A Prioritized Random Access with Discriminative Power Ramping Step Size

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Abstract

Power ramping makes the access more likely succeed in a contention, so power ramping can be modified to support the multi-class services in random access channel. In this paper, we introduce the discrminative power ramping into slotted-ALOHA channel and 3GPP common packet channel. The proposed scheme serves the high-priority service more rapidly and more efficiently with few defects in both channels.

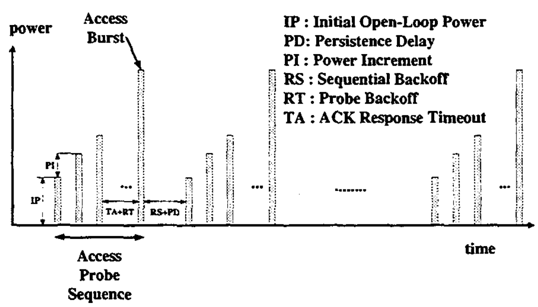

Figure 1. Random Access Channel Attempts

1 Introduction

Unlike previous mobile-communication-systems, the support of enhanced information service and high-speed data service is the goal of the 3rd generation system. Recently, the explosive increase of World Wide Web(WWW) service makes Internet very popular and it is expected that the data service should be the major part of mobile communication service.

IMT-2000 systems define a set of channels, among which some channels are dedicated and some are common. Real-time services and high-rate data services are supported through dedicated traffic channel, while other data services of short burst, such as Short Message Service and E-mail Indication Services, are provided through common channels[1].

Random access channel is a reverse link common channel that is used to transport short data bursts or control signals. In IS-95, random access channel is employed for the call setup or location register messages. The operation of random access channel is shown in Figure 1.

Random access channel in CDMA system is based on the ALOHA channel. The slotted ALOHA system gets twice throughput comapared with pure ALOHA system and many complex schemes, such as the separate transmission of preamble part and message part, are introduced to 3rd generation mobile communication system for the enhanced throughput.

In 3GPP, Common Packet Channel(CPCH) is newly introduced to support the data service more efficiently. CPCH is an uplink common channel that transports packets of medium size[2]. CPCH is evolved out of 3GPP Random Access Channel(RACH). RACH is a contention based common channel which is used to transport bursts of 10ms size. Generally, short control messages are transported in RACH.

CPCH guarantees more confident transmission than RACH does. CPCH has two phases of contention: random access phase and contention resolution phase. In RACH, if two MSs send the same preamble in the same slot, both MSs receive ACK and transmit the message part. Then, collision occurs. The collision of a long burst may cause serious problems in view of the channel

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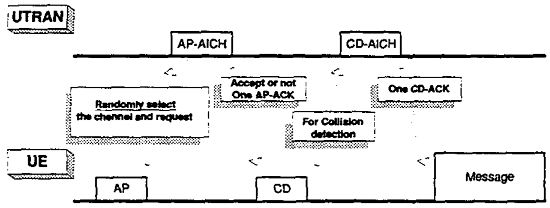

Figure 2. CPCH procedure

efficiency, so CPCH introduces two contention phases. The procedure of CPCH access is described in [2]

As Internet service becomes more popular, the support of data service is a matter of great concern in the mobile communication system. Where two or more services with different priorities exist in a channel, it is necessary to manage them with a discrnminative treatment. Some priority schemes are suggested for random access channel[3][4]. In this paper we propose a new priority scheme with some modification of power ramping for the purpose of multi-class services.

The rest of this paper is organized as follows. In the next section, we introduce the new access scheme for the priority service. In section 3 and 4, we describe the system model and simulation environments. Results and discussion are presented in Section 5 and section 6 concludes this paper.

2 Proposed Scheme

Power ramping is the increase of the power level of a burst for the purpose of obtaining the higher success probability in random access. MS, initially, starts the burst transmission at low power level to reduce the interference. If an access attempt fails, the MS retries the transmission of the burst with higher power level and continues power ramping till it will succeed. If the power reaches the limit value, MS waits for some slots and goes through the initial power ramping sequence.

The power ramping step size means the increment of power level. It is related to the increase of access probability after an access failure. Large power ramping step size guarantees less retransmissions, that is, smaller delay. But too large step size brings about the burst transmission with very high power level which may cause serious problems to the CDMA system capacity.

