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Resource Allocation with QoS Supporting in Macro-Femtocell Networks

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Abstract

The macro-femto overlaid LTE-Advanced networks have been drawing many attentions from mobile operators with their capability of extending coverages and supporting higher data rates. Effective and efficient resource allocation schemes must be preceded in order to deploy this overlaid cellular network successfully. This paper proposes the adaptive resource management scheme which categorizes the entire time-frequency resource blocks of the overlaid cellular network into the dedicated and the shared one, and allocates these resources stage by stage on the basis of user location and user-required data rate in order to expand the user accommodation capacity. Moreover, it enables to share loads evenly in the overlaid cellular network by performing cross-tier handovers from the macrocell to the femtocell so as to maximize the total packet throughput to a certain degree. We used a simulation to evaluate the effectiveness of our scheme with the performance measure of the outage probability and total packet throughput.

Keywords: *OFMDA, resource allocation, SINR, QoS, minimized power radiation, multimedia service*

1. Introduction

Various broadband services such as online game, voice over IP(VoIP), video streaming and cloud computing require high-speed network access. Explosive demands for these services are increasing Internet traffics by 50~60 percent each year, which necessitates expansion and speed-up of the communication network infra-structure. The femtocell, also called the home base station, is one of the cost-effective solutions to enhance coverage and to support higher data rate. A femtocell is a low-power cellular base station that operates in licensed spectrum to connect a mobile terminal to the cellular network via digital subscriber line (DSL) connection. It allows mobile service providers to extend service coverage indoors, especially where access would otherwise be limited or unavailable [1-5]. Moreover, it enables the mobile operator to both expand system capacity and distribute loads increasing rapidly in the mobile networks with little investment. At the same time, users have benefits from improved coverage, better voice and data quality, and prolonged battery life. Depending on the pricing policy of the service provider, users may also be offered discounted tariffs [6-11]. Owing to the variety of benefits, the femtocell has become a viable solution to support broadband mobile multimedia services (MMS) in the mobile cellular networks.

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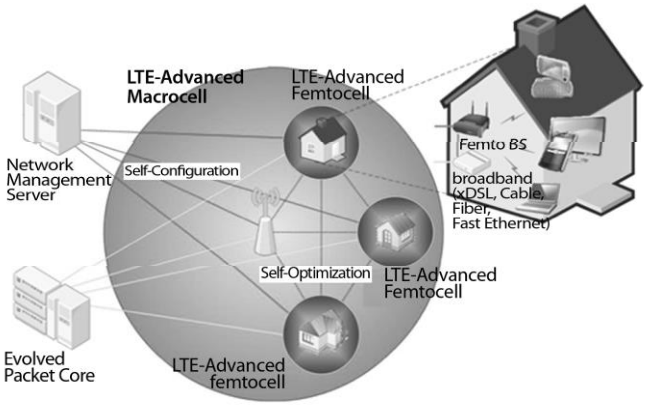

Figure 1. The Concept of the Femtocell for LTE-Advanced System [12-14]

Despite these benefits, the deployments of femtocells give rise to several technical challenges. Femtocells can cause potential interference with co-located femtocell and macrocell users operating in the same frequency band. Usual uncoordinated femtocell deployment complicates the challenge of managing interference in such two-tier networks. New resource management paradigms should be devised to handle the associated challenges involved in multi-tier environments. Dynamic channel allocation (DCA) schemes have been proposed to mitigate the effect of intercell interferences and expand the accommodation capacity in the multicell environments. These schemes can be categorized into Centralized DCA [15] and Distributed DCA [16-17]. In Centralized DCA the central system manages the information on free channels and selects proper channels for new services. This scheme has good performance. However, it increases system loads because information needs to be exchanged between base stations frequently and excessive calculations are required for channel selections and allocations. On the other hand, channel selection and allocation are performed separately by each base station in Distributed DCA scheme. Carrier to Noise and Interference Ratio (CINR) can be taken into consideration to alleviate the intercell interferences by each base station.

