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Resource Allocation Scheme to Support QoS in Mobile Multimedia Networks

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Abstract

The macrocell–femtocell overlaid system is a promising means by which to extend coverage and to support higher data rates for mobile multimedia services. This paper proposes a resource allocation mechanism to enhance service continuity in a Long Term Evolution Advanced system. In order to support service continuity in real-time services, it performs load control to satisfy maximal data throughput. Moreover, it considers the QoS requirements of real-time and non–real-time services, such as voice, video streaming, and data. Simulation results show that our scheme provides better performance than a conventional one with respect to outage probability and data transmission throughput.

Keywords: *QoS, Service Continuity, Real-time Services, Macrocell, Femtocell*

1. Introduction

The macrocell–femtocell overlaid Long Term Evolution Advanced (LTE Advanced) network calls for the development of new frameworks and approaches to meet the specific challenge of supporting adaptive QoS in a controlled manner, although it considers the frequent and random mobility of the mobile terminal (MT) and the dynamically changing network resource availability [1-2]. Figure 1 shows the concept of femtocell networks overlaid within the macrocell network considered in this research. Multimedia services on the Internet differ from each other with respect to their resource requirements, performance objectives, and resource usage efficiencies.

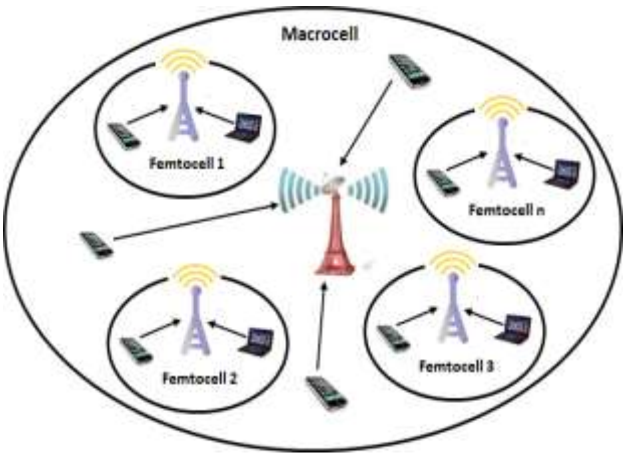

Figure 1. Two-tier macro–femtocell System Model

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QoS issues relate to how handovers must be managed and carefully controlled in order to minimize dropped service due to insufficient resources available in the new cell [3-7]. Wireless resource availability varies especially frequently as users move from one access point to another. In order to deterministically guarantee QoS support for an MT, the amount of resources required to successfully perform a handover may vary arbitrarily over a wide range in mobile multimedia networks. For example, data and video applications may adapt to different service-quality levels, and consequently, may accept different levels of resources in order to ensure a successful handover [8-9]. We apply different resource control mechanisms, depending on the service class, in order to manage radio resources more efficiently [10-12]. For a low-delay, low-loss class (LL) service, throughout its entire service duration a mobile terminal can use a constant transmission rate allocated at the time of call set-up. For a low-delay, high-loss class (LH) service, the allowable minimum and maximum rates are determined at the time of call set-up. And depending on the available resources and the radio link state, the terminal controls the transmission rate between these two values. Meanwhile, for either high-delay, low-loss class (HL) or high-delay, high-loss class (HH) services, because they tolerate some delay or loss, the user does not assign the required bandwidth. Rather, the base station controls the transmission rate, depending on the network state.

In this paper, we propose a resource allocation scheme for mobile multimedia services in LTE Advanced systems. For a new call, a new resource allocation scheme is achieved by using resource reservation and load control. For a handover call, we suggest a novel resource reservation scheme to adjust the number of reserved sub-channels. Our scheme has the fundamental functions of coordinating the use of the available radio resources, and carries the maximum number of subscribers.

The remainder of this paper is organized as follows. Section 2 describes the resource management structure for our proposed system. The details of our proposed resource allocation scheme are presented in Section 3. In Section 4, performance analysis verifies the effectiveness of the proposed scheme using a computer simulation. We focus on the outage probability and total throughput. Finally, the conclusion is given in Section 5.

2. Resource Management Structure

We use a hybrid approach, as shown in Figure 2. Among all the radio frequencies, macrocells and femtocells have their own dedicated bands. In addition, macrocells and femtocells can share some bands. As we consider an orthogonal frequency-division multiple access (OFDMA)-based cellular network, these bands are divided into subchannels and further divided into frames, which are shown in Figure 2 [11-15]. R_{ma}, R_{sh}, and R_{fe} denote resources 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 certain criteria.

