# Study of Leakage-Based Precoding Scheme that Supports Coordinated Multi-Point Operation for LTE

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***Abstract*—This paper investigates leakage-based precoding schemes that support coordinated multi-point (CoMP) operation for Long-Term Evolution (LTE) systems studied in the 3rd Generation Partnership Project. CoMP operation, which improves cooperative transmission among cells and reduces or eliminates intercell interference, enables performance improvement in cell edge and average throughputs. Although leakage-based precoding has been investigated for multiuser multiple-input multiple-output (MIMO) systems, its extension to CoMP requires further analysis of the near–far effect under multicell deployment scenarios. To this end, we propose to incorporate the channel between a victim user equipment (UE) and the cell that serves the victim UE into the leakage-based precoding calculation. We investigated optimal linear scaling of the covariance matrix involving this channel. To determine the benefits of the investigated algorithm, multicell system level evaluations were carried out. This confirmed the improved performance of the system's average and cell edge throughputs.**

***Index Terms*—Precoding, Multicell MIMO, LTE**

## I. INTRODUCTION

Intercell interference is a key challenge for cellular systems, whose coverage areas span multiple cells. To mitigate such interference, newer cellular systems employ robust channel coding schemes and/or spreading schemes. However, the available data rate at the cell edge region may decrease. Recent attempts to overcome this data rate degradation include the implementation of multiple-input multiple-output (MIMO) techniques [1] combined with multicell transmission. This approach improves cooperative transmission among cells and reduces or eliminates intercell interference. Multicell MIMO utilizes the interference path as an additional link for channel quality improvement at the receiver side [2, 3].

Multicell MIMO techniques have also been investigated by the 3rd Generation Partnership Project (3GPP), whose goal is to improve user throughput at cell edges, in particular for the Long-Term Evolution (LTE)-Advanced downlink [4–7]. Coordinated multipoint (CoMP) transmission technologies are also being considered as viable methods that support MIMO by using geographically separated transmission points [8].

To efficiently obtain macrodiversity gain using CoMP transmission, it is important to provide a sophisticated precoding scheme that mitigates interuser interference. For this purpose, leakage-based precoding [9] has been investigated, which can reduce interference to other users by providing null for them. However, multicell MIMO requires further examination because users in neighboring cells should be considered for multicell operations. Therefore, it is important to investigate an extension of leakage-based precoding by considering the near–far effect under multicell deployment scenarios, particularly for the condition where victim users of neighboring cell are placed.

In this paper, we propose to incorporate into the leakage-based precoding calculation the channel between the victim user equipment (UE) and the cell that serves the victim UE. Furthermore, we investigate optimal linear scaling of the covariance matrix regarding this channel and perform a multicell system level evaluation to determine its impact on the system throughput.

## II. SYSTEM MODEL

### A. Coordinated beamforming

The CoMP transmission technology supports MIMO techniques by using geographically separated transmission points for data transmission to the UE. One of the major candidates for the CoMP transmission scheme is coordinated beamforming (CB). In the CB scheme, data for each UE is stored in a single cell (referred to as a serving cell in this paper). As shown in Fig. 1, the signal from the nonserving cell (i.e., Cell#B) is considered by UE#1 to be interference. With the CB scheme, this intercell interference can be reduced by modifying the transmitter's parameters such as precoder, transmission power, and frequency resource allocation. By appropriately controlling these parameters, the signal quality can be improved while the interfering signal can be reduced at the UE side. It has been reported that in some cases, a compromise is necessary because an improvement in the signal quality may increase interference while reduction in the interfering signal's strength to other UEs may result in a weaker signal [3].

### B. Procedure for coordinated beamforming

#### 1) Determination of cells to be incorporated into CoMP operation

As mentioned above, a single serving cell is set from the network side to each UE. This is carried out via long-term measurement at the UE side. In addition, for a CoMP operation, multiple cells that can potentially be incorporated are selected by the network on the basis of the UE measurement. We assume that for the UE of interest, if the reported value of the received power at the UE side is within a