Many studies have been done on resource allocation for Macro-Femto overlay LTE-Advanced cellular networks, and several techniques have been proposed to both minimize interference and improve system efficiency from the perspective of a capacity and resource management. Fractional frequency reuse (FFR) scheme in [18-19] partitions the usable spectrum into some sub-bands and assigns different sub-bands between the regions inside and outside of the macrocell coverage in order to mitigate interferences between the macrocell and the femtocell. The mobile terminal (MT)s use different frequency bands in these different regions respectively. FFR can be implemented easily in OFDMA systems because the spectrum of a cell is divided into many sub-channels and the unit of sub-channel is a group of orthogonal sub-carriers. FFR is now considered as one of the key component technologies in LTE-Advanced standard. Dynamic FFR scheme [20] allows the femtocell to make use of any subchannels which are available in some sectors of the macrocell so as to mitigate interferences. However, this scheme still has the drawback of low frequency usage efficiency and small total capacity. In Urgaonkar's scheme [21], when the macrocell user and the femtocell user attempt to access the same subchannel simultaneously, it gives the precedence I n accessing the subchannel to the macrocell user by taking one of the following two procedures: the femtocell user relays data of the macrocell user to the femtocell link or waits for a free subchannel until the macrocell user completes his transmission. However, if the macrocell load increases with this scheme, the femtocell becomes unable to secure adequate subchannels for its user, which results to the limited capacity of femtocell user accommodation. In [22] K. Zeng et. al. proposed a two-step interference coordination scheme which allocates resources through interference avoidance among femtocells. It assigns only one carrier to each femtocell in the first step based on the measurement of the inter-cell interference. Then, in order to improve the system spectrum efficiency, it attempts to assign more carriers of least interference by exchanging the measurement results among neighboring femtocells. In [23] the femtocell system controller per macrocell obtains all the necessary knowledge of femtocell system configuration and performs the necessary computations. To mitigate interference, it dynamically allocates frequency channels among femtocells and macrocells using the graph coloring algorithm. However, interferences among femtocells increase with this scheme as some femtocells access additional channels. In [24] M. Rosdi *et. al.*, proposed a FFR based scheme that allocates all the subchannels with the categorization of cell center area and cell edge in order to enhance the fairness of resource partition and the maximized accommodation capacity in the femtocell. Because this scheme focused too much on the fairness of resource partition, it is not able to utilize resources efficiently, which results to lower total throughput. Moreover, imbalances in user distributions can cause major system performance degradations that are due to shortages or surpluses of resources. A. Hatoum *et. al.*, proposed a cluster-based hybrid centralized/distributed scheme which consists of three main phases such as femtocell cluster formation, intra-cluster resource allocation, and inter-cluster resource contention resolution. It aims to satisfy a maximum number of Quality of Service (QoS)-constrained high-priority users and simultaneously serve the best-effort users as best as possible [25]. However, it needs to both gather surrounding information and perform complicated calculations for cluster formation and intra-cluster resource allocation repetitively. As its functional complexity increases with the increasing number of users, it may not be suitable for the practical systems. Moreover, it did not consider the necessity of effective resource allocation based on the characteristics of various multimedia services. Therefore, it does not seem to be eligible for the commercial system which should accommodate diverse multimedia services. Packet-based mobile multimedia services for the Internet differ with respect to their resource requirements, performance objectives, and resource usage efficiencies. Nonetheless, each mobile terminal should support a variety of multimedia services without any discontinuity, sometimes even simultaneously. In this context, adaptive resource management schemes are required which can consider dynamically the subchannel conditions, interference amount, user location and user-required data rate. This paper proposes the adaptive resource management scheme which attempts to achieve both optimized satisfaction of user requirements and maximized user accommodation in the macro-femto overlaid LTE-Advanced networks to a certain degree. Our scheme categorizes the entire time-frequency resource blocks of the overlaid cellular network into the dedicated and the shared one, and allocates these resources stage by stage on the basis of user location and user-required data rate in order to expand the user accommodation capacity. Moreover, it enables to share loads evenly in the over-laid cellular network by performing cross-tier handovers from the macrocell to the femtocell so as to maximize the total packet throughput. The rest of this paper is organized as follows. Section II describes the system model for discussing the resource allocation in the OFDMA system. The details of our proposed resource allocation scheme are presented in Section III. Simulation results and performance evaluation are discussed in Section IV. Section V concludes this paper.

