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ภาคผนวก

บทความทางวิชาการที่ได้รับการเผยแพร่

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An analysis of a new access control technique for channel request in wireless communications

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Abstract

Medium access control protocols are at the core of many wireless communication systems with shared channel resources. Recent proposed MAC protocols tend to divide bandwidth into 2 parts. The first part is used to contend among all users for channel reservation and the second part used for actual data transmission for users who succeed in reservation. From the significant role of the first part, the access probability used by all users for determining whether or not to access the request slot for channel reservation, is an important factor effecting on the system performance. Therefore, this paper presents a full analysis for deriving a new optimal access technique that an optimal access probability used in the system is selected in accordance with the present system condition taking the number of users and number of request slots into consideration. The results from our analysis show that in the system which each user has only a single access per frame the new technique outperforms all conventional techniques in all tested traffic and system environments.

1. Introduction

Due to the mobility and access flexibility features in wireless communications, the demands for wireless communication services are growing at rapid pace. A wireless access system consists of one base station and several wireless users. The base station uses the downward channel to broadcast control traffic and/or information traffic to users, while users use the upward channel to transmit their traffic to the base station. Since the upward channel is shared among all users, who are usually distributed over the service area. It is not possible for these users to synchronize their transmission with base station. Therefore, some means of media access control (MAC) protocols are needed.

A number of distinct MAC protocols have been developed over the past years. For early or conventional MAC protocols, they can be classified into two categories, namely contention-free [1] and contention-based [1]. More recently developed protocols tend to organize the channel bandwidth into a frame structure that is composed of two parts, reservation part and information part, see Figure 1. The reservation part consists of a number of request slots, which is used by all users on a contention basis for channel reservation. A user that succeeds in the reservation process will be assigned data slot within the information part for its data transmission. These protocols derive their improved efficiency from the fact that reservation periods are shorter than transmission periods by several orders of magnitude. Examples for this type of protocol are ALOHA Reservation [2], DQRUMA [3], PRMA [4].

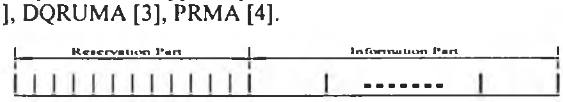

Figure 1 Frame Structure

In order to achieve the maximum throughput of the system, it is found that the vital part effecting the system performance is the reservation part. In the reservation process, each user accesses the request slots with a certain probability. In this paper, we propose a new access technique that can select an appropriate access probability for channel reservation considering both the number of active users and the number of available request slots in the reservation part. Key assumption made in this study is that all users in the system are allowed only one access per frame.

2. Conventional techniques

There are many access techniques for selecting an access probability of users. With conventional schemes, all users use a constant access probability for request channel. But it is very difficult to choose an appropriate value of access probability that can achieve a good system performance under dynamic load conditions. Therefore various techniques have been developed to improve the system performance. An interesting one is an exponential backoff-scheme [5]. In this technique, it is assumed that each user can know the outcome of their request within the same slot. Also it is supposed that there is a ternary feedback (idle when there are no users access in that request slot, success when only one user access, and collision when there are more than one user access in the same slot) for a slot. If the previous frame is idle, each user increases an access probability, by q. Conversely, if a collision occurs, each user decreases the access probability, by 1/q, in order to decrease the chance of packet collision. In addition, if there is a successful user in the previous contention, it means that an access probability is suitable. Another technique is to use a fixed access probability equal to $1/N_u$ (N_u = total number of users in the system). It is found that the use of access probability equal to $1/N_u$ for each user is much appropriate since the total access probability of all users equal to 1. The modified scheme of this technique use a dynamically adjusted access probability according to the number of active users in contention at that time. With the adaptive access probability, all users in contention use the access probability equal $1/N'_u$ (N'_u = the number of users contending in that request slot). This technique is effective because if the number of users in contention is large, each user should access with lower access probability. Theoretically, this scheme is always better than the previous one because it concerns only active users, not all users.

All these techniques described above are only suitable for the system that users can know the outcome of their request within the same slot and can access immediately in the following slot if it is not successful owing to collision. This assumption may not be realistic for some practical system where the forward and backward propagation delay between base station and users are relatively much larger than the request slot length. This is partially the case with high bitrate system when users maybe obtain the outcome of their request after the end of the request slot. It is not clear whether these known techniques are effective when applied to the system that allows all users to access only once in the frame. Therefore, we propose a new algorithm using for selection an appropriate access probability for channel request that concerns both the number of users and the number of request slots. In the next section, we shall derive an appropriate access probability in general cases.

3. Appropriate access probability for channel request

In this paper, three distinct access schemes are presented. In the first scheme, it is assumed that base station can acquire the total number of users attempting to gain access at the beginning of each frame. For the second and third schemes, it is assumed that base station know the total number of active users at the beginning of each request slot. The first scheme is perhaps more realistic, as it requires much less information associated with the system status than the other two. Nevertheless if the extra information required by the second and third schemes can be obtained, the access performance are expected to be better. This issue will be comprehensively discussed in the next section after the analysis of appropriate probability for each scheme is described below.

