A Queue Length-based Scheduling Scheme in ATM Networks

Hyun-Ho Yoon*, Hakyong Kim, Changhwan Oh, and Kiseon Kim

Department of Information & Communications,
Kwang-Ju Institute of Science & Technology (KJIST)
1 Oryong-dong, Puk-gu, Kwangju, 500-712 Republic of Korea
*E-mail: hhyoon@kjist.ac.kr

Abstract

In this paper, we propose a new scheduling algorithm, named Queue Length-based Weighted Round Robin (QLWRR), in order to improve the efficiency of the WRR under burst traffic environment.

The proposed scheme can efficiently support the burst traffic by using a threshold value of a queue length and a weight-up factor. Through simulation study, we evaluate performances of the proposed scheme and compare the scheme with the round robin and WRR disciplines, in terms of mean cell delay, 99 percentile cell delay bound, and cell loss rate.

I. INTRODUCTION

Broadband Integrated Services Digital Network (B-ISDN) has to cope with the services which are considerably different in terms of their traffic characteristics and required quality of service (QoS) in a single integrated environment [1]. In order to meet these requirements, switch designers have to grasp the characteristics of traffics and select a processing mechanism suitable for their services and performance requirements.

An ideal scheduling algorithm should be fair and provide isolation among several flows. It is also necessary to computationally simple to allow implementation on high-speed networks [2]. From this viewpoint, per-Virtual Connection (VC) queueing is a good alternative. Per-VC queueing grants that a packet switch schedules cells to be transmitted on a link based on their VC. Furthermore, the switching system using per-VC queueing can efficiently support traffic shaping, connection isolation, and fairness among several flows [3].

In recent years, a number of scheduling schemes for the per-VC queueing have been proposed. Among them, a simple scheduling scheme with firm performance guarantee is Weighted Round Robin (WRR) [4]. The WRR scheme is commonly used as a cell scheduling scheme in the high-speed packet switching networks, such as ATM networks, because of its computational simplicity and low implementation cost. This scheme is designed to assign bandwidth by controlling the amount of time that a particular queue accesses to the server.

However, the WRR scheme has a well-known problem of low efficiency caused by burst traffic. Since the WRR schedules input traffic at a constant rate, burstiness of input traffic should increase its VC queue length. In consequence, cells in such VC queues become to be more delayed. Therefore, it is clearly necessary to improve the efficiency of the WRR scheme under burst traffic environment. Here, we propose a new scheduling scheme in order to diminish the problem caused by the burst traffic, by using a threshold value of a queue length and a weight-up factor.

The remainder of this paper is organized as follows: In Section II, the operation of the round robin discipline and a method to implement a WRR scheduler are briefly described. We then elaborate on the basic concept and algorithm of the proposed scheduling scheme, named Queue Length-based Weighted Round Robin (QLWRR). Section III shows the simulation model and results of the proposed scheduling scheme compared with those of the round robin and WRR disciplines. Finally we conclude this work in Section IV.

II. QUEUE LENGTH-BASED WEIGHTED ROUND ROBIN

Before we explain the basic idea behind the proposed scheme, the brief notion of the round robin and WRR disciplines is described. Fig. 1 depicts a schematic structure of a buffer with multiple VC queues. Each VC queue operates as a FIFO queue for each flow. If there are cells to be sent in the queues, a scheduler determines which cell to be served by a predefined manner.

The round robin discipline is simpler than other scheduling mechanisms for achieving global fairness. It usually operates with a separate FIFO queue for

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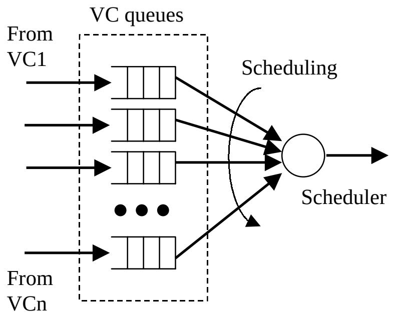

Fig. 1. A structure of a buffer with multiple VC queues.

