General Modeling of Radio Resource Management Scheme for Multimedia Data Packet Transmission in Wireless Forward Channel

Jun-Hee Seok, Young-uk Chung and Dong-Ho Cho

Communication and Information Systems Lab.
Department of Electrical Engineering
Korea Advanced Institute of Science and Technology (KAIST)
373-1 Kusung-Dong Yusung-Ku Taejon, Korea
TEL : +82-42-869-3467 Fax : +82-42-867-0550
Email : {aham,thatfox}@comis.kaist.ac.kr and dhcho@ee.kaist.ac.kr

Abstract

Up to now, much portion of studies for mobile communication is focused on reverse link because the current mobile communication is adapted to voice traffic. But as data traffic increases, researches to use forward link resource efficiently providing QoS service become important. In this paper, a general model of resource management schemes that provide QoS service is proposed and its characteristics are also shown. The proposed general model is verified through numerical examples for a system that provide voice and web service.

I. Introduction

Current mobile wireless communication systems are adapted to voice traffic, and they provide limited data traffic services with 14.4kbps or 9.6kbps. But as the number of Internet users increases, requests for wireless multimedia data services also increase. And to provide multimedia data services, current mobile communication systems have evolved to the next generation mobile communication systems such as IMT2000. [1]

Forward link traffic and reverse link traffic are symmetric in the current mobile communication systems because voice traffic is main traffic. And radio resource of reverse link traffic is more limited than that of forward link traffic as its non-orthogonal property. Because of this reason, much portion of researches for wireless mobile communication systems is focused on reverse link traffic. But as data traffic increases, the studies for forward link traffic become important because of its non-symmetric property. Because forward link traffic is much more than reverse link traffic for data traffic, it is important to use forward link radio resource efficiently. [2][3]

Up to now, several resource management schemes are proposed. [4] Through those works, we can know only characteristics of their scheme. Also, it is hard to know general characteristics of resource management scheme that can provide QoS service. In this paper, a general model of forward link resource management schemes is proposed and its general characteristics are also shown through QoS regions. And we verify the proposed model through numerical analysis.

Following this introduction, in section II, the general model of resource management scheme is proposed. In section III, numerical analysis of the proposed model for voice and web traffic is shown. Finally, conclusions are made in section IV.

II. The Proposed General Model

This section presents the proposed general model of radio resource management schemes. From required packet loss rate and maximum delay of the proposed model, constraints that a resource management scheme should obey are obtained. First, we examine a general model of a single class service, and next, we examine for multi-class services.

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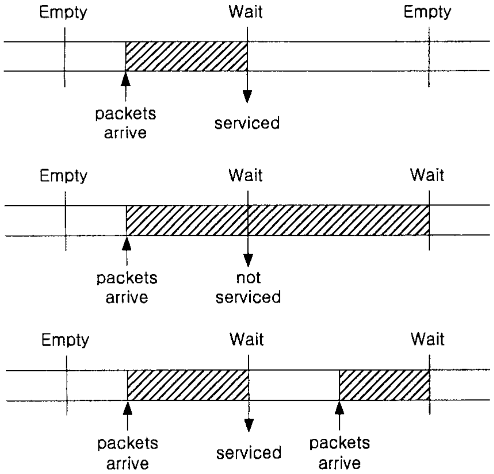

Fig. 1. change of state at the end of each time frame

A. A general model for a single class service

Under a certain resource management scheme f, a base station transmits traffic to mobile stations at the end of each time frame and new traffic arrives at the base station during a time frame. A mobile station can have two states, *Wait* state and *Empty* state. If a mobile station is in Empty state, there is no traffic to be transmitted from a base station to the mobile station. If traffic to be transmitted to a mobile station arrives from the core network, the mobile station moves Wait state from Empty state by *Request* event. For simplicity, we assume that no traffic arrives from core network if there is already traffic to be transmitted to a mobile station.[some] If a base station transmits traffic to a mobile station that is in Wait state, the mobile station moves to Empty state by *Service* event. But if other traffic arrives during the very next time frame, the mobile station remains in Wait state. Of course, if the traffic is not transmitted the mobile station remains in Wait state. Fig. 1 shows how the state of a mobile station changes.

If traffic to be transmitted to a mobile station does not transmitted for sometime, the requested traffic is dropped and the mobile station moves to Empty state by *Drop* event. The dropped time of traffic can be determined from maximum delay of traffics. Fig. 2. shows the state diagram of a mobile station in the proposed model.

