A Dynamic Weighted Round-Robin Scheduling in ATM Multiplexer

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Abstract

The weighted round-robin (WRR) scheduling in ATM multiplexer has been proven to be an effective and simple method to implement for priority traffics. However, it is hard to determine exactly how much weight should be assigned to a variable bit rate (VBR) source. Beside, its delay performance becomes poor under bursty traffic conditions, especially for VBR video sources. In order to improve the performance of multiplexer, changing weight dynamically and, if handling video sources, smoothing video traffic are the ways. For multiplexing schedulers, we propose a new dynamic weight-based Round-Robin scheduling scheme. It shows that the new proposed scheme provides delay performance about 81% improvement over the WRR. In smoothing video traffic, we find that the demand of bandwidth and the cell loss probability can be greatly reduced, if we control the initial time of each video connection. Through these two ways, we can improve the system performance which includes reducing the bandwidth requested, the waiting time, and cell loss probability.

Keywords: Dynamic Weighted Round-Robin, Scheduling, ATM, Multiplexer, VBR, video source, MPEG

1. Introduction

In the ATM network, the bit streams of different sources are multiplexed for further transmission or switching. Different sources usually operate with a separate First Come First Service (FCFS) queue for each connection. Therefore, proper multiplexer scheduling the use of a share resource for different connections under a limited bandwidth becomes a very critical problem. There are two levels of multiplexing in the ATM network, namely the physical layer multiplexing and the cell layer multiplexing[1]. Multiplexing in the physical layer deals with the speed aggregation where several low speed links are bundled in a high speed link, e.g., the bundle of four OC-3 links into one OC-12 link in the SONET level. The cell layer multiplexing deals with the multiplexing of various logical connections over the link.

Most of the previous works on the cell level multiplexing were based on the static or fixed assignment. In [2], a Weighted Round-Robin (WRR) cell multiplexer scheduling for multiplexing cells with different priority levels was introduced. Some improved WRR were proposed in [3-5] to improve the delay performance of WRR. Basically, those schemes were still based on fixed weight assignment for each connection. There are some shortcomings in the schemes with fixed weight assignment. First, the improvement is limited for VBR sources. Secondly, for a VBR source, it is hard to determine exactly how much weight must be assigned.

In this paper, we investigate the scheduling scheme of WRR and propose a dynamic weighted round robin algorithm (DWRR) scheme to improve the performance of each connection. In addition to multiplexer scheduling, from simulation runs for video sources, we find the demand of bandwidth and the cell loss probability can be greatly reduced, if we control the initial time of each video connection.

This paper is organized as follows. In Section 2, a simple multiplexing model and an overview of WRR are described. We continue with the description of DWRR in Section 3. Section 4 presents how to control the initial time to smooth the traffic. Finally in Section 5, we give the conclusions.

2. Model of Multiplexer and WRR

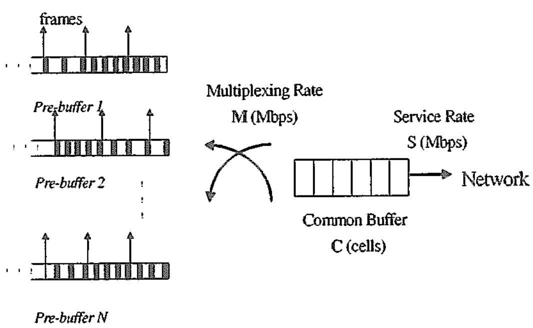

Figure 1. Model of Multiplexer

In this paper, the attention is limited to a single-stage multiplexer, shown in Figure 1. The model of the multiplexer consists of a server, i.e., the shared ATM link, transmitting cells at service rate S Mbps, a common buffer with size C cells, which can be determined by the delay constraints of cells, and N pre-buffers to accommodate VBR video sources. Owing to the rates of video codecs are controllable or predictable, the pre-buffers can be designed large enough to make no cell loss. Therefore, the size of each pre-buffer is assumed to be infinite. The multiplexing rate, i.e., processing or transmission speed, of the multiplexer is assumed to be M Mbps, generally greater than S such that the common buffer is not lossless. Besides, most of the Codec usually use one frame as a unit, so we assume that the cells are transmitted at a constant rate during interframe period, i.e., the cells are uniformly allocated in a frame.

The scheduling scheme WRR was proposed by M. Katevenis et al. in 1991 [2]. It is an extension of Round-Robin and commonly used as a cell scheduler in ATM network because of its computational simplicity and low implementation cost. The WRR multiplexing has been proven to be an effective and simple method to implement for priority traffics. In WRR, each incoming video source was isolated and putted into a different FCFS queue. Each queue has a counter specifying the number of cells that can be sent from it. The counter value is initially set equal to the weight value assigned to that queue. Cells sent in a cycle are from those queues which are not empty and with positive counter value. Just one cell can be sent per visit time. After sending a cell, a queue's counter value is reduced by one. When the counter value or the queue length has reached zero in each queue, all counters are reset to their weight values [3].