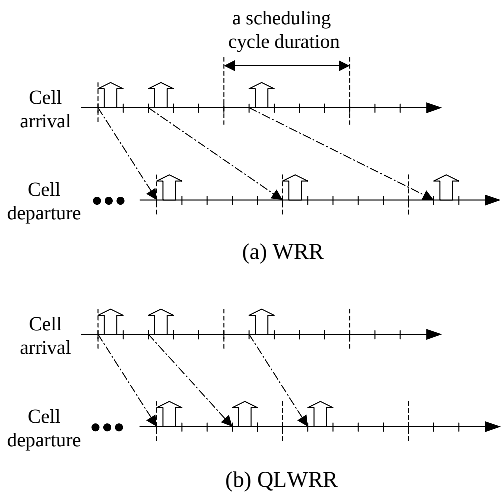

Fig. 2. An example of cell scheduling of WRR and QL-WRR.

each flow. In more detail, multiplexing should be performed by circularly scanning all the VC's and by transmitting one cell from each queue. Empty queues are skipped during the current round.

In the round robin discipline, the scheduler does not take the arrival rate of each flow into account. On the other hand, in the WRR, the scheduler assigns different opportunities of transmission of cells to a VC queue, with regard to its allocated bandwidth. All VC's are visited different number of times during N round cycles. If certain VC's are visited more times than others, then they will get a relatively high share of the bandwidth.

One of simple methods to implement the WRR scheduler is the use of counters, corresponding to the chances to transmit cells for VC queues, which are referred to weights. A counter value of a VC queue is initially set to the weight assigned to the VC. Basically, only VC queues that have their counter value greater than zero can be served in round robin manner. After serving a cell, the counter value is decreased by one. For all VC queues, when the counter value or the queue length has became zero, all counters are reset to their original weight values.

As described before, the WRR scheme has a significant drawback in terms of its performance under burst traffic environment. In order to overcome this inefficiency, we employ two factors, a threshold value of a VC queue length, denoted as Q_{th}, and a weight-up factor, denoted as μ, in the proposed scheme. Here, we show an example which describes the problem of the WRR and the its improvement by using two factors, Q_{th} and μ.

Fig. 2 exhibits an example of the cell scheduling of the WRR and QLWRR. In this figure, we assume that the length of the VC queue of interest has already been excess of the threshold value, and incoming traffic of VC_i has the burst property. In addition, the weight for VC_i is assumed as 1, and μ is equal to the weight.

The cell scheduling of the WRR scheduler is shown in Fig. 2 (a). In a certain scheduling cycle duration, two cells arrive in a queue. However, since the weight is equal to 1, the queue can serve only one cell in a scheduling cycle duration, thus the other cell must wait until the next scheduling cycle. Consequently, the delay of the cell increases.

In this case, if the scheduler allocates more chances to transmit a cell than the weight to the VC queue, which has more cells than a predetermined value, the cell delay and loss would be degraded. In the QLWRR scheduler, we assign an extra weight to the queue whose length is larger than Q_{th}, thus the queue can serve cells more than the preassigned value, as shown in Fig. 2 (b). In this case, since the weight index, which denotes the number of opportunities to send a cell in a scheduling cycle duration, is equal to 2, the queue can serve 2 cells in a scheduling cycle.

As shown in the example, by using two factors of Q_{th} and μ, QLWRR seems to outperform the WRR, in terms of cell delay and cell loss ratio, which will be proved in Section III. Determining the optimal value of the threshold value and the weight-up factor is most consequential to achieve the good performance in the proposed scheme. In this paper, however we do not consider the optimal values of two factors, and we will use fixed values. These must be further studied.

A pseudo code for the proposed scheme is shown in Fig. 3. Here, we define some notations which in the pseudo code.

- Q_i: allocated queue size of VC_i.
- q_i: current queue length of VC_i.
- w_i: allocated weight for VC_i.
- w_i': weight index for VC_i.

