Resource Reservation to Support Service Continuity in OFDMA Systems

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Received May 18, 2014; revised July 29, 2014; accepted October 22, 2014; published December 31, 2014

Abstract

When the load in a multi-cell orthogonal frequency division multiple access (OFDMA) system is allowed to excessively increase in face of frequent handover, the cell area becomes smaller than the designed size, and thus continuity of quality of service (QoS) for handover requests cannot be guaranteed. To efficiently support the mobility of a mobile terminal (MT), we should adaptively cope with the resource demand of handover calls. This paper proposes a twofold resource-reservation scheme for OFDMA systems to guarantee continuity of QoS for various mobile multimedia services during MT handover from lightly to heavily loaded cells. Our twofold scheme attempts to guarantee service continuity for handover and to maximize resource allocation efficiency. We performed a simulation to evaluate our scheme in terms of outage probability, handover failure rate, total throughput, and blocking rate.

Keywords: OFDMA, Resource Reservation, Handover, QoS, Accommodation Capacity

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This work has been supported by the 2014 Academic Research Promotion Program of Chungwoon University.

http://dx.doi.org/10.3837/tiis.2014.12.007

1. Introduction

Recent development in powerful smart mobile devices has created explosive demands for versatile mobile multimedia services (MMSs) such as high-quality broadcasting, interactive game, voice over IP (VoIP), and Web browsing as well as conventional voice/video. Orthogonal frequency division multiple access (OFDMA) is considered as a multiple-access scheme most eligible to provide different quality of service (QoS) levels to users of these versatile MMSs. It can simultaneously transmit a large volume of data over several subcarriers, dynamically increasing or decreasing the number of subchannels allocated on the basis of the service-required throughput or signal environments [1]–[5].

Handover is one of the basic techniques in cellular systems to maintain the connection and to support continuity of QoS while a user moves across the coverage of several base stations. Such MMSs as high-quality broadcasting have critical QoS requirements. A slight handover delay or failure may cause severe degradation to these MMSs during the mobile terminal (MT) movement. Moreover, in supporting the MMS, the cell radius becomes smaller, and more frequent handovers are inevitable. Effective and efficient resource management schemes in each cell are required to guarantee end-to-end QoS comparable with that of wired networks [6][7]. Resource allocation during MT mobility has a close relationship with call admission and load control [8][9].

Many studies on handover resource allocation have been conducted. Some studies emphasized more on the continuity of user QoS, whereas others emphasized on the expansion of user accommodation. Continuity of user QoS means to guarantee individual QoS for each user regardless of the handover. Meanwhile, maximization of the user accommodation capacity refers to the maximized utilization of available resources through expansion of new calls being admitted. An exclusive emphasis on either optimized user satisfaction or maximized utilization leads to conflicting results. When most of the available subchannels are allocated to guarantee QoS continuity during handover, the user-required throughput can be effectively supported. However, this process may drastically decrease the overall system accommodation capacity. In contrast, if the subchannels are allocated so that new calls are excessively admitted to maximize the system accommodation capacity, then dynamic control in subchannel allocation may not guarantee continuity of individual QoS. Therefore, a tradeoff exists between individual QoS satisfaction and system capacity. Because of these complexities, few studies have attempted to effectively satisfy these two objectives at the same time. Generally, MMS occupies resource in the cell rapidly with the increase of their arrival rate. Less resource is left for allocation in the shorter term, which results to the increased blocking probability. In addition, the increased user population will boost up the handover traffic, and handover failure rate becomes increased because of resource shortage. Furthermore, the outage probability increases due to the consistent delay and loss of user packets. In our paper, we attempt to hold off these performance degradations by utilizing both the load control strategy and the twofold resource-reservation scheme. We first consider the call admission control strategy to maintain balance in the cell load within the permissible range to more efficiently support handovers. Then, we propose a twofold resource-reservation scheme to guarantee continuity of QoS for the MMS handover during the MT handover from lightly to heavily loaded cells. We devise a static resource-reservation mechanism that regularly reserves a fixed amount of resources on the basis of the status of previous occupancy in the cell in each frame. Next, we devise a dynamic mechanism that temporarily reserves resources in advance for pending handover requests until it finally allocates these reserved resources to these requests. We attempt to achieve both guaranteed continuity of QoS and maximized efficiency of resource allocation by having a part of the reservations delayed as much as possible. The rest of this paper is organized as follows. Section 2 summarizes and reviews the recent related studies. The details of our proposed resource-reservation scheme are presented in Section 3. Simulation results and performance evaluation are discussed in Section 4. Section 5 concludes this paper.

2. Recent Studies

Mohnram and Bhashyam proposed a resource-allocation algorithm that performs joint subcarrier and power allocation in an OFDMA system while taking into account the frequency-selective nature of user channels [10]. In [11], Song and Li proposed subcarrier rate adaption, dynamic subcarrier assignment, and adaptive power allocation scheme in an OFDMA system utilizing the concept of utility function. Shen et al. proposed a resource-allocation scheme that maximizes the total capacity while maintaining proportional fairness among users [12]. However, these three schemes did not consider the actual QoS requirements of the users, and the required QoS may not be achieved because the resources were unfairly or insufficiently allocated to some users.

Ali et al. proposed a handoff scheme that not only gives priority to handoff calls but also protects new originating calls to maintain the system capacity at an acceptable level using channel reservation. They analyzed some periods in which the reserved channels are not actively utilized [13]. In [14] Su and Chen proposed a cell-level resource-allocation scheme that grants higher priority to handover users. It prioritized other active users based on a unified cell division model that divides a cell into different inter-cell interference-sensitive areas. Further, it defines a subcarrier preferred list to optimize allocation. In [15], Venkatachalam and Balasubramanie proposed a handover resource management strategy that utilizes a cell-segmentation technique to more accurately predict the resource demands of handover calls in a real-time manner. Based on the MT location in the segmented cell, this scheme determines whether a system should reserve or release resources and to which neighboring cell should these resources be reserved. Ye et al. proposed a predictive resource-reservation scheme. To reduce handover performance degradation due to incorrect reservation, this scheme considers the MT speed toward a target cell as well as its position and orientation [16]. Shehada et al. proposed a QoE-based resource-reservation scheme that statically or dynamically reserves resources to maintain unperceivable quality fluctuation in video during handover in LTE mobile networks [17]. To reduce unnecessary resource reservation, this scheme dynamically reserves the actual resource demand on the basis of prior knowledge of the handovers. However, it did not include a mobility prediction model. Failure in mobility prediction aggravates the handover failures, and resources cannot be utilized because of incorrect reservation. Li et al. suggested a resource-reservation scheme that differentiates the amount of reserved resource in the target and prepared cells [18]. In the prepared cell, handover terminals share a resource pool to increase the resource utilization efficiency. This scheme reserves the resources in multiple cells, and network-wide waste is inevitable. The above schemes emphasized only the optimal resource allocation to guarantee continuity of user services. They did not consider control or expansion of the capacity for user accommodation in the system, which is the primary concern of a system operator.

3. Service Continuity of Handover

3.1 Call Admission Control

Fig. 1 shows the logical subchannel distribution of the OFDMA used in our study. The minimum unit to be used for resource allocation is a resource block (RB) (or a subchannel). The RB consists of seven OFDM symbols within a transmission time interval (TTI) and 12 subcarriers with a 15-kHz bandwidth each [19]. **Fig. 1** shows that the subchannels in each frame n are classified into four kinds of service blocks (SBs), namely, SC_{SB}, N_{SB}, IH_{SB}, and OH_{SB}, and each SB has a certain number of reserved physical subchannels. Here, SC_{SB} denotes the SB occupied by the ongoing MTs in the current cell, N_{SB} denotes the SB to be occupied by new calls, IH_{SB} denotes the SB to be occupied by MTs handed over from the neighboring cells, and OH_{SB} denotes the SB currently occupied by MTs handed over to the neighboring cells. Each SB size indicates the number of RBs needed to guarantee a minimum bit rate (MiBR) of the MMS. It dynamically varies in each frame depending on the status of the subchannel occupancy in the previous frame. The frequency efficiency can be increased by dynamically allocating multiple RBs on the basis of both the current status of the subchannels and the type and transmission rate of MMS requested by a user.

