An Enhanced UBR+(EUBR+) scheme to improve the performance of TCP-over-ATM

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ABSTRACT

TCP is the most widely-used transport layer protocol in current Internet, while ATM technology is used to increase the data communication speed at data link layer and network layer. In the TCP-over-ATM architecture, the most significant problems are (i) the partial packet discarding problem, and (ii) the TCP window timeout problem. Several approaches have been proposed to solve the partial packet discard problem and the timeout problem individually, but none of them considered the two problems together.

In this paper, we propose an enhanced UBR+ scheme which supports fairness among the TCP connections using UBR+ scheme, and provides protection of *damaged VC* from the multiple packet losses in the same TCP sliding window. To analyze its performance, we simulate the proposed scheme using OPNET. The simulation results show that the proposed scheme supports fairness, and also increases the throughput by reducing the probability of multiple cell losses in the same TCP window.

Ⅰ. Introduction

TCP has become the most widely-used transport protocol of current Internet because of its ability to provide reliable end-to-end transport capability with window-based flow control. It provides several congestion control schemes such as slow-start, congestion avoidance, and fast retransmit with fast recovery. In TCP-over-ATM interworking architecture, however, TCP suffers from the partial packet discard problem because of the ATM cell fragmentation of TCP segment. The TCP segment must be fragmented into ATM cells, and these multiple ATM cells should be delivered to the destination correctly to ensure the correct TCP segment delivery.

The two major reasons of the performance degradation in the TCP-over-ATM are the *partial packet discard problem* and *the timeout problem.*

When a congested ATM switch drops a single ATM cell that is a part of a TCP segment, the entire segment is corrupted. This results in the upper TCP layer segment-loss. Consequently, in worst case, TCP may often lose several segments from the same window, and can usually recover from that only after the expiration of retransmission timer. This retransmission following relatively long timeout significantly reduces the overall TCP performance.

Even though a partial packet discard occurred, he rest of the cells belonging to a partially discarded packet(TCP segment) may continue to travel through the network, consuming bandwidth and buffer space unnecessarily. Furthermore, the transmission of these useless cells at congestion period may makes the situation worse, and cause other TCP segments to be discarded partially. As a result, the loss of cells belonging to other packets, due to the resource consumption by cells of a corrupted packet, reduces the network performance significantly.

In order to minimize the effect of the partial packet problem, the *Partial Packet Discard (PPD)* [1], and the *Early Packet Discard(EPD)*[2] schemes

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have been proposed. In PPD, when a cell is discarded, the congested ATM switch discards the rest of cells belonging to the same packet, and the preceding cells are delivered to the destination. However these cells consume the network resource. To eliminate the network resource consumption by the preceding cells, the EPD scheme discards all cells belonging to a TCP segment when the buffer occupancy exceeds the fixed buffer threshold. This mechanism improves performance of TCP better than the PPD. But it also suffers from low fairness[3,4]. The original URB+ algorithm supports fairness using selective discarding and fair allocation[4,5]. But this scheme suffers from timeout problem caused by multiple cell losses in the same TCP window size.

In this paper, we enhance the UBR+ algorithm to remedy the timeout problem. To guarantee the fairness among the TCP connections and to protect the multiple packet losses from the same window, we propose an enhanced UBR+(EUBR+) algorithm. To analyze and evaluate the proposed scheme, we simulated various environments with OPNET. The rest of this paper is organized as follows: Section 2 discusses in detail the two main problems that degrade the performance of TCP-over-ATM. Section 3 discusses the proposed scheme that solves timeout problem and supports fairness in detail. In Section 4 we present the simulation results and analyze the performance of the proposed scheme. Finally, we conclude this paper in Section 5 .

Ⅱ. Performance of TCP over ATM

The performance of TCP-over-ATM is degraded due to the two following problems:

(i) Timeout Problem The loss of a single cell at ATM layer causes the loss of one TCP segment at the upper TCP layer. So, the multiple cell losses make multiple segment losses at the TCP layer. If multiple packet-losses occur in the same TCP sliding window by the multiple ATM cell losses, the retransmission time of the partially corrupted TCP segment is delayed, in worst-case to the time-out period. This delayed retransmission causes the performance degradation at TCP layer.

(ii) Partial Packets Problem The rest of the cells belonging to a partially discarded datagram continue to travel over the network, consuming bandwidth and buffer space unnecessarily.

Two mechanisms have been proposed to solve the partial packet problem: Partial Packet Discard (PPD) and Early Packet Discard (EPD). In PPD, when a cell has been discarded, the same ATM switch discards the rest of the cells belonging to the same packet. Still, some bandwidth and network resources are wasted while delivering the preceding cells of the packet, which arrived and has been stored in the buffer prior to the loss.

The EPD saves this bandwidth, by identifying in advance the possible packet that is likely to encounter a cell loss, and discarding all the cells of the would be-partially-discarded packet. These mechanisms do improve the performance, but they suffer from low fairness, and their contribution is negligible when the network is not in heavily congested states.

Retransmission of timeout TCP-segment cