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# Resource Allocation Scheme for Multi-Cell OFDMA Considering the Interference to Cell-Edge Users

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*Abstract*-**In this paper, we propose a resource allocation scheme that limits allocating sub-channels to other cells based on the amount of interference estimated by beacon signals from adjacent cells' BSs (base station) to users to reduce the co-channel interference and re-allocates sub-channels to cell-edge users in multi-cell orthogonal frequency division multiplexing access (OFDMA) system. The proposed scheme can improve the outage probability that users don't achieve the required rate. The computer simulation shows that the proposed scheme can provide better system utilization and outage probability performance compared with the conventional scheme.**

*Keywords:* OFDMA, Resource Allocation, Multi-Cell.

## I. INTRODUCTION

Orthogonal Frequency Division Multiple Access (OFDMA) based on OFDM is considered as one of the most attractive multiple access schemes for next-generation mobile communications. An advantage of OFDMA over OFDM-TDMA (Time Division Multiple Access) and OFDM-FDMA (Frequency Division Multiple Access) is the allocating resource flexibly in the transmission condition. Therefore, resource allocation scheme plays an important role in optimizing the performance of OFDMA systems. However, up to date, most schemes on OFDMA resource allocation have been limited to single-cell scenarios [1]-[3]. Therefore, we think the research of the resource allocation scheme for multi-cell environment is needed in OFDMA system. In the resource allocation scheme for multi-cell environment, it is necessary to consider the interference to adjacent cells unlike the allocation scheme for single-cell. This reason is that the co-channel interference is induced if the same sub-channels are used simultaneously by other users in adjacent cells. When the allocation scheme to maximize the throughput performance in each cell is used, the total system throughput performance is not maximized because of co-channel interference. Thus, in the multi-cell environment it is necessary to suppress the interference from adjacent cells in allocating the sub-channels. The conventional scheme uses the beacon signals to manage the transmission condition, and reduces the value of information for feedback [4]. The beacon signals are broadcasted to all users from BSs of each cell. The users calculate the achievable rates by using the received beacon signals, and feedback the rates to their corresponding BSs as CSI (Channel State Information). All BSs are controlled by RNC (Radio Network Controller). RNC allocates the sub-channels to a user that has the most throughput improvement value by using the CSIs feed-backed from BSs. Thus, the conventional scheme can achieve the better throughput performance by using the beacon signals in the multi-cell environment.

This conventional scheme allocates the sub-channels by comparing the user's throughput improvement value without considering the cell-edge user. Thus, the cell-edge users influenced strongly by co-channel interference might not satisfy the required rate. As a result, outage probability performance is degraded in the conventional scheme, where we define the outage probability as the probability that a user cannot achieve the required rate. Therefore, resource allocation scheme is needed to improve the outage probability performance of cell-edge users in the multi-cell environment.

In this paper, we propose the resource allocation scheme that restricts allocating sub-channels to cells with maximum interference determined by beacon signals from adjacent cells to reduce the co-channel interference. And the proposed scheme re-allocates these sub-channels to cell-edge users to improve their outage probabilities in multi-cell OFDMA system. Furthermore, the proposed scheme provides power allocation of sub-channels to improve system utilization if the number of allocated sub-channels is changed. We show that the proposed scheme can achieve the better system utilization performance and outage probability performance than the conventional scheme by computer simulation.

## II. CONVENTIONAL SCHEME

In the multi-cell environment, it is necessary to allocate the resource optimally considering the co-channel interferences. In [5], the SINR (Signal to Interference Noise Ratio) is fedback from each user at regular time interval as well as the case of a single cell increases signaling overhead because of a numbers of cells.