2. System Model

We describe the system model for efficient allocation of time-frequency resource blocks in the OFDMA based Macro-Femto overlay cellular networks. There exist two major schemes to implement the two-tier cellular network: split-spectrum and shared spectrum schemes. In the former scheme, by dividing the spectrum into two independent fragments, the cross-tier interference, which is the interference between macrocell and femtocells, can be eliminated with an orthogonal channel assignment.

However, this scheme has poor spectral efficiency. In the shared spectrum scheme, on the other hand, the femtocells and macrocells reuse and/or share the total allocated frequency band partially or totally. This scheme has better spectral efficiency. Meanwhile, it leads to the cross-tier or co-channel interference. Depending on a user location in the macrocell or femtocell, the interference may become intolerable. When the user locates at the region where the strength of signals received from macrocell stations are much greater, he is connected to the macrocell. He is not able to access the femtocell. We use a hybrid approach as shown in Figure 2. Among the entire frequency spectrum, the macrocells and the femtocells have their own dedicated frequency bands respectively. In addition, the macrocell and the femtocell can share some bands. As we consider the OFDMA based cellular network, these bands are divided into subchannels and further into frames, which is shown in Figure 2. R_{ma} , R_{sh} and R_{fe} denote resources (subchannels and frames) dedicated to macrocells, resources shared among macrocells and femtocells, and resources dedicated to femtocells respectively. When our system cannot accommodate user requests with R_{fe} and R_{ma} , it allocates shared resources R_{sh} to either femtocell-located users or macrocell-located users on the basis of some criteria.

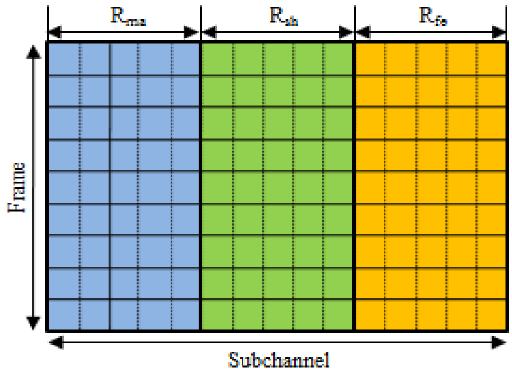

Figure 2. Resource Allocation Strategy

We consider two aspects on the basis of cross-tier interferences while allocating shared resource R_{sh} . At first our scheme allocates subchannels whose channel gain is maximal to the user. The transmission rate of the subchannel is affected by not only transmit power but also channel status (channel gain) perceived by the user. Therefore, when it allocates subchannels whose channel gains are greatest to individual users, we can have greater throughput rate with the same amount of resources. Moreover, this strategy enables us to decrease power radiations, thereby mitigating interferences to other users. Secondly when it allocates some of this shared resource to a user, we force him to decrease his data rate within an allowable range. Maintaining the data transmission rate to a minimum required rate enables us to decrease both the usage of resources and the radiated power. This strategy allows us to alleviate cross-tier interferences which occur when both the macrocell and the femtocell use shared resources simultaneously. Even though both a macrocell user and a femtocell user access the same subchannel, of R_{sh} , the cross-tier interference may not be harmful when they do not locate close to each other. However, since the radiating power of the macrocell is higher than that of the femtocell considering the same distance, the femtocell user is more fragile to interferences. When the femtocell user accesses the subchannel of R_{sh} , we allow him to transmit at Average Bit Rate

(AvBR) R_k^{ave} . On the other hand, we allow a macrocell user of R_{sh} to transmit at Minimum Bit Rate (MiBR) $R_k^{\min}$. The states of channels in OFDMA systems vary through time. The Signal to Interference plus Noise Ratio (SINR) value of a specific sub-channel may be below the desired limit for one user and it may be over the desired limit for another. Especially when the shared resource R_{sh} is accessed, depending upon the location of the femtocell user or the macrocell user, the excessive interference may be imposed on the femtocell user which results to unacceptable channel gain. The difference in the data rate for a user over a subchannel indicates the difference in. the SINR level of the subchannel. The SINR level, which indicates the state of the sub-channel, represents the grade of the Modulation and Coding Scheme (MCS). The higher the MCS grade, the better the state of sub-channel is. The MT reports information about the channel state to the base station periodically, including the MCS. Based on this information, the base station selects users and/or allocates sub-channels to them. The number of packets that can be sent over a basic channel unit is determined by the channel state. In this way, our scheme is able to allocate sub-channels reasonably for user-required throughput. The equation (1-4) provides the downlink SINR of the user for the subchannel n [26]. Each different power is allocated to each individual subchannel in a base station. $p_k^{(n)}$ denotes the power of the subchannel n that is allocated to the user k . Then we can formulate the power that will be allocated for the user k by the set $P_k = (p^{(1)}, p^{(2)}, \cdots, p^{(N)})$, where N denotes the number of subchannels that are allocated the user k on the basis of his required data rate. The link gain between the subchannel n and the user k is denoted by $L_k^{(n)}$, which consists of the path loss and the lognormal fading. $\Phi^{(n)}$ denotes the noise as received over the subchannel n * by the user k . $IMM_k^{(n)}$ represents the interference from the neighboring macrocells that affects the macrocell user, and $IFM_k^{(n)}$ the interference from the neighboring femtocells that affects the user being connected to the macrocell. Moreover $IMF_k^{(n)}$ indicates the interference from the neighboring macrocells that affects the femtoocell user, and $IFF_k^{(n)}$ the interference from the neighboring femtocells that affects the user being connected to the femtocell.

$$SINR(M)_k^{(n)} = \frac{L_k^{(n)} + p_k^{(n)}}{IMM_k^{(n)} + \Phi^{(n)}} \tag{1}$$

$$SINR(F)_k^{(n)} = \frac{L_k^{(n)} + p_k^{(n)}}{IFF_k^{(n)} + \Phi^{(n)}}) \tag{2}$$

$$SINR(Msh)_k^{(n)} = \frac{L_k^{(n)} + p_k^{(n)}}{IFM_k^{(n)} + IMM_k^{(n)} + \Phi^{(n)}}) \tag{3}$$

$$SINR(Fsh)_k^{(n)} = \frac{L_k^{(n)} + p_k^{(n)}}{IFF_k^{(n)} + IMF_k^{(n)} + \Phi^{(n)}}) \tag{4}$$

Based on the equations (1) ~ (4), let us express the channel state or the level of SINR for each user's subchannel by the equation (5). Here c denotes the number of subchannels, and L the number of users. Therefore, f_{ck} indicates the SINR level of the subchannel c for the user k . The base station allocates the multiple number of subchannels whose SINR is optimal to provide the user- required data rate. In this way, it can perform the optimized resource allocation, which enables to provide the best data rate with the same bandwidth.

$$F = \begin{bmatrix} f_{11} & f_{12} & f_{13} & \cdots & f_{1K} \\ f_{21} & f_{22} & f_{23} & \cdots & f_{2K} \\ f_{31} & f_{32} & f_{33} & \cdots & f_{3K} \\ \cdots & \cdots & \cdots & \ddots & \cdots \\ f_{C1} & f_{C2} & f_{C3} & \cdots & f_{CK} \end{bmatrix} \quad (5)$$

For this purpose, we select the N_k largest f_{ck} s for each user k respectively using the equation (5). Let n_i^* denote the subchannel *i* whose SINR value belongs to the N_k largest f_{ck} s, and $n^* = (n_1^*, n_2^*, n_3^*, \cdots, n_N^*)$. The total N_k subchannels can be allocated to a user k on the basis of his required data rate. We can derive the data rates of the macrocell user and the femtocell user as shown in the equations (6) ~ (9). Here $W_k^{(n_i^*)}$ denotes the bandwidth that is allocated to the subchannel n_i^* of the user k . $Mr_k^{(n_i^*)}$ and $Fr_k^{(n_i^*)}$ represent data rates that can be allocated to the user k over each subchannel n_i^* of R_{ma} and R_{fe} respectively. In addition $Mr(sh)_k^{(n_i^*)}$ and $Fr(sh)_k^{(n_i^*)}$ indicate data rates that can be allocated to the user k over the subchannel n_i^* of R_{sh} from the macrocell and the femtocell respectively.

