New Buffer Management Scheme to Support TCP/IP Traffic over ATM GFR service

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Abstract: We propose new buffer management scheme for GFR service through FIFO queuing discipline. Proposed scheme can provide minimum bandwidth guarantees for GFR VCs as well as improve the fairness among the competing GFR VCs on a single FIFO queue. From simulation results, we demonstrate the proposed scheme fulfills the requirements of GFR service as well as improves the TCP throughput.

1. Introduction

The Guaranteed Frame Rate service category was proposed by the ATM Forum as an enhancement to the UBR service [1]. This service aims to support minimum cell rate guarantee for each virtual connection and allow any excess bandwidth in the network to be shared among the contending VCs in a fair manner. IP routers connected by ATM networks can setup GFR VCs for data transport and then TCP/IP traffic can benefit from ATM GFR services.

GFR service category is designed to support classical best-effort traffic such as TCP/IP based traffic. It provides the user with a minimum cell rate (MCR) guarantee under a given maximum frame size (MFS) and maximum burst size(MBS). The identification of packets to which the service guarantee applies is based F-GCRA(Frame-Generic Cell Rate Algorithm)[1].

In this paper, we propose new buffer management scheme to provide QoS for GFR service based on perVC-accounting. The organization of this article is as follows. Section 2 gives an overview of GFR service category and an insight into the problems of previous schemes. In section 3, we present our proposed buffer management scheme. In section 4, we present the simulation results with TCP traffic over LANs interconnected via an ATM network. Finally, section 5 gives conclusion.

2. Overview of GFR implementation

Several approaches have been proposed to provide bandwidth guarantee to TCP sources through FIFO queuing in ATM networks. The Selected Drop(SD) and Fair Buffer Allocation(FBA) schemes use perVC-accounting to maintain the current buffer utilization for each UBR VC[2]. They can just guarantee equal throughput but not specific rate for competing VCs. Another scheme to implement GFR service is Double-EPD(Early Packet Discard). Double-EPD proposed in [3] is the simplest mechanism that neither uses perVC-accounting nor perVC-scheduling. It designates two global thresholds based on the packet priorities. When queue length exceeds LBO(Low Buffer Occupancy) threshold, newly arrived tagged packet(CLP = 1) are dropped. When queue length exceeds HBO (High Buffer Occupancy) threshold, newly arrived untagged packet (CLP = 0) are dropped. Double-EPD neither provides MCR nor is fair in allocating bandwidth to VCs.

The Differential Fair Buffer Allocation (DFBA) buffer management scheme proposed in [4] is based on perVC-accounting. DFBA utilizes some of the features of the Double-EPD, WFBA (Weighted FBA) and RED (Random Early Detection) buffer acceptance. It maintains two global thresholds same as Double-EPD. When queue length exceeds LBO, all incoming tagged packets are discarded. When queue length exceeds HBO, all incoming packets are discarded.

When queue length is between two thresholds, untagged packets are dropped according to a probabilistic manner if a VC has larger buffer occupancy than its fair share.

When buffer occupancy is lower than LBO, DFBA can not allocate buffer space to GFR VCs fairly. Thus, this makes it possible that VC with small MCR achieves more throughput than its fair share.

3. Proposed buffer management scheme

This paper develops a packet drop policy to design a buffer management scheme for the GFR service category. The proposed scheme supports GFR service according to GFR.2 conformance definition. The conformance test of F-GCRA is intended to allow the network to satisfy GFR service guarantee. The previous buffer management schemes can achieve MCR throughput for GFR service by keeping the throughput of untagged cells. However, the amount of untagged packets is insufficient to achieve MCR throughput due to burstness nature of TCP traffic [5]. The proposed scheme use dynamic threshold and estimation of service rate to provide MCR guarantee and to improve fairness.

3.1 Dynamic threshold and estimation of service rate

The proposed scheme uses two global thresholds and one dynamic perVC threshold. Two global thresholds are similar to the Double-EPD scheme. The first threshold is LBO to handle tagged packets and the second threshold is HBO to handle untagged packets. A dynamic perVC threshold Th_i assigned to individual VC is used to limit buffer occupancy of ill-behaviored VCs in fair manner.

$$Th_i = w_i / C_{GFR} \times \min(\max(QT, LBO), HBO) \quad (1)$$

Where w_i is the weight of i-th GFR VC and be set to MCR + fair share. C_{GFR} is allocated bandwidth for GFR service and QT is total buffer occupancy.
Equation 2 gives the weight of VC in MCR + equal share manner [1].

