Scheduling Algorithms with Transmit Power Constraint for CDMA Packet Services

Minjoung Sheen, Seungbeom Lee and Sin-Chong Park
School of Engineering, Information and Communications University (ICU)
58-4, Hwaam-Dong, Yuseong-gu, Daejeon, 305-732, Korea
Fax: +82-42-866-6164, Tel: +82-42-866-6151
E-mail: {sheen, moonleaf, scpark}@icu.ac.kr

Abstract: In 3rd-generation mobile communication systems providing packet service, optimal scheduling algorithms are needed to increase service efficiency. In this paper, three scheduling algorithms (SP, EDF, and RPQ) which have been studied in the field of computer networks are applied with transmit power constraint to an interference-limited CDMA system, proving to be efficient.

Key Words – Scheduling, Packet Service, Power Constraint, Radio Resource Management,

1. Introduction

The 3rd-generation communication systems based on CDMA use packet switching to provide multimedia services. These packet services usually provide several classes of variable data rates and different data characteristics, whereby scheduling has gained more significance. Scheduling algorithms which have been studied in the field of computer networks may be classified into three categories: SP(Static Priority), EDF(Early Deadline First), and RPQ(Rotating Priority Queue). These scheduling algorithms have their own goals to satisfy the requirements on the delay bound of each packet. In the SP scheduling algorithm, queues are provided for each traffic class and packets are serviced according to the priority of the queues. SP is simple since each queue is FIFO. On the other hand, the EDF scheduling algorithm uses only one queue. It calculates the deadlines of all the packets. After sorting by deadlines in increasing order, it services sorted packets. In this case, its performance is better than the other two scheduling algorithms, but it needs to calculate and sort every time a new packet comes in. Since RPQ has queues for every traffic class and provides services to packets according to the priority of the queues, it can reduce the complexity which is unavoidable with the EDF scheduling algorithm. The difference between SP and RPQ is that in RPQ, the priority is rotated at every rotating time. RPQ performs as SP when rotating time goes to infinity, and as EDF when rotating time goes to the infinitesimal. Therefore, RPQ is simple and comparable to SP from the viewpoint of complexity, and its performance is similar to that of EDF with an appropriate selection of rotating time[1]. (cf. complexity: EDF > RPQ > SP, transmitted bits: EDF > RPQ > SP)

In [2] where these scheduling algorithms were applied to a CDMA system, the performances of FIFO, SP, and EDF were compared and analyzed in terms of delays in general packet radio service (GPRS). But, the transmit power level depending on the interference level should be considered in order to adapt these scheduling algorithms to CDMA systems. The transmit power of a base station is limited since the interference by adjacent cells has considerable effects on the downlink. In this paper, performances of SP, EDF, and RPQ are compared by considering both the delay bound and the transmit power level in CDMA system.

2. Algorithm

The deadline of each packet is obtained by adding the delay bound of the packet to the packet generation time. Each scheduling algorithm regards a packet exceeding the deadline as a loss. The transmit power of each packet to each user is expressed as follows:

$$transmit\ power = \frac{E_b / N_0}{PG} \times r^{\alpha} \times 10^{\varsigma/10} \times (N_0 + I)$$

where E_b / N_0 is the bit energy-to-noise ratio, PG is the processing gain, r is the distance between a base station and a mobile station, α is the law factor,

ς is the shadowing-effect factor, N_0 is the noise power, and I is the interference power. Each packet is stacked in the corresponding queues according to the scheduling algorithm and the transmit power for each user is calculated. As the CDMA system is interference-limited, the total transmit power of each cell in the downlink should be restricted in order to keep the adjacent cell interference bounded at some finite level. Each queue is serviced by the FIFO scheme with restriction of the total transmit power. Thus, a modified FIFO scheme is proposed. In the modified scheme, priority is passed to the next packet if the updated transmit power, by adding the power of the current packet to previous power, exceeds the maximum allowed transmit power of the base station. But, in basic FIFO, more packets can not be served in current frame. This is shown in Fig.1. The packet has to wait for the next frame when it is not capable to be serviced in the current frame.