The scheme using the beacon signals for the multi-cell environment has been proposed to reduce the amount of information for CSI and to simplify resource allocation [4]. CSI is periodically provided by the users who listen to the broadband beacon signals broadcasted from BSs. Each BS transmits a beacon signal having the information of available sub-channels among N sub-channels by using fixed transmission power at difficult time slot, and the user receives the signals from BS at different time. Therefore, the user can estimate the signal strength from each BS, and determine the dominant interference BS. For example, on a particular sub-channel, the SINR received by the user who is communicating with $BS_i$ can expressed as

$$p_i h_i \Big/ \sum_{j \neq i}^{L} (h_j p_j + N_0) \qquad (1)$$

where $L$ is the number of BSs in the system, $N_0$ is the AWGN spectral density and $p_i h_i$ represents the signal strength received by the user from $BS_i$ with $p_i$ and $h_i$ being the transmitting power of $BS_i$ and channel gain between $BS_i$ and the user, respectively. Next, using beacon signals, the user can determine the strongest interfering BS,

$$k = \underset{j \neq i}{\arg\max}\ p_i h_i \qquad (2)$$

Then, the SINR without this dominant interference is from BS $k$ defined as SINR`. For the calculation of SINR', the signal strength from BS $k$ is removed from SINR's denominator coefficient. The user then calculates SINR' as

$$SINR' = p_i h_i / \sum_{j \neq i, j \neq k}^{L} (h_j p_j + N_0) \qquad (3)$$

The user calculates two achievable rates

$$I_{mn} = \log_2(1 + SINR) \qquad (4)$$

$$s_{mn} = \log_2(1 + SINR') \qquad (5)$$

by using the SINR and SINR'. This two rates and dominant interference BS's information are used as user m's CSI on sub-channel n. The user can know the available sub-channel by getting the sub-channel information of beacon signal. The purpose of calculating a CSI of each sub-channel is to allocate one sub-channel to one user in each cell. By defining such a CSI structure, the channel and interference information need to be indicated from $L$ BSs, instead of feeding back the signal strength and interference received from $L$ BSs. Such information exchange leads to signaling overhead reduction between users and BSs.

RNC attempts to assign a sub-channel to the user which has the highest throughput improvement value within each cell. Improvement value is defined as the system throughput improvement by allocating the current channel to the user. The sub-channel allocation is progressively performed to provide the most improvement to the system throughput. When RNC receives CSI from BS, RNC decides the sub-channel allocated to each BS, and the user allocated the sub-channel firstly. Multi-cell environment differs from a single cell environment in that when RNC allocates the sub-channel to the user, the throughput performance is not surely improved because of co-channel interference. Thus, it is necessary to calculate the difference between the improvement of throughput by allocating sub-channels and the degradation of throughput influenced by co-channel interference to adjacent cells.

In the conventional scheme, when the value of this difference is calculated, RNC uses CSI. [$I_{mn}$, $s_{mn}$] and dominant interference BS's information are included in user $m$'s CSI for channel $n$. $I_{mn}$ and $s_{mn}$ represent user $m$'s achievable rates (bits/s/sub-channel) on channel $n$ with and without the dominant interference, respectively. Therefore the difference $\partial_{mn} = s_{mn} - I_{mn}$ is defined as the degradation of throughput influenced by co-channel interference to adjacent cells. The throughput improvement in the case that sub-channel n is allocated to user m is calculated based on $s_{mn}$. If the certain cell allocated the sub-channel n is user m's dominant interference cell, throughput improvement $s_{mn}$ is reduced by the influence of co-channel interference $\partial_{mn}$. The total throughput of each sub-channel is calculated as

$$T_n = \sum_{m=1}^{M_t} (s_{mn} - \sum_{i \in \eta_{mn}} y_{in} \partial_{mn}) \qquad (6)$$

where $T_n$ represents the throughput of sub-channel n, $M_t$ is total users in the system, $\eta_{mn}$ represents the index of user m's dominant interfering BS on channel n, $y_{in}$ is a element of an allocation matrix. $y_{in}$ = 1 indicates that channel $n$ is assigned to user $i$ and 0 otherwise. $\sum_{i \in \eta_{mn}} y_{in} \partial_{mn}$ represents the total degradation of throughput influenced by co-channel interference to adjacent cells. To achieve maximum throughput, RNC calculates the throughput improvement value of sub-channel n when the sub-channel n is allocated to user m, as

$$\Omega_m = T_n(y + e_m^{M_t}) - T_n(y) \qquad (7)$$

where $e_m^{M_t}$ is a $M_t$-length vector with all 0s except 1 at the $m^{th}$ position. Thus, $T_n(y + e_m^{M_t})$ is the throughput when RNC newly allocates the sub-channel n to user m. In multi-cell environment, allocating the sub-channel doesn't always improve the throughput. The throughput might be degraded if the degradation of influence by co-channel interference is larger than improvement of allocating the sub-channel. RNC compares $\Omega_m$ of all users, and decides the user with the largest $\Omega_m$ in each cell. If no user in the cell has a positive improvement value, then the sub-channel is not assigned to this particular cell.

## III. PROPOSED SCHEME

The conventional resource allocation scheme in [4] compares the throughput improvement values by calculating the difference between improvement of throughput by allocating sub-channels and degradation of throughput influenced by co-channel interference to adjacent cells, and allocates the sub-channel to the user with the largest improvement value. Therefore, a user on the cell-edge in each cell is not allocated many sub-channels because the a cell-edge users are suffered from heavy co-channel interference and cannot be allocated high SINR sub-channels. This is because a cell-edge user receives a weak signal strength(SINR's numerator coefficient). When the co-channel interference(SINR's denominator) is increased because of sub-channel allocation in adjacent cells, SINR of cell-edge user is degraded even if the total system throughput is improved. Therefore, achievable rate for cell-edge user is reduced, and the outage probability performance is degraded.

In addition, the conventional scheme provides fixed power allocation. The power for each sub-channel is fixed at $P_{\max}/N$ in this scheme, where $P_{max}$ is maximum total power of each BS, N is the number of sub-channels. Therefore, unused power exists when all sub-channels are not allocated in each cell and the number of allocated sub-channels is changed. In the conventional scheme, even if the number of allocated sub-channels is reduced by sub-channel allocation, each power of sub-channel is always fixed. An appropriate power allocation is needed, especially in the multi-cell environment. When the power allocated to a particular user is increased, the influence of interference to a user allocated in the same sub-channel in the adjacent cell is also increased, and thus, appropriate power allocation to all users is required. Therefore, in the multi-cell OFDMA environment the resource allocation scheme is needed to reduce the outage probability of cell-edge user and to allocate appropriate power for sub-channels in a low complexity.

In this paper, we propose the resource allocation scheme that restricts allocating the sub-channel to a BS considering dominant interference, determined by beacon signals from adjacent cells, to reduce the co-channel interference and re-allocates these sub-channels to cell-edge users to improve their outage probability for cell-edge user in multi-cell OFDMA system. Furthermore, in the proposed scheme power of sub-channels is re-allocated, if the number of allocated sub-channels is reduced to improve system utilization.

The proposed scheme needs the beacon signals to simplify the resource allocation similar as the conventional scheme [4]. The users feedback $I_{mn}$, $s_{mn}$ and dominant interfered BS's CSI. Using CSI of two achievable rates from users, the signaling overhead can be reduced. CSIs fed back from users in each cell are collected to RNC through BSs.

### *A. Resource Allocation of the Proposed Scheme*

#### *1) Initial Allocation Step*

At the beginning, RNC compares the system throughput improvement value of users don't satisfy the required rate, and allocates sub-channels to a user that improves most of the throughput. The calculation method of the system throughput improvement value is the same as the conventional scheme as explained in section II. Note that the conventional scheme compares the throughput improvement values of all users in each cell. On the other hand, the proposed scheme compares only users who don't satisfy the required rate and allocates sub-channels to these users. Users who don't satisfy the required rate are defined as outage users. This sub-channel allocation is defined as fist allocation step. Fist allocation step allocates sub-channels to outage user who has largest throughput improvement. Therefore, when the cell-edge users require the high required rate, outage users who don't satisfy the required rate exist. In the case that outage users exist, after the initial allocation step, the re-allocation step is implemented to reduce their outage probability.

#### *2) Re-allocation Step (Dividing Sub-channels into $\Phi 1$ and $\Phi 2$)*

In the re-allocation step, when the sub-channels allocated by the initial allocation step to cell-edge users, defined as the sub-channels group $\Phi_1$, are strongly influenced by even weak interference, their allocation to only users in adjacent cells will be restricted because of interference to outage user in these adjacent cells. Fig.1 shows the re-allocation method of $\Phi_1$. In the example, cell-edge user i, user m, and user u are allocated the same sub-channel n of $\Phi_1$ by the initial allocation step. In the proposed scheme, cell-edge user *i*'s throughput can be improved by re-allocation step to satisfy required rate. Fig.1 shows the case that the allocation to user m of sub-channel n of $\Phi_1$ is restricted. In Fig.1, the user m is restricted using the sub-channel n for improving the throughput of user *i*.

