Sub-channel Allocation Based on Multi-level Priority in OFDMA Systems

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Abstract

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, sometimes even simultaneously. This paper proposes a sub-channel allocation scheme based on multi-level priority for supporting mobile multimedia services in an Orthogonal Frequency Division Multiple Access (OFDMA) system. We attempt to optimize the system for satisfying the Quality of Service (QoS) requirements of users and maximize the capacity of the system at the same time. In order to achieve this goal, the proposed scheme considers the Signal-to-Interference-plus-Noise Ratio (SINR) of co-sub-channels in adjacent cells, the Signal-to-Noise Ratio (SNR) grade of each sub-channel in the local cell on a per-user basis, and the characteristics of the individual services before allocating sub-channels. We used a simulation to evaluate our scheme with the performance measure of the outage probabilities, delays, and throughput.

Keywords: OFDMA, Sub-channel Allocation, QoS, SNR/SINR, Priority Index.

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1. Introduction

OFDMA can maximize the channel capacity by adapting different modulation techniques depending on the Signal-to-Noise Ratio (SNR) of each sub-channel, which reflects the state of the channel. It also transmits a large volume of data simultaneously over several sub-carriers, dynamically increasing or decreasing the number of sub-channels that are allocated based on the service-required throughput or the signal environments. This enables it to provision different Quality of Service (QoS) levels to users of versatile Mobile Multimedia Services (MMS) [1][2].

Radio resource management plays an important role because of its close connection to network performances. Base stations, which have a fixed number of sub-channels within the permitted bandwidth, allocate and release sub-channels for MMS repetitively in predefined time intervals. Moreover, packet-based MMSs on the Internet differ with respect to their resource requirements, performance objectives, and resource usage efficiencies. Nonetheless, each mobile terminal should support a variety of MMSs, sometimes even simultaneously. In this context, adaptive resource management schemes are required [3][4][5]. Several resource management schemes for OFDMA systems have been studied. Some studies place an emphasis on satisfying user requirements optimally, while others put more emphasis on maximizing the number of users that can be accommodated within the system. In order to optimize the satisfaction of user requirements, it is necessary to optimize the channel capacities so that the QoS requirements will be met for individual services. Meanwhile, in order to maximize the number of users that are accommodated within a system, it is necessary to reduce co-sub-channel interference so that the utilization of available resources will be maximized. However, an exclusive emphasis on either optimized user satisfaction or maximized utilization leads to conflicted outcomes. The throughput that is needed for optimized satisfaction of user requirements can be supported effectively by allocating the sub-channel with the best SNR in a dynamic way. However, this scheme only considers a single local cell, thereby imposing intolerable levels of interference on the co-sub-channels in the adjacent cells. This can cause an extreme decline in the accommodation capacity of the overall system. On the other hand, when sub-channels are allocated with minimized inter-cell interferences in order to increase the overall user accommodation capacity, the dynamic control of sub-channel allocation may not be prioritized so that it will satisfy individual QoS requirements. Therefore, there is a tradeoff between individual QoS requirements and system capacity. Due to these complexities, few studies have attempted to satisfy these two objectives effectively at the same time.

This paper proposes a multi-level priority-based sub-channel allocation scheme for OFDMA systems that considers both the optimized satisfaction of user requirements and the maximization of system accommodation capacity. Our proposed scheme determines the sub-channel occupation priority for each user in the local cell based on the characteristics of the MMSs before it allocates sub-channels. Then, this scheme figures out the grade of each sub-channel for each user based on its SNR. In order to consider the channel states of the adjacent cells for local sub-channels when performing an allocation, it considers the Signal-to-Interference-plus-Noise Ratio (SINR) of co-sub-channels in adjacent cells and, using this information, defines a modification factor for the SNR. The sub-channel priority index is calculated using the SNR index and this modification factor. Finally, based on the user priority, it adjusts dynamically the number of sub-channels having higher priority index to be allocated.

2. Recent Studies

OFDMA systems have much higher frequency efficiency, but due to their structural characteristics, co-sub-channel interferences inevitably occur. No interference occurs owing to the frequency orthogonality in the local cell. However, when a co-sub-channel is used in the adjacent cell, inter-cell interferences occur and thereby reduce user throughput.