The basic idea of WRR scheduling is stated as follows. In Fig. 2(a), for example, all queues are visited different times during every 10-visit cycle. Queues *a*, *b*, *d*, and *f*, are visited twice more times than queues *c* and *e*, then they will get a relatively high share of the bandwidth. In order to have a smaller inter-service delay jitter of a queue, for example, two successive visits to *a* are separated by either three or five other visits. In Figure 2.2 (b), the frequencies of visits are maintained the same, but the visits to the "frequent" clients are spread more evenly in time [2].

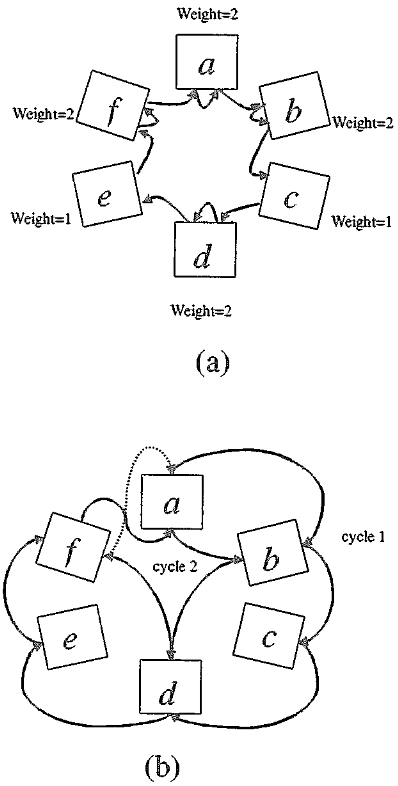

Figure 2. WRR (a) Simple Indication (b) Evener visiting manner

An example of WRR used in scheduling scheme of multiplexer is shown in Figure 3. Output cells are transmitted in a fixed fashion, which called a counter reset cycle. The length of a counter reset cycle is the summation of all weights of pre-buffers, if each pre-buffer is not empty in every visit. WRR scheduling scheme is based on the static weight and multiplexes cells from each pre-buffer with different priority level. It is well suited to CBR video sources. However, it does not suit to bursty traffic, VBR video sources especially. For a VBR video source using WRR, there may at times be more cells arriving than its weight value supported in one counter reset cycle. Therefore burstiness in input traffic becomes a major factor in creating delay. In such a cycle, the counter value will reach zero before all the cells in the pre-buffer have been sent. Thus, many cells will be suspended until the next or an even later counter reset cycle. This incurs large delay. Consequently, the delay performance of WRR becomes poor under bursty traffic conditions [3, 4].

If we use a static weight for a pre-buffer, it is difficult to handle the bursty traffic of for the pre-buffer. In order to improve the performance of the multiplexer, changing weight dynamically and smoothing video traffic are the ways. In multiplexing scheduler, we propose a new DWRR scheduling scheme. Generally, the weight of WRR is obtained according to the bit rate or delay constraint. In this paper, the bit rate is adopted as the criterion to determine the weight, since all the real-time data are movie-like video sources which have the same delay constraint. On the other hand, the variation of bit rates of frames in MPEG-1 video source is large. This is caused by the compression technique [6]. In smoothing traffic, we find that if we control the initial time of each video connection, the demand of bandwidth and the cell loss probability can be significantly reduced. These two issues, changing weight dynamically and smoothing video traffic, will be studied below.

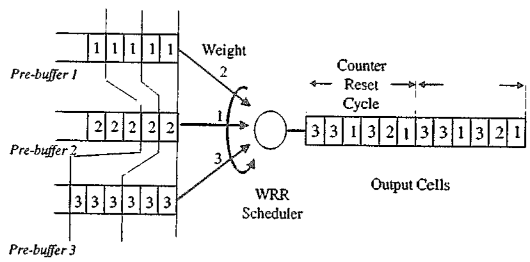

Figure 3. Weighted Round Robin Scheduler [3]

3. Dynamic Weighted Round-Robin

If the bit rate is used to be the base for determining the weight, then the time to change weight in DWRR is whenever the bit rate changes. Therefore, the time to change weight can be simply chosen at a new frame arriving at the head of pre-buffer. Nevertheless, what value should be the weight changed to? The weight in fact is the number of cells should be served in a round, so the number of cells in a frame can be used as the weight. Consequently, the weight will be changed to be the number of cells in the new frame when the new frame is just the head of pre-buffer. Additionally, to avoid the DWRR degrading to the round-robin when the traffic is very high, the video frames of all video sources are synchronized. In this way, there is a side effect. The moment to change weights of all video sources is aligned to a single point, because all the video sources begin a new frame at the same moment. Using this scheduling scheme DWRR, the following numerical examples will illustrate it reserves the advantage of WRR to suit for CBR video sources and improves the delay performance of WRR for VBR video.

Table 1 shows the simulation results of WRR and DWRR. The input to the multiplexer is six CBR video sources whose transmission rates are 0.3, 0.5, 0.45, 0.4, 0.42 and 0.47 Mbps, respectively. The Multiplexer Rate M and Service Rate S are fixed to 5 Mbps and 2.6 Mbps, respectively. The size of common buffer is 200 cells. When the number of total clls entering the common buffer reaches 1000000, the simulation will be terminated. In Table 1, the results of WRR are the same as those of DWRR, i.e., DWRR reserves the advantage of WRR and suits for CBR video sources.

As regards the VBR sources, table 2 illustrates DWRR improves the drawback of the poor delay performance of WRR under bursty traffic conditions. In this case, the input to the multiplexer is 12 VBR MPEG-1 video sources. The VBR sources are taken from [7]. The multiplexing rate, the service rate, and the common buffer size are 15 Mbps, 5 Mbps, and 200 cells, respectively. In Table 2, the average waiting time is reduced from 2.112 ms to 0.393 ms after dynamically changing the weight. For a given tolerable cell loss probability, the delay performances are improved about 81% by DWRR. Furthermore, the differences of delay among pre-buffers are reduced, i.e., the DWRR provided a fairer treatment for all video sources. In a word, DWRR provides a better scheduling scheme than WRR.

	WRR	*DWRR*		*WRR*	*DWRR*
Overall loss probability	0	0			
Overall mean waiting time (ms)	0.326	0.326			
Pre-buffer #1			***Pre-buffer #4***		
Loss probability	0	0	**Loss probability**	0	0
Served Number	118193	118193	**Served Number**	157465	157465
Block Number	0	0	**Block Number**	0	0
Mean waiting time(ms)	0.350	0.350	**Mean waiting time(ms)**	0.376	0.376
Pre-buffer #2			***Pre-buffer #5***		
Loss probability	0	0	**Loss probability**	0	0
Served Number	196935	196935	**Served Number**	165295	165295
Block Number	0	0	**Block Number**	0	0
Mean waiting time(ms)	0.323	0.323	**Mean waiting time(ms)**	0.324	0.324
Pre-buffer #3			***Pre-buffer #6***		
Loss probability	0	0	**Loss probability**	0	0
Served Number	177195	177195	**Served Number**	184923	184923
Block Number	0	0	**Block Number**	0	0
Mean waiting time(ms)	0.288	0.288	**Mean waiting time(ms)**	0.307	0.307

Table 1. WRR and DWRR with CBR sources

	WRR	*DWRR*		*WRR*	*DWRR*
Overall loss probability(%)	1.034	0			
Overall mean waiting time (ms)	2.112	0.393			
Pre-buffer #1			*Pre-buffer #7*		
Loss probability(%)	0.062	0	Loss probability(%)	0.135	0
Served Number	78598	89836	Served Number	77873	89623
Block Number	49	0	Block Number	105	0
Mean Waiting Time(ms)	1.865	0.361	Mean Waiting Time(ms)	1.737	0.319
Pre-buffer #2			*Pre-buffer #8*		
Loss probability(%)	0.163	0	Loss probability(%)	0.162	0
Served Number	93783	102253	Served Number	93781	102221
Block Number	154	0	Block Number	152	0
Mean Waiting Time(ms)	2.142	0.441	Mean Waiting Time(ms)	2.295	0.313
Pre-buffer #3			*Pre-buffer #9*		
Loss probability(%)	0.062	0	Loss probability(%)	0.074	0
Served Number	55236	61964	Served Number	55182	62171
Block Number	34	0	Block Number	41	0
Mean Waiting Time(ms)	1.325	0.282	Mean Waiting Time(ms)	2.328	0.375
Pre-buffer #4			*Pre-buffer #10*		
Loss probability(%)	0.097	0	Loss probability(%)	0.055	0
Served Number	98863	104779	Served Number	98750	104784
Block Number	96	0	Block Number	54	0
Mean Waiting Time(ms)	1.681	0.381	Mean Waiting Time(ms)	2.006	0.362
Pre-buffer #5			*Pre-buffer #11*		
Loss probability(%)	0.097	0	Loss probability(%)	0.096	0
Served Number	91509	104953	Served Number	91529	105358
Block Number	89	0	Block Number	88	0
Mean Waiting Time(ms)	3.161	0.653	Mean Waiting Time(ms)	2.685	0.636
Pre-buffer #6			*Pre-buffer #12*		
Loss probability(%)	0.127	0	Loss probability(%)	0.083	0
Served Number	81846	88474	Served Number	82028	88483
Block Number	104	0	Block Number	68	0
Mean Waiting Time(ms)	2.266	0.426	Mean Waiting Time(ms)	1.530	0.353