The first scheme (Method 1)

Let N_u : the number of active users at the start of each frame

N_s : the number of request slots per frame

There are N_u+1 situations that can happen for the system with N_u users and N_s request slots. The calculation of probability for each case is below.

Case 1: The probability that no user accesses the request slot $= \binom{N_u}{0} p^0 (1-p)^{N_u-0}$

Case 2: The probability that 1 user accesses the request slot $= \binom{N_u}{1} p^1 (1-p)^{N_u-1}$

Case 3: The probability that 2 users access simultaneously the request slot $= \binom{N_u}{2} p^2 (1-p)^{N_u-2}$

⋮

Case N_u : The probability that N_u-1 users access simultaneously the request slot $= \binom{N_u}{N_u-1} p^{N_u-1} (1-p)^1$

Case N_u+1 : The probability that N_u users access simultaneously the request slot $= \binom{N_u}{N_u} p^{N_u} (1-p)^0$

If there is only one user accessing that request slot, the user will succeed in the reservation and wait for the information slot assignment from the base station. Therefore, throughput can be calculated by the following recursive formula.

$$
\begin{aligned}
T(N_u, N_s) = & \binom{N_u}{0} p^0 (1-p)^{N_u-0} T(N_u, N_s-1) \\
& + \binom{N_u}{1} p^1 (1-p)^{N_u-1} \left(1 + T(N_u-1, N_s-1)\right) \\
& + \binom{N_u}{2} p^2 (1-p)^{N_u-2} T(N_u-2, N_s-1) \qquad *** (1) \\
& \vdots \\
& + \binom{N_u}{N_u-1} p^{N_u-1} (1-p)^1 T(1, N_s-1) \\
& + \binom{N_u}{N_u} p^{N_u} (1-p)^0 T(0, N_s-1)
\end{aligned}
$$

$T(i,j)$ is defined as the throughput of the system with i users and j request slots where i = 0 , 1, ... , N_u and j = 0, 1, ..., N_s .

The throughput of some specific cases are obtained as follows:

$T(i,0), T(0,j) = 0$ and $T(1,j) = 1$

These specific cases are useful for obtaining the throughput of other more general cases through the recursive formula in equation (1). We can then find an appropriate access probability of each frame by differentiating equation (1) with respect to p, setting it to 0, and finding p that gives maximum throughput.

The second scheme (Method 2)

As for the second scheme, all mobile users know about the number of active users at the beginning of each request slot. Intuitively it is more efficient for all users to dynamically adjust the access probability at each request slot according to the present system states (i.e., the number of active users and the number of remaining request slots) instead of using a fixed value as in Method 1. Indeed, it is possible and useful to adopt the table of an appropriate access probability obtained from Method 1 for use in choosing appropriate access probability at each request slot. This technique will be referred to as Method 2.

The third scheme (Optimal method)

Although Method 2 described above may appear superior to Method 1, this scheme does not offer true optimum system throughput. In fact, there exists a technique that can achieve optimal access performance. Such a technique can be derived as follows. The same recursive formula in equation (1) can be used for derivation with some modifications. Instead of using a fixed value of p for all request slots, p must be determined optimally for each slot according to the present system status; in other word it must be a function of the number of active users at each request slot and the number of remaining slots, i.e. $p_{i,j}$ where i = 0 , 1, ... , N_u and j = 0, 1, ..., N_s . To determine a proper value of $p_{i,j}$ for each case, a recursive formula is applied in the same manner as in equation (1).

4. Results and Discussion

We shall first illustrate how the access probability has an effect on the system performance, which is measured in terms of the average number of successful users in each frame. By using the equation previously derived in section 3 of the first scheme, it is possible to obtain a relation between the average number of successful users and the access probability; this is depicted in Figure 2. In this Figure, the number of slots (N_s) is fixed at 50 and the total number of users (N_u) varied from 1 to 10. As we can see, at small values of access probability the average number of successful users increases with the access probability. This is simply because under this condition users do not access the request slots frequently enough; a lot of time these slots are idle. Therefore, an increase in the access probability will reduce the number of idle slots and thus improving the system throughput. When increasing the access probability up to a certain value, the number of successful users begins to decline. This performance degradation is due to an increase in the number of collisions caused by too many accessing attempts. A further increment of the access probability beyond this will only generate more collisions and results in the reduction of the number of successful users. For example, the maximum number of successful users for the system of 5 users occurs at the access probability of 0.06. Approximately 4.2 users on average succeed in accessing the request slots, an equivalence of 84% throughput.

Consider Figure 3 that shows the relation between the average number of successful users and the access probability for the system of 10 users using different number of slots, *i.e.* 5, 10, 15, 20, 25 and 30 of the first scheme. It is apparent that the average number of successful users rises as the number of request slots increases. An interesting point to highlight here is that the maximum number of successful users for different number of available slots occurs at different value of access probability. The maximum number of successful users for large number of slots appears at lower access probability than the system with smaller number of slots. This is because when there are larger number of request slots, the users can lower the risk of collision by reducing the access probability. On the contrary, when there are few slots available, all users should attempt access at greater probability.

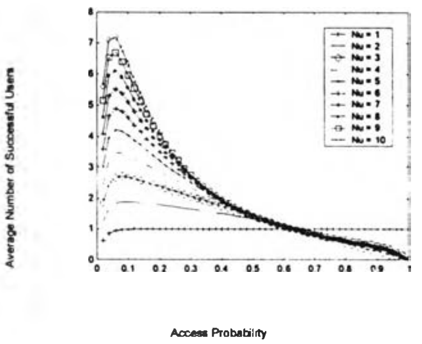

Figure 2 The average number of successful users vs the access probability with the total number of users varied from 1-10 and the number of request slots fixed at 50

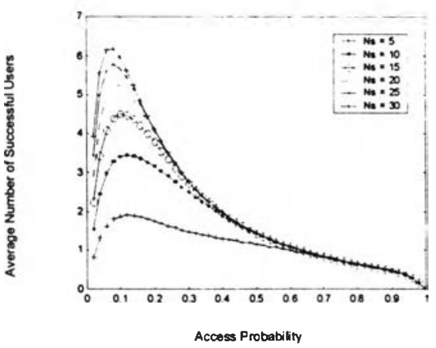

Figure 3 The average number of successful users vs the access probability with various number of request slots from 5,10, 15, 20, 25 and 30 for a system of 10 users

All the above investigations indicate that the access probability is a key factor to the system performance and to determine an appropriate access probability it is essential to take account of both the total number of users and the number of slots available into consideration. Figure 4 summarizes an appropriate access probability for a various total number of users and request slots of the first scheme. Notice that when number of request slots is large, the appropriate access probability tends to be small and will approach zero in the extreme case where the number of slots is infinite. This is because when there are increased number of request slots, users gain greater opportunity for access. Therefore, they can access using the lower access probability to avoid collision. In other word, in the system that has a little number of request slots, the users must attempt to increase their success opportunity by increasing their access probability.

Using the appropriate access probability in Figure 4, we can now obtain the maximum system performance for systems with different total number of users and request slots and this is depicted in Figure 5. As we can see, the number of successful users clearly increases with the number of slots.

For a given number of slots, the more the users access the system the greater the number of successful users. However, its corresponding system throughput which is defined as the average number of successful users divided by the total number of users becomes degraded.

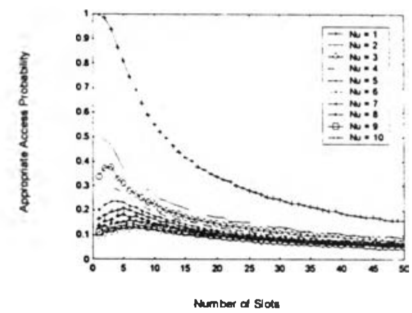

Figure 4 Appropriate access probability with the number of request slots varied from 1-50 and the total number of users varied from 1-10

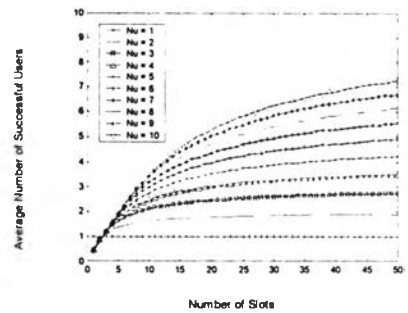

Figure 5 The number of successful users vs the number of request slots using the access probability from Figure 4

The remainder of this section will compare the system performance of these three proposed access schemes with three other known techniques. The other techniques considered are as follows:

1. $1/N_u'$ technique: this technique changes the access probability in according with the number of remaining users, *i.e.* using the access probability of $1/N_u'$ where N_u' is the number of remaining users.
2. $1/N_u$ technique: this technique uses a fixed access probability of $1/N_u$ for all request slots.
3. Exponential Backoff technique (EB): this is a technique that dynamically adapts the access probability in each request slot based on the access outcome of the previous slot. If the previous request slot is idle, success or collision then the access probability used is made double, kept the same, or reduced by half, respectively. In this simulation the initial value of the access probability in the slot is set to $1/N_u$ (N_u = the total number of users in the system) and q is set to 2.

Figure 6 illustrates the throughput performance of all access techniques as a function of the number of users in the system using 15 request slots. It appears that among these six techniques the EB technique offers the lowest throughput, despite this technique is found effective and widely adopted for many studies on MAC protocols that users can access more than once in each frame. When the access attempts are limited to only once per frame, the performance becomes rather poor. This is because users that encounter collisions in their access attempts will no longer take part in the remaining slots. Consequently, the access probability that has been consecutively updated to fit the channel condition will affect only users that remain. This means that if a lot of users crease their access attempts before the appropriate probability is acquired through the dynamic adjustment of access probability, such an access mechanism will no longer be effective or useful.

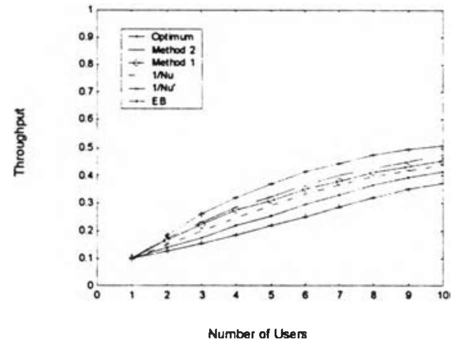

Figure 6 Throughput vs the number of users with N_s=15 slots

For the $1/N_u'$ and $1/N_u$ technique, the throughput performance is better than the EB technique. However, the performance still lower than our proposed schemes.

For the proposed techniques, In case of Method 1, the simulation results illustrate that the performance of this scheme is better than all above access techniques. With closer examination, it is observed that in all previous schemes frequent collisions occur at early few request slots and no active users are left in the system at later slots. As opposed to this behavior, Method 1 chooses access probability by considering both the total number of users and the number request slots. As a consequence, the protocol uses relatively low access probability to avoid early collisions and tends to distribute the access attempts equally over the available slots.

Consider the throughput of Method 2, which dynamically adjust the access probability in every request slots based on the number of remaining request slots and active users. It is apparent that Method 2 gives higher throughput than Method 1. For the optimal method, the system throughput is the highest. Note that Figure 7 summarizes the optimal access probability as a function of the number of slots for different number of users from 1 to 10.

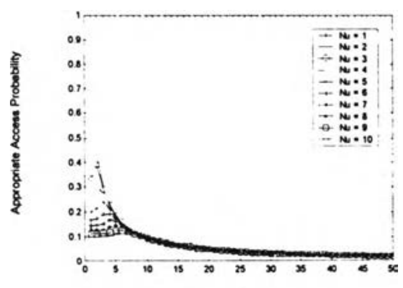

Figure 7 Access probability for the optimal method

To further highlight some key points of these various system performances, the results of similar systems with increased request slots to 50 are depicted in Figure 8. It can be seen that no significant improvement of system throughput is observed for the EB and the $1/N_u'$ techniques when compared to the system with 15 request slots. These results indicate that these two protocols are unable to utilize the additional request slots. This is as expected because a large portion of users end their accesses in early few request slots due to collision or success as mentioned before.

Therefore, the remaining slots are mostly left unused. On the contrary, the system throughputs of Method 1 Method 2 and Method 3 are increased noticeably, meaning that these proposed schemes are able to make effective use of these extra request slots. The performance improvement is achieved by lowering the access probability of users and hence in effect distributing the access attempt over a larger number of request slots and reducing the chance of collision. For the $1/N'_u$ technique, the system throughput improves with the number of slots available, but the amount of improvement is also relatively less than our schemes.

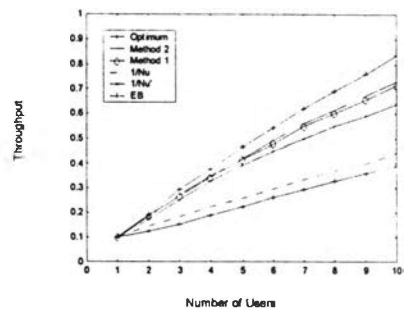

Figure 8 Throughput vs the number of users with N_s=50 slots

5. Conclusion

This paper has introduced a new access protocol for channel reservation in wireless communications and provided a full analysis of its throughput performance. It is revealed that the system throughput depends largely on the access probability used by each user. Simulation results show that the proposed schemes, Method 1, Method 2 and the optimal method, offer much higher level of throughput in comparison to the other three known techniques, the EB, the $1/N_u'$ and $1/N_u$. This is because appropriate access probability is determined by taking both the number of users and the number of slots into consideration and thus these three techniques can distribute the access attempts properly over the entire request slots whereas the other three techniques do not pose such a feature.

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Design and Performance Evaluation of New Channel Reservation Schemes for Supporting Multi-Class Traffics

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Abstract

We consider a single-access system where high bit-rate communication systems constrain the propagation delay between users and the base station. In this scenario, we found that existing channel reservation schemes cannot guarantee the satisfaction to all users regarding different Quality of Service (QoS). Thus in this paper, we propose two new channel reservation schemes which taken into consideration priority service to more delay-sensitive traffics, namely, UNI+DS and UNI+DS+MLA schemes, an extension of our recently proposed UNI scheme for single-class traffic. The goal is to achieve the highest system performance and enable each traffic types to meet their QoS requirements. We evaluate the performance of each scheme by mathematical analysis. The numerical results show that our proposed schemes are effective in enabling different traffic users to achieve the best successful rate possible in this kind of environment.

1. Introduction

The rapid growing of multimedia communications applications today has resulted in the extensive use of communication technology. Several emerging applications such as wireless and internet multimedia communication services, including streaming video, and video phone, etc., play an increasingly important role in current systems. These systems will support a wider range of applications involving information such as packet data, voice, image, and video. When there are many different classes of end-users in the system, the user's requests are likely to collide with each other. Thus, some means of medium access control (MAC) protocols are needed. This MAC protocols will have a significant impact on the user performance, system capacity, and hardware complexity. A successful MAC protocol should indeed take full advantage of the different kinds of traffic to achieve high multiplexing efficiency.