In order to resolve this issue, IEEE 802.20 proposed Fractional Frequency Reuse (FFR). It reuses the frequency in order to improve the reception performance for users that are experiencing degradation due to inter-cell interference at the cell boundary. It enhances the system performance by adjusting the frequency reuse ratio differently based on the mobile terminal location. In 3GPP Long Term Evolution (LTE), Soft Frequency Reuse (SFR) has been proposed in order to provide better performance than FFR. SFR divides a cell into two areas and, in the inner area, all of the frequency resources can be used [6][7]. However, in these two methods, it is not possible to use all of the frequencies, so the overall capacity is reduced. Moreover, imbalances in user distributions can cause major system performance degradations that are due to shortages or surpluses of resources.

Various schemes have been studied for provisioning QoS in OFDMA systems. Yanhui et al. proposed a resource allocation and scheduling scheme for maximizing total throughput, while maintaining fairness in wireless resource allocation with respect to QoS requirements [8]. Their scheme focused on the fair allocation of wireless resources, but overlooked the necessity of efficient resource allocation based on the inherent characteristics of each service. In this scheme, when the relative ratio of real-time and non-real-time services fluctuates greatly, the number of accommodated users may be reduced severely. As a result, this scheme is unsuitable for commercial systems that require stability in overall operation. Bashar et al. proposed a resource allocation and admission control scheme for heterogeneous OFDMA wireless networks [9]. Their scheme has more advantages for real-time services. However, it may cause deterioration in the performance of non-real-time services. It does not consider the inherent characteristics of the various services in detail. Bashar's scheme is supposed to be unsuitable for commercial systems that accommodate versatile multimedia services. Fan et al. proposed a block-level resource allocation scheme that aims to maximize the overall network throughput by allocating resource blocks and power to each user [10]. However, this scheme is not suitable for satisfying different user service requirements as it considers only power and channel conditions, irrespective of different service characteristics. Zhang et al. proposed a resource allocation scheme that aims to support real-time services that have strict delay and throughput requirements [11]. It considers delays, queue statuses, and user data rates in order to develop an algorithm. Fraimis et al. suggested a mechanism for provisioning QoS using a Proportional Fair (PF) scheduling algorithm [12]. This scheme allocates a minimum data rate to each user and then reallocates remaining resources according to the PF scheduling algorithm. The last two schemes that are mentioned above place an emphasis on channel capacity optimization for user-specific QoS requirements, but they do not consider the expansion of user accommodation capacity through the reduction of co-sub-channel into adjacent cells.

3. Multi-level Sub-channel Allocation

This section describes the multi-level priority-based sub-channel allocation scheme that we propose. It consists of the following five phases.

① The user priority for sub-channel occupation is determined.

② The SNR index of each sub-channel is calculated on a per-user basis.

③ The co-sub-channel weight index of the adjacent cell is calculated for each sub-channel. This plays the role of the weight to the SNR index.

④ Based on these two indexes, the priority index is calculated for each sub-channel.

⑤ Based on the user's priority, the sub-channel with a higher priority index is allocated preferentially.

3.1 Determining User Priority

When the base station receives a user service request, it performs the admission control process for the connection request, the wireless resource allocation, and the reservation and configuration of network resources. If handovers occur later on, it repeats the above-mentioned procedures in order to support service continuation. Before allocating resources to new calls or handover calls, our scheme uses three parameters to determine the user's priority for sub-channel occupancy in each cell. The three parameters are class of user service, service duration, and delay requirements.

We classify MMS user requests into four major classes: LL (Less Delay Less Loss), LM (Less Delay More Loss), ML (More Delay Less Loss), and MM (More Delay More Loss). **Table 1** shows typical applications for these four classes.