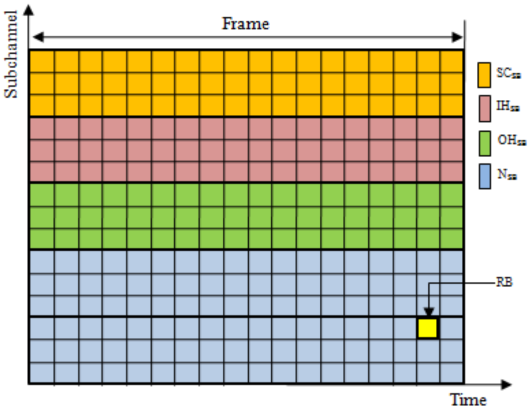

Fig. 1. Subchannel Distribution Based on MMS

When the load is allowed to excessively increase within a cell in the face of frequent handover, the cell area becomes smaller than the designed size, and thus continuity of quality of service (QoS) for handover requests cannot be guaranteed. To efficiently support the MT mobility, we should adaptively cope with the resource demand of handover calls. New calls should be admitted by considering both the current resource usage and the new requirement imposed by the MT movement, and the load should always be balanced within a permissible range to efficiently support the handovers. Let us define the parameters for the new call admission, as expressed in Equation (1). Here SC_{ij} denotes the amount of resource occupied by MT j in cell i, N_{ij} denotes the resource amount demanded by a new call of MT j in cell i, IH_{ij} represents the resource amount demanded by MT j handed over to cell i, and OH_{ij} denotes the resource amount returned by MT j handed over from cell i to the adjacent cells.

$$f(SC_{ij}, N_{ij}, IH_{ij}, OH_{ij}) \tag{1}$$

The following two conditions should be considered before a new call can be admitted.

- Admission is allowed only when the MiBR for both the new and handover calls can be guaranteed.
- Admission is allowed only when the admittance of a new call does not affect the delay of the existing services, and its own delay limits can also be simultaneously guaranteed.

From Equation (2), we can obtain $r_{ij}^{(n)}$, which is the transmission throughput allowable over subchannel n assigned to MT j under the assumption that MT j demands a minimum transmission rate per OFDM symbol. To ensure the user-required throughput, we need to consider the transmission power as well as the allocated number of subchannels and their signal conditions. Different powers are allocated to the individual subchannels in each cell. $p_{ij}^{(n)}$, the power allocated to subchannel n of MT j, is defined by set $P_{ij} = (p^{(1)}, p^{(2)}, \cdots, p^{(N)})$. $H_{ij}^{(n)}$ denotes the link gain, which indicates the channel condition of subchannel n for MT j. $\Phi_i^{(n)}$ expresses the noise received over subchannel n. $IF_{ij}^{(n)}$ denotes the interference imposed by neighboring base stations, and $W_{ij}^{(n)}$ represents the bandwidth allocated to subchannel n of MT j.

$$r_{ij}^{(n)} = W_{ij}^{(n)} \ln(1 + \frac{H_{ij}^{(n)} p_{ij}^{(n)}}{IF_{ij}^{(n)} + \Phi_i^{(n)}}) \tag{2}$$

We should ensure that MT j provides throughput rate R_j to guarantee its QoS. Therefore, we allocate a total of N subchannels until Equation (3) is satisfied.

$$\sum_{n=1}^{N} r_{ij}^{(n)} \ge R_j \tag{3}$$

A new call is admitted if Equation (4) is satisfied. Here, i denotes the cell number, j denotes the MT number, and RC_i denotes the amount of resource currently available.

$$\sum_{n=1}^{N} W_{ij}^{(n)} = N_{ij} \le RC_i \tag{4}$$

Equation (5) provides RC_i in frame n, where RT_i denotes the total amount of resources physically allocated to cell i in frame n. $\sum SC_{ij}$ represents the total amount of resources occupied by the MTs in the frame n, which are currently serviced in cell i. $\sum IH_{ij}$ represents the total amount of resources demanded by the MTs in the frame n, which are handed over to cell i. $\sum OH_{ij}$ represents the total amount of resources returned by the MTs in the frame $n+1$, which are handed over from cell i to the adjacent cells, and thus made available for allocation in the frame n.

$$RC_i = RT_i - \sum SC_{ij} - \sum IH_{ij} + \sum OH_{ij} \tag{5}$$

Our proposed scheme regularly recalculates RC_i in every frame or upon each request for admission control. On this basis, it reestablishes its resource-allocation strategy to efficiently cope with the increasing cell load resulting from handover requests. Recalculating RC_i and re-establishing the allocation strategy deal more actively with the status of the resource occupancy that is changed by frequent handovers. This mechanism will work very effectively in cell environments where MTs move at high velocities.

3.2 Resource-reservation Mechanism

Because the transmission rate of each MMS varies with time, it may demand more radio resources than anticipated after its handover. When the load is allowed to excessively increase within a cell, the cell area becomes smaller than the designed size, and the QoS of the MMS cannot be guaranteed during the handover requests. Therefore, to support QoS continuity, we should ensure availability of resources within a cell at an appropriate level by considering both the current amount of resources and the handover traffic from the neighboring cells. For this purpose, a twofold resource reservation scheme—static and dynamic resource reservation—is presented in our study.