$$w_i = MCR_i + \frac{C_{GFR} - \sum_{j=1}^{N} MCR_j}{N} \quad (2)$$

Where MCR_i is minimum cell rate of i-th GFR VC and N is the number of GFR VC.
It is difficult to provide MCR guarantee and fairness to GFR VCs due to busty nature of TCP traffic. To solve this problem, we consider the service rate of GFR VC. The service rate combined with dynamic perVC threshold is Th_i used to improve fairness.
The service rate of GFR VC can be estimated by the exponential average method as follows.

$$r_i = (1-\alpha)\frac{l_i^k}{T_i^k} + \alpha \cdot r_i \quad (3)$$

Where α is exponential weight and $0 < \alpha << 1$. l_i^k is k-th incoming packet length of i-th GFR VC and T_i^k is inter-arrival time of k-th packet.

3.2 Packet dropping policy

Packet dropping procedure of the proposed buffer management algorithm is described as follows.
When buffer occupancy is lower than LBO, buffer occupancy of i-th VC exceeds Th_i and service rate r_i exceeds weight w_i, newly incoming tagged packets are dropped.
When buffer occupancy exceeds LBO and buffer occupancy of i-th VC exceeds Th_i, newly incoming tagged packets are dropped. In case of untagged packet, when buffer occupancy is lower than HBO, r_i exceeds w_i and buffer occupancy of i-th VC exceeds its threshold, untagged packets are dropped. If buffer occupancy exceeds HBO, all incoming packets are dropped as like Double-EPD.

4. Simulation

4.1 Simulation model

For computer simulation, we made the ATM simulator using C++ language. Our ATM simulator is based on event-driven simulator composed of various components such as switch, end system, link, traffic source that interacts with other component by events.
A network topology shown in Figure 1 is used to illustrate the performance of our proposed scheme. As shown in the figure 1, local IP/ATM edge routers are connected to backbone ATM switches. Each router fairs carries traffic from 5 TCP connections which are all greedy sources. The backbone link carries 6 GFR VCs. All links are OC-1(51.84 Mbps) and the transmission delay is 10 msec between two ATM switches and 0.5 msec between router and adjacent ATM switch.

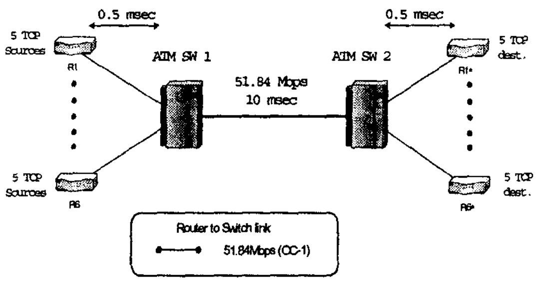

Fig. 1. The network configuration used in simulation.

The maximum segment size of TCP is 960 bytes, window size is 65,535 bytes and retransmission timer granularity is set to 50 msec. In this simulation, we compare performance of our proposed scheme with Double-EPD and DFBA. The major performance measures considered here are TCP goodput and fairness index.

4.2 Numerical result

Simulation results in TCP goodput and fairness index are shown in Table 1.
Fairness index is defined as follows.

$$fairness\ index = \frac{\left(\sum_{i=1}^{N} x_i / f_i\right)^2}{N \times \sum_{i=1}^{N} (x_i / f_i)^2} \quad (4)$$

Where x_i is the actual throughput of VC_i, f_i is fair share of VC_i and N is number of VCs.
Figure 2 shows aggregated TCP goodput for different MCR allocation. As shown in figure 2, Double-EPD and DFBA fail to satisfy minimum throughput of VCs which have large MCR. However, the proposed scheme can satisfy those in all VCs.

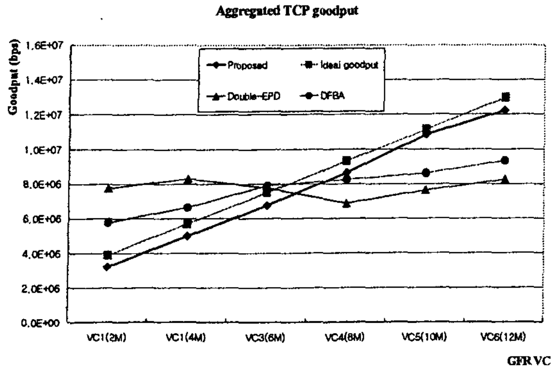

Fig. 2 Aggregated TCP goodput (LBO = 2K cell, HBO = 6K cell, Buffer size = 8K cell)

Table 1. Performance comparison with Double-EPD, DFBA, Proposed

	Double-EPD	DFBA	Proposed
Fairness index	0.831762	0.937876	0.9972715
Total goodput	46.62 Mbps	46.59 Mbps	46.74 Mbps

The proposed scheme improves the fairness index by approximately 16% and 6% from Double-EPD and DFBA as well as provides better total TCP goodput than others as shown in Table 1. The improvement of fairness and total goodput in the proposed scheme is due to dynamic perVC threshold and estimation of service rate.