$$Mr_k^{(n_i^*)} = W_k^{(n_i^*)} \ln(1 + SINR(M)_k^{(n_i^*)}) \quad (6)$$

$$Fr_k^{(n_i^*)} = W_k^{(n_i^*)} \ln(1 + SINR(F)_k^{(n_i^*)}) \quad (7)$$

$$Mr(sh)_k^{(n_i^*)} = W_k^{(n_i^*)} \ln(1 + SINR(Msh)_k^{(n_i^*)}) \quad (8)$$

$$Fr(sh)_k^{(n_i^*)} = W_k^{(n_i^*)} \ln(1 + SINR(Fsh)_k^{(n_i^*)}) \quad (9)$$

We can obtain the total data rates that are provided to the user k as shown in the equations (10) ~ (13). Let R_k^{Fe} and R_k^{Ma} denote the total data rates that the femtocell-located user k and the macrocell-located user k can obtain in available subchannels of R_{fe} and R_{ma} respectively. In addition let $R_k^{Fe(sh)}$ and $R_k^{Ma(sh)}$ represent the total data rates that the femtocell-located user k and the macrocell-located user k can obtain in available subchannels of R_{sh} respectively. They can be derived from the equations (6) to (9) respectively. Here N_k is the total number of the subchannels that are allocated to each user k .

$$R_k^{Ma} = \sum_{i=1}^{N_k} Mr_k^{(n_i^*)} \quad (10)$$

$$R_k^{Ma(sh)} = \sum_{i=1}^{N_k} Mr(sh)_k^{(n_i^*)} \quad (11)$$

$$R_k^{Fe} = \sum_{i=1}^{N_k} Fr_k^{(n_i^*)} \quad (12)$$

$$R_k^{Fe(sh)} = \sum_{i=1}^{N_k} Fr(sh)_k^{(n_i^*)} \quad (13)$$

3. Dynamic Resource Allocation

The user-required data rate can be described by the equation (14), where MiBR and MaBR are specified by the description of each service. Based on this equation, our system allocates the resources to the user who requests the data rate of R_k^{req}. Here $R_k^{\min}$ denotes MiBR, and $R_k^{\max}$ MaBR respectively.

$$R_k^{\min} \le R_k^{req} \le R_k^{\max} \tag{14}$$

The equation (15) states that MiBR should be provided in minimum in order to guarantee the user service continuity. Otherwise, the service is forcibly terminated. Here N_k denote the number of subchannels that are allocated to the user k, $R_k^{\min}$ his MiBR., and $r_k^{(n*)}$ the user-required data rate respectively.

$$\sum_{n=1}^{N_k} r_k^{(n_i^*)} \le R_k^{\min} \tag{15}$$

3.1. Resource Allocation for the New Service

In order to satisfy the request of the femtocell-located user, our scheme allocates the femtocell-dedicated resource at first. If there is no femtocell-dedicated resource left, then it allocates the femtocell-shared resource to him. Further, if there is no femtocell-shared one either, it attempts to allocate the macrocell-shared and the macrocell-dedicated one. However, our scheme restricts the macrocell-located user to the macrocell-dedicated and the macrocell shared resource only. Even though our scheme categorizes the entire time-frequency resource blocks into the dedicated and the shared one, it investigates, in order to satisfy the user's request, these entire resources for their availability stage by stage in the similar manner as when the macrocell and the femtocell share the entire resources. In this way, we can mitigate co-subchannel interferences to the smallest extents, which are the main drawback of the shared resource scheme.

3.1.1. Resource Allocation for the Femtocell-located User: As a general rule, we allow our system to allocate R_k^{max}, which is MaBR , to the femtocell-located user k that requests R_k^{req} for his new service. We can consider the following two cases based on the amount of R_k^{Fe}, which is the total data rate that can be obtained over available subchannels of the femtocell.

$$R_k^{Fe} \ge R_k^{max} \tag{16}$$

If the equation (16) holds, then our system allocates R_k^{max} to the femtocell-located user k that requests the resource amount of R_k^{req} for his new service.

$$R_k^{Fe} < R_k^{max} \tag{17}$$

However, else if the equation (17) holds, it attempts to follow the adjusted allocation policy.

$$R_k^{Fe} \ge R_k^{min} \tag{18}$$

In other words, if the equation (18) holds, it assigns the resource amount of $R_k^{min} \le R_k^{req} \le R_k^{max}$ to the user k.

$$R_k^{Fe} < R_k^{min} \tag{19}$$

Finally, if the equation (19) holds, we need to secure the additional resource. For this purpose, our scheme resorts to the availability of R_{sh}, which is designated to be shared by both the femtocell-located user and the macrocell-located user. As we stated in Section 2, when the femtocell-located user needs to access the shared resource R_{sh}, we allow the system to allocate the resource amount R_k^{ave} to him as follows.

$$R_k^{Fe} + R_k^{Fe(sh)} \geq R_k^{ave} \tag{20}$$

If the equation (20) holds, our system allocates R_k^{ave} to the user k.

$$R_k^{Fe} + R_k^{Fe(sh)} < R_k^{ave} \tag{21}$$

Else if the equation (21) holds, it attempts to follow the adjusted allocation policy as follows.

$$R_k^{Fe} + R_k^{Fe(sh)} \geq R_k^{min} \tag{22}$$

In other words, if the equation (22) holds, it assigns the resource amount of $R_k^{min} \leq R_k^{req} < R_k^{ave}$ to the user k.

$$R_k^{Fe} < R_k^{min} \tag{23}$$

If the equation (23) holds, the femtocell is not able to satisfy this request. Then our scheme attempts to make a handover to the macrocell for this session. In order to secure necessary resource in R_{ma}, it requests the resource amount of MiBR as stated in the equation (24).

$$R_k^{Ma} \geq R_k^{min} \tag{24}$$

If the equation (24) holds, the system allocates R_k^{min} to the user k.

$$R_k^{Ma} < R_k^{min} \tag{25}$$

Else if the equation (25) holds, our scheme attempts to access the shared resource. Since we allow our system to allocate only MiBR to the macrocell-located user who attempts to access R_{sh}, it attempts to allocate the resource amount R_k^{min}.

$$R_k^{Ma} + R_k^{Ma(sh)} \geq R_k^{min} \tag{26}$$

If the equation (26) holds, the system allocates R_k^{min} to the user k.

$$R_k^{Ma} + R_k^{Ma(sh)} < R_k^{min} \tag{27}$$

Else if the equation (27), the system is not able to accommodate R_k^{min}, and forces to block this service request.

3.1.2. Resource Allocation for the Macrocell-located User: In principle our scheme allocates R_k^{max}, which is MaBR , to the macrocell-located user k that requests R_k^{req} for his new service. Then we can consider the following two cases based on the amount of R_k^{Ma}, which is the total data rate that can be obtained over available subchannels of the macrocell.

$$R_k^{Ma} \geq R_k^{max} \tag{28}$$

If the equation (28) holds, then our system allocates R_k^{max} to the macrocell-located user k that requests the resource amount of R_k^{req} for his new service. Otherwise, it attempts to follow the adjusted allocation policy as follows.

$$R_k^{min} \leq R_k^{Ma} < R_k^{max} \tag{29}$$

If the equation (29) is true, the system allocates the resource based on the adjusted policy.

$$R_k^{Ma} < R_k^{min} \tag{30}$$

Else if the equation (30) holds true, the macrocell is not able to satisfy this request, we need to secure the additional resource. For this purpose, our scheme resorts to the availability of R_{sh}, which is designated to be shared by both the femtocell-located user and the macrocell-located user. As we state in Section 2, when the macrocell-located user needs to access the shared resource R_{sh}, we allow the system to allocate only the amount of MiBR to him. So our scheme requests the resource amount of R_k^{min}.

$$R_k^{Ma} + R_k^{Ma(sh)} \geq R_k^{min} \tag{31}$$

If the equation (31) is true, it allocates R_k^{min} to the user.

$$R_k^{Ma} + R_k^{Ma(sh)} < R_k^{min} \tag{32}$$

Else if the equation (32) is true, this service request is blocked.