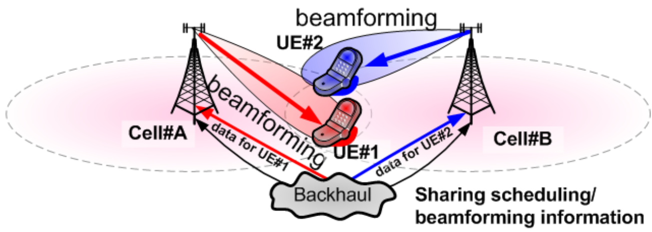

Fig. 1. Coordinated beamforming

predetermined threshold compared to that of the serving cell, the cell is included for a CoMP operation. To avoid wastage of resources due to unreliable reporting, wideband and long-term averaged values are used. In addition, regarding the network operating cost, it is beneficial to have a predefined combination of cells for the CoMP operation, referred to as "cell clustering."

### 2) *Implicit feedback*

For LTE systems, implicit feedback is defined using a combination of predefined parameters such as the precoding matrix indicator (PMI) and the channel quality indicator (CQI) that achieves the highest throughput with a transport block error probability of less than 10% under given channel conditions. A straightforward extension of this method to CoMP operation would target the per cell PMI/CQI feedback. For example, the precoder for Cell#A that strengthens the desired signal and the precoder for Cell#B that weakens the interference signal can be selected. Thus, an improvement in signal to interference plus noise ratio (SINR) of the data from Cell#A is expected at UE#1 because of the coordination between Cell#A and Cell#B.

Regarding PMI, based on the LTE specifications, the following codebook structure for a 4 transmit antenna is assumed in this paper for measurements.

$\mathbf{W}_n^{\{s\}}$ denotes the precoding matrix defined by the columns given by the set {s}, as shown in equation (1)

$$\mathbf{W}_n = \mathbf{I} - 2\mathbf{u}_n\mathbf{u}_n^H / \mathbf{u}_n^H\mathbf{u}_n \tag{1}$$

where $\mathbf{I}$ is a $4\times4$ identity matrix and the exact values of $\mathbf{u}_n$ are given in Table I.

Regarding CQI, the SINR observed at the UE assumes that precoders have been assigned to cells, and SINR is reported as CQI for each sub-band, which comprises a predefined number of consecutive resources in the frequency domain. In this paper, to facilitate the gain of CB, CQI is determined by assuming that interference from cells within the CoMP measurement set is neglected.