In this paper, we propose to use the different power ramping step size for each class. The high priority service should have larger step size to get the fast acceptance. Meanwhile, the low priority service should have lower step size. The step size of low priority class should be lower than the size of non-priority case, since the increase of total transmission power may be harmful to system capacity. So, we suggest the increase and the decrease of power ramping step size for high and low priority services.

We, also, apply the new proposed scheme to CPCH. In CPCH, two contention phases, such as access phase and contention resolution phase, are introduced for the reduced collision probability. With the proposed scheme, both phases have benefits. In the access phase, the effect is the same as the case of random access channel. High preamble power guarantees the high detection probability. At the second phase, the proposed scheme produces a greater profit. In CPCH, when two or more users send their CD preambles for the same CPCH in the second phase, only one user with the highest preamble power can be allowed to transmit the message part[5]. Since large step size makes the preamble power high, the success probability is raised. The power ramping is only applied to the first phase. But, because the power of CD preamble is equal to the power of access preamble, this scheme takes effects in both phases. These two phases in CPCH based on the proposed scheme makes the management of multi-class services more effective than in random access channel.

3 System Modeling of Random Access Channel with Proposed Scheme

We suggest the EPA model of slotted-ALOHA channel. EPA is based on equating flow-rates into and out of each system state[6]. The performances of common channels like Aloha or S-Aloha channels, are generally evaluated by the EPA method. Figure 3 shows the system model of slotted-ALOHA channel with the proposed priority scheme. We assume that two service-classes exist and the arrival of access attempts has Poisson distribution. The states in the upper side handle high priority class and those in the lower side do low priority class. Through this paper, class1 means high-priority service and class2 means the low priority service.

MSs in IDLE state does not send bursts. An MS in IDLE state tries to access with probability a in each slot and the success probability is equal to Ps. If an MS failed in contention, it is transited to Backoff state and tries a retransmission with the probability p at each slot. In backoff states, power ramping is performed. First, we define some variable for the equilibrium equations.

N_S : Number of the MSs in state S

$Ps(i)$: Probability of success in an access attempt in the ith backoff state

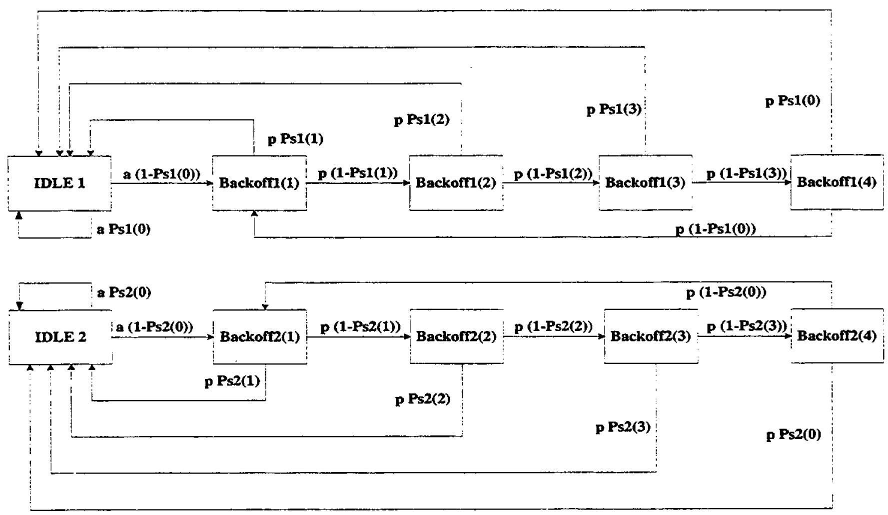

Figure 3. EPA model of random access channel

Ps : Probability of success in contention
a : Access trial probability
p : Persistence value
P_d : Access detection probability

The collision in access channel means the simultaneous access of two or more users with the same code. If many users try accesses at the same slot of the same channel, the burst message cannot be interpreted correctly by BS. But, if the burst of one user is received by the BS with very high power compared with the bursts of other users, other bursts may not influence the reception of the high power burst, which is called *Capture Effect*. But in this paper, the capture effect is assumed to occur only when the low power burst transmission is not detected by BS.

