Iterative Inter-Cluster Interference Cancellation for Cooperative Base Station Systems

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***Abstract*— This paper proposes an iterative inter-cluster interference (ICI) cancellation method for cooperative base station systems on the downlink/uplink. System level simulations were conducted with the parameter sets of cluster size and iteration order. The result showed that even in the imperfect CSI case, the spectral efficiency performance of the proposed method with the optimum parameter set is comparable to that of cooperative transmission/reception via MU-MIMO which can completely remove inter-cell interference. In addition, since the proposed method can be practiced in a simple manner, it also has a remarkable advantage to reduce computational complexity. It is a practical way to realize the nationwide wireless systems.**

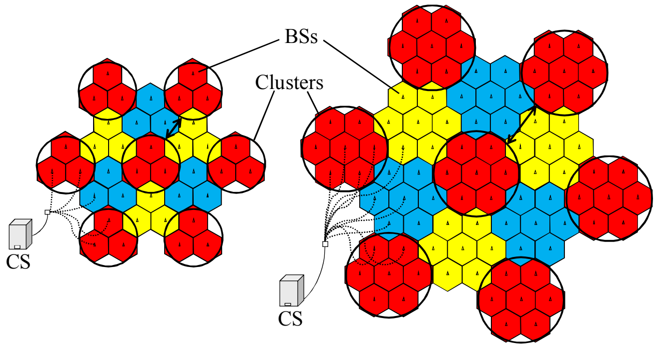
Keywords- Cooperative communicasions, Interference suppression, MIMO systems

I. INTRODUCTION

The Multiple Input Multiple Output (MIMO) technique [1] has been applied to many systems with limited frequency resources such as WiMAX [2] and LTE [3] in order to improve their transmission rate. Multiuser MIMO (MU-MIMO) [4], in which the base station (BS) communicates with multiple subscriber stations (SSs) simultaneously in the same frequency channel, increases system capacity.

Another approach for system capacity enhancement is dividing the service area into many microcells [5]. Though this environment yields large SNR (Signal to Noise power Ratio) around the cell edge, SIR (Signal to Interference power Ratio) becomes the dominant factor determining system capacity. The cooperative base station (CBS) [6] has been investigated because of its effective spatial diversity and reasonable power consumption. In CBS, all BSs are connected to a control station (CS) with optical fibers. The CS processes all signals from/to all BSs' antennas. Since the widely separated cooperating BSs offer low antenna correlation, this system structure is suitable for MU-MIMO. It virtually constructs the large cell without inter-cell interference and can further enhance the system capacity. Cooperative transmission is an essential technique to meet the requirement of LTE-Advanced [7] in order to increase the capacity especially for cell-edge users.

It is not practical to apply MU-MIMO to CBS if there is a large number of BSs because the computational complexity imposed by multiuser beamforming/detection is excessive. This complexity can be significantly reduced by establishing clusters, each of which consists of a small number of cooperating BSs. With this method, the transmission weight matrix is determined on a cluster-by-cluster basis and the size



(a) C=3 (b) C=7

Fig. 1. Cluster layouts of cooperative base station systems

of each channel matrix becomes small. Clustering, however, causes co-channel inter-cluster interference (ICI) if the clusters are not adequately isolated.

We previously proposed an ICI cancellation method [8] for CBS with MU-MIMO on downlink (DL). When the CS knows the ICI signals and the inter-cluster channel state information (CSI), the ICI cancellation signal is calculated by simple linear processing. In [9], using a multicluster system model, we confirmed that the proposed method offers improved spectral efficiency and discussed its optimal conditions. In order to reduce the computational complexity, the proposed method simply subtracting interference replica signals from original transmission signal. Therefore, ICI is not cancelled perfectly.

This paper newly proposes an iterative ICI cancellation method that suppresses both the computational complexity and the performance degradation caused by imperfect ICI cancellation. In addition, we extend the proposed method to the uplink (UL). System level simulations considering CSI estimation error show that it can achieve higher spectral efficiency even in the single cell cluster case. The rest of the paper is organized as follows. Section II describes the system model of clustered CBS. Section III proposes the iterative ICI cancellation method and extends it to the UL. Computer simulation results are presented in Section IV. Finally, the paper is concluded in Section V.