As expressed in Equation (6), we define δ as the weight index for the decision in the frame $n+1$ which enables a system operator to decide whether to put the emphasis on increasing the accommodation of new calls or optimizing support for the user QoS requirements. δ determines the amount of reserved resources in cell i. We assume that the system operator regularly changes the δ value following his policy.

$$Tr = \sum SC_{ij} + (1-\delta)\sum L_i^{nw} + \delta \sum L_i^{ho} \tag{6}$$

Here, Tr denotes the total amount of resources that will be occupied in frame $n+1$, $\sum SC_{ij}$ denotes the amount of resources that has been occupied in frame n, $\sum L_i^{nw}$ represents the amount of resources required by the new call requests in frame $n+1$, and $\sum L_i^{ho}$ denotes the amount of resources needed by the handover requests in frame $n+1$. In addition, $\delta \in (0,1)$ indicates the weight value, which approaches zero when the system operator prefers the increase of new calls for expanded accommodation. On the other hand, it approaches one when the operator chooses optimization of resource allocation for handover requests to guarantee continuity of user services. For example, when $\delta = 1$, the system does not accept new calls but only handover calls, and it only allocates the resources to the latter. Our proposed scheme generates the information on available resources per frame utilizing the resource occupancy status during the previous frame and executes load control based on the amount of anticipated available resources, as described earlier. Moreover, it reserves subcarriers to handle the increased cell load due to the forthcoming handover sessions. In this manner, it can more actively deal with frequent handovers.

3.2.1 Weight Index of the Subchannel

We perform static resource reservation to handle the situation where the system cannot accept handover requests because of shortage in available resources. This process aims to guarantee service continuity of handover requests by regularly reserving resources on the basis of the occupancy of radio resources within the cell. It also suppresses admission of new calls, if necessary. To calculate the amount of resources to be reserved in cell i , we define static resource-reservation parameter ζ_s , as expressed in Equation (7). We obtain this parameter by adding the amount of occupied resources to the amount of resources demanded by the new calls. The purpose of this parameter is to curtail the blockage of the new calls, which may be caused by resource reservation, by reflecting the new call requests at the time of the resource reservation. Here, $\sum N_{ij}$ represents the sum of the resources demanded by the new calls.

$$\zeta_s = \sum SC_{ij} + \sum N_{ij} \tag{7}$$

New services are blocked if the static resource-reservation parameter ζ_s exceeds the total amount of resources RT_i ($\zeta_s > RT_i$). We set threshold values T_{-0}, T_0 , and T_{+0} to determine R_s^{ho} , which is the amount of resources reserved by the static resource reservation.

Equation (8) shows that R_s^{ho} has different values in each of the six cases. This equation states that appropriate amount of resources should be reserved in advance because larger amount of current resource occupancy indicates smaller probability of satisfying the resource requirements of handover calls. Therefore, if ζ_s is less than T_{-0}, the static resource-reservation mechanism does not work, and no reservation is made. If ζ_s is between T_{-0} and T_0 and RC_i is simultaneously larger than or equal to the average resource occupancy of handover calls h_i^a , the mechanism will reserve as many resources as h_i^a . If ζ_s is between T_{-0} and T_0 and RC_i is simultaneously smaller than h_i^a , it will reserve as many resources as RC_i . Setting δ at a larger value will reserve a larger amount of resources. In other words, optimized support for user QoS requirement is preferred over the expansion of the system accommodation capacity. The scheme will reserve the amount $(h_i^a)^\delta$ if ζ_s is between T_0 and T_{+0} and RC_i is larger than or equal to $(h_i^a)^\delta$. In addition, it will reserve the amount RC_i if ζ_s is between T_0 and T_{+0} and RC_i is smaller than $(h_i^a)^\delta$. Finally, if ζ_s is larger than T_{+0}, it will reserve RC_i , which represents all the available resources. It reserves or release resources by regularly repeating these procedures.

There are no specific standards to set threshold values T_{-0}, T_0 , and T_{+0}. They are set on the judgement of the system operator. In order to place an emphasis on satisfying QoS requirements for MMS handover optimally, the system operator can set some or all of three thresholds T_{-0}, T_0 , and T_{+0} to lower values so that the system reserve much more resource for supporting handover. On the other hand, the system operator puts more emphasis on the increased number of users that can be accommodated within the system, by setting some or all of these thresholds to higher values so as to have it reserve less resource.