### 3) *Transmitter covariance matrix*

TABLE I
ASSUMED CODEBOOK

| $n$ | $\mathbf{u}_n$ | $\upsilon=1$ | $\upsilon=2$ |
|---|---|---|---|
| 0 | $\mathbf{u}_0=[1\ \ -1\ \ -1\ \ -1]^T$ | $\mathbf{W}_0^{\{1\}}$ | $\mathbf{W}_0^{\{14\}}/\sqrt{2}$ |
| 1 | $\mathbf{u}_1=[1\ \ -j\ \ 1\ \ j]^T$ | $\mathbf{W}_1^{\{1\}}$ | $\mathbf{W}_1^{\{12\}}/\sqrt{2}$ |
| 2 | $\mathbf{u}_2=[1\ \ 1\ \ -1\ \ 1]^T$ | $\mathbf{W}_2^{\{1\}}$ | $\mathbf{W}_2^{\{12\}}/\sqrt{2}$ |
| 3 | $\mathbf{u}_3=[1\ \ j\ \ 1\ \ -j]^T$ | $\mathbf{W}_3^{\{1\}}$ | $\mathbf{W}_3^{\{12\}}/\sqrt{2}$ |
| 4 | $\mathbf{u}_4=\left[1\ \ (-1-j)/\sqrt{2}\ \ -j\ \ (1-j)/\sqrt{2}\right]^T$ | $\mathbf{W}_4^{\{1\}}$ | $\mathbf{W}_4^{\{14\}}/\sqrt{2}$ |
| 5 | $\mathbf{u}_5=\left[1\ \ (1-j)/\sqrt{2}\ \ j\ \ (-1-j)/\sqrt{2}\right]^T$ | $\mathbf{W}_5^{\{1\}}$ | $\mathbf{W}_5^{\{14\}}/\sqrt{2}$ |
| 6 | $\mathbf{u}_6=\left[1\ \ (1+j)/\sqrt{2}\ \ -j\ \ (-1+j)/\sqrt{2}\right]^T$ | $\mathbf{W}_6^{\{1\}}$ | $\mathbf{W}_6^{\{13\}}/\sqrt{2}$ |
| 7 | $\mathbf{u}_7=\left[1\ \ (-1+j)/\sqrt{2}\ \ j\ \ (1+j)/\sqrt{2}\right]^T$ | $\mathbf{W}_7^{\{1\}}$ | $\mathbf{W}_7^{\{13\}}/\sqrt{2}$ |
| 8 | $\mathbf{u}_8=[1\ \ -1\ \ 1\ \ 1]^T$ | $\mathbf{W}_8^{\{1\}}$ | $\mathbf{W}_8^{\{12\}}/\sqrt{2}$ |
| 9 | $\mathbf{u}_9=[1\ \ -j\ \ -1\ \ -j]^T$ | $\mathbf{W}_9^{\{1\}}$ | $\mathbf{W}_9^{\{14\}}/\sqrt{2}$ |
| 10 | $\mathbf{u}_{10}=[1\ \ 1\ \ 1\ \ -1]^T$ | $\mathbf{W}_{10}^{\{1\}}$ | $\mathbf{W}_{10}^{\{13\}}/\sqrt{2}$ |
| 11 | $\mathbf{u}_{11}=[1\ \ j\ \ -1\ \ j]^T$ | $\mathbf{W}_{11}^{\{1\}}$ | $\mathbf{W}_{11}^{\{13\}}/\sqrt{2}$ |
| 12 | $\mathbf{u}_{12}=[1\ \ -1\ \ -1\ \ 1]^T$ | $\mathbf{W}_{12}^{\{1\}}$ | $\mathbf{W}_{12}^{\{12\}}/\sqrt{2}$ |
| 13 | $\mathbf{u}_{13}=[1\ \ -1\ \ 1\ \ -1]^T$ | $\mathbf{W}_{13}^{\{1\}}$ | $\mathbf{W}_{13}^{\{13\}}/\sqrt{2}$ |
| 14 | $\mathbf{u}_{14}=[1\ \ 1\ \ -1\ \ -1]^T$ | $\mathbf{W}_{14}^{\{1\}}$ | $\mathbf{W}_{14}^{\{13\}}/\sqrt{2}$ |
| 15 | $\mathbf{u}_{15}=[1\ \ 1\ \ 1\ \ 1]^T$ | $\mathbf{W}_{15}^{\{1\}}$ | $\mathbf{W}_{15}^{\{12\}}/\sqrt{2}$ |

As introduced in [9], leakage-based precoding provides good performance for a multiuser operation using a transmitter covariance matrix. To obtain this covariance matrix with a minimum increase in the signaling overhead, an uplink signal is utilized (e.g., an uplink sounding reference signal is introduced for closed-loop link adaptation on the uplink) by assuming channel reciprocity. This reciprocity assumption is particularly true if antenna calibration is applied appropriately, even for systems that employ frequency division duplex averaging over the frequency domain, which reduces the impact of fast fading. For example, for the link between cell $i$ and UE $k$, the following covariance matrix for all cells joining $k$'s CoMP operation is as follows:

$$\mathbf{R}_{UEk\_celli} = \mathbf{H}_{UEk\_celli}^H \mathbf{H}_{UEk\_celli} \tag{2}$$

In addition to reporting the covariance matrix for cells within the measurement set, we assume that the UE also provides feedback using the total interference covariance matrix, which represents noise and interference external to the measurement set.

### 4) *UE scheduling based on proportional fair (PF) metric*

Here, we show how an eNB allocates resources for the UE as part of its physical resource scheduling functionality, according to the PF metric calculated from the implicit

$$\gamma'_{UEk\_cellp,l}(t) = \frac{trace(\mathbf{W}_{UEk\_cellp,l}^{(t)}{}^H \mathbf{R}_{UEk\_cellp}^{(t)} \mathbf{W}_{UEk\_cellp,l}^{(t)})}{trace(\mathbf{I}_{UEk}) + \sum_{L\neq p}\sum_{c\neq k} trace(\mathbf{W}_{UEc\_cellL,l}^{(t)}{}^H \mathbf{R}_{UEk\_cellL}^{(t)} \mathbf{W}_{UEc\_cellL,l}^{(t)})} \tag{3}$$

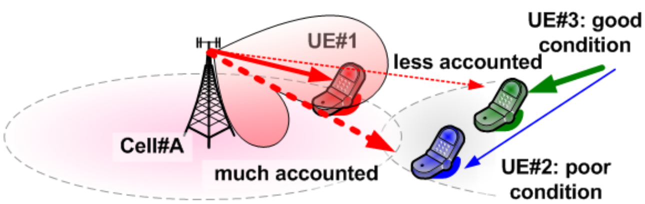

Fig. 2. Concept of the proposed precoder calculation

feedback.