Table 1. Classification of MMS

Class	Characteristics	Applications	Priority
LL	Real-time service delay-sensitive and also fragile to data loss	- High quality broadcasting - 911 emergency service - Location sensing service - High-quality voice/audio - Interactive game	1
LM	Real-time services delay-sensitive but tolerable to data loss in a certain extent.	- Stream Audio/Video - Conversational Voice/Video	2
ML	Non-real-time service not sensitive to delay but fragile to data loss.	- WWW Browsing - E-mail - FTP	3
MM	General services neither sensitive to delay nor fragile to data loss.	- Background service (E-mail, Fax)	4

The service class is determined at the time of the user service request. Five types of priorities are subsequently assigned as explained below:

① Priority per class: The priority of the class to which a user service is affiliated is determined using **Table 1**.

② Priority per service within the same class: Each service having the same class priority needs to be prioritized further based on additional criteria such as service duration. Higher priorities are given to services that have been executing for a longer period of time.

③ Priority of user service within a cell: The priorities of individual user services within a cell can be defined further by pairing the two priority policies above.

④ Delay priority: Each service has a delay limit reference that is calculated based on its minimum transmission rate. If a service has been delayed longer than 85% of its delay limit, it is assigned a delay priority that gives it preferential treatment during the allocation of maximum sub-channels.

⑤ User priority: User priority is determined based on both the priority of user service within a cell and the delay priority. Services with delay priorities have the highest user priorities.

Let us consider the possibility that different user services may have the same user priority index values. First, services that have originated from mobile terminals in the same local cell will not have the same user priority index values. The reason is that the call admission control mechanism admits the services sequentially and one at a time even if the services requests have come in simultaneously from several mobile terminals. They cannot have the same service durations as their admittances occur sequentially. On the other hand, a service that is handed over from an adjacent cell may have a small probability of getting the same priority index as another service that originated from the terminal in the local cell. In this case, our algorithm gives more precedence to the locally constructed service. Furthermore, services handed over from the same adjacent cell cannot have the same user priority indexes. Meanwhile, services handed over from different adjacent cells have a very small chance of getting the same priority indexes. If this occurs, our algorithm gives precedence to the user service that obtains an earlier handover acceptance into the local cell.

Fig. 1 describes the algorithm for determining user priority. **Table 2** shows an example of a user priority table that was generated using this algorithm.

Table 2. Example of User Priority

User ID	class	Priority per criteria				Final priority
		class	Within class	delay	Within a cell	User
UR000	LL	1	1	0	1	3
UR001	ML	3	1	1	4	1
UR002	LL	1	2	0	2	4
UR003	LM	2	1	0	3	5
UR004	MM	4	1	0	5	6
UR004	MM	4	2	1	6	2

Algorithm I * Determination of User Priority*

```
 Define
  $i$ : User
  $s_i$ : Claas of service
  $D_i$ : Transmission delay of service
  $n$ : Number of User
  $TH_i$ : Delay limit reference at the minimum transmission rate
 ResourceAllocation()
```

```
while ( $i \le n$ )
  if ( $s_i$ ==LL Class)  then
      Assign class priority 1 ;
      Assign priority within LL class service;
      if ( $D_i > TH_i$ ) then
          Assign delay priority;
      end if
  else if ( $s_i$ ==LM Class) then
      Assign class priority 2;
      Assign priority within LM class service;
      if ( $D_i > TH_i$ ) then
          Assign delay priority;
      end if
  else if ( $s_i$ ==MLClass) then
      Assign class priority 3;
      Assign priority within ML class service;
      if ( $D_i > TH_i$ ) then
          Assign delay priority;
      end if
  else if ( $s_i$ ==MM Class) then
      Assign class priority 4;
      Assign priority within MM class service;
      if ( $D_i > TH_i$ ) then
          Assign delay priority;
      end if
  end if
  $i = i + 1$;
end while
Determine Service priority within the cell;
Determine user priority;
end;
```

Fig. 1. Determination of User Priority

3.2 SNR Index of Sub-channels

The states of channels in OFDMA systems vary through time. In order to utilize limited radio resources effectively and to enhance transmission efficiency, different modulation or encoding techniques can be adapted based on the SNR value of each channel. The SNR 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. Our scheme takes advantage of this fact when allocating a sub-channel. A user who receives a specific sub-channel signal in its best state can transmit data adaptively over the corresponding sub-channel. As a result, maximum throughput can be obtained.