$$R_s^{ho} = \begin{cases} 0 & if\ T_{-0} \geq \zeta_s \\ h_i^a & if\ T_{-0} \leq \zeta_s \leq T_0,\ and\ RC_i \geq h_i^a \\ RC_i & if\ T_{-0} \leq \zeta_s \leq T_0,\ and\ RC_i < h_i^a \\ (h_i^a)^\delta & if\ T_0 \leq \zeta_s \leq T_{+0},\ and\ RC_i \geq (h_i^a)^\delta \\ RC_i & if\ T_0 \leq \zeta_s \leq T_{+0},\ and\ RC_i < (h_i^a)^\delta \\ RC_i & if\ T_{+0} \leq \zeta_s \end{cases} \tag{8}$$

3.2.2 Subchannel Priority Index

As stated in the previous section, RB is the minimum resource unit that an OFDMA system allocates, and this allocation is done per TTI. In our system, we assume that TTI is 0.5 ms, and a frame lasts for 10 ms. Completion of this procedure takes approximately 15 ms after a handover request by allocating resources to this request in the target cell. Sometime during the interval of these 20 TTIs, new calls are highly likely to occupy the resources ahead of the handover calls. Thereafter, these new calls will take these resources again in the next TTI because allocation priority is given to calls that have been connected and executed up to the current time. Few resources are left to satisfy the imminent handover requests; thus, they cannot be accommodated. Therefore, to guarantee continuity of QoS by avoiding or minimizing these failures, our proposed dynamic mechanism temporarily reserves resources ahead for pending handover requests until it finally allocates these reserved resources to these requests. This mechanism is activated when the dynamic reservation parameter becomes larger than a certain threshold, as stated below. Our twofold scheme attempts to achieve both guaranteed continuity of QoS and maximized efficiency of resource allocation by delaying as late as possible parts of the reservations.

From Equation (9), we can calculate $Fr^{\min}$, the minimum amount of resources that the dynamic reservation procedure must reserve to guarantee the MiBR requirements of handovers into cell i. Further, Equation (10) provides $Fr^{\max}$, the amount of resources that the dynamic procedure must reserve to satisfy the maximum bit rate (MaBR) requirements of handovers into this cell. Here, $\sum IH_{ij}^{\min}$ denotes the minimum amount of resources required to guarantee the MiBR requirements of the handovers into cell i, and $\sum IH_{ij}^{\max}$ indicates the resource amount required to support the MaBR requirements of the handovers into this cell. When the static resource-reservation procedure has already reserved some of the resources for the handover requests, the dynamic procedure only needs to reserve additional small amount to facilitate smoother handovers, which is essential in guaranteeing QoS. If the static procedure has reserved more resources in cell i than those required for the handovers, then the dynamic procedure does not make a reservation. Therefore, both $Fr^{\min}$ and $Fr^{\max}$ are zero.

$$Fr^{\min} = \begin{cases} \sum IH_{ij}^{\min} - R_s^{ho} & if \sum IH_{ij}^{\min} > R_s^{ho} \\ 0 & if \sum IH_{ij}^{\min} \leq R_s^{ho} \end{cases} \tag{9}$$

$$Fr^{\max} = \begin{cases} \sum IH_{ij}^{\max} - R_s^{ho} & if \sum IH_{ij}^{\max} > R_s^{ho} \\ 0 & if \sum IH_{ij}^{\max} \le R_s^{ho} \end{cases} \tag{10}$$

Let us define ζ_d as a dynamic resource-reservation parameter to determine the resource amount that the dynamic reservation procedure must reserve. Using Equation (11), we can calculate ζ_d from the current resource occupancy in cell i, which is the maximum amount of resources that the dynamic reservation procedure must reserve, and the current resource occupancy of the calls that will be handed over to the adjacent cells.

$$\zeta_d = \sum SC_{ij} + Fr^{\max} - \sum OH_{ij} \tag{11}$$

We set threshold values T_{-0}, T_0, and T_{+0} to determine R_d^{ho}, which is the amount of resources reserved by the dynamic reservation mechanism. Using these values, we can consider four different cases, as expressed in Equation (12). If ζ_d is less than T_{-0}, the dynamic reservation procedure does not make a reservation. If $T_{-0} \le \zeta_d \le T_0$, the dynamic reservation needs to reserve the amount $Fr^{\max}$, which means that the handover requests are provided with all their resource requirements for MaBR regardless of the policy of the system operator. In addition, If $T_0 \le \zeta_d \le T_{+0}$, it reserves the amount $Fr^{\max} * \delta$. Here, δ denotes the weight index for the decision in frame $n+1$, as defined in the previous section, which indicates whether the handover requests may be provided with all the required resource for MaBR or not, depending on the system operator policy. Finally, if ζ_d is greater than T_{+0}, the dynamic reservation mechanism will reserve the amount $Fr^{\min}$. The system provides the handover requests with the resources to guarantee their MiBR.