Several MAC protocols have been developed over the past years. Conventional MAC protocols have been classified into contention-free and contention-based [1,2]. Presently high performance MAC protocols designate a frame structure which consists of a reservation and an information parts, as shown in Fig. 1. A reservation part consists of a number of request slots. All users are given a chance to reserve slots on a contention basis. Qualified users from the reservation process will be assigned slots in the information part for traffic transmission. By using much lower ratio of reservation period and transmission period by several orders of magnitude, these protocols has been shown to improve efficiency. Examples for this type of protocol are ALOHA Reservation [3], HAR [4], DR-TDMA [5], SND-MAC [6] and others [7,8]. However, these protocols are not suitable for single-access reservation systems where users are limited to make a single request per frame as the protocols become unstable when too many terminals try to communicate at a time.

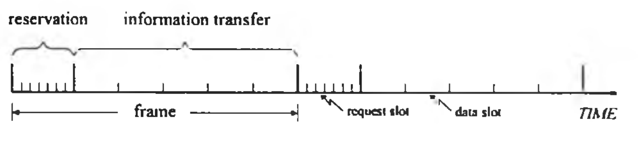

Figure 1 Frame structure under relatively long propagation delay

We have studied and proposed a channel reservation schemes for single-access systems, namely, Uniform (*UNI*), Uniform as in [9]. In *UNI* scheme, users can choose to reserve one slot out of all available slots with equal probability. The scheme is practical in the sense that the system no longer needs to know the number of active users at the start of each frame and all request slots can now be uniformly assigned. However, one problem associated with the *UNI* scheme is that it does not take the number of active users into account.

In this paper, we extend our previous work in [9] to be namely, Uniform and Divided Slots (*UNI+DS*) and Uniform with Divided Slots and Mulitple Limited Access (*UNI+DS+MLA)* schemes, to handle multi-class traffic. The objective is to achieve the highest system performance and enable each traffic types to meet their QoS requirements. The effectiveness of the schemes is verified by mathematical analysis in generalized form and numerical results. In the following sections, we discuss reservation techniques for single-access systems we proposed and show numerical results and discussions.

2. Proposed Channel Reservation Schemes for Multi-Class Traffics

For certain classes of traffic, the contention phase limits part of the scheme while other classes are less sensitive to the introduced delay. The examples of packets sensitive to contention delay are the first packet of a voice talkspurt, a request for new bit-rate in a connection, or a handoff request for real time connection. On the other hand, packets that contain data messages or a request to establish a new connection are considered less time sensitive. It is thus necessary to find a contention access mechanism that will give priority to delay sensitive service. Therefore, the new channel reservation schemes, as shown in Fig. 2, which are suitable for the systems with different classes of users, are developed and their complete analysis is given in this paper. The purpose of these schemes is to prioritize delay sensitive service over the less sensitive ones while maintaining the channel bandwidth utilization.

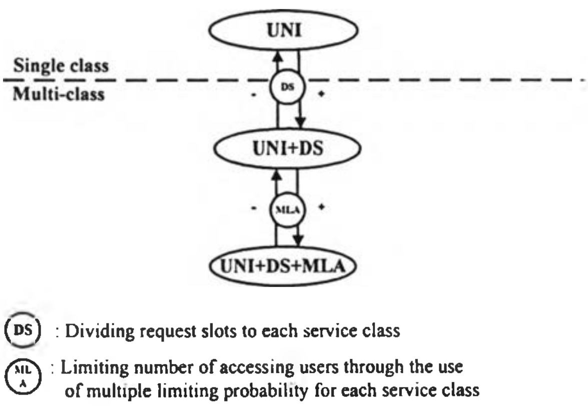

Figure 2 Relations among two proposed channel reservation schemes with *UNI*.

Let we first define the following variables which will be used correspondingly in the mathematical analysis:

C = the number of priority classes in the system.

n_i = the number of request slots for priority class i.

N = total number of request slots in the frame.

m_i = the number of users in priority class i.

k_i = the number of successful users in priority class i.

2.1. Uniform and Divided Slots Scheme (UNI+DS)

The *UNI+DS* scheme is a straightforward scheme and easy to implement. Each class of users will receive its own portion of request slots according to its QoS requirement, i.e., more delay-sensitive traffics tend to receive higher portions of the number of slots. All active users in each class will later randomly select one of the n_i available request slots in its group for requesting a slot of transmission. By doing this, prioritized users will have higher chance to successful request and transmission.

In terms of performance analysis, we can calculate $P_{UNI+DS}[k_1,k_2,...,k_C \mid m_1,m_2,...,m_C,n_1,n_2,...,n_C]$, the probability that k_i successful users of priority class i with the number of users m_i and n_i request slots, by using the equation below:

$$P_{UNI+DS}[k_1,k_2,...,k_C \mid m_1,m_2,...,m_C,n_1,n_2,...,n_C] = \prod_{i=1}^{C} P_{UNI}[k_i \mid m_i,n_i] \qquad (1)$$

where $P_{UNI}[k_i \mid m_i,n_i]$ is the probability of k_i successful users of priority class i given that each of m_i users randomly selects one of the n_i request slots in its group and can find by using the recursive formula as follows:

$$\begin{aligned} P_{UNI}[k_i \mid m_i,n_i] &= b[m_i,0,1/n_i]P_{UNI}[k_i \mid m_i,n_i-1] \\ &+ b[m_i,1,1/n_i]P_{UNI}[k_i-1 \mid m_i-1,n_i-1] \\ &+ \sum_{a=2}^{m_i}\left(b[m_i,a,1/n_i]P_{UNI}[k_i \mid m_i-a,n_i-1]\right) \end{aligned} \qquad (2)$$

where $b[m,i,x] = \binom{m}{i} x^i (1-x)^{m-i}$

The boundary conditions of this equation are:

$$P_{UNI}[k \mid M,N] = \begin{cases} 0 & if\ k<0, M\ge 0, N\ge 0 \\ 1 & if\ k=0, M\ge 0, N=0 \\ 0 & if\ k>0, M\ge 0, N=0 \\ 1 & if\ k=0, M\ge 2, N=1 \\ 0 & if\ k>0, M\ge 2, N=1 \\ 1 & if\ k=0, M=0, N\ge 1 \\ 0 & if\ k=0, M=1, N\ge 1 \\ 1 & if\ k=1, M=1, N\ge 1 \end{cases}$$

In this case, the average number of successful users of the frame ($T_{UNI+DS}[m_1,m_2,...,m_C,n_1,n_2,...,n_C]$), system throughput, is calculated by the summation of the average number of successful users of each priority class and is given by the following equation:

$$T_{UNI+DS}[m_1,m_2,...,m_C,n_1,n_2,...,n_C] = \sum_{i=1}^{C}\sum_{j_i=0}^{m_i}\left(j_i \times P_{UNI+DS}[j_i \mid m_1,m_2,...,m_C,n_1,n_2,...,n_C]\right) \qquad (3)$$

where $P_{UNI+DS}[j_i \mid m_1,m_2,...,m_C,n_1,n_2,...,n_C]$

$$= \sum_{k_1=0}^{m_1} \cdots \sum_{k_i=j_i}^{j_i} \cdots \sum_{k_C=0}^{m_C} P_{UNI+DS}[k_1,...,k_i,...,k_C \mid m_1,...,m_i,...,m_C,n_1,...,n_i,...,n_C]$$

2.2. Uniform with Divided Slots and Multiple Limited Access Scheme (UNI+DS+MLA)

For *UNI+DS* scheme, the performance is achieved by assigning different number of request slots to each traffic class according to its QoS requirement. However, when number of users is higher than the number of slots, the performance of each group will be degraded. Therefore, we also include the different limiting probability in accordance with the traffic classes. Intuitively, it is possible to adjust both parameters simultaneously so that the resource allocation can be more flexible and hence potentially leading to more effective reservation. Thus, in this scheme, each priority class has its separating request slots and its own limiting probability used in its group. Therefore, the probability that k_i successful users of priority class i with number of users m_i, number of request slots in its group n_i and limiting probability p_i, $P_{UNI+DS+MLA}[k_1,k_2,\ldots,k_C \mid m_1,m_2,\ldots,m_c,n_1,n_2,\ldots,n_c]$, is defined by the equation as follows:

$$P_{UNI+DS+MLA}[k_1,\ldots,k_C \mid m_1,\ldots,m_C,n_1,\ldots,n_C] = \prod_{i=1}^{C} P[k_i \mid m_i,n_i] \quad (4)$$

$$\text{where } P[k_i \mid m_i,n_i] = \sum_{i=0}^{m_i} \left(b[m_i,i,p_i]\, P_{UNI}[k \mid i,n_i] \right)$$

In addition, the average number of successful users of the frame ($T_{UNI+DS+MLA}[m_1,m_2,\ldots,m_c,n_1,n_2,\ldots,n_c]$) is calculated by using the equation as follows:

$$T_{UNI+DS+MLA}[m_1,m_2,\ldots,m_C,n_1,n_2,\ldots,n_C] = \sum_{i=1}^{C} \sum_{j_i=0}^{m_i} \left(j_i \times P_{UNI+DS+MLA}[j_i \mid m_1,m_2,\ldots,m_C,n_1,n_2,\ldots,n_C] \right) \quad (5)$$

$$\text{where } P_{UNI+DS+MLA}[j_i \mid m_1,m_2,\ldots,m_C,n_1,n_2,\ldots,n_C] = \sum_{k_1=0}^{m_1} \cdots \sum_{k_i=0}^{m_i} \cdots \sum_{k_C=0}^{m_C} P_{UNI+DS+MLA}[k_1,k_2,\ldots,k_C \mid m_1,m_2,\ldots,m_C,n_1,n_2,\ldots,n_C]$$

3. Numerical Results and Discussions

For conveniences, these notations will be used in the following discussions:

M_1	= Total number of users of service class 1
M_2	= Total number of users of service class 2
N	= Total number of request slots in the frame
N_1	= Number of request slots for service class 1
N_2	= Number of request slots for service class 2
p_1	= Limiting probability of service class 1
p_2	= Limiting probability of service class 2
T_s	= Average number of successful users
T_{S1}	= Average number of successful users of service class 1
T_{S2}	= Average number of successful users of service class 2
T_{total}	= Total average number of successful users of 2 service classes = $T_{S1} + T_{S2}$
γ	= QoS Controller = $(T_{S1} / M_1) / (T_{S2} / M_2)$

Note that we define service class 1 to have higher priority than service class 2 and the number of request slots is fixed at 16 for all results.