The SNR level for each sub-channel can be calculated using Equation (1). Here, $\gamma_k(f)$, $H_k(f)$, E_s, and N_0 denote the SNR level for the sub-carrier, the frequency response of the sub-carrier, the transmission symbol energy, and the noise power density at the receiving end, respectively [13].

$$\gamma_k(f) = |H_k(f)|^2 \frac{E_s}{N_0} \tag{1}$$

As adjacent sub-carriers are grouped into a sub-channel in OFDMA, a sub-channel can be formed by grouping a unit of F_B sub-carriers. The average SNR of each sub-channel can be used as the information about channel quality. The SNR of sub-channel b for user k is calculated by performing arithmetic averaging as shown in Equation (2).

$$\gamma_{k,b,mean} = \frac{1}{F_B} \sum_{l=(b-1)F_B}^{bF_B - 1} \gamma_k(f) \tag{2}$$

Using the SNR that was obtained from Equation (2), we can formulate the SNR level, i.e. the channel environments of the sub-channels for each user, as shown in Equation (3). Here c denotes the number of sub-channels in the frequency range and n denotes the number of users. So, S_{nc} is the SNR level of the $c\,th$ sub-channel as received by user n.

$$S = \begin{bmatrix} S_{11} & S_{12} & S_{13} & \cdots & S_{1c} \\ S_{21} & S_{22} & S_{23} & \cdots & S_{2c} \\ S_{31} & S_{32} & S_{33} & \cdots & S_{3c} \\ \cdots & \cdots & \cdots & \ddots & \cdots \\ S_{n1} & S_{n2} & S_{n3} & \cdots & S_{nc} \end{bmatrix} \tag{3}$$

The SNR 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 [7]. Based on this information, it 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.

3.3 Weight Index of Sub-channels

Intolerable interference may be imposed on adjacent cells if sub-channels for a user service are selected using information about current sub-channel availability within a local cell or its present signal state based on SNR values. This interference causes delays and/or loss of data. Moreover, the overall frequency efficiency may be reduced and some sub-channels may remain unusable. Even though a sub-channel has been successfully allocated to the local user service, interferences may be inflicted on co-sub-channels in adjacent cells. As a result, the SINR decreases and enforced termination occurs. The SNR index only reflects the state of the local cell.

Thus, in order to reflect channel states of adjacent cells during the allocation of local sub-channels, we introduce the concept of a weight index as a modification factor for the SNR index. The weight index helps to maintain the maximum capacity in the reuse cluster by minimizing the effect of the co-channel interference that is mentioned above. The cell cluster is the set of adjacent cells that will be influenced by interference when the co-sub-channel is being utilized by a user at the cell boundary. A clustered cell is a cell that is in the cell cluster. For each sub-channel in cell l, we examine its cell cluster for any sub-channel that does not satisfy the SINR reference. In other words, a cell may belong to several cell clusters at the same time so its sub-channel fails to satisfy the SINR reference due to interferences overlapping with those within such a distance that the co-channel interference occurs.

In order to estimate the total number of these sub-channels having the smaller value than SINR reference in cell clusters, we can formulate Equation (4) for sub-channel j in cell l. Here, IS_{kj} is the index that is used to determine whether sub-channel j of its clustered cell k satisfies the SINR reference or not. When it fails to satisfy this reference, IS_{kj} is set to 1. Otherwise, it is set to 0. The variable n denotes the total number of clustered cells for sub-channel j of cell l. The variable θ_{lj} indicates the total number of sub-channel j s that fail to satisfy the SINR reference among respective sub-channel j s of all the clustered cells for sub-channel j in cell l.

$$\theta_{lj} = \sum_{k=1}^{n} IS_{kj} \tag{4}$$

such that $IS_{kj} = \begin{cases} 1 & \text{if SINR reference unsatisfied} \\ 0 & \text{otherwise} \end{cases}$

Sub-channel j, which has a value 1 for IS_{kj}, cannot be used in cell k due to its poor channel state. If the corresponding sub-channel j is preferentially allocated in cell l, then the interference is overlapped in the cell k, avoiding detrimental influences on other cells that are in better channel states. As a result, increased utilization of channel capacity can be expected.