$$R_d^{ho} = \begin{cases} 0 & if\, T_{-0} \ge \zeta_d \\ Fr^{\max} & if\, T_{-0} \le \zeta_d \le T_0 \\ Fr^{\max} * \delta & if\, T_0 \le \zeta_d \le T_{+0} \\ Fr^{\min} & if\, T_{+0} \le \zeta_d \end{cases} \tag{12}$$

On the other hand, if Equation (13) is satisfied, the system will not be able to meet the resource requirements of the handover requests. It has to secure additional resources in the amount of $\zeta_d - RT_i$.

$$RT_i < \zeta_d \tag{13}$$

Our proposed scheme secures this additional amount through load control using the concept of service priority and Equation (14). Here, objects $O_{1,\ldots,}O_m$ indicate parts of the data, image, audio, or video queued in the frame $n+1$ until the system can supply them with resources for their handover requests. Λ_j, which is the packet loss rate of O_j, denotes the QoS deterioration, which is caused by the shortage of resources during the transmission of O_j. $\left|O_j\right|$ is the normalized value of O_j in the frame $n+1$.

θ_j, which is a reliability requirement of object O_j, indicates that the service user can accept a loss rate of $(1-\theta_j)$% for object O_j.

$$\sum \Lambda_j \left|O_j\right| = \zeta_d - RT_i, \quad 0 \le \Lambda_j \le 1-\theta_j \tag{14}$$

Our scheme controls the system loads by applying the service priority algorithm [20], which decreases the resource usages of the MMSs down to the MiBR on the basis of their service priorities until the system secures additional resources in the amount of $\zeta_d - RT_i$. From Equation (15), we can obtain ψ_i^R, which is the adjusted total resources available in cell i. Here, $\sum \psi_j$ is the total amount of resources that the MTs return during the handover from cell i.

$$\psi_i^R = \sum \psi_j + RC_i \tag{15}$$

If Equation (16) is satisfied, incoming handover requests can be successfully accepted because the available resources are greater than $IH_i^{\min}$.

$$\psi_i^R \ge IH_i^{\min} \tag{16}$$

The handover requests will be forcefully terminated because of shortage in the resources if Equation (17) holds.

$$\psi_i^R < IH_i^{\min} \tag{17}$$

4. Performance Analysis

To evaluate the performance of our proposed reservation scheme, we use the OFDMA system model below. We assume a two-tier model in which 19 base stations are arranged in two tiers of regular hexagons. Every MT always has packets in queue for transmission. Service requests from the MTs uniformly occur within the cell. The occurrence rate of MMS follows a Poisson distribution. Each MT moves in an arbitrary direction in the 0–2π range. The speed or direction of movement may continuously change. Handovers occur with a Poisson distribution at an average rate of 40%. **Table 1** lists the radio propagation model parameters used in our simulation, which considers channel fading, path loss, shadowing, noise, and frequency reuse.

Table 1. Propagation Model

Parameter	Value
Channel Fading Model	ITU-R M.1225 pedestrian model B with 5 dB [21]
Path-Loss Index	4 (Urban Macro Type)
Shadowing	WINNER Channel Model II [22]

Shadowing Standard Deviation	8dB
Noise Figure	6dB
Frequency Reuse	1

Table 2 lists the system-level simulation environment employed in our study. We based the channel structure and system-level parameters on the FDD radio frame of the OFDMA-based 3GPP LTE-Advanced system [19] and the 3GPP LTE Ericsson model [23][24]. The major system-level simulation parameters considered are listed in **Table 2**. The TTI is assumed to be 0.5 ms, and 20 TTIs are deployed in each frame (10 ms). Seven OFDM symbols are fitted into the time interval corresponding to the TTI. The subcarriers are separated by 15-kHz interval. The minimum unit to be used for the resource allocation is an RB (or a subchannel). The RB consists of seven OFDM symbols within a TTI and 12 subcarriers with a 15-kHz bandwidth each [19]. Each RB is assigned to one user only, and many RBs may be allocated to a user, depending on the throughput requirements of the user.