The detection probability, P_d, is dependent of the channel characteristics, but to simplify our analysis and simulation, we used very simple channel model. For BS to detect the access burst, the received bit energy to noise must be larger than the threshold value[7]. The received bit energy to noise is uniformly distributed in an interval between 0 and the initially transmitted value, so the detection probability P_d is defined by,

$$\begin{aligned} P_d &= Pr(10log\frac{E_b}{N_0} > 10log[\frac{E_b}{N_0}]_{th}) \\ &= Pr(10log[\frac{E_b}{N_0}]_{th} + \delta + 10log\alpha > \quad (1) \\ &\quad 10log[\frac{E_b}{N_0}]_{th}) \\ &= 1 - 10^{-\frac{\delta}{10}} \end{aligned}$$

where α is a random variable uniformly distributed in an unit interval and δ is the marginal energy transmitted by a MS and has something to do with the power ramping.

The equilibrium flow equations are as follows.

$$N_{IDLE1} \cdot a \cdot (1 - P_S1(0)) + N_{B1(4)} \cdot p \cdot (1 - P_S1(0)) = N_{B1(1)} \cdot p \quad (2)$$

$$N_{B1(1)} \cdot p \cdot (1 - P_S1(1)) = N_{B1(2)} \cdot p \quad (3)$$

$$N_{B1(2)} \cdot p \cdot (1 - P_S1(2)) = N_{B1(3)} \cdot p \quad (4)$$

$$N_{B1(3)} \cdot p \cdot (1 - P_S1(3)) = N_{B1(4)} \cdot p \quad (5)$$

$$N_{IDLE2} \cdot a \cdot (1 - P_S2(0)) + N_{B2(4)} \cdot p \cdot (1 - P_S2(0)) = N_{B2(1)} \cdot p \quad (6)$$

$$N_{B2(1)} \cdot p \cdot (1 - P_S2(1)) = N_{B2(2)} \cdot p \quad (7)$$

$$N_{B2(2)} \cdot p \cdot (1 - P_S2(2)) = N_{B2(3)} \cdot p \quad (8)$$

$$N_{B2(3)} \cdot p \cdot (1 - P_S2(3)) = N_{B2(4)} \cdot p \quad (9)$$

$$G1 = N_{IDLE1} \cdot a \cdot P_d1(0) + p \cdot (N_{B1(1)} \cdot P_d1(1) + N_{B1(2)} \cdot P_d1(2) + N_{B1(3)} \cdot P_d1(3) + N_{B1(4)} \cdot P_d1(0)) \quad (10)$$

$$G2 = N_{IDLE2} \cdot a \cdot P_d2(0) + p \cdot (N_{B2(1)} \cdot P_d2(1) + N_{B2(2)} \cdot P_d2(2) + N_{B2(3)} \cdot P_d2(3) + N_{B2(4)} \cdot P_d2(0)) \quad (11)$$

$$ \tag{12} $$

$$P_S1(i) = P_s \cdot P_d1(i) \tag{13}$$

$$P_S2(i) = P_s \cdot P_d2(i) \tag{14}$$

$$P_s = e^{(-G1-G2)} \tag{15}$$

We get the three performance measures: *delay*, *throughput* and *transmission power*. *Delay* is the time interval between start of access attempt and success. *Throughput* means the time percentage of channel occupancy. *Transmission power* is the summation of power transmitted in access phase and is described as *transmission power factor* . We define the *transmission power factor* as k where $power = k * [\frac{E_b}{N_0}]_{min}$.

$$Delay\ of\ class\ i = \frac{N_{Bi(1)} + N_{Bi(2)} + N_{Bi(3)} + N_{Bi(4)}}{a \cdot N_{IDLEi}} \tag{16}$$

$$Throughput\ of\ class\ i = N_{IDLEi} * a * P_Si(0) + \sum_{k=1}^{4} N_{Bi(k)} \cdot p \cdot P_Si(k) \tag{17}$$

$$Transmission\ power\ factor\ of\ class\ i = N_{IDLEi} * a * 10^{\frac{\delta_i(0)}{10}} + \sum_{k=1}^{4} N_{Bi(k)} \cdot p \cdot 10^{\frac{\delta_i(k)}{10}} \tag{18}$$

$\delta_i(k)$ is the kth marginal power level in dB and the initial level $\delta_i(0)$ is equal to $\delta_i(4)$.

4 Simulation Environments and Parameters

For the computer simulation of random access channel with the proposed scheme, we use some assumptions. Two class exist in random access channel and have the same access probability, a. The MS knows whether it succeeds or not, in slot next to the accessed slot. Channel model is defined in the previous section and MS does not give up the access attempt regardless of the number of failures.

We apply the proposed scheme to CPCH and get the simulation result. We assume that there exist 16 equivalent CPCH channels with different access signatures and two class services, such as low priority and high priority, are served in CPCH. The backoff scheme is based on the simple persistence check and channel model is the same as the previous case. Message transmission is not lost in air and CD preamble is always received by BS.