First, based on the reported CQI/PMI/RI, eNB calculates the PF metric with equation (3) as the nominal SINR, where the identity matrix $\mathbf{E}$ is assumed to be the initial value of iteration steps for $\mathbf{W}^{(t)}_{UEc\_cellL,l}$.

Then, eNB decides the UE time–frequency resource allocation according to the above PF metric. Accordingly, eNB calculates the precoder and determines the CQI for the t-th step, and it iteratively calculates the precoder and the CQI using the following equations:

- Update γ for the link between cell $p$ and UE $k$ using the reported CQI as the initial value.

$$\gamma_{UEk\_Cellp}(t)=\gamma'_{UEk\_Cellp}(t-1),$$

$$\gamma_{UEk\_Cellp}(t)=\begin{cases}\gamma_{UEk\_Cellp,1}(t) & If\ RI=1\\ [\gamma_{UEk\_Cellp,1}(t),\gamma_{UEk\_Cellp,2}(t)]^{T} & Otherwise\end{cases}\qquad(4)$$

- Perform SLNR-based weight calculation for the link between cell $m$ and UE $n$.

$$I^{m-}_{UEk}=trace(\mathbf{I}_{UEk})+\sum_{p\in A_k\backslash\{m,s(k)\}}trace(\mathbf{W}^{(t-1)H}_{Cell\,p}\mathbf{R}_{UEk\_cellp}\mathbf{W}^{(t-1)}_{Cell\,p})$$

$$\mathbf{W}^{(t)}_{UEn\_Cellm}=eig\left[\left(\sum_{k\in B_m}\frac{\mathbf{R}_{UEk\_Cellm}}{I^{m-}_{UEk}}+\alpha\mathbf{E}\right)^{-1}\mathbf{R}_{UEn\_Cellm}\right]\qquad(5)$$

where $\mathbf{I}_{UEk}$ is the feedback interference and noise external to the measurement set, and $I^{m-}_{UEk}$ represents the victim *UE $k$ 's total interference* power from both within the measurement set (precoding is based on the previous iteration or initial condition) and outside the measurement set, *except the interference from cell m* [9]. $A_k/\{m,s(k)\}$ denotes the CoMP measurement set of the k-th UE excluding the m-th cell and its own serving cell $s(k)$. $\mathbf{W}^{(t-1)}_{Cell\,p}$ denotes tentative precoder composed of SLNR-based weight for allocated UE(s) at cell $p$, obtained at the previous iteration step. Here, scaling factor $\alpha$ is applied in order to account noise and interferences outside of CoMP measurement set, which can be determined corresponding to the value for CoMP threshold.

- Apply the CQI update according to the given precoder (equation (6))

Here, $\gamma_{UEk\_cellp,l}(t)$ accounts for the behavior of the UE-side receiver that is not available via explicit feedback.

## III. Improvement of Precoder Calculation

Equation (3) is a straightforward extension of a single-cell SLNR precoding to a multicell environment, where the noise power is directly replaced by noise and interference power (with the exception of interference from the calculating cell). The reason for placing $I^{m-}_{UEk}$ in the denominator is that if the existing interference is already large, relatively high leakage power can be provided to the victim UE.

However, in multicell environments, other factors may allow relatively high leakage power to the victim UE. For example, if the channel between the victim UE and the cell serving victim UE is very strong, it is possible to allow high leakage power. However, equation (5) does not reflect the above phenomenon.

To resolve the above problem, we revise the total interference power calculations from equations (5) to (7). In the revised equation, the condition representing the channel between the victim UE and the victim UE's serving cell is included.