Table 2. WRR and DWRR with VBR sources

4. Initial Time and Bandwidth Requested

After some simulation runs, we find that the initial time of each video source can affect the bandwidth required very significantly. If initial time of each source starts during the I-frame period of connected sources, it will cause the required bandwidth to increase suddenly, owing to the overlap of I-frames. This phenomenon can be illustrated by Figure 4. In Figure 4, assume the initial time of the second and the third video sources are t0 and t1, respectively. Owing the DWRR, they will be delayed to the time t2. It will cause a very high cell rate during the time interval between t2 and t3. It will increase the cell loss probability if the network has not enough bandwidth. According to the

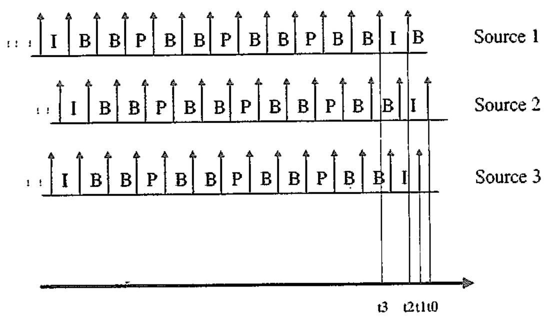

Figure 4. Arbitrary initial time

result of simulation in which we use the same input as Table 2, the peak rate into the common buffer in case of arbitrary initial set-up time is 12.6 Mbps. It is very difficult to decide the bandwidth required since the peak rate is too large. If we control the initial time of each connection, there gains a different result.

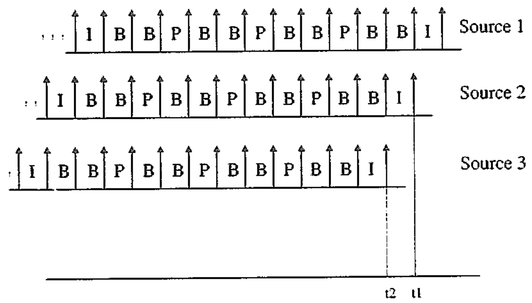

Figure 5. Initial time under control

For any new set-up request, we let it start outside the I-frame period of any connected sources (see Figure 5). In this way, the rate variation of cell stream after aggregation can be lowered down to reduce the bandwidth requested and simultaneously to cause the cell loss probability lower. According to the result of simulation, the peak bit rate of the same input as above with initial times under control is 6.12 Mbps. The decrement is over 50%. That is, it is lessened largely, by paying only a little additional cost. The cost of controlling the initial time is to delay the beginning time of the connection. For example, if we use 2 video sources, in the worse case where the initial time of the second video is the same as the I-frame of the first video, the second video will be delayed for about 1 frame time (40 ms) at most. In the case of n video sources, the delay time of the last video source is about $n-1$ frame times in the worse case. It is worth to exchange a little delay time with a lot bandwidth reduced. For a better performance, we suggest that the initial time of new connection should not start inside the I-frame period of any connected sources.

5. Conclusions

The WRR multiplexing has been proven to be an effective and simple method to implement for priority traffics. The WRR scheduling scheme is based on the static weight and multiplexes cells from each pre-buffer with different priority level. It is well suited to CBR video sources. However, it does not suit to bursty traffic, VBR video sources especially. In order to improve the performance of the multiplexer, changing weight dynamically and smoothing video traffic are the ways. Therefore, this paper proposes a new scheduling scheme DWRR to change the weight dynamically. DWRR reserves the advantage of WRR to suit for CBR video sources and improves the delay performance of WRR for VBR video. For a given tolerable cell loss probability, the delay performances are improved about 81% by DWRR. Furthermore, the differences of delays among pre-buffers are reduced, i.e., the DWRR provided a fairer treatment for all video sources. In a word, DWRR scheduling scheme is a better scheduling scheme than WRR. In smoothing traffic, we find that if we control the initial time of each connection, we will greatly decrease the demand of bandwidth and the cell loss probability. For a better performance, we suggest that the initial time of new connection should not start inside the I-frame period of any connected sources. Through these two ways, the system performance can be improved, including reducing the bandwidth requested, the waiting time, and cell loss probability.

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