We can obtain Equation (5) for all of the sub-channels in cell l. Here c denotes the total number of sub-channels in that cell.

$$W = (\theta_1,\ \theta_2,\ \theta_3, \ldots, \theta_c) \tag{5}$$

In order to formulate the modification factor for the SNR index, we generate normalized weights as shown in Equation (6). The Γ variable represents the frequency reuse factor, which is assumed to be 1 in this paper. The γ variable represents the capacity expansion index that indicates how much emphasis will be put on the previously mentioned co-sub-channel interference overlap during system operation. The w_m is the weight value for the SNR index S of sub-channel m in cell l.

$$w_m = \sqrt{\Gamma} + \frac{(\theta_m)^{\gamma}}{\sum_{j=1}^{c} \theta_j} \qquad m \in \{1, 2, \cdots, c\} \tag{6}$$

Setting the value of γ higher causes the weight of w_m to increase. This means that we are giving more consideration to the benefit of the previously mentioned co-sub-channel interference overlap during system operation. In other words, increases in the system capacity are being given preference over optimization of the QoS for users.

3.4 Sub-channel Priority Index

The priority index is determined after the sub-channel SNR index and weight index have been calculated. The sub-channel priority index per frame is calculated using Equation (7) with the assumption that the sub-channel state does not change during a frame in the time axis. Here each element p_{ij} indicates the priority index of j *th* sub-channel for i *th* user. Therefore, each row of this matrix represents a set that expresses the priority level for i *th* user. As shown in Equation (3), s_{ij} signifies the SNR level of j *th* sub-channel as received by i *th* user. Also, w_j is the weight value for the SNR level of the j *th* sub-channel.

$$P = \begin{bmatrix} s_{11}w_1 & s_{12}w_2 & s_{13}w_3 & \cdots & s_{1c}w_c \\ s_{21}w_1 & s_{22}w_2 & s_{23}w_3 & \cdots & s_{2c}w_c \\ s_{31}w_1 & s_{32}w_2 & s_{33}w_3 & \cdots & s_{3c}w_c \\ \cdots & \cdots & \cdots & \ddots & \cdots \\ s_{n1}w_1 & s_{n2}w_2 & s_{n3}w_3 & \cdots & s_{nc}w_c \end{bmatrix} \quad (7)$$

3.5 Sub-channel Allocation

User priority determines the sub-channel priority p_{ij}. As m sub-channels may be allocated in total depending on the throughput requirements of users, m p_{ij} are selected. From Equation (7), the priority index that is chosen by the user is expressed as shown in Equation (8). Here, c is the number of sub-channels and n is the number of user services. N_{ij} represents the j *th* sub-channel with the highest priority index, which will be allocated to the i *th* user service.

$$N_{ij} = \arg \max_{j=\{1,\cdots,c\}} (s_{ij} w_j) \quad i \in \{1,2,\cdots,n\} \quad (8)$$

The total required bits of R_i should be transmitted to user i per unit time. Let $r_i(N_{ij})$ be the total number of bits transmitted to user i over sub-channel N_{ij} .Then, m_i sub-channels are allocated by repeating the procedure in Equation (8) m_i times until Equation (9) is satisfied.

$$\sum_{j=1}^{m_i} r_i(N_{ij}) \geq R_i \quad (9)$$

4. Performance Analysis

The OFDMA system model that is used for analyzing the performance of our proposed dynamic sub-channel scheme is described below. We consider an LTE-Advanced system with a frequency reuse factor of value 1, where 19 base-stations are distributed uniformly. 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 0~2π. The speed or direction of movement may change continuously. Handovers occurs in Poisson distribution with the average rate of 40%. Channel fading follows the ITU-R M.1225 pedestrian B model [14] with a standard deviation of 5 dB. Path-loss assumes Urban Macro type with the application of value 4 for the path-loss exponent. The shadowing model follows the WINNER II channel model [15] with 8 dB of standard deviation. The SINR is assumed to follow the log distribution with a reference value of 3 dB. 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 [16] and the 3GPP LTE Ericsson model [17][18]. The major system level simulation environments that are considered are summarized in **Table 3**. The Transmission Time Interval (TTI) is assumed to be 0.5 ms and 20 TTIs are deployed in each frame (10 ms). 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. **Fig. 2** depicts the channel structure based on the FDD radio frame of the 3GPP LTE-Advanced system [16], in which *n* sub-channels exist and multiple TTIs form a frame.