We observe that the terms that directly sum up the interference power (second term in eq. (7)) and UE $k$'s signal power (third term in eq. (7)) are not appropriate because they have different physical natures. One option is to scale the signal power to reflect the differences. Although there are no limitations in the range of the scaling factor, numerical results reveal that a fractional number yields better performance, as shown in section IV. This is expected because in most cases, the signal power is higher than the interference power, implying that a scaling factor greater than one will allow a high leakage power, which is generally not the case.

The final concept is implemented using equation (7) for precoder calculations. This equation aims to scale the covariance matrix for the UE of interest by considering the link between the victim UE and the cell serving the victim UE.

For larger values of $\theta$, eNB calculates the precoder that allows a certain level of leakage to the victim UE according to its channel condition. If the value $\theta$ is set to zero, the resultant precoder is identical to conventional ones.

$$\gamma'_{UEk\_cellp,l}(t)=sqrt\left(\gamma_{UEk\_cellp,l}(t)\times\frac{trace(\mathbf{W}^{(t)}_{UEk\_cellp,l}{}^{H}\mathbf{R}^{(t)}_{UEk\_cellp}\mathbf{W}^{(t)}_{UEk\_cellp,l})}{trace(\mathbf{I}_{UEk})+\sum_{L\neq p}\sum_{c\neq k}trace(\mathbf{W}^{(t)}_{UEc\_cellL,l}{}^{H}\mathbf{R}^{(t)}_{UEk\_cellL}\mathbf{W}^{(t)}_{UEc\_cellL,l})}\right)\qquad(6)$$

$$I'^{m-}_{UEk}=trace(\mathbf{I}_{UEk})+\sum_{p\in A_k\backslash\{m,s(k)\}}trace(\mathbf{W}^{(t-1)H}_{Cell\,p}\mathbf{R}_{UEk\_cellp}\mathbf{W}^{(t-1)}_{Cell\,p})+\theta\times trace(\mathbf{W}^{(t-1)}_{Cell\,s(k)}{}^{H}\mathbf{R}_{UEk\_cells(k)}\mathbf{W}^{(t-1)}_{Cell\,s(k)})\qquad(7)$$

TABLE II
SIMULATION ASSUMPTIONS

| Parameters | Assumption |
|---|---|
| Carrier frequency | 2 GHz |
| Cell layout | Hexagonal grid, 19 cell sites,<br>3 sectors per cell site |
| Intersite distance (ISD) | 500 m (3GPP case1) |
| Antenna pattern at eNode B<br>(antenna gain + cable loss) | 70 deg. sectored beam with tilt<br>(14 dBi, $\theta_{etilt}$ = 15 deg.) |
| Subframe (TTI) length | 1 msec |
| Transmission bandwidth | 9000 kHz (50 Resource blocks (RB)s) |
| RB bandwidth | 180 kHz (12 subcarriers) |
| Distance dependent path loss | $128.1 + 37.6\log_{10}(r)$ dB |
| Penetration loss | 20 dB |
| Shadowing standard deviation | 8 dB |
| Shadowing correlation | 0.5 (intersite) / 1.0 (intrasite) |
| Transmission power | 46 dBm |
| Channel model | 3GPP spatial channel model (SCM)<br>Angle Spread = 15 [deg] |
| Antenna configuration | 4x2 closely spaced cross polarized antenna |
| HARQ | Asynchronous adaptive, Incremental redundancy |
| MCS set | QPSK ($R$ = 0.076, 0.117, 0.188, 0.301, 0.438, 0.588)<br>16QAM (R = 0.369, 0.479, 0.602)<br>64QAM ($R$ = 0.455, 0.554, 0.65, 0.754, 0.853, 0.926) |
| AMC target BLER | 20% for 1st transmission |
| Rank adaptation | Rank adaptation, and up to 2 for one UE |
| Scheduling algorithm | Proportional fairness |
| Channel estimation for demodulation | Realistic |
| UE receiver assumption | MMSE without other cell information |
| Overhead of reference signal (RS) and control signalling | Control signalling (3/14 OFDM symbols for 4/10 subframes, 2/14 OFDM symbols for 6/10 subframes)<br>Demodulation RS (12 resource elements per RB)<br>Cell-specific RS (2 ports in 4/10 subframes) |

TABLE III
COMP AND CSI FEEDBACK RELATED ASSUMPTIONS

| Parameters | Assumption |
|---|---|
| Coordinating cluster size | 9 cells |
| CoMP Threshold | -9, -6, -3 [dB] |
| Channel state information feedback | Implicit feedback, sub-band PMI/CQI report,5RB sub-band size Feedback periodicity is 5 ms with 6 ms delay<br>Frequency response for each cell in measurement set<br>Covariance matrix (interference and noise) |
| Feedback delay | 4 ms |
| Feedback interval | 1 TTI |

# IV. SIMULATION

In this section, using the investigated precoding scheme, we evaluate improvements in the system performance in terms of the average cell and cell edge user throughputs obtained by system level simulations.