1. RNC researches the dominant interfered BS of user *i* in cell 1 allocated sub-channel n by using CSI, and determines the BS of cell 2 as dominant interfered BS.
2. RNC restricts that sub-channel n is allocated to user m because the cell 2 is the dominant interfered BS for user *i*, if user m satisfies the required rate.

The purpose is to suppress the interference because of the weak signal strength from own cell. Since uses in each cell receive the beacon signals, they can estimate the strength of interference from each cell. Therefore, since sub-channels allocated to cell-edge users are restricted using in cells interfere in adjacent cells, the degradation of SINR can be reduced. Thus, the high SINR sub-channels can be allocated to cell-edge users. When the user has been already allocated the sub-channel of $\Phi_1$ in adjacent cell by the initial allocation step, this user is restricted using this already allocated sub-channel in the re-allocation step only if this user satisfies the required rate after restricting this sub-channel is restricted. When this user cannot be restricted using the sub-channel because of not satisfying the required rate, RNC recommends another user allocated sub-channel of $\Phi_1$ in other cell to restrict using this sub-channel for re-allocation step.

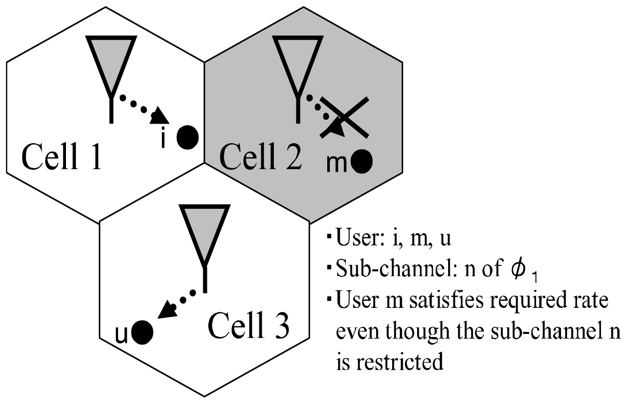


Figure1. Re-allocation step in the proposed scheme.

In contrast, the sub-channels allocated to near users from BS are defined as the sub-channels group $\Phi_2$ not influenced by weak interference, can be allocated to users in adjacent cells because of weak influence to near user from BS. This reason is that near user's SINR is not degraded greatly if the sub-channel is allocated to user in dominant interfered BS and other users in adjacent cells. Therefore, dividing the sub-channels into $\Phi_1$ and $\Phi_2$ in re-allocation step can improve the cell-edge user's SINR without degrading the total throughput greatly because of not restricting allocation of $\Phi_2$.

#### *3) Re-allocation Step (Handing over the Sub-channel among outage users)*

Then, the proposed scheme hands over sub-channels among outage users. This purpose is to improve the throughput and outage probability by handing over the sub-channels that already are allocated to outage users to the other outage users. This scheme determines the user that has the most potential to satisfy the required rate among outage users in each cell, and hands over the sub-channels allocated other outage user to a determined user to satisfy the required rate for this user. RNC compares the degradation of throughput by restricting allocation of sub-channel to an outage user and throughput improvement of allocating to a determined outage user. The throughput improvement value of this re-allocation is explained as

$$\Omega_o = T_n(y + e_o^{M_t}) - T_r(y - e_s^{M_r}) \quad (8)$$

This function explains the case that the sub-channel allocated user s is handed over to user o. RNC compares these values of all outage users in each cell. And RNC hands over the sub-channel allocated user that can improve the most system throughput to user o. In this case, the user o allocated sub-channel can be improved the throughput. Fig.2 shows the hanging over sub-channel r to user o to satisfy required rate of user o. In this example of Fig.2, the user o is allocated not only sub-channel n but also sub-channel r. Thus, the throughput of user o is increased. Therefore, the outage probability performance is improved by handing over sub-channel among outage users in re-allocation step.