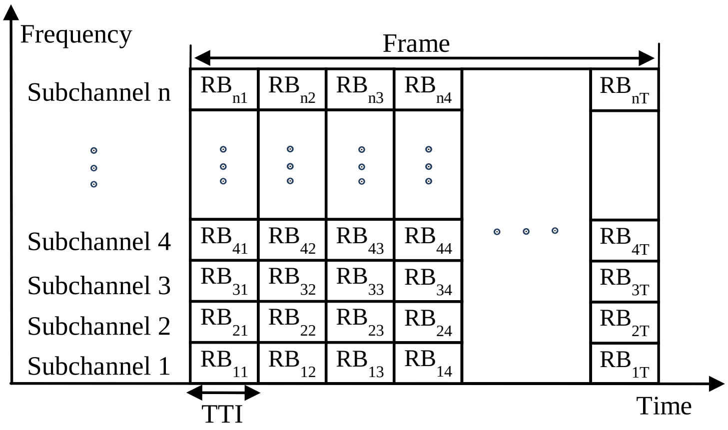

Fig. 2. Channel Structure

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.

Table 3. System-level Simulation Parameters

Parameter	**Value**
Frequency Range	2.3GHz
Channel Bandwidth	10MHz
Number of FFT points	1,024
Number of Cyclic prefix	128
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. Retransmission 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

Fig. 3 shows the probabilities of outages based on increasing MMS arrival rates. This result is obtained by calculating the percentage of MMSs whose mean arrival rate is less than the Minimum Bits Rate (MiBR) based on the total of MMSs being serviced. Our proposed scheme has much lower outage probabilities than the schemes in Zhang [11] and Fraimis [12]. This is attributable to the fact that the MMS assigned with delay priority has the highest precedence in occupying a sub-channel and is guaranteed to have permissible MiBR. In Zhang's scheme [11] and Fraimis's scheme [12], the outage probabilities increase remarkably due to resource shortages or surpluses that are caused by inter-cell interference as the load increases within a cell (where the load is greater than 0.5).

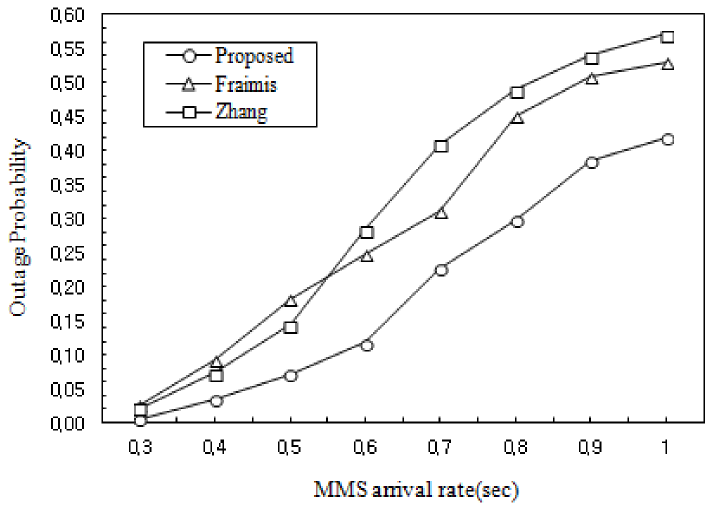

Fig. 3. Outage Probability

The average packet throughputs are compared in **Fig. 4**. It is shown that throughputs decrease for all schemes because inter-cell interference also increases as the number of MMSs increases in the network. However, our scheme has better performance than Zhang's scheme [11] or Fraimis's scheme [12]. Though the increased SNR brings about excessive co-sub-channel interference in adjacent cells, our scheme can increase sub-channel availability within a cell by utilizing the concept of interference weight. As a result, it has greater throughput as compared to the existing schemes.

