies i.i.d. zero-mean, unit-variance complex Gaussian distribution, and the signal-to-noise ratio (SNR) as ML_k/N_0 for UE k ($k \in \{1,\ldots,N\}$) due to the multiple BSs' service in JT.

The system in simulations contains two BSs each with 6 transmit antennas, and two UEs each with 4 receive antennas. Moreover, each UE receives 3 spatial streams. All results are conducted using QPSK modulation, and the data frame for each UE includes 960 bits. The simulation results are averaged over 60000 channel realizations, while 10000 error bits are counted at each SNR for bit error rate (BER) curve. In addition, the results don't contain channel coding since only the performance of TSPS is interested. Finally, the condition of convergence is given as the difference between the values of objective function after two consecutive iterations are no more than 1×10^{-10} or the number of iterations reaches 100, and the initialization of precoders are constituted by the columns of the identity matrix.

TSPS is compared to two precoding schemes:

1) : Antenna selection (AS): A precoder is composed by the columns of the identity matrix and the precoders corresponding to different UEs are distinct, which means BSs simply choose different antennas to transmit different streams.

2) : Beamforming (BF): The precoders are composed as the right singular vectors of the desired channels

$$\mathbf{H}_{k,i} = \mathbf{U}_{k,i}\mathbf{\Sigma}_{k,i}\mathbf{V}_{k,i}^{H} \tag{26}$$

$$\mathbf{W}_{k,i} = \mathbf{V}_{k,i}^{(L_k)} \tag{27}$$

Fig. 2 presents the performance comparison. In Fig. 2(a), it can be found that neither AS nor BF takes the necessary methods to suppress IUI and inter-stream interference (ISI). Although BF obtain a little gain by utilizing the information of desired channels, the bit error rate (BER) declines also slowly when the system is interference-limited at medium and high SNR where the impact of the noise is slight. Contrast to the above schemes, the downward trend of the BER curve for TSPS is obvious. Since the effective IUI suppression at step 1, we can find the BER of TSPS at 10 dB is lower than that of AS and BF. Furthermore, with the coherent combination and ISI inhibition based on QR decomposition, the BER at 20dB attains about 10^{-3} by executing both step 1 and 2. Notice that there is only one extra dimension at each UE employed to construct the interference subspace. If the number of dimensions increases, the system BER should be lower than that in Fig. 2(a).

The system sum rate is calculated as [10] [16]

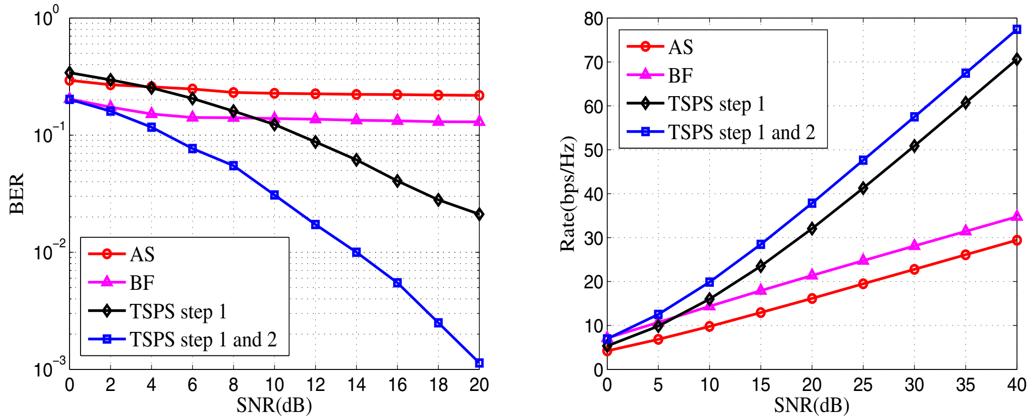
$$R_k = \mathbb{E}\left(\sum_{k=1}^{N} \log_2 \left|\mathbf{I}_{N_k} + \mathbf{\Phi}_k^{-1}\mathbf{S}_k\mathbf{S}_k^H\right|\right), \forall k \tag{28}$$