The basic operation of the proposed scheme is al-

Connection setup phase

```
q_i := 0;
w'_i := w_i;
```

Cell arrival phase

```
if ( q_i ≤ Q_i ) then
    Enqueue the cell in VC queue i;
    q_i := q_i + 1;
end if
```

Cell scheduling phase

```
if ( w'_i ≠ 0 and q_i ≠ 0 ) then
    Dequeue a cell in VC queue i;
    q_i := q_i − 1;
    w'_i := w'_i − 1;
end if
```

Weight index reset phase

```
for all i
    if ( q_i ≥ Q_th ) then
        w'_i := w_i + μ_i;
    else
        w'_i := w_i;
    end if
end for
```

Fig. 3. QLWRR algorithm.

most same as that of the WRR, except the weight index reset phase. The major difference of the proposed scheme from ordinary WRR is to employ a threshold value of a VC queue length, Q_{th}. In the weight index reset phase, a WRR scheduler always resets weight indexes, which represent the counter values for VC's, to the constant preassigned weights. In the QLWRR, if the current queue length of VC queue i, q_i, is less than Q_{th}, the weight index for VC_i, w'_i, is reset to the given weight, w_i, which is identical to WRR. On the other hand, if q_i is greater than or equal to Q_{th}, then w'_i is reset to $w_i + \mu_i$, where μ_i is a weight-up factor for VC_i.

III. PERFORMANCE EVALUATION

In this section, we evaluate the performance of the proposed QLWRR cell scheduling scheme by computer simulation, after developing a simulation model. We also compare performances of the proposed scheme with those of the round robin and WRR disciplines, in terms of the mean cell delay, 99 percentile cell delay bound, and cell loss rate.

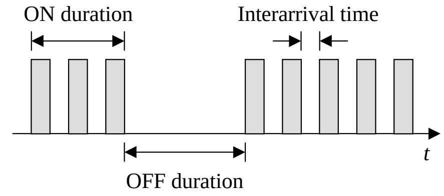

Fig. 4. ON/OFF traffic model.

A. Simulation Model

We consider N traffic sources, where $N \geq 1$, in following simulations. All sources are assumed to be well-behaving users, which means, they always observe allocated traffic parameters at connection setup. The cell generation of the traffic sources follows the ON/OFF traffic model, as shown in Fig. 4. This traffic source model is generally used for the standard voice sources, and is consider as a proper traffic model to represent the burst traffic. It basically has two states, ON state and OFF state. The duration times of ON state and OFF state are exponentially distributed with mean of 10 and 15 cells, respectively. Cells are generated at a fixed interval, T, which is the inverse of the peak cell rate (PCR) of the source, only when the source is in the ON state.

In following simulations, we just consider that the amount of the arrival rates of all VC's, namely the total offered load in an input link, can not exceed the unity, and there is also no overbooking in an output link. We also assume that the aggregate link capacity is 150 Mb/s, and we consider two types of traffic source with different PCR's. The PCR's of type 1 and 2 are 10 Mb/s and 5 Mb/s, respectively. The number of sources of type 1 is assumed to be stationary. Therefore, the total offered load increases as the number of sources of type 2 increases.

Through several experiments, we choose the value of weight-up factor same as the weight value, and the threshold value of VC queue length is set to 6 cells.

B. Simulation Results and Discussion

The first simulation is to show the mean cell delay in various scheduling schemes with infinite VC queues, as shown in Fig. 5. Note that there is no cell loss with infinite VC queue size. At lower offered load than 0.9, the curves for all schemes are almost same. Otherwise, the cell delay in the proposed scheme is less than the WRR. This shows that the QLWRR scheduler can efficiently treat the burst traffic, especially at high offered load.