Table 2. System Level Simulation Parameters [20]

Parameter	Value
Frequency Range	2.3GHz
Channel Bandwidth	10MHz
TTI Length	0.5ms
Frame Length	10ms
OFDM symbol per TTI	7
Sub-channel per Frame	50
Sub-carrier per Sub-channel	12
Sub-carrier per Frame	600
RBs per TTI	50
RBs per Frame	1000
Max. Retransmisiion Allowed	3
Retransmission Period	4ms
Level of MCS	QPSK 1/2, QPSK 3/4, 16QAM 1/2, 16QAM 3/4, 64QAM 2/3, 64QAM 5/6

The performance measures we considered are the outage probability, handover failure rate, total throughput, and blocking rate. Outage probability is defined as the ratio of the MMS whose average transmission rate is less than the MiBR. In our simulation, we assume the weight index for the decision as $\delta = 0.7$. We select 0.7 for the value of this index, since we are concentrating on continuity of user QoS for the MMS handover. Using this value, our scheme is able to optimize support for the user QoS requirements regardless of handover, and also keep the blocking rate to an acceptable level. We compare our proposed scheme with those used by Shehada [17] and Li [18]. **Fig. 2** shows the outage probabilities based on increasing MMS arrival rates. Our proposed scheme shows much lower outage probabilities than the other two schemes because our scheme more flexibly allocates resources and guarantees each MMS for permissible MiBR. In the schemes used by Shehada [17] and Li [18], the outage probabilities remarkably increased because of resource shortages or surpluses caused by imbalance in the user distribution as the load within the cell increased (where the load was greater than 0.5).

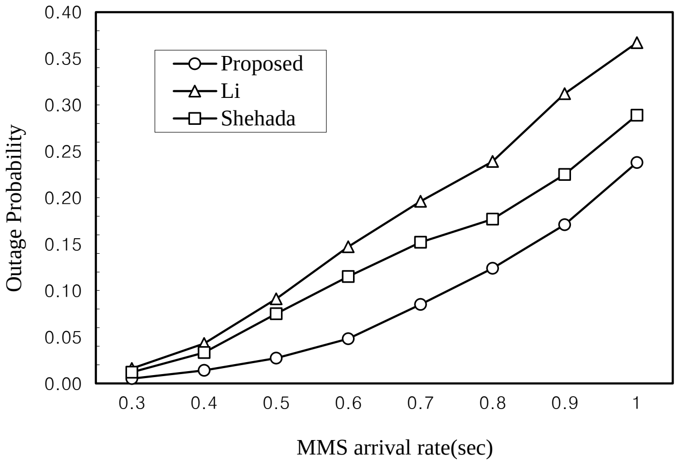

Fig. 2. Comparison of Outage Probability

The handover failure rates are compared in **Fig. 3**, which shows that our scheme has a much lower failure rate than those of Shehada [17] and Li [18] when the load is larger than 0.6. Our proposed scheme accommodates more MMS because the static reservation mechanism in our scheme regularly reserves subchannels for handover requests at every frame on the basis of the current occupancy of radio resources within the cell. Moreover, to prevent handover failure, our dynamic mechanism temporarily reserves resources in advance for pending handover requests until it finally allocates these reserved resources to these requests.

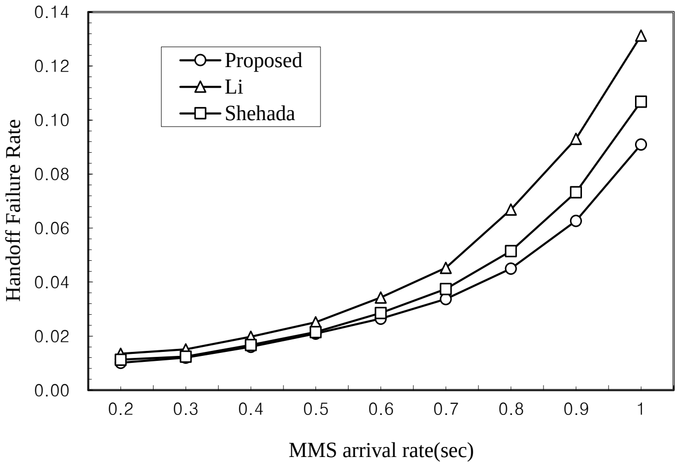

Fig. 3. Comparison of Handover Failure Rate

The blocking rates are compared in **Fig. 4**. Our proposed scheme has a much lower blocking rate than the other two schemes in the load range beyond 0.7. The reason for this is twofold. First, in our scheme, the system operator can adequately control resource allocation between new and handover calls by manipulating the weight index for decision δ, as expressed by Equation (4). Second, our scheme can more positively handle changes in the subcarrier occupancy by executing load control on the basis of the anticipated amount of resources available, which is determined from the status of the resource occupancy in the previous frame.