Table 1. Parameters used in the performance evaluation

	parameters	value
S-ALOHA	access probability	0.01
	persistence value	0.05
CPCH	access probability	0.002
	persistence value	0.05
	# of channels	16
	avg. message length	100 slots

Table 2. 4 cases used in performance evaluation

	step size of class 1	step size of class2
case 0	1.5 dB	1.5 dB
case 1	2.0 dB	1.0 dB
case 2	2.5 dB	0.5 dB
case 3	4.0 dB	1.0 dB

Simulation parameters are shown in Table 1.

Through the analysis and simulation, we used 4 kinds of step size set shown in Table 2. The initial δ is 2dB and the power step is added to δ in power ramping.

5 Results and Discussion

Figure 4 is the graph of throughput vs number of users in slotted-ALOHA channel with the proposed scheme. As the number of users increases, the gap between the low and the high priority class is widened. Figure 5 is the graph of delay vs number of users. At heavy traffic, the average delay of class1 is much smaller, so fast success is guaranteed.

But, in Figure 6, the power transmitted in random access channel is rarely changed compared with the previous scheme. This means that the increase of step in class1 and the decrease in class2 make the average power transmission unchanged and there is no adverse effect on the system using the proposed scheme.

However, too large step size of class1, such as case 3, makes the average power transmission too high, which can be a serious problem to the system capacity. Moreover, at heavy traffic, the throughput and delay characteristic are degraded. So case 3, where the step size is too large, is not desirable.

The delay graph when the ratio of class1 to class2 users are varying is shown in Figure 7. As the number of class 1 MSs increases, the delay increases totally.

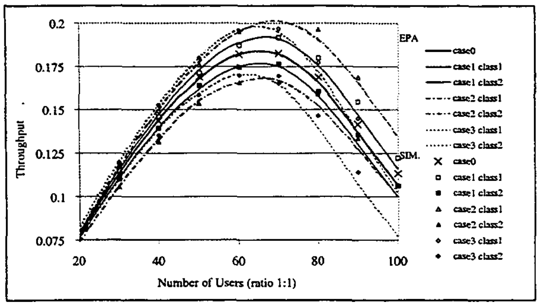

Figure 4. Throughput vs Number of users for S-ALOHA(# of class1: # of class2 = 1:1)

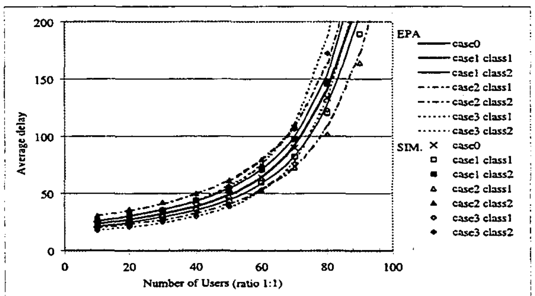

Figure 5. Average Delay vs Number of users for S-ALOHA(# of class1: # of class2 = 1:1)

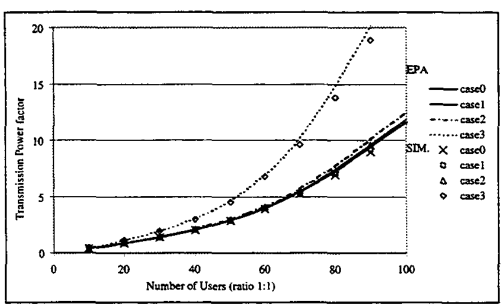

Figure 6. Average Transmission Power vs Number of users for S-ALOHA(# of class1: # of class2 = 1:1)

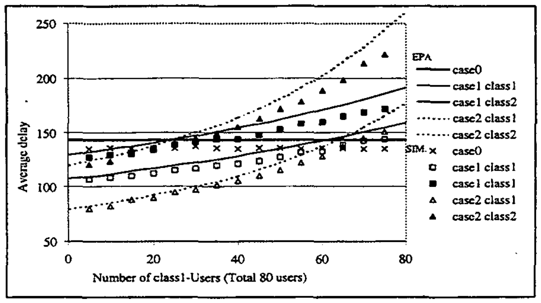

Figure 7. Average Delay vs Number of class1-users for S-ALOHA(# of total users = 80)