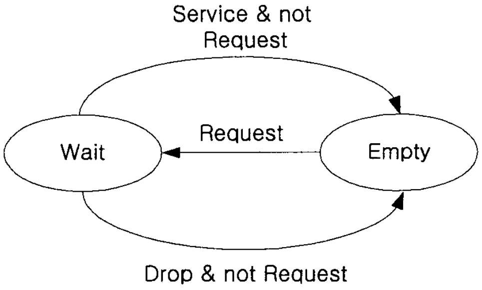

Fig. 2. state diagram of a mobile station

For a mobile station that is supported a certain class service c under a certain resource management scheme f, let the probability that the mobile station is in Wait state at the end of a time frame to be W_c^f. Also, let the probability that the mobile is in Empty state to be E_c^f. Let the probability that Request Event, Service event and Drop event occurs to be R_c^f, S_c^f and D_c^f respectively. From Fig. 2, we can obtain balance equations as like,

$$W_c^f = \left[1 - S_c^f\left(1 - R_c^f\right) - D_c^f\left(1 - R_c^f\right)\right]W_c^f + R_c^f E_c^f \tag{1}$$

$$E_c^f = \left[S_c^f\left(1 - R_c^f\right) + D_c^f\left(1 - R_c^f\right)\right]W_c^f + \left(1 - R_c^f\right)E_c^f \tag{2}$$

$$W_c^f + E_c^f = 1 \tag{3}$$

If we denote maximum delay of service class c traffic as d_c, we can present probability that Drop event occurs as like,

$$D_c^f = \left(1 - S_c^f\right)^{d_c+1} \tag{4}$$

From equations (1) ~ (4), we can obtain W_c^f and E_c^f as following.

$$W_c^f = \frac{R_c^f}{R_c^f + S_c^f\left(1 - R_c^f\right) + \left(1 - S_c^f\right)^{d_c+1}\left(1 - R_c^f\right)} \tag{5}$$

$$E_c^f = \frac{S_c^f\left(1 - R_c^f\right) + \left(1 - S_c^f\right)^{d_c+1}\left(1 - R_c^f\right)}{R_c^f + S_c^f\left(1 - R_c^f\right) + \left(1 - S_c^f\right)^{d_c+1}\left(1 - R_c^f\right)} \tag{6}$$

Loss rate can be obtained as sum of drop loss rate and air loss rate. Drop loss rate is given as like (4). Let error probability of wireless channel to be γ, and assume a base station retransmit traffic n_c times. Then, we can get air loss rate as like,

$$L_{air} = S_c^f \gamma^{n_c+1} \prod_{k=0}^{d_c} \left(1 - S_c^f\right)^k \tag{7}$$

Hence, loss rate is given as like,

$$L_c^f = \gamma^{n_c+1} + \left(1 - S_c^f\right)^{d_c+1}\left(1 - \gamma^{n_c+1}\right) \tag{8}$$

To support QoS service for service class c, L_c^f must be less than a certain maximum loss rate of service class c,

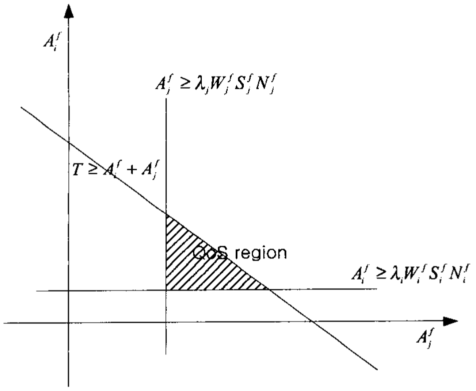

Fig. 3. QoS region of the example system

Table I. characteristics of traffics

parameter	symbol	voice	web
maximum loss rate	l	10^{-3}	10^{-6}
maximum delay	d	0 (frames)	100 (frames)
retransmission times	n	0	4
required resources per a frame	λ	1	8
number of users	N	20	40
traffic arrival probability	R	1	0.1, 0.7

Table II. parameters of the system

parameter	symbol	Value
Total resource	T	50
channel loss rate	γ	10^{-5}

$L_c^{\max}$. Hence, the probability that a mobile in Wait state is serviced must satisfy the following.

$$S_c^f \geq 1-\left(\frac{L_c^{\max}-\gamma^{n_c+1}}{1-\gamma^{n_c+1}}\right)^{\frac{1}{d_c+1}} \tag{9}$$

Assume that there are N_c mobile stations that want to be provided service class c and assume that a base station should allocate radio resource as much as λ_c to each mobile station to provide service class c. If we denote total amount of radio resource that should be allocated for service class c users as A_c^f, the condition that A_c^f should satisfy under a certain radio resource management scheme f is given as like,

$$A_c^f \geq \lambda_c W_c^f S_c^f N_c^f \tag{10}$$

Equation (10) shows a general relationship between allocated resource and effective capacity. W_c^f can be determined from equation (5) and constraint (9). And also A_c^f can be determined from equation (10). If a certain radio resource management scheme allocates resource to service class c users with constraint (10), all service class c users can be serviced with desirable loss rate and delay.