3.1. Performance of UNI+DS scheme

Now we will discuss the performance of *UNI+DS* scheme. Fig 3 shows the characteristics of the basic *UNI+DS* scheme when considering the average number of successful users of each service class (T_{S1} and T_{S2}) on different number of request slots for service class 1 (N_1). As one may expect, T_{S1} increases proportionally to N_1 while T_{S2} decreases. The value of T_{S1} and T_{S2} depend on the number of users in each class, i.e., M_1 and M_2. The more users in the service class, the more request slots are needed to support high traffic load. Therefore, if there are only a few number of request slots for that service class, the average number of successful users (T_s) tends to be small.

Fig 4 shows the relationship between the number of request slots for service class 1 and the total average number of successful users of 2 service classes (T_{total}). By looking at a specific example, when there is only one user of service class 1 and 15 users of service class 2, the increment of the number of slots assigned for service class 1 results in the significantly reduced of T_{total}. This is because only one slot is sufficient for resolving contention of one user i.e., no collision and it reduces the remaining slots available for service class 2. The similar behavior occurs in the case of 15 users of service class 1 and one user of service class 2, but in reverse order. This is because at high traffic load, there is not enough number of request slots for service class 1. For other cases, different characteristics can be noted. When N_1 is less than M_1, the value of T_{total} increases according to the number of slots assigned and reaches the maximum value when the number of users of service class 1 equals the number of request slots. After that, when increasing the number of request slots for service class 1 than this point, the value of T_{total} starts to decrease as there are more request slots than needed. These results imply that it is nearly impossible to achieve the highest value of T_{total} if the different ratio of classes is to be met i.e., the tradeoff T_{total} can be decreased or changed if priority of service class 1 over service class 2 is desired.

Fig. 5 shows the relationship between γ and T_{total}. From this figure, there are different combinations of the number of users of class 1 and class 2. It appears that, for all cases, the T_{total} decreases at high value of γ . This means that, if the QoS is to be greatly differentiated, the overall system throughput will be affected considerably. We also notice that the overall system throughput is degraded more severely when there are small numbers of class 1 users. The reason is as follows: in order to achieve high value of γ, it is necessary to allocate sufficiently high number of request slots to class 1 users. Unfortunately, for small number of class 1 users, these allocated slots are not utilized effectively (this is due to underlying performance characteristics of *UNI* system). On the other hand, there are not enough slots left for large portions of class 2 users resulting in less number of successful class 2 users. As a result, the T_{total} suffers throughput degradation when there are small numbers of class 1 users.

Fig. 6 shows the relationship between N_1 and the QoS controller γ among five choices of different proportions of the number of users of service class 1 and 2. We can see from the results that by increasing the number of available request slots for service class 1, the probability of success for users of service class 1 is increased. The value of γ increases with the number of request slots assigned to service class 1. But if the number of users of service class 1 is high, the system has to assign more slots for service class 1 to be able to maintain the same level of γ. For example, if the number of users of service class 1 is 15, it is very difficult for the system to maintain γ at the desired level since the maximum number of request slots given to service class 1 is limited to 15 slots. Thus, this scheme has weakness in controlling γ, as there are a limited number of feasible values of γ.

3.2. Performance of UNI+DS+MLA scheme

The *UNI+DS+MLA* scheme is the most flexible and complicated scheme among the algorithms we proposed. Fig. 7 illustrates the throughput performance of the *UNI+DS+MLA* scheme as a function of γ. We also observe the similar results as of *UNI+DS* scheme. In addition, figs. 8, 9 and 10 show the values of p_1 and p_2 and the number of request slots for service class 1.

From Fig. 8, we can see that the system tries to set most values of p_1 to 1 in order to meet the highest T_{S1} at every γ except some points where γ =1 and where the number of users of service class 1 is relatively low such as 1 or 4 users. This is because at this point of γ there is no p_2 to satisfy such condition γ including maximize T_{S1}. We also observe p_2 in Fig. 9 and see that in general the value of p_2 decreases as the γ increases. In addition, the value of p_2 varies according to the changing of N_1. Another factor that affects the performance is the number of request slots N_1. As we can see in Fig. 10 that the number of request slots for service class 1 needs to be increased to support more users of that service class. In the case of γ, we found that an increase in γ makes the service class 1 require more request slots. In addition, more request slots given to support service class 1 result in the increment of T_{S1} and the decrement of T_{S2}.

4. Conclusions

In this paper, we have presented two new channel reservation schemes for supporting multi-class traffic with guaranteed different QoS requirements. The mathematical analysis derived in this paper enables us to numerically evaluate the performance of all proposed schemes. Through numerical results, we found that the *UNI+DS+MLA* scheme is more effective and flexible in adjusting the system parameters to meet QoS requirements than *UNI+DS* scheme because of its ability to control system parameters even with more complexity. Thus, our proposed *UNI+DS+MLA* scheme can control QoS and yet maintain the throughput performance as high as the scheme used in practical environment. This is a necessary step toward the design of multimedia delivery system that supports different QoS requirements.