II. SYSTEM MODEL

In the system model, all BSs are connected to one CS. The BSs in a cluster work cooperatively via MU-MIMO (except the case that the cluster is composed of one cell). The transmission /reception weight matrix for MU-MIMO in each cluster is controlled by the CS. We first define the number of cooperating BSs as cluster size C. Fig. 1 shows the cluster layouts for the cases of (a) C=3 and (b) C=7, respectively. In the figures, frequency reuse factor of 3 is exhibited for example. As C increases, the cooperating BSs are more widely separated and ICI becomes weaker. However, note that a small value of C is preferable to reduce the computational complexity imposed by MU-MIMO signal processing in each cluster.

Channel matrix H is formed by L BSs and K SSs ($L \geq K$) which use the same frequency channel to communicate simultaneously. When clustered channel submatrices are introduced, H is expressed as,

$$H = \begin{pmatrix} H_{11} & H_{12} & \cdots & & H_{1M} \\ H_{21} & H_{22} & & & \\ & & \ddots & & \\ \vdots & & H_{ij} & & \vdots \\ & & & \ddots & \\ H_{M1} & & \cdots & & H_{MM} \end{pmatrix}. \tag{1}$$

H_{ij} denotes the clustered channel submatrices that include CSIs from BSs in the j-th cluster to SSs in the i-th cluster. Diagonal components (i=j) represent intra-cluster channel submatrices in the i-th cluster and non-diagonal components ($i \neq j$) represent ICI channel submatrices from the j-th cluster to the i-th cluster. M is the number of clusters hence L=MC. The weight matrix should be calculated using the entire H but the computational complexity explodes as the size of H increases. Interference suppression techniques for wide area coverage (*i.e.* large size of H) with practical computational complexity are desired.

III. Proposed Iterative Inter-Cluster Interference Cancellation Method

The proposed ICI cancellation method is described in this section. Moreover, the method is extended to the UL. Details are described in this section.

A. Iterative ICI Cancellation Method on the Downlink

The weighted initial transmission signal vector on the DL T_i at the i-th cluster is written as $T^{(0)}_i$=$W_i s_i$ where W_i denotes the transmission weight matrix for the i-th cluster generated from H_{ii} and s_i denotes the transmission signal vector. Signal vector R_i^{DL} received by the SSs in the i-th cluster is written as follows,

$$\begin{aligned} R_i^{DL} &= \sum_j^M H_{ij} \, T_j^{(0)} + N \\ &= H_{ii} T_i^{(0)} + \sum_{j \neq i}^M H_{ij} T_j^{(0)} + N, \end{aligned} \tag{2}$$

where $H_{ii}T_i^{(0)}$ is the desired signal for SSs in the i-th cluster, $H_{ij}T_i^{(0)}$ ($i \neq j$) is the ICI signal from surrounding j-th cluster, and N denotes the additive white Gaussian noise (AWGN) vector. The proposed method subtracts interference replica signals from initial $T_i^{(0)}$. The first order weighted transmission signal vector at the i-th cluster is defined as,

$$T_i^{(1)} \equiv T_i^{(0)} - \sum_{j \neq i}^M W_i \left(H_{ii} W_i \right)^{-1} H_{ij} T_j^{(0)}. \tag{3}$$

The second term of (3) is the interference replica signals that cancel the second term of (2) at the receiver side. From (2) and (3), the new reception signal vector R_i^{DL} is rewritten as,

$$\begin{aligned} R_i^{DL} &= \sum_j^M H_{ij} T_j^{(1)} + N \\ &= H_{ii} T_i^{(0)} + \sum_{j \neq i}^M H_{ij} T_j^{(0)} \\ &\quad - \sum_{j \neq i}^M H_{ij} T_j^{(0)} - \sum_{j \neq i}^M H_{ij} \sum_{k \neq j}^M W_j \left(H_{jj} W_j \right)^{-1} H_{jk} T_k^{(0)} + N \\ &= H_{ii} T_i^{(0)} - \sum_{j \neq i}^M H_{ij} \sum_{k \neq j}^M W_j \left(H_{jj} W_j \right)^{-1} H_{jk} T_k^{(0)} + N. \end{aligned} \tag{4}$$

The proposed method replaces the second ICI term of (2) with that of (4), that is, residual ICI. In order to make ICI cancellation effective, the intensity of the second term of (2) needs to be much smaller than that of the first term indicated by

$$\| H_{ii} W_i s_i \| >> \left\| \sum_{j \neq i}^M H_{ij} W_j s_j \right\|, \tag{5}$$

where ||.|| denotes the Frobenius norm. By multiplying $(H_{ii}W_i)^{-1}$, the following equation is derived;

$$\| s_i \| >> \left\| \sum_{j \neq i}^M (H_{ii} W_i)^{-1} H_{ij} W_j s_j \right\|. \tag{6}$$

Therefore, the following relationship is obtained;

$$\left\| \sum_{j \neq i}^M H_{ij} T_j^{(0)} \right\| >> \left\| \sum_{j \neq i}^M H_{ij} \sum_{k \neq j}^M W_j \left(H_{jj} W_j \right)^{-1} H_{jk} T_k^{(0)} \right\|. \tag{7}$$

According to (7), the intensity of the second term of (4) is much smaller than that of (2). It indicates that the ICI can be suppressed when relationship (5) is satisfied.

The first order residual ICI in the second term of (4) can be suppressed by using a higher order cancellation, that is, iteratively generating the interference replica signals. The second order weighted transmission signal vector, $T_i^{(2)}$, is generated with reference to the residual ICI term in (4).

$$\begin{aligned} T_i^{(2)} &\equiv T_i^{(0)} - \sum_{j \neq i}^M W_i \left(H_{ii} W_i \right)^{-1} H_{ij} T_j^{(0)} \\ &\quad + \sum_{j \neq i}^M W_i \left(H_{ii} W_i \right)^{-1} H_{ij} \sum_{k \neq j}^M W_j \left(H_{jj} W_j \right)^{-1} H_{jk} \, T_k^{(0)} \\ &= T_i^{(0)} - \sum_{j \neq i}^M W_i \left(H_{ii} W_i \right)^{-1} H_{ij} \left\{ T_j^{(0)} - \sum_{k \neq j}^M W_j \left(H_{jj} W_j \right)^{-1} H_{jk} \, T_k^{(0)} \right\}. \end{aligned} \tag{8}$$

As the expression of $T_i^{(2)}$ in (8) contains the same expression of $T_i^{(1)}$ in (3), (8) can be rewritten as

$$T_i^{(2)} = T_i^{(0)} - \sum_{j \neq i}^M W_i \left(H_{ii} W_i \right)^{-1} H_{ij} \, T_j^{(1)}. \tag{9}$$

Upon proceeding to higher order ICI cancellation, the α-th and (α-1)-th order weighted transmission signal vectors are related to each other by simple descriptions as follows;

$$T_i^{(\alpha)} = T_i^{(0)} - \sum_{j \neq i}^M G_{ij} \, T_j^{(\alpha - 1)}. \tag{10}$$

$$G_{ij} = W_i \left(H_{ii} W_i \right)^{-1} H_{ij}. \tag{11}$$

Therefore, iteratively solving the recurrence equation (10) yields the higher order weighted transmission signal vector in a simple manner. The resulting reception signal vector is,

$$\begin{aligned} R_i^{DL} &= \sum_j^M H_{ij} T_j^{(\alpha)} + N \\ &= H_{ii} W_i \, s_i + (-1)^{\alpha} \sum_{j \neq i}^M H_{ij} \sum_{k(1) \neq j}^M G_{ij} \cdots \sum_{l \neq k(\alpha)}^M G_{ij} W_l s_l + N_i. \end{aligned} \tag{12}$$

When relationship (5) is satisfied, the intensity of the second term of (12) can be decreased as α is increased.