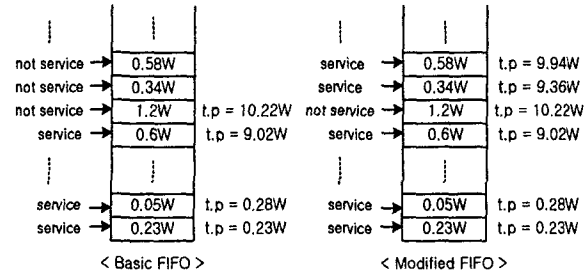

Figure1. Modified FIFO compared with the basic FIFO (t.p: transmit power)

3. Simulation Environment

Three different service classes are defined. Class 1 is a voice service with 12.2kbps, class 2 is a video service with 144kbps, and class 3 is a data service with 384kbps. Class 1 has the highest priority, then class 2, and class 3. The required E_b / N_0 of class 1, class 2, and class 3 are given as 5dB, 3dB and 2dB, respectively. For each class, the call generation is modeled by Poisson process with an exponentially distributed call duration parameter. In class 3, the number of packet calls is modeled with geometric distribution, the number of packets in a packet call with Pareto distribution, and inter-arrival time between packet calls with geometric distribution [3]. In class 1, packets are divided into silence and talk spurt. The delay bounds of each class are set to 20ms, 50ms, and 6s. These delay bounds are used to calculate the deadlines of each packet. The maximum transmit power of each base station is 10W. It is assumed that the common channels are ignored and only the traffic channels are considered to transmit packet. The scheduling unit is 1 frame(=10ms). Simulation was performed for 2000s with 40erlangs. In class 3, it is assumed that a user exists in the presence of a packet session. Each user has a corresponding channelization code. Rotating time in RPQ is 0.5s. The transmit power with different scheduling algorithms for only 5seconds(=500frames) out of the total simulation time, 2000seconds, is depicted in Fig.2.

4. Simulation Results

EDF using the basic FIFO cannot utilize the total allowable power in the interval, A-A', in Fig.2. In EDF using the basic FIFO, packets of all the classes are sorted in one queue in the order of deadline. In the queue, each packet has different transmit power. Therefore, if the total transmit power is over 9W and there is a high power packet to be included, having over 1W, which may be the packet of the user at the edge of the cell asking class 3 service, then this packet cannot be serviced and must wait till the next frame. The A-A' interval in Fig.2 shows such a situation.

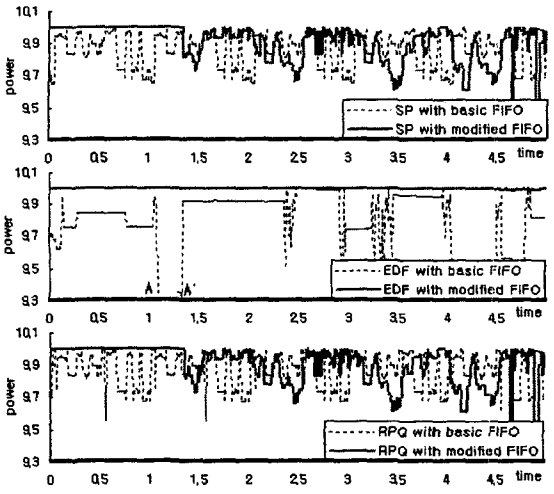

Figure2. Transmit power with different scheduling algorithms (Maximum base station power = 10W)

From the observation in Fig.2, it is found that SP

using the basic FIFO is more efficient than the EDF using the basic FIFO in terms of the transmit power. Now, let us consider the scheduling algorithm that uses modified FIFO. Transmit power with various scheduling algorithms using the proposed modified FIFO scheme is depicted in Fig 2. As shown in Fig.2, the total allowable power is used in EDF using modified FIFO. Hence, the problem of A-A' mentioned above is solved by using the modified FIFO. In SP and RPQ, efficiencies of the transmit power are enhanced by employing the modified FIFO. As shown in Table 1, the ratio of the total loss bits to the total transmitted bits also improves with the modified FIFO for all the scheduling algorithms, especially for SP and RPQ.

	SP	EDF	RPQ (r.t.=0.5s)
Basic FIFO	6.1%	4.4%	6.0%
Modified FIFO	3.4%	3.0%	3.3%

Table1. (the total loss bits) / (the total transmitted bits), simulation time=2000seconds

5. Conclusions

The performances of the three scheduling algorithms which are adapted to an interference-limited CDMA system with fixed maximum allowed transmit power are compared. As a result, though the complexity of EDF is high, it appears to perform best in terms of loss / transmit bit ratio. With the modified FIFO, EDF substantially improves in terms of the transmit power. SP and RPQ with the modified FIFO exhibit better results than EDF with the basic FIFO in terms of low transmit loss rate. Therefore, if the modified FIFO is employed, SP and RPQ can perform scheduling with low complexity, efficient transmit power, and low transmit loss rate.

References

[1] J. Liebeherr, D. E. Wrege, and D. Ferrari, "Exact admission control for networks with a bounded delay service," Networking, IEEE/ACM Trans. on, pp. 885-901, Dec. 1996

[2] O. Pang, A. Biglio, V. C. M. Leung, C. Scholefield, "Service scheduling for general packet radio service classes," Wireless Comm. and Networking Conference, pp. 1229-1233, 1999

[3] TR45.5, The cdma2000 ITU-R RTT candidate submission, v0.17, June, 1998