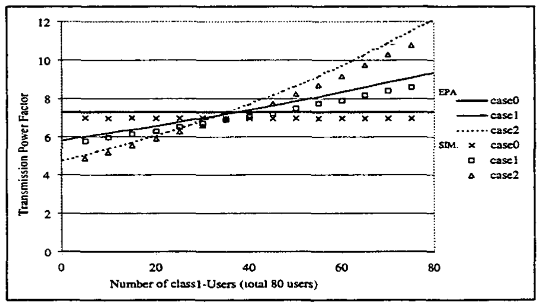

Figure 8. Average Transmission Power vs Number of class1-users for S-ALOHA(# of total users = 80)

When there are not so many class1 users, the proposed scheme can make the average delay of class 1 less than that the non-priority class. When many class 1 users exist, the average delay of class 1 is larger than the non-priority case. Moreover, the average power transmission in this case is also larger for non-priority case. So when the number of class 1 users are very large for class2 user, the proposed scheme is not so efficient. But, when there are not so many class1 users, the proposed scheme is very effective and multi-class service can be served efficiently. Besides, in case that there are few class1 users and many class2 users, this scheme makes the average transmitted power very low.

Figure 9 and 10 show the result of CPCH simulation with the proposed scheme. The resultant characteristic is similar to that of random access channel, but more effective. The throughput of class1 is increased and the delay is definitely reduced. The throughput of class1 at heavy load is large while the throughput of class2 or non-priority scheme is not.

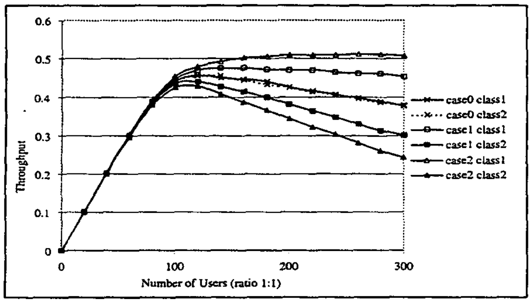

Figure 9. Throughput vs Number of users for CPCH(# of class1: # of class2 = 1:1)

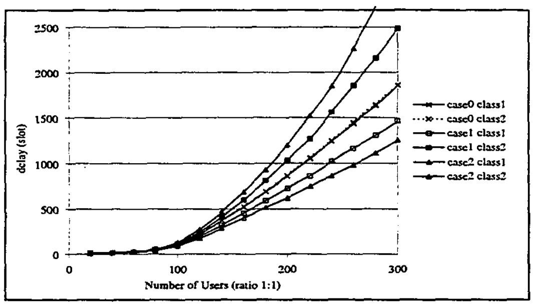

Figure 10. Average Delay vs Number of users for CPCH(# of class1: # of class2 = 1:1)

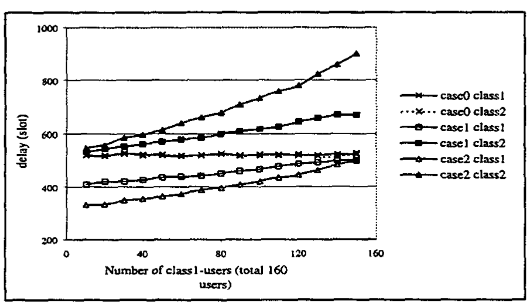

Figure 11. Average Delay vs Number of class1-users for CPCH(# of total users = 160)

The throughput and delay graph of CPCH when the ratio of class1 to class2 users are varying is shown in Figure 11. As the ratio of class 1 user increases, the average delay of class 1 increases. But the delay of class 1 is always lower than the delay of non-priority scheme. So in any situation, class 1 can be served more rapidly than in non-priority scheme, which is a great benefit. In CPCH, the preamble signatures are orthogonal and many signature are used in the access attempt. Thus the total increase of the transmission power does not deteriorate the delay characteristic unlike the random access channel. So the proposed scheme can be used in CPCH regardless of the class 1 to class 2 ratio. But too large power step is not desirable.

6 Conclusions

In this paper, we introduced the new random access scheme for multi class services and applied it to S-ALOHA and CPCH. With the proposed scheme in S-ALOHA, high priority class service can be served efficiently. Although conventional power ramping scheme is modified in this paper, the total transmitted power is not increased. Also, when class1 users are not so many, the power transmission is decreased instead. In CPCH, the proposed scheme also can have more benefits.

As the need of data service in the mobile communication system is brought out, the prioritized service is issued importantly and the proposed scheme can supports such services very effectively.

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