B. Extension to the Uplink

In the conventional cooperative method on the UL, the CS gets the information for large numbers of signals received at all BSs and executes signal detection processing for the MU-MIMO channels. The sheer size of the complete matrix, however, causes the computational complexity to explode. To solve this problem, we applied the iterative ICI cancellation method to the reception signals. Signal vector R_i^{UL} received at the BSs in the i-th cluster is written as,

$$\begin{aligned} R_i^{UL} &= \sum_{j}^{M} H_{ij} s_i + N_i \\ &= H_{ii} s_i + \sum_{j\neq i}^{M} H_{ij}\, s_j + N_i . \end{aligned} \tag{13}$$

H_{ij} denotes the UL channel submatrices from SSs in the j-th cluster to BSs in the i-th cluster and N_i denotes the noise vector added at BSs in the i-th cluster. Initial weighted reception signal vector at the i-th cluster, $r_i^{(0)}$, is written as,

$$\begin{aligned} r_i^{(0)} &= W_i\left(\sum_{j}^{M} H_{ij} s_j + N_i\right) \\ &= W_i H_{ii} s_i + \sum_{j\neq i}^{M} W_i H_{ij}\, s_j + W_i N_i , \end{aligned} \tag{14}$$

where W_i denotes the reception weight matrix for H_{ii}. The second term of (14) is ICI on the UL. In order to cancel this ICI term, the interference replica signals generated by $r_i^{(0)}$ is subtracted from the weighted reception signal vector. The resulting reception signal vectors are expected to be close to the transmission signal vectors. The weighted reception signal vector under first order ICI cancellation, $r_i^{(1)}$, is defined as,

$$\begin{aligned} r_i^{(1)} &\equiv r_i^{(0)} - \sum_{j\neq i}^{M} W_i H_{ij}\left(W_j H_{jj}\right)^{-1} r_j^{(0)} \\ &= W_i H_{ii} s_i + \sum_{j\neq i}^{M} W_i H_{ij}\, s_j + W_i N_i \\ &\quad - \sum_{j\neq i}^{M} W_i H_{ij}\left(W_j H_{jj}\right)^{-1}\left(W_j H_{jj} s_j + \sum_{k\neq j}^{M} W_j H_{jk}\, s_k + W_j N_j\right) \\ &= W_i H_{ii} s_i - \sum_{j\neq i}^{M} W_i H_{ij}\left(W_j H_{jj}\right)^{-1} \sum_{k\neq j}^{M} W_j H_{jk}\, s_k + N_i^{(1)} , \end{aligned} \tag{15}$$

$$N_i^{(1)} = W_i N_i - \sum_{j\neq i}^{M} W_i H_{ij}\left(W_j H_{jj}\right)^{-1} W_j N_j . \tag{16}$$

The second ICI term of (14) is replaced by that of (15). The intensity of the replaced term is expected to be smaller than that of the original. Similar to the case of the DL, this process can be continued in an iterative manner. The higher order weighted reception signal vector on the UL has the following relationship,

$$r_i^{(\alpha)} = r^{(0)} - \sum_{j\neq i}^{M} G'_{ij}\, r_j^{(\alpha-1)} . \tag{17}$$

$$G'_{ij} = W_i H_{ij}\left(W_i H_{ii}\right)^{-1} . \tag{18}$$

Finally, (17) approaches to the desired signal vector by higher order ICI cancellation.

$$\begin{aligned} r_i^{(\alpha)} &= W_i H_{ii} s_i + (-1)^{\alpha} \sum_{j(1)\neq i}^{M} G'_{ij} \cdots \sum_{k\neq j(\alpha)}^{M} G'_{j(\alpha)k} \sum_{l\neq k}^{M} W_k H_{kl} s_l + N_i^{(\alpha)} \\ &\approx W_i H_{ii} s_i + \widetilde{N} , \end{aligned} \tag{19}$$

$$N_i^{(\alpha)} = W_i N_i - \sum_{j\neq i}^{M} G'_{ij} W_j N_j + \cdots + (-1)^{\alpha} \sum_{j(1)\neq i}^{M} G'_{ij(1)} \cdots \sum_{k\neq j(\alpha)}^{M} G'_{j(\alpha)k} W_k N_k . \tag{20}$$

Though the number of noise term in (20) increases as the cancellation order is set higher, the noise enhancement is expected to be quite small under the condition of (5).

It should be noted that (10) and (17) contains only a single summation and sums up the ICI signals from only M clusters around the i-th cluster. This means that $T_i^{(\alpha)}$ or $r_i^{(\alpha)}$ can be calculated from the limited information of M submatrices, G_{ij}, and M vectors, $T_j^{(\alpha-1)}$ or $r_i^{(\alpha-1)}$. This operation can be executed in a distributed manner by exchanging information with neighboring clusters; this further suppresses the computational complexity.

C. Achievable spectral efficiency

The spectral efficiency of the u-th SS in the i-th cluster achieved by the α-th order ICI cancellation on the DL is defined as,

$$\Gamma_u^{DL} = \frac{1}{F}\log_2\left[1 + \frac{(h_u w_u)(h_u w_u)^H}{\sum_{k\neq u}^{C} (h_u w_k)(h_u w_k)^H + q_u q_u^H + n_u n_u^H}\right], \tag{21}$$

$$[q_1, \ldots, q_C]^T = \sum_{j\neq i}^{M} H_{ij} \sum_{k(1)\neq j}^{M} G_{jk(1)} \cdots \sum_{l\neq k(\alpha)}^{M} G_{k(\alpha)l} W_l . \tag{22}$$

$(.)^H$ denotes the Hermitian transpose. h_u is the u-th row vector of H_{ii}, w_u is the u-th column vector of W_i, and the u-th row vector q_u indicates a suppressed residual ICI derived from second term of (12). n_u is the u-th noise element of N_i. If CSI is perfectly estimated, intra-cluster interference term $\Sigma^{C}_{k\neq u}(h_u w_k)(h_u w_k)^H=0$. F is frequency reuse factor. Since the total channel bandwidth of the system is assumed to be fixed, it should be noted that it contains the term of $1/F$.

Similarly, the achievable spectral efficiency of the u-th SS on the UL is also formulated as,

$$\Gamma_u^{UL} = \frac{1}{F}\log_2\left[1 + \frac{(w_u h_u)(w_u h_u)^H}{\sum_{k\neq u}^{C} (w_u h_k)(w_u h_k)^H + q'_u q'^H_u + n'_u n'^H_u}\right], \tag{23}$$

$$[q'_1, \ldots, q'_C]^T = \sum_{j(1)\neq i}^{M} G'_{ij} \cdots \sum_{k\neq j(\alpha)}^{M} G'_{j(\alpha)k} \sum_{l\neq k}^{M} W_k H_{kl} s_l , \tag{24}$$

where q'_u is a suppressed residual ICI derived from (19) and n'_u is the u-th element of $N_i^{(\alpha)}$ from (20).

IV. Performance Evaluations

A. Simulation Parameters

System level simulation parameters are shown in Table I. Clusters are hexagonally sited based on the frequency reuse pattern shown in Fig. 1. We focus on the characteristics of the center cluster. In the evaluation, number of interfering clusters M is taken into account in the area where received ICI power is more than -15 dB relative to the noise power. SSs are uniformly distributed in each hexagonal cell. MU-MIMO is applied to each cluster. Transmission power is determined by average reception SNR for SSs located around the cell edge. For instance, we assume the cell edge SNR value of 20 dB. The total transmission power of all BSs is assumed to be constant in order to compare each method appropriately in terms of reception SINR (Signal to Interference and Noise power Ratio). In [9], we have shown that the case of F=3 provides the largest spectral efficiency performance compared to the cases of F=1

TABLE I
SIMULATION PARAMETERS

Parameters	Values
Cell / Cluster deployment	Hexagonal
Cell edge SNR	20 dB
Cluster Size C	1, 3, 7
Reuse Factor F	3
ICI cancellation order α	0, 1, 2, 3, 4, 5, 6, 8, 10
MU-MIMO transmission/ reception weight	Gram-Schmidt orthogonalization [10]
Carrier frequency	2 GHz
Propagation model	ITU-R M.2135 Urban macro NLOS [11] $39.1\log_{10}(d[\mathrm{m}]) + 19.56$ dB
Fading model	i.i.d Rayleigh
BS / SS height	30 / 1.2 m
BS / SS antenna	Single, Omni antenna

or 7. Therefore, we focus on the case of F=3 and discuss its further spectral efficiency improvement achieved by the proposed method. We evaluate the achievable spectral efficiencies for several parameter sets of C and ICI cancellation order α by the computer simulations. The spectral efficiencies defined in (21) and (23) are calculated. The same parameters are used on the DL and the UL in order to compare the characteristic of the proposed method fairly.