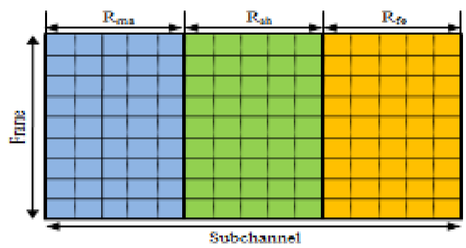

Figure 2. Resource Allocation Strategy

2.1. Secondary Load Control

In order to prevent a shortage of resources in the face of handovers, our proposed scheme decreases the usage rate permitted to user services through secondary load control [14-15]. Figure 3 describes the algorithm for secondary load control in detail. That is, if the total available capacity, φ_T, stays lower than T_{Low} in a certain time interval, $[T_i - T_{i+1}]$, it decreases the resource usage rate of user services under execution until φ_T becomes greater than or equal to the available resource threshold, R_{TH}. The usage rate decreases to the minimum bit rate (MiBR) in reverse order of occupation priority, that is, HH, HL, LH, and LL. When overall transmission rates are rearranged, the data rate for MiBR should be guaranteed to each multimedia service at least. On the other hand, if φ_T remains greater than T_{High} over a certain interval, this algorithm increases the resource usage rate to the maximum bit rate (MaBR) for as long as the resources left do not become less than R_{TH}.

Algorithm I * Secondary Load Control *

φ_T : Total available capacity;

ψ_i^R : Capacity returned by load control;

if ($\varphi_T < T_{Low}$) **then**

  while ($\varphi_T \le R_{TH}$)

    Decrease usage rate to MiBR for all services in order (HH, HL, LH) stepwise;

    $\varphi_T = \varphi_T + \sum_{i=1}^{n} \psi_i^R$;

  end while;

else if ($\varphi_T > T_{High}$) **then**

  while ($\varphi_T \ge R_{TH}$)

    Increase usage rate to MaBR for each service in order (LL, LH, HL) stepwise;

    $\varphi_T = \varphi_T - \sum_{i=1}^{n} \psi_i^R$;

  end while;

else

    Terminate load control;

end if

Figure 3. Secondary Load Control

2.2. Primary Load Control

Primary load control is executed as shown in Figure 4 if resources run out at the occurrence of a handover [14-15]. It aims to secure subchannels for handover traffic of LL or LH class services by adjusting the transmission rate of HL or HH class services. This is repeatedly executed until resources are secured amounting to MaBR or MiBR for LL or LH class services, respectively. At a minimum, resources should be guaranteed to each mobile terminal, so transient road control is done only as long as the MiBR usage rate remains for each mobile service.

Algorithm II * Primary Load Control *

n : Total number of multimedia services;
R_{LL} : Resource (sub-channel) reserved for LL service;
R_{LH} : Resource reserved for LH service;
ψ_i^R : Capacity returned from user by load control;
$C_i^{\min}$: Capacity required for service i to transmit at MiBR;
$C_i^{\max}$: Capacity required for service i to transmit at MaBR;

```
if (LL services) then
    while ( n > i )
        Decrease usage rate to MiBR in order (HH, HL) stepwise;
        R_LL = R_LL + ψ_i^R;
        if ( C_i^min ≤ R_LL ≤ C_i^max ) then
            Admit handover;  Terminate load control;
        else
            i = i +1;
        end if
    end while;
        Handover failure;  Terminate load control;
else if (LH services) then
    while ( n > i )
        Decrease usage rate to MiBR in order (HH, HL) stepwise;;
        R_LH = R_LH + ψ_i^R;
        if ( C_i^min ≤ R_LH ) then
            Admit handover;  Terminate load control;
        else
            i = i +1;
        end if;
    end while;
        Handover failure;  Terminate load control;
end if;
```

Figure 4. Primary Load Control

3. Resource Reservation and Resource Allocation

3.1. Resource Reservation

This strategy is explained in Figure 5.

① **Step 1:**
- Resource reservation need not be performed.

② **Step 2:**

- If any resources are available in each of the cells, the resources are then reserved for each of the real-time services.
- If there are not enough resources available to accommodate a new service, a set of the reserved resources for real-time handover services can be taken up by a real-time handover service, a non–real-time handover service, and a non–real-time new service.
- If there are any resources available to support the reservation in the estimated cell, and a moving service competes with a new service for the resources, the resources are taken in the following order: a real-time handover service, a real-time new service, a non–real-time handover service, and a non–real-time new service.
- If no resources are available, the reservation is not made.

③ **Step 3:**

- A set of reserved resources for real-time handover services can be taken up by a real-time handover service and a non–real-time handover service.
- If there are resources available to support the reservation in the estimated cell, and a moving service competes with a new service for the resources, the order for taking up the resources is the same as Step 2.
- If no resources are available for the reservation in R_{ma} of the macrocell, the resources for R_{fe} or R_{sh} are reserved for a real-time service.

④ **Step 4:**

- A set of the reserved resources can be taken up only by a real-time handover service.
- If a moving service competes with a new service for the available resources in the estimated cell, the resources are taken up in the following order: a real-time handover service, a non–real-time handover service, a real-time new service and a non–real-time new service.
- If no resources are available for the reservation in R_{ma} of the macrocell, the resources for R_{fe} or R_{sh} can be reserved for real-time services.

Algorithm III * Resource Reservation *

while (1)
  If (*Step 1*) **then**
    The resource reservation need not be performed;
  else if (*Step 2*) **then**
    if (there are available resources in each of the estimated cells) **then**
      Reserve the resources;
    end if
    If (enough resources are not available for the new service in the estimated cells) **then**
      The reserved resources are occupied by the new services;
    end if
  else if (*Step 3*) **then**
    if (no resources are available for the reservation in the estimate cell) **then**
      Reserve the resources of R_{fe} or R_{sh} for a real-time service;
    end if

If (there are not enough resources available to accommodate the new service in the estimated cells) **then**
The reserved resources for real-time handover services can be taken by non–real-time new services;
end if
else if (*Step 4*) **then**
if (no resources are available for the reservation in the estimate cell) **then**
Reserve the resources of R_{fe} or R_{sh} for a real-time service;
end if
If (there are not enough resources available to accommodate the new service in the estimated cells) **then**
The new service cannot take the reserved resources;
end if
end if

Figure 5. Resource Reservation for Multimedia Services

3.2. Resource Allocation Scheme for New and Handover Services

The resource reservation is made for real-time handover services, and a set of the reserved resources can be taken up temporarily by non–real-time MTs within the target cell. On the other hand, a non–real-time MT does not make resource reservations for handovers, and its resource allocation request is buffered in the waiting queue of the target base station during handover duration time, and is given priority based on the service demand time. If the reserved set is returned because the corresponding real-time MT is handed off, the priority of the non–real-time MT that has occupied the reserved resource becomes the lowest order. This algorithm strategy is explained in Figure 6.

Algorithm IV * Resource Allocation*

while (1)
If (*Handover service***) then**
if (*Services of macrocell*) **then**
if (there are reserved resources for R_{ma} or R_{sh}) **then**
Allocate the reserved resources;
else if (there are available resources for R_{ma} or R_{sh}) **then**
Allocate the available resources;
else
Drop the service request;
end if
else if (*Services of femtocell*) **then**
if (there are available resources for R_{fe} or R_{sh}) then
Allocate the available resources;
else if (there are reserved resources for R_{fe} or R_{sh}) **then**
Allocate temporarily the reserved resources;
else
Buffer the service in a non–real-time queue;
end if
end if
else if (*New service***) then**
if (*Services of macrocell*) **then**
if (there are available resources for R_{ma}) **then**
Allocate the available resources;


```
            else
                Block the new real-time service;
            end if
        else    // Services of femtocell
             if (there are available resources for R_fe ) then
                    Allocate the available resources;
            else if (there are reserved resources for R_fe or R_sh ) then
                Allocate temporarily the reserved resources;
            else
                Block the new non–real-time service;
            end if
        end if
    end if
end while
```

Figure 6. Resource Allocation for New and Handover Services

4. Performance Analysis

We refer to the 3rd Generation Partnership Project (3GPP) model in [16] for radio propagation model parameters, such as channel fading, path loss, shadowing, noise, and frequency reuse. We based the channel structure and system-level parameters on the frequency division duplex radio frame of the OFDMA-based 3GPP LTE Advanced system [17] and the 3GPP LTE Ericsson model [18, 19]. Our analysis is limited to downlink only. The major system-level simulation environments that we consider are summarized in Table 1 [20]. The transmission time interval (TTI) is assumed to be 0.5 ms, and 20 TTIs are deployed in each frame. Seven OFDM symbols fit into the time interval corresponding to the TTI. The subcarriers are separated at 15 KHz intervals. The minimum unit to be used for resource allocation is a resource block (RB). It has a two-dimensional structure in which an RB consists of seven OFDM symbols within a TTI and 12 subcarriers each using a 15 KHz bandwidth. Each frame comprises 600 RBs (20 TTIs multiplied by 30 RBs). Every RB can be allocated to a single user, and each single user may be allocated multiple RBs based on rate requirements.

Table 1. Simulation Parameters

Parameter	Value or Range
Frequency bandwidth	8.75 MHz
Number of macrocells	19
Number of femtocells per macrocell	20
Macrocell radius	500 m
Femtoell radius	10 m
Macrocell transmit power	60 dBm
Femtocell transmit power	20 dBm
Macrocell shadow shadowing	8 dB
Femtocell shadow fading	10 dB
Noise figure	8 dB
Macrocell path loss exponent	3
Femtocell path loss exponent	3.7
Macrocell SINR threshold	20 dB
Femtocell SINR threshold	10 dB
Modulation scheme	QPSK 3/4, 16QAM, 64QAM

We consider the following simulation parameters regarding received signal strength [21-22]. The mean signal attenuation by the path loss is proportional to 3.5 times the propagation distance, and the shadowing has a log-normal distribution with a standard deviation of σ = 6 dB. A value for the received signal strength of less than –16 dB is regarded as an error, which was therefore excluded from the calculations.