B. A general model for multi-class services

Assume that a system provides C services different from each other. Under a certain resource management scheme f, the sum of allocated resources for each service class should be equal or less than the total amount of radio resource. If we denote the total amount of radio resource of a system as T, this constraint can be represented as like,

$$T \geq \sum_{i=1}^{C} A_i^f \tag{11}$$

Hence, constraint (10) and (11) determine a region that all mobiles in a system can be serviced with their own QoS in C-dimensional space. Fig. 3 shows an example of QoS regions when a system provide two kinds of service, i and j. QoS regions are general methods to constrain resource allocation. [5]

III. Numerical Results

In this section, we analyze a system that provide voice service and web data service numerically. Table I shows the characteristics of voice traffic and web traffic. And table II shows parameters of the systems. A system does not retransmit voice traffic and drops voice traffic immediately if it is not serviced because voice traffic is real time traffic. Hence, retransmission time and maximum delay of voice traffic are 0. If we assume that the voice traffic is continuous, we can determine the traffic arrival probability of voice traffic as 1.

Fig. 4 shows amount of radio resources to be allocated to voice users and web users as change of traffic arrival probability. As expected, as the traffic arrival probability increases, the amount of requested resource increases. In the case of voice traffic, requested resource increases linearly. Because voice traffic does not be delayed, it needs radio resource that is proportional to arrival

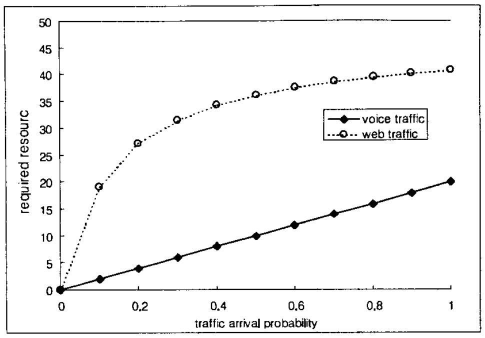

Fig. 4. amount of required resource vs. traffic arrival probability

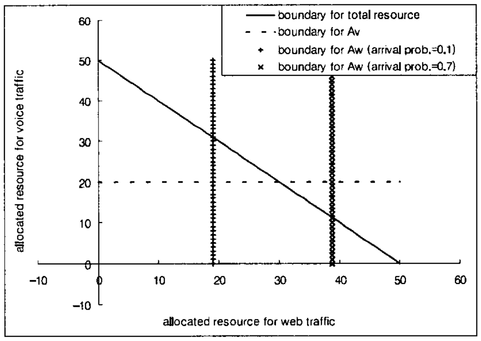

Fig. 5. QoS region vs. arrival probability of web traffic

probability. In the case of web traffic, the increasing rate of requested resource decreases as traffic arrival probability increases. It is because unallocated web traffic can be delayed for sometime due to its long delay time. Here, the probability to be serviced is determined as minimum from constraint (9) for the most efficient usage of radio resource.

We can notice QoS region of the assumed system in Fig. 5 when arrival probability of web traffic is 0.1 and 0.7 while arrival probability of voice traffic does not change. When arrival probability of web traffic is 0.1, there exists a QoS region that the system can provide services for all users satisfying their own QoS quality. But when arrival probability is 0.7, there exist no QoS region. In this case, the system can make a QoS region by blocking some web traffic users according to a certain principle.

IV. Conclusions

In this paper, we proposed a general model for resource management schemes. First a general model for schemes that provide a single class service is proposed, and it is extended to multi-class services. From constraints of the proposed general model, QoS regions can be determined. If a resource management scheme does not determine QoS region, it cannot provide QoS services. Hence, we can see that to make a QoS region is one of general characteristics of resource management schemes that support QoS services.

Works of this paper are based on simple probability. It is simple but inaccurate. For more accurate models, random variables and their distributions may be used.

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