■ Effect of LBO threshold

To investigate effect of LBO threshold, we vary LBO threshold from 500 to 3K cell. Total TCP goodput and fairness index is shown in figure 3 and 4. As shown in figure 3 and 4, the proposed scheme provide better throughput and fairness index than other schemes in any LBO threshold. It is due to dynamic perVC threshold that decrease the effect of LBO threshold.

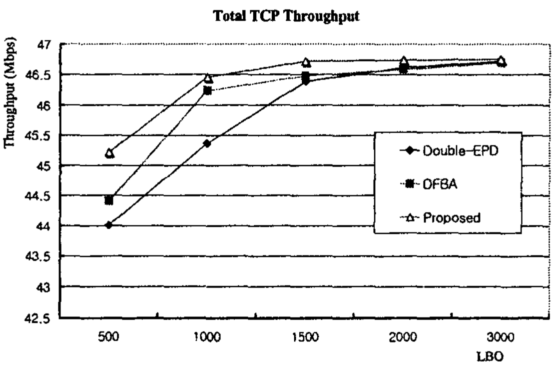

Fig. 5. Total TCP goodput with different LBO

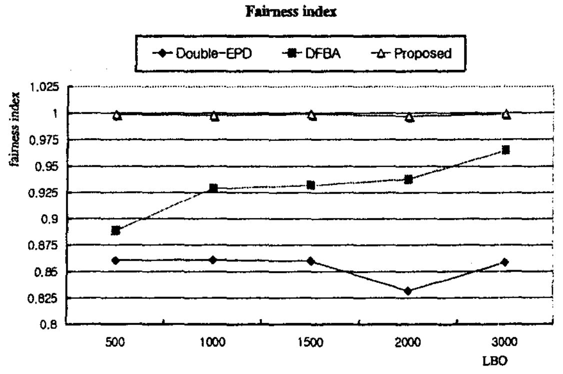

Fig. 6. Fairness index with different LBO

■ Effect of heterogeneous transmission delay

To investigate the effect of heterogeneous transmission delay, we separate six VCs into two groups. The first group is VC1 to VC3 that is assigned a transmission delay with 6 msec and the second group is VC4 to VC6 that is assigned a transmission delay with 11 msec. Figure 7 shows TCP goodput of VC with different MCR. In cases of Double-EPD and DFBA, VC4 to VC6 with larger transmission delay obtain less goodput than ideal TCP goodput, whereas VC1 to VC3 with smaller transmission delay obtain much more goodput than ideal TCP gooput. Simulation result with the proposed scheme reveals a small influence of the transmission delay in TCP goodput. Therefore, all VCs can achieve TCP goodput closed to ideal goodput.

Table 2 shows total TCP goodput and fairness index of Double-EPD, DFBA and the proposed scheme in different transmission delay. The proposed scheme improves fairness index when compared to Double-EPD and DFBA for 4% and 4.6%, respectively.

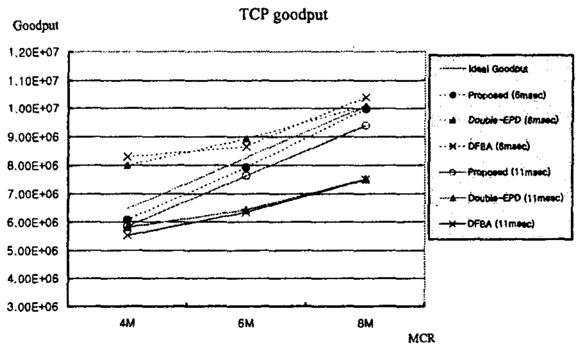

Fig. 7. Aggregated TCP goodput with different transmission delay

Table 2. Performance comparison with different transmission delay.

	Double-EPD	DFBA	Proposed
Fairness index	0.969004	0.9627986	0.99918432
Total goodput	46.80 Mbps	46.79 Mbps	46.90 Mbps

5. Conclusion

Guaranteed Frame Rate service category has been designed to support TCP/IP traffic through ATM network. In this paper, the proposed buffer management scheme is able to fulfill the QoS of GFR service in single FIFO queue. The dynamic perVC threshold combined with service rate estimation provides nearly optimal throughput and improves fairness performance of network resource among GFR VCs as well as guarantees MCR of all VCs.

References

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