$$p_{k,l,i}(n-1) = \left\|\mathbf{H}_{k,i}\mathbf{W}_{l,i}^{(a)}(n-1) - \mathbf{C}_k(n-1)\mathbf{C}_k^H(n-1)\mathbf{H}_{k,i}\mathbf{W}_{l,i}^{(a)}(n-1)\right\|_F^2 \tag{16}$$

$$a_k(n) = \mathrm{tr}\left(\mathbf{C}_k^H\left(\sum_{l=1,l\neq k}^{N}\sum_{i=1}^{M}\left(\mathbf{H}_{k,i}\mathbf{W}_{l,i}^{(a)}(n-1)\left(\mathbf{H}_{k,i}\mathbf{W}_{l,i}^{(a)}(n-1)\right)^H\right)\right)\mathbf{C}_k\right) \tag{18}$$

$$\hat{p}_{k,l,i}(n-1) = \left\|\mathbf{H}_{k,i}\mathbf{W}_{l,i}^{(a)}(n-1) - \mathbf{C}_k(n)\mathbf{C}_k^H(n)\mathbf{H}_{k,i}\mathbf{W}_{l,i}^{(a)}(n-1)\right\|_F^2 \tag{20}$$

$$b_{l,i}(n) = \mathrm{tr}\left(\mathbf{W}_{l,i}^{(a)H}\left(\sum_{k=1,k\neq l}^{N}\mathbf{H}_{k,i}^H\left(\mathbf{I}_{N_{Rk}} - \mathbf{C}_k(n)\mathbf{C}_k^H(n)\right)\mathbf{H}_{k,i}\right)\mathbf{W}_{l,i}^{(a)}\right) \tag{22}$$



(a) The system BER

(b) The system sum rate

Fig. 2. Performance comparision in a CoMP system with JT, $M = N = 2$, $N_{Ti} = 6$, $N_{Rk} = 4$ and $d_k = 3$ $(i, k \in \{1, 2\})$.

where $\mathbf{S}_k$ is the desired information of the UE k, which is $\mathbf{S}_k = \sum_{i=1}^{M} \mathbf{H}_{k,i}\mathbf{W}_{k,i}$; while $\mathbf{\Phi}_k$ denotes the covariance matrix of the interference and the noise which should be expressed as $\mathbf{\Phi}_k = N_0\mathbf{I}_{N_k} + \sum_{\substack{l=1 \\ l\neq k}}^{N} \sum_{i_1,i_2=1}^{M} \mathbf{H}_{k,i_1}\mathbf{W}_{l,i_1}\mathbf{W}_{l,i_2}^H\mathbf{H}_{k,i_2}^H$. Fig. 2(b) illustrates the comparison of the system sum rate. As we can see, TSPS can attain much higher rate than that of the other two schemes since the interference suppression and the signal coherent combination. For example, at 40 dB, the rates of TSPS exceed 70 bps/Hz by only executing step 1 and implementing both of the two steps, higher than the twice of the rate via applying AS or BF scheme. Through observing the simulation results in this section, it illustrates the precoding efficiency of TSPS is obvious, thus utilizing this scheme can decrease the BER and increase the system rate simultaneously.

VI. Conclusion

This paper has proposed a precoding scheme called TSPS for multi-user JT in a CoMP system. In TSPS, firstly an alternating minimization algorithm based on IA has been applied to suppress IUI, then we have jointly processed the results of step 1 and the desired channels by QR decomposition to attain the signal coherent combination. The alternating minimization in TSPS has been proved to converge, which means IUI can achieve IUI suppression. Furthermore, implementing TSPS needs perfect CSI, that is difficult to acquired in practice. Therefore, a novel precoding scheme with imperfect or quantized CSI should also be researched in the future work.

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