Table 2. Multimedia Services

Service		Data rate (Min-Max)	Average rate	Transmission delay
Real-time service	High-quality voice	64 K	32 K	150 ms
	Video conference	64~384 K	256 K	150 ms
	Video on demand	3~10 M	5 M	150 ms
Non–real-time service	World Wide Web	256K~ 2 M	1 M	20 s
	Electronic commerce	64K ~384 K	256 K	4 s
	FTP	1M ~5 M	3 M	15 s

The performance measures we considered are outage probability and total throughput. We compared our proposed resource allocation with those used by Saeed [23] and Wang [24]. Figure 7 shows the outage probabilities based on increasing the mobile multimedia service arrival rates. These results were obtained by calculating the percentage of mobile multimedia service where the mean arrival rate is less than MiBR based on all the mobile multimedia service. Our proposed scheme has much lower outage probabilities than both Saeed [23] and Wang [24]. This is attributable to the fact that the multimedia services assigned with delay priority have the highest precedence for occupying a sub-channel and are guaranteed to have a permissible MiBR.

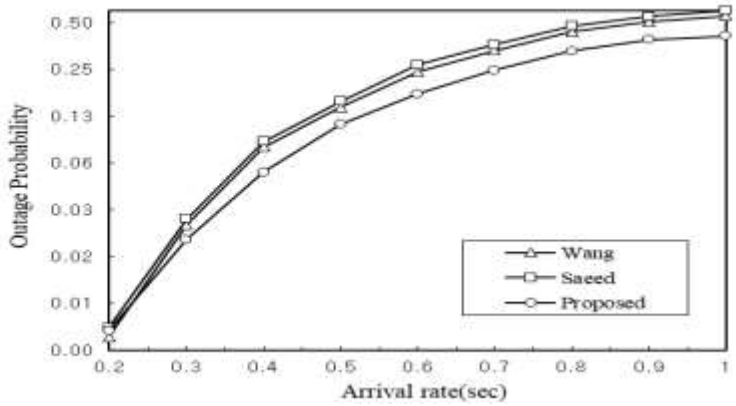

Figure 7. Comparison of Outage Probability

Figure 8 shows the variations in total throughput for the different methods when the arrival rate of new service requests increases. Results demonstrate that the total throughput of the proposed scheme decreased to about 28% and 17%, compared to Saeed [23] and Wang [24], respectively. It allows overlaid-cell handovers from macrocells to femtocells for the purpose of load control. In this way, it can keep resources within the overlaid cell available at 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 the more actively changing occupancy of resources that the increasing number of users causes.

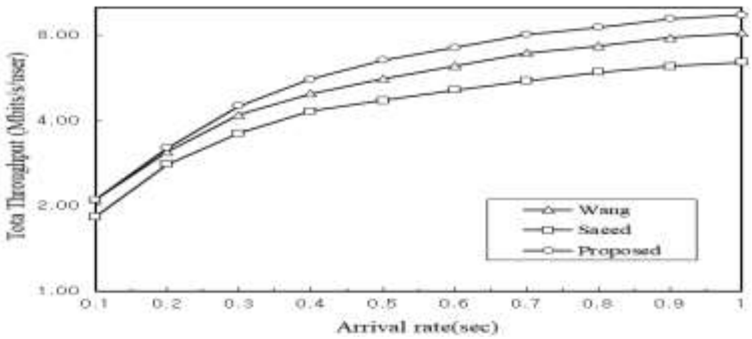

Figure 8. Comparison of Total Throughput

5. Conclusion

Macrocell–femtocell overlaid networks using a single terminal should be able to provide high-speed data communications services, mainly in the femtocell regions, and support the continuity of these services in any areas other than femtocell regions through coordination with legacy systems. In this paper, we proposed an adaptive resource management scheme that attempts to achieve both optimized satisfaction of user requirements and that maximizes user accommodation in macro–femto overlaid LTE Advanced networks to a certain degree. In the proposed scheme, radio resources are classified as ones having priority over new services and ones having priority over handover services, based on reservation variables. Using this, we improved the outage probability and total throughput by dynamically adjusting the amount of reserved resources according to the amount of occupied resources.

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Jong-Chan Lee, he received the M.S. and Ph.D. degrees in computer science and engineering from Soongsil University, Korea, in 1996 and 2000 respectively. He as a senior member of engineering staff in ETRI from 2000 to 2005.Since 2005, he has worked in the Department of Computer Information Engineering, Kunsan National University. His current research interests are in the areas of resource management for mobile multimedia networks.