Fig. 5 compares the average delay of real-time service as the SNR increases. It shows that our scheme (for $\gamma=1, 2$) has better performance than the Fraimis scheme [12]. In addition, for the range of SNR over 18 dB, it is shown to have a lower average delay than the Zhang scheme [11]. The reason for this result seems to be twofold. Firstly, in our scheme real-time services have greater chances of occupying sub-channels with higher priorities than non-real-time services. In addition, delays may occur that are within the permissible limits based on the delay priority, but once a delay exceeds the delay limit, the service can return immediately to its required throughput by taking back the highest priority for channel occupancy. Secondly, our scheme can minimize delays from non-real-time services by having their data that is buffered in the base station sent out instantaneously.

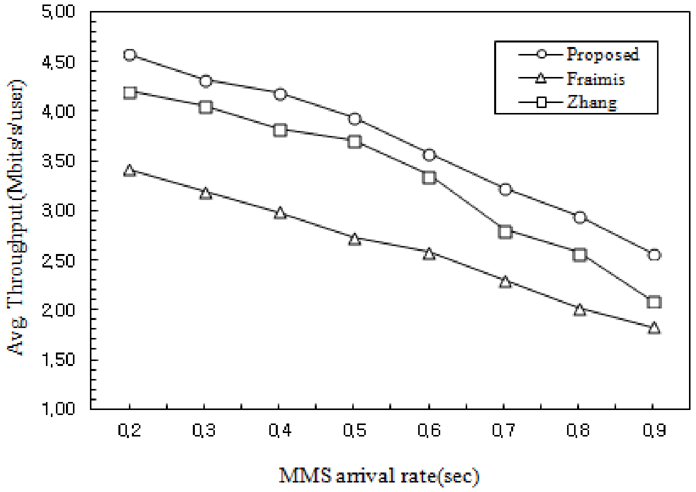

Fig. 4. Average Packet Throughput

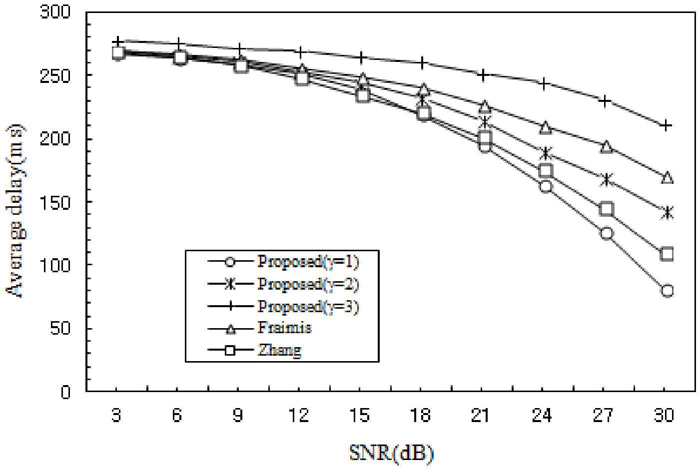

Fig. 5. Average Delay of Real-time Service

5. Conclusion

This paper proposed a sub-channel allocation scheme based on multi-level priority for supporting mobile multimedia services in OFDMA systems. In our scheme, the sub-channel occupation priority of each user in the local cell is determined before a sub-channel is allocated. The priority index of the sub-channel is calculated using the SNR grade and the weight index of the sub-channels for each user. Then successive sub-channels with higher priority index are allocated in proportion to the sub-channel occupancy priority of the user. Using these mechanisms, our proposed scheme is able to optimize the satisfaction of user QoS requirements and also maximize the accommodation capacity of the system at a certain level. A simulation has been used to evaluate our scheme with the performance measure of the outage probabilities, delays, and throughput. The simulation results show that it has better performance than the existing methods in [11][12]. In order to realize our scheme in commercial systems, more detailed studies are required for power allocation, interference, and time assignments.

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