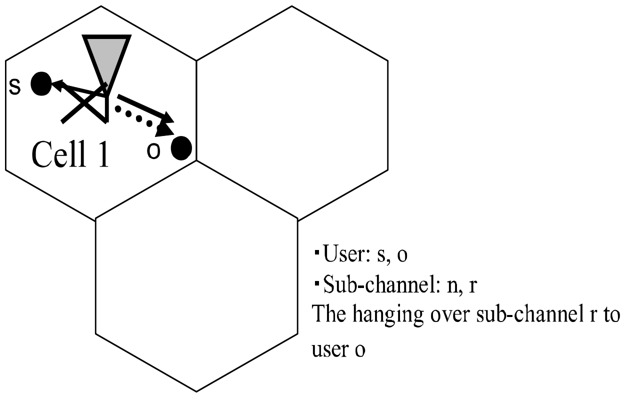


Figure 2. Hanging over the sub-channel.

### B. Power Allocation

Lastly, the proposed scheme increases the power of sub-channels of $\Phi_1$ to improve the throughput performance. Power allocation of the conventional scheme fixes the power of sub-channels from BSs. However, the proposed scheme re-calculates the allocated power of each sub-channel by using the total number of sub-channels used by users in each cell. Each power is formulated as:

$$p = \frac{P_{\max} - (P_{\max}/N) \times \overline{\phi_2}}{\overline{\phi_1}} \quad (9)$$

where $\overline{\phi_1}$ , $\overline{\phi_2}$ represent the number of sub-channels $\Phi_1$, $\Phi_2$ used by users, respectively. Thus,

$$\phi_1 + \phi_2 = N \quad (10)$$

while,

$$\overline{\phi_1} + \overline{\phi_2} < N \quad (11)$$

The reason is that allocation scheme in the conventional scheme shown in sub-section II and initial allocation step shown in sub-section III-A-1 don't allocate sub-channel to a user if the throughput performance of sub-channel is not improved. Thus, all N sub-channels are not always allocated in multi-cell environment. The proposed power allocation subtracts power allocated already to $\phi_2$, $(P_{\max}/N) \times \overline{\phi_2}$ from maximum power $P_{max}$ and divides this value by the number of sub-channels allocated actually $\overline{\phi_1}$. Therefore, this power allocation can allocate all power without remaining power. In the conventional scheme, the increase of the allocated power strengthens the influence of interference to adjacent cells. However, since the proposed scheme increases the power of only sub-channels $\phi_1$ restricted using in adjacent cells, the increase of co-channel interference can be reduced. Thus, the proposed scheme can improve the throughput performance by increasing the power of sub-channels as well as power allocation in multi-cell environment.

## IV. Computer Simulation

Table.1 shows the simulation parameters. These parameters are same in the conventional scheme. In this simulation, the users are randomly distributed in each cell. All users have common required rates varying from 200 kbps to 1 Mbps. Each sub-channel is only allocated to one user within each cell. Thus, there is no intra-cell interference.

TABLE I
Simulation Parameters

| | |
|---|---|
| Cell radius | 2000m |
| Sub-Carrier bandwidth | 10KHz |
| Number of Sub-Carriers | 512 |
| System bandwidth | 5.12 Mhz |
| Number of Sub-Channels | 32 |
| Number of Cells | 7 |
| Number of Users | 10 Users/cell |
| Doppler Spread | 10 Hz |
| Traffic Load | 200～1000 kbits/s/user |

Fig.3 shows the comparison of system utilization in the conventional scheme and the proposed scheme. We define the system utilization as the ratio of total throughput of all users, and system bandwidth. Also, we define the user's required rate as traffic load. All users in each cell have the common traffic load. The triangle plot indicates the system utilization performance of the proposed scheme (Initial allocation and Re-allocation) without power allocation, and square plot indicates the performance of the proposed scheme with power allocation. In Fig.3 we can see that system utilization performance of the proposed scheme is better than that of the conventional scheme. This reason is the proposed scheme can allocate the sub-channel to the cell-edge users effectively by restricting the allocation of cell-edge user's sub-channel to other users in adjacent cells. Also, the proposed scheme with power allocation has the best system utilization. This reason is the proposed power allocation can allocate more power to sub-channels compared fixed power allocation of the conventional scheme without increasing the co-channel interference. Therefore, this power allocation is needed to improve system utilization performance in multi-cell environment.