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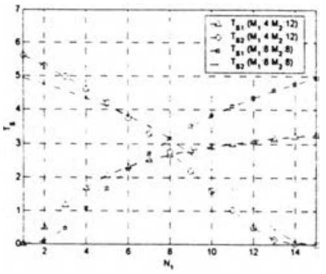

Figure 3 Comparison between different combination of number of users of each service class on the number of request slots for service class 1 (N_1) and the average number of successful of users of service class 1 and service class 2 (T_{S1},T_{S2}) for *UNI+DS* scheme.

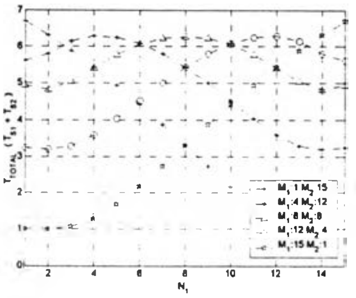

Figure 4 Comparison between different combination of users of each service class on the number of request slots for service class 1 (N_1) and the maximum total average number of successful users of 2 service classes (*MAXIMUM* T_{total}) for *UNI+DS* scheme.

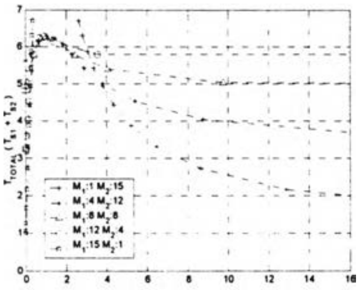

Figure 5 Comparison between different combination of number of users of each service class on the QoS Controller (γ) and the maximum total average number of successful users of 2 service classes (*MAXIMUM* T_{total}) for *UNI+DS* scheme.

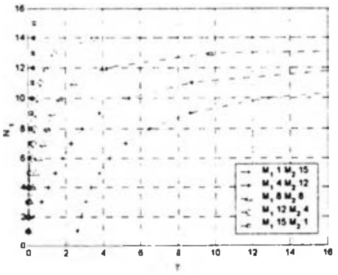

Figure 6 Comparison between different combination of number of users of each service class (M_1,M_2) on the number of request slots for service class 1 (N_1) and QoS Controller (γ) for *UNI+DS* scheme.

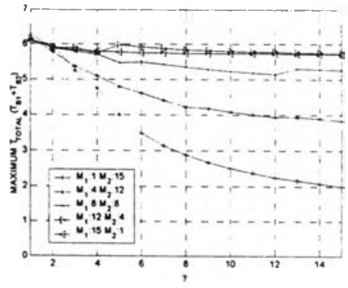

Figure 7 Comparison between different combination of the number of users of each service class on the QoS Controller (γ) and the maximum total average number of successful users of 2 service classes (*MAXIMUM* T_{total}) for *UNI+DS+MLA* scheme.

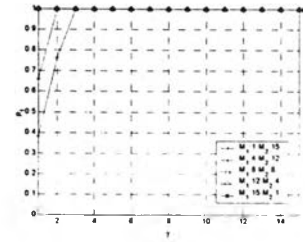

Figure 8 Comparison between different combination of the number of users of each service class on the QoS Controller (γ) and the limiting probability for users of service class 1 (p_1) for *UNI+DS+MLA* scheme.

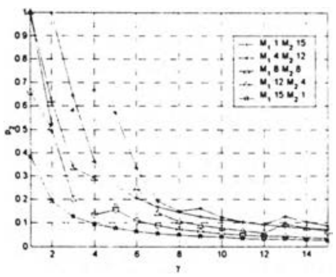

Figure 9 Comparison between different combination of the number of users of each service class on the QoS Controller (γ) and the limiting probability for users of service class 2 (p_2) for *UNI+DS+MLA* scheme.

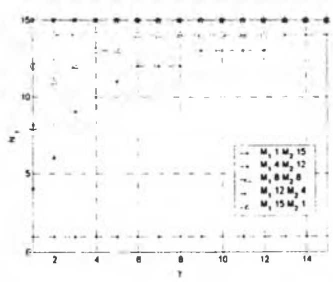

Figure 10 Comparison between different combination of the number of users of each service class on the QoS Controller (γ) and the number of slots assigned to service class 1 (N_1) for *UNI+DS+MLA* scheme.

ประวัติผู้เขียนวิทยานิพนธ์

นางสาวอัครภัทร เจริญพาณิชกิจ เกิดเมื่อวันที่ 31 มีนาคม พ.ศ. 2522 ที่จังหวัดกรุงเทพ สำเร็จการศึกษาปริญญาตรีวิศวกรรมศาสตรบัณฑิต ภาควิชาวิศวกรรมไฟฟ้า คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย ในปีการศึกษา 2541 จากนั้นได้ศึกษาต่อในหลักสูตรวิศวกรรมศาสตรมหาบัณฑิต สาขาวิศวกรรมไฟฟ้า ภาควิชาวิศวกรรมไฟฟ้า ที่จุฬาลงกรณ์มหาวิทยาลัย ในปี พ.ศ. 2542