3.2. Resource Allocation for Handover

In our study, we allow the handover from the femtocell to macrocell without any limitation and apply the same resource allocation policy as that for the new service request. On the other hand, we selectively permit the handover from the macrocell to the femtocell subject to the following criteria. In order to maintain the proper balance in the loads among the cells, we allow the handover only from the macrocell subject to the requirement 1 to the femtocell subject to the requirement 2.

- requirement 1: in case that the macrocell-located user has accessed R_{sh} in the previous frame.
- requirement 2: in case that the available resource of the femtocell is greater than or equal to a threshold.

In principle, regardless of handover, we guarantee to maintain the user's QoS (here, the data rate) that the system has allowed for his corresponding new service in the macrocell. Let us assume that the macrocell has allocated the data rate R_k^{rev} to the user k in the previous frame and that he is required to handover to the femtocell. Here $R_k^{min} \leq R_k^{rev} \leq R_k^{max}$. We can consider two cases based on the amount of available subchannels in the femtocell.

$$R_k^{Fe} \geq R_k^{rev} \tag{33}$$

If the equation (33) holds, our scheme allocates R_k^{rev} to the user k, and allows the handover to the femtocell.

$$R_k^{Fe} < R_k^{rev} \tag{34}$$

Else if the equation (34) is true, our scheme attempts the allocation as adjusted in the equation (35).

$$R_k^{Fe} \geq R_k^{min} \tag{35}$$

Further, else if the equation (35) holds true, our scheme allocates $R_k^{min} \leq R_k^{req} < R_k^{rev}$, and allows the handover to the femtocell.

$$R_k^{Fe} < R_k^{min} \tag{36}$$

Finally, if the equation (36) holds, our scheme does not allow the handover to the femtocell.

4. Performance Analysis

In this section, we describe the OFDMA system model that is used for analyzing the performance of our proposed resource allocation scheme. We consider an LTE-Advanced system with a frequency reuse factor of value 1, where 19 hexagonal cells are distributed uniformly. For our simulation, we refer the channel structure and the system level parameters to FDD radio frame of the OFDMA-based 3GPP LTE-Advanced system [27] and the 3GPP LTE Ericsson model [28-29]. We restrict our analysis to the down-link only. The major system level simulation environments that are considered are summarized in Table 1.

Table 1. System-level Simulation Parameters

Item	Parameter	Value
Frequency Bandwidth	Carrier Frequency	2.3 GHz
	Effective Frequency	8.75 MHz
BS Tx	BS Tx power	43.0 dBm
	BS Max EIRP	60 dBm
Channel Model	path-loss Model	- Urban Macro Type - path-loss exponent: 4
	Shadowing Model	- WINNER Channel Model II - 8dB
	Fading Model	- ITU-R M.1225 pedestrian B - 5dB
SINR	Exponential	3dB

The Transmission Time Interval (TTI) is assumed to be 0.5 ms and 20 TTIs are deployed in each frame (10ms). Seven OFDM symbols fit into the time interval corresponding to the TTI. The sub-carriers are separated at 15 KHz intervals. The minimum unit to be used for resource allocation is a resource block (or a sub-channel). It has a two- dimensional structure, such that a Resource Block (RB) consists of seven OFDM symbols within a TTI and twelve sub-carriers with 15 KHz bandwidth each [27]. Each frame consists of 20 TTIs and 50 RBs, thereby having 1000 RBs in total. Each RB is assigned to one user only and many RBs may be allocated to a user, depending on the through-put requirements of the user. Service requests from MTs occur uniformly within the cell. The occurrence rate of MMS follows a Poisson distribution. Each MT moves in an arbitrary direction of $0 \sim 2\pi$. The speed or direction of movement may change continuously. The type of MMS that are used in our simulation is classified in Table 2.