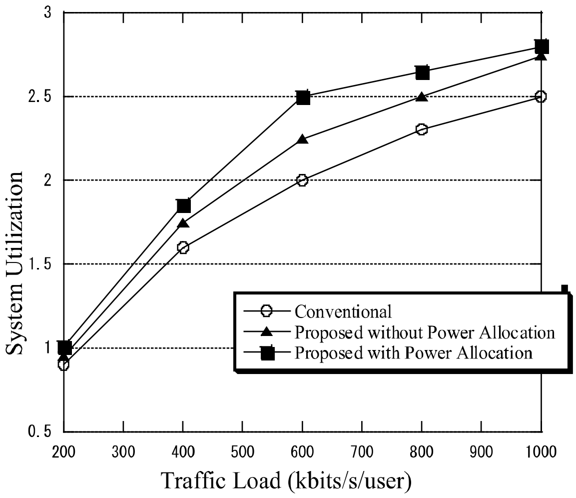


Figure 3. System Utilization performance.

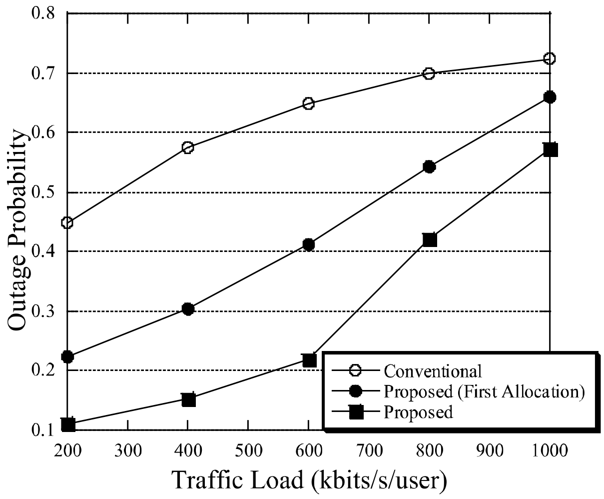


Figure 3. System Utilization performance.

Fig.4 shows the comparison of outage probability performance in the conventional scheme and the proposed scheme. The black circular plot of Proposed (Initial Allocation) indicates the performance of only the initial allocation without re-allocation, and the square plot indicates the performance of the proposed scheme (Initial allocation and Re-allocation) with power allocation.

We can see from Fig.4 that outage probability performance of the proposed scheme is better than that of the conventional scheme. The conventional scheme compares the throughput improvement value of all users in each cell. However, the proposed scheme compares the improvement value of users who don't satisfy the required rate. Therefore even if the system throughput is improved, the proposed scheme doesn't allocate sub-channel to the user that satisfies the required rate. Thus, the satisfied users are not allocated extra sub-channels and the proposed scheme can allocate the sub-channels to outage users preferentially. Furthermore, in Fig.4 the re-allocation of the proposed scheme can improve the outage probability performance compared the performance of only the initial allocation. The re-allocation can allocate the sub-channels, which are not used in adjacent cells, to outage users. Also when outage users exist in particular cell, re-allocation can hand over the sub-channels, which are already allocated, to an outage user that has the potential to satisfy the required rate. Therefore, re-allocation of the proposed scheme can achieve the better outage probability.

## V. Conclusions

In this paper, we have proposed the resource allocation scheme that limits allocating the sub-channel to cells which have maximum interference determined by beacon signals from adjacent cells to reduce the co-channel interference. And the proposed scheme re-allocates sub-channels to cell-edge users to improve the outage probability for cell-edge users in multi-cell OFDMA system. Furthermore, the proposed scheme provides power allocation of sub-channels to improve system utilization if the number of allocated sub-channels is reduced. It is shown that the proposed scheme can achieve the better system utilization performance and outage probability performance than the conventional scheme by computer simulation.

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