B. Imperfect CSI

We introduce an imperfect CSI for practical evaluation of the proposed method. The degree of CSI estimation error is determined by considering the average reception SNR at the SS. The imperfect CSI $\tilde{h}$ which is the element of H_{ij} is defined as,

$$\tilde{h} = h_{iid} + e. \tag{25}$$

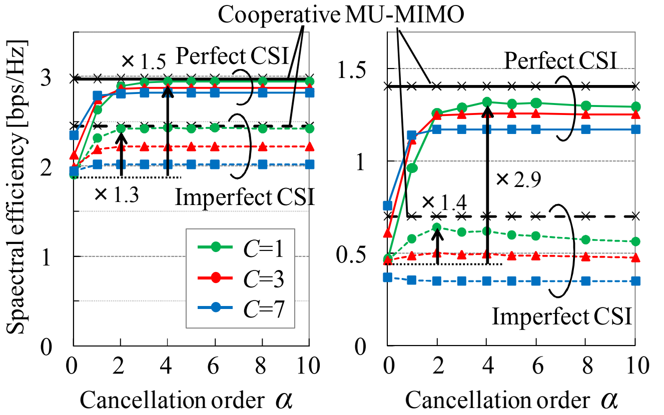
h_{iid} is an independent identically distributed (i.i.d) Rayleigh fading channel coefficient modeled as zero-mean complex Gaussian random variables with unit variance. e represents the CSI estimation error modeled as zero-mean complex Gaussian random variables with variance of σ^2. Assuming CSI estimation by using sounding reference signal (SRS) based on LTE-Advanced, value of σ^2 corresponding to reception SNR is obtained through a link level simulation in [12].

$$10\log_{10}(\sigma^2) = -8.7458 - 3.027 \times \mathrm{SNR}. \tag{26}$$

In this evaluation, each CSI element $\tilde{h}$ is assumed to be estimated independently hence the channel estimation error is influenced by only SNR.

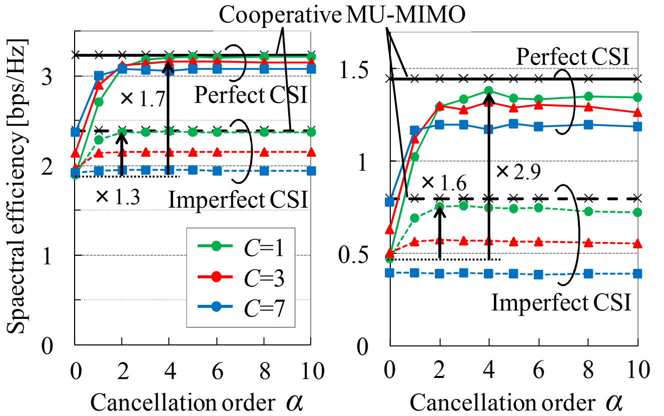
C. Simulation results

Spectral efficiencies with ICI cancellation order α are shown in Figs. 2 and 3 for the DL and the UL cases, respectively. Each figure shows cell average and CDF=5% performances in order to evaluate characteristics of the whole cell and the cluster or cell edge region. The cases with α=0 indicate the conventional clustered CBS to which the proposed ICI cancellation are not applied. The cases with α=1 or larger indicate the proposed iterative ICI cancellation method. As a comparison, the performance of cooperative transmission/ reception via MU-MIMO which can completely remove inter-



(a) Average spectral efficiency (b) CDF=5% spectral efficiency

Fig. 2. Spectral efficiency performance with ICI cancellation order α on the Downlink, F=3



(a) Average spectral efficiency (b) CDF=5% spectral efficiency

Fig. 3. Spectral efficiency performance with ICI cancellation order α on the Uplink, F=3

cell interference among all BSs (called as cooperative MU-MIMO hereafter) is also plotted. The characteristics for the proposed method on the DL and the UL are almost the same for all examined parameters. This is because the process is essentially the same except for where the processing is done at transmitter or receiver side.

If the CSI can be perfectly estimated, the average spectral efficiency increases as α is increased and it saturates when α=3~4. When the ICI power is much larger than the noise power, the first order residual ICI is not negligible compared to the noise power. In this case, the iterative ICI cancellation method further increases the spectral efficiency. A notable characteristic is that the spectral efficiency for large C is inferior to that for small C when $\alpha \geq 2$. Furthermore, the upper limit of the spectral efficiency for C=1 (*i.e.* clusters are not established) is comparable to that for cooperative MU-MIMO. The orthogonalization loss for MU-MIMO null steering generally becomes large when the number of spatially multiplexed data streams is large. The degradation of the reception SNR for SSs which is caused by the orthogonalization breaks the requirement (5) and it reduces the effectiveness of the proposed method. This is the reason why the small C provides higher spectral efficiency.