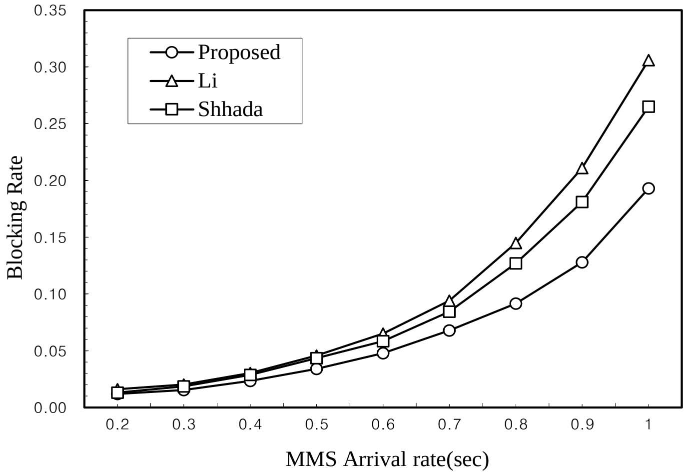

Fig. 4. Comparison of blocking rate

Fig. 5 shows the total throughput on the basis of increasing MMS arrival rates. Our scheme performs better than those by Shehada [17] and Li [18] throughout the entire load range because it postpones the dynamic reservations for imminent handover requests as late as possible and minimizes the reserved resources to always provide maximum resources for new calls. In addition, it is partly because in each frame, our scheme reduces the resource usages of each MMS to the MiBR using load control if additional resources must be secured for reservation to satisfy cell load increase in future handover sessions, depending on the anticipated amount of available resources determined from the resource occupancy status in the previous frame. Using this procedure, our scheme can more actively handle changing occupancy of subcarriers caused by frequent handovers.

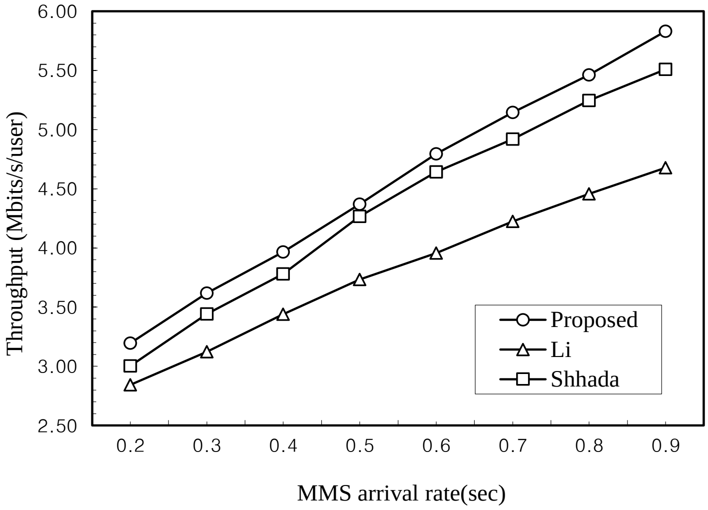

Fig. 5. Comparison of Total Throughput

We calculate the computational complexity of the resource reservation algorithm itself, excluding other common procedures. We use the following notation for each variable. K and A denote the user populations in a cell and in an adjacent one respectively. C, M, and N represent the numbers of subchannels, handover requests, and handover candidate cells respectively. Moreover, T, J, D, and L indicate the repeat counts for estimating available resources, calculating the amount of resource to be reserved, predicting movement directions and executing load controls respectively. Finally σ means an arbitrary constant. Shehada's scheme requires the repetitive operations of $KC + KT + KJ$ for static, and $MC + MT + MJ + MD$ for dynamic resource reservation. Li's needs the operations of $N(AC + AT + AJ)$, Finally our proposed scheme requires the operations of $KC + KT + KJ$ for static, and $MC + MT + MJ + \sigma L$ for dynamic resource reservation. Therefore our proposed scheme has lower complexity than Li's, and similar to Shehada's.

5. Conclusion

This paper has proposed a twofold resource-reservation scheme to support the service continuity of handover in OFDMA systems. Our proposed scheme generates information on available resources per frame utilizing the status of resource occupancy in the previous frame. From this information, its static resource-reservation mechanism regularly performs reservation of subcarriers to handle the increased cell load of forthcoming handover requests and conducts load control. Moreover, when immediate handover requests are present, our dynamic resource-reservation mechanism temporarily reserves resources in advance for these pending requests until it finally allocates these reserved resources to these requests. A simulation was conducted to evaluate the performance of our scheme in terms of the outage probability, handover failure rate, total throughput, and blocking rate. The simulation results show that our proposed scheme performed better than the existing methods in [17] and [18]. Our twofold scheme can achieve both guaranteed continuity of QoS and maximized efficiency of resource allocation. We will conduct the study to apply our algorithm to the heterogeneous LTE-Advanced networks in the near future.

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