## *A. Simulation Assumption*

Table II shows the main simulation assumptions, which are based on 3GPP case 1 that corresponds to homogeneous macrocell deployment [7]. For the multicell environment, assuming that an eNB is located at the center of each site, we use 19 sites comprising three tiers, where each site has three macrocells (Fig. 3). Table III shows assumptions applied to CSI feedback and CoMP operation for our evaluation. With respect to CB, the coordination area is restricted to three sites (of nine cells), as shown in Fig. 3. In each macrocell, 10 UEs are dropped with uniform distribution. The 3GPP spatial channel model (SCM) is used by assuming 15 degrees of

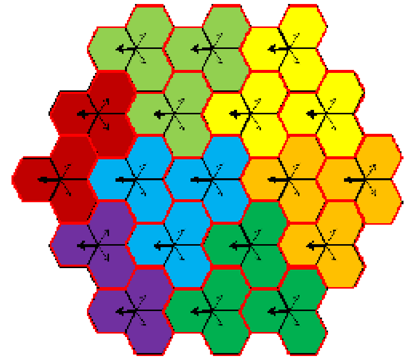

Fig. 3. Coordination area

angular spread. In the evaluation, the downlink signal power received on the UE side is applied for UE association, i.e., each UE is associated with the cell that has the highest power. For the transmit antenna at the eNB side, a closely spaced antenna with a cross-polarized setting is applied.

## *B. Simulation Results*

In this section, we present the simulation results. The single-user MIMO scheme without intercell coordination is referred to as non-CoMP.

Figs. 4 and 5 show user throughput performances for cell edge and cell average, respectively. We aim to verify the benefit of scaling in terms of precoding control for CoMP. In the figures, solid lines with {circles, squares, diamonds} indicate the results with CoMP thresholds of {−9, −6, −3 dB, respectively}. The plots show the variation of relative gain with throughput performance (without the CoMP scheme), i.e., the results with a single-cell MIMO operation.

First, we show the cell edge user throughput gain in Fig. 4. From these results, we observe that a nonzero scaling factor positively affects performance, particularly for small scaling factors and large CoMP threshold values. For the results with a scaling factor of 0.25 and CoMP threshold of −9 dB, an additional 3.4% gain is observed compared to the results for CoMP without the scaling factor. Then, a performance improvement of around 9.2% is realized by investigating the CoMP scheme in terms of cell average throughput. In contrast, performance degradation with larger scaling factors such as 0.75 or more is more than that with smaller scaling factors such as 0.25. This is mainly because the scaling factor allows high leakage power to the victim UEs in adjacent cells.

Second, Fig. 5 shows the cell average user throughput gain. The observed tendency is almost similar to that shown in Fig. 4. One difference is that the results with the CoMP threshold of −9 dB show a significant improvement in performance compared to that with the CoMP threshold of −6 dB. This is primarily because a smaller CoMP threshold is given. UEs that have wide coverage areas benefit from CoMP transmission. Another difference is that a relatively small scaling factor is preferred from the perspective of performance gain. In particular, some performance degradation is observed with scaling factors that exceed 0.50, whereas the best performance is realized with the given CoMP threshold. This is primarily because with a large scaling factor, the precoder focuses on the cell edge UE while the cell center UE has less