Table 2. Classification of Multimedia Services

Service		Data rate (Min-Max)	Average rate	Transmission Delay
Realtime service	High Quality Voice	64K	32K	150ms
	Video Conference	64~384K	256K	150ms
	VOD	3~10M	5M	150ms
Nonreal time service	WWW	256K~ 2M	1M	20s
	Electronic Commerce	64K ~384K	256K	4s
	FTP	1M ~5M	3M	15s

The performance measures we considered are the outage probability and total throughput. We compare our propose resource allocation with those used in Rosdi [24] and Hatoum [25]. Figure 3 shows the outage probability on the basis of increasing service arrival rates. Outage probability is defined as the ratio of the MMS whose average transmission rate is less than the MiBR. In the schemes used by Rosdi [24] and Hatoum [25], 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. Their schemes have not dealt with resource occupation changes in the femtocell and macrocell properly. Meanwhile, our scheme shows remarkably lower outage probability than other two schemes in [24-25] when the load is larger than 0.6.This is attributable to the fact that our scheme investigates stage by stage the possibilities of allocation for both the dedicated and the shared resources in the overlaid cell and can thereby more adaptively allocate the resource on the basis of current resource availability.

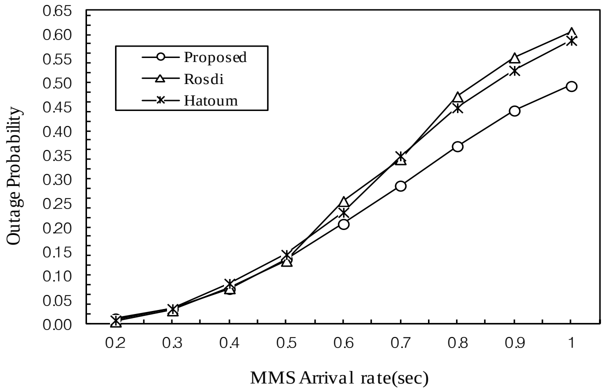

Figure 3. Comparison of Outage Probability

The total throughputs are compared in Figure 4. Our scheme has better performance than other two schemes in [24-25] throughout the entire load range. It allows overlaid-cell handovers from macrocell to femtocell for the purpose of load control. In this way, it can keep resources within the overlaid cell to be available in an appropriate level. Moreover, since our scheme investigates stage by stage the possibilities of allocation for the categorized resources in the overlaid cell, it can handle more actively changing occupancy of resources which the increasing users cause.

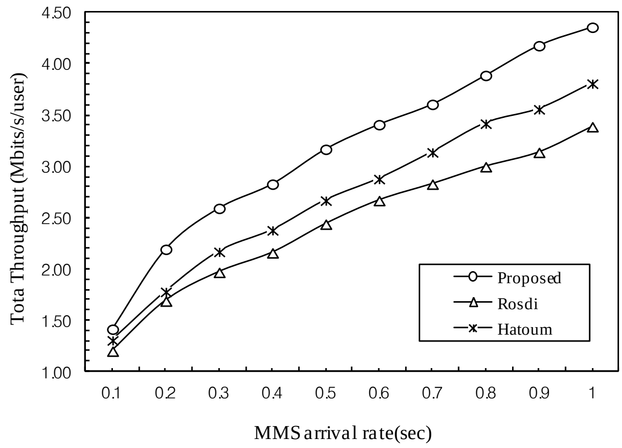

Figure 4. Comparison of Total Packet Throughput

5. Conclusion

The LTE-Advanced networks, using a single terminal, should be able both to provide high-speed data communication services in the femtocell regions mainly and to support the continuity of these services in any other areas than the femtocell regions through coordination with legacy systems. In this paper, we proposed the adaptive resource management scheme which attempts to achieve both optimized satisfaction of user requirements and maximized user accommodation in the macro-femto overlaid LTE-Advanced networks to a certain degree. Our scheme categorizes the entire time-frequency resource blocks of the overlaid cellular network into the dedicated and the shared one, and allocates these resources stage by stage on the basis of user location in order to expand the user accommodation capacity. Moreover, it enables to share loads evenly in the over-laid cellular network by performing cross-tier handovers from the macrocell to the femtocell so as to maximize the total packet throughput. A simulation has been used to evaluate the effectiveness of our scheme with the performance measures of the outage probability, and the total packet throughput. The simulation results show that it has better performance than the existing methods in [24-25]. Our scheme is able to increase both the number of accommodated users and the total packet throughput remarkably. In order to realize our scheme in commercial systems, more detailed studies are required to refine it further.

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