TABLE II
NUMBER OF MULTIPLICATIONS

Conventional cooperative MU-MIMO	L^3+L^2
Proposed ICI cancellation method	$LC\{C(4+M)+1+\alpha M\}$

When CSI estimation is imperfect, both performances of the proposed method and the cooperative MU-MIMO are degraded. As the result, the gain of the proposed method for C=7 is negligibly small. The performances of the proposed method for C=1 with α=2~3, however, can keep to be comparable to that for cooperative MU-MIMO even in the imperfect CSI case.

In Fig. 2(b) and Fig. 3(b), the spectral efficiency tends to degrade slightly in large α region. Generating interference replica signals with imperfect CSI may bring the undesirable incorrect replica and it causes performance degradation. With increasing α, the interference replica signal contains a number of terms with such error (as seen by second terms in (12) and (19)) and it enhances the incorrectness of the replica generation. Because the optimum value of α is determined with balancing ICI suppression and accumulation of its error caused by the incorrect replica signals, inaccurate CSI makes the optimum α small. As shown in Fig.2 and Fig. 3, the spectral efficiency strongly depends on the accuracy of CSI estimation. Therefore, establishing the technique for improving the accuracy is one of the most important items to be studied further.

D. Computational Complexity Analysis

We verified the effectiveness of the proposed method from the viewpoint of computational complexity. Table II and Fig. 4 compare the number of multiplications required for the signal processing with the cooperative MU-MIMO and the proposed method. Signal processing includes transmission/reception weight matrix calculation and symbol-by-symbol multiplication. In this evaluation, M (=L/C) is determined as mentioned in Section IV *A*. In case of the cooperative MU-MIMO, signal processing is typically based on the inversion of H and the order of complexity is known to be $O(L^3)$. On the other hand, the proposed method reduces the complexity since it requires only $O(L)$ operations. When L>5 for C=1, the proposed method yields lower complexity than cooperative MU-MIMO. It indicates that our method is applicable to even such small scale CBS systems. As discussed above and in this figure, the proposed method with the parameter set of {C=1, F=3, α=2} is the best solution for both achieving high spectral efficiency and reduced computational complexity.

As mentioned in Section III *B*, the proposed method needs only the local information of surrounding clusters to cancel the ICI. This means that CS functionality can be distributed. The distributed CSs (DCSs) process the signals individually with (10) and (17), and they exchange the results with each other. Thus, the hardware impact (*i.e.* computational complexity) of each DCS can be kept to be practically small even in the case of nationwide service.

V. CONCLUSION

In this paper, we have proposed an iterative ICI cancellation method for CBS on the DL and the UL. ICI can be reduced by iteratively subtracting interference replica signals in a simple manner. Computer simulations were conducted with the parameters of cluster size and iteration order in the multicluster configuration. The result showed that even in the imperfect CSI case, the achievable spectral efficiency of the proposed method with the optimum parameter set is comparable to that of cooperative MU-MIMO which can completely remove inter-cell interference. In addition, the proposed method also has an advantage to achieve less computational complexity. It is a practical approach for system implementation.

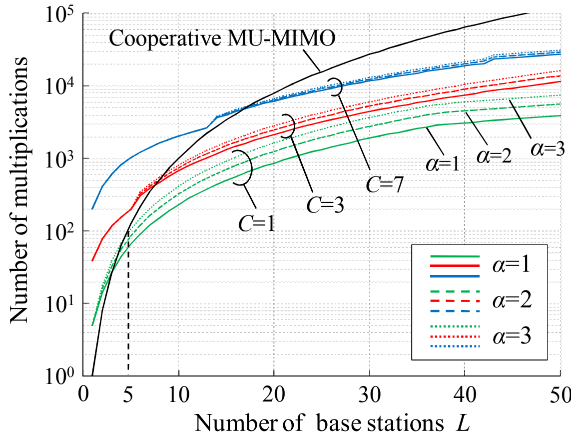


Fig. 4. The number of multiplications with the number of BSs

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