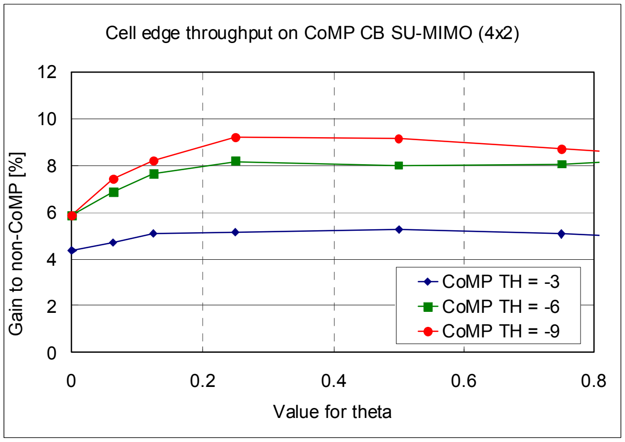


Fig. 4. CoMP gain in cell edge throughput

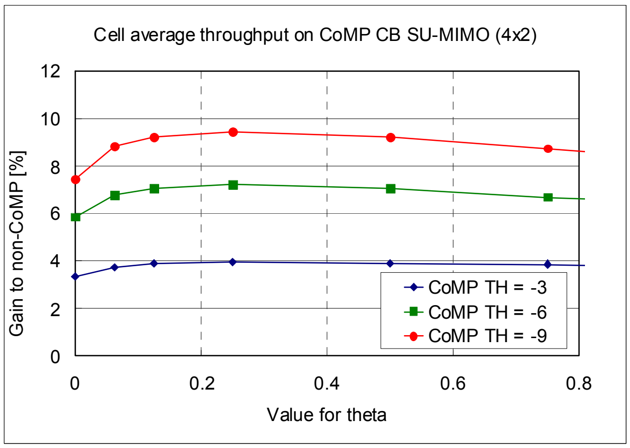


Fig. 5. CoMP gain in cell average throughput

priority in terms of leakage. Therefore, the cell average gain is more sensitive to large scaling factors. For the results with a scaling factor of 0.25 and a CoMP threshold of −9 dB, the gain increases by 2.0% compared to that for CoMP without the scaling factor. Then, a performance improvement of approximately 9.4% is achieved with the investigated CoMP scheme in terms of the cell average throughput.

Table IV shows a summary of the evaluation results with the optimized scaling factor per given CoMP threshold. We observe that the scaling factor of 0.25 with a CoMP threshold of −9 dB has the best performance for both cell edge and cell average user throughput gains.

These results verify that the introduction of scaling factors improves the throughput performance for CoMP schemes, and the factors enable better processing of precoders in terms of both inter- and intracell leakage. This is an attractive method for LTE-Advanced CoMP operations.

## V. Conclusion

This paper investigated a leakage-based precoding scheme that supports CoMP operation for LTE-Advanced systems, which accounts for the channel quality for the link between the victim UE and the cell serving data for the victim UE. Furthermore, use of the scaling factor in the covariance matrix that represents the aforementioned channel may further improve the system performance. The proposed algorithm was verified by multicell system level simulations. The results confirmed that CoMP with a leakage-based precoding scheme provides a performance improvement of the system throughput for both cell average and cell edge cases. Moreover, an appropriate scaling factor provides an additional gain of approximately 3%, particularly for the cell edge region. Furthermore, CoMP achieves a throughput improvement of more than 9% compared to conventional systems. In this paper, the victim UE's channel condition is simply summed with the interference power. It is still possible to pursue other forms that may better reflect the victim UE's channel condition, such as nonlinear averages of the interference power and signal power (victim UE's channel condition). This issue should be investigated further in future.

TABLE IV
Summary Table

| CoMP TH [dB] | CoMP scheme | Cell average throughput [bps/Hz] | Gain over Non-CoMP [%] | Cell edge throughput [bps/Hz] | Gain over Non-CoMP [%] |
|---|---|---|---|---|---|
| - | Non-CoMP | 2.321 | - | 0.066 | - |
| -3 | CoMP CB | 2.398 | 3.343 | 0.069 | 4.337 |
| | CoMP CB θ=0.50 | 2.411 | 3.888 | 0.070 | 5.253 |
| -6 | CoMP CB | 2.456 | 5.850 | 0.070 | 5.863 |
| | CoMP CB θ=0.25 | 2.488 | 7.195 | 0.072 | 8.175 |
| -9 | CoMP CB | 2.494 | 7.449 | 0.070 | 5.845 |
| | CoMP CB θ=0.25 | 2.540 | 9.448 | 0.073 | 9.192 |

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