The QLWRR helps improve the delay performance of the WRR without allocating a large extra bandwidth. Fig. 6 shows the 99 percentile cell delay bound for various scheduling schemes with infinite

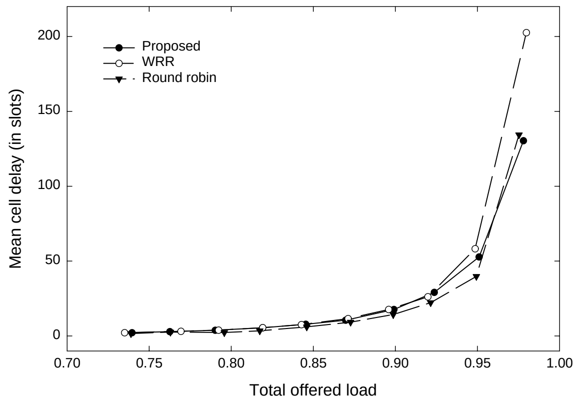

Fig. 5. Mean cell delay with infinite VC queues.

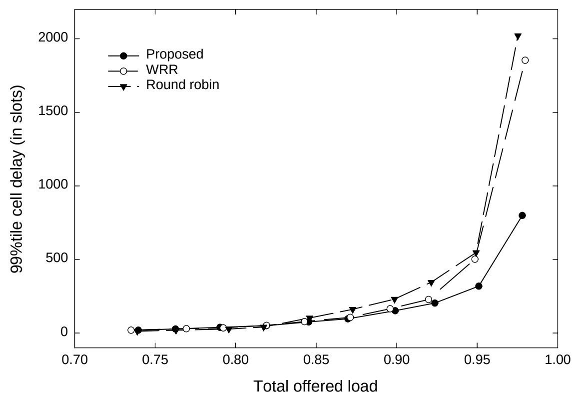

Fig. 6. 99 percentile cell delay bound with infinite VC queues.

VC queues. The 99 percentile cell delay in the QLWRR is significantly less than that in others, at high offered load. From this figure, we can confirm that the QLWRR has preferable traffic sharing characteristics in the burst case, by using the queue length as part of the scheduling information.

The last experiment shows the cell loss performance in various schemes with the finite queue size of 10 cells, as shown in Fig. 7. As mentioned before, the round robin scheduler handles cells from all VC's in the same manner. Consequently, cells from VC's with high rate should be more delayed and lost in the round robin discipline than the other schemes. The cell loss in the QLWRR shows better performance than that of WRR, as expected in the previous section.

IV. CONCLUSIONS

Although the WRR is a simple scheduling scheme, it suffers from the low efficiency in the bursty environment. In this paper, we proposed an efficient cell scheduling scheme, named Queue Length-based Weight Round Robin (QLWRR), which employs the threshold value of the VC queue length, in order to

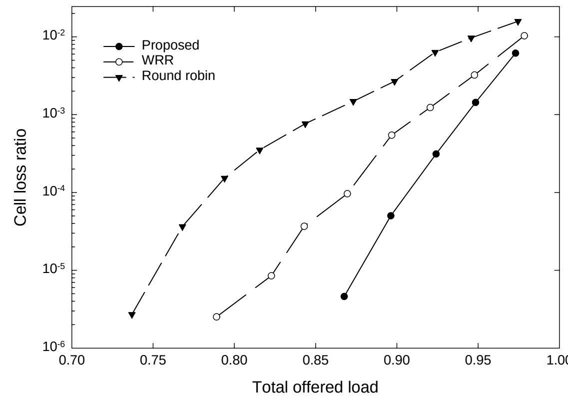

Fig. 7. Cell loss ratio in various scheduling schemes with VC queues of 10 cells.

improve the delay and cell loss performance in the burst traffic case. The proposed scheduling scheme enhances this low efficiency by using the threshold value of the VC queue length and the weight-up factor.

Simulation results show that the QLWRR scheduler can achieve better performance compared with the round robin and WRR disciplines, in terms of mean cell delay and cell loss rate. Furthermore, since QLWRR is a modified version of WRR, it also inherits the computational simplicity of WRR.

To develop the optimal threshold value and weight-up factor is under consideration yet. We remain the determination of the optimal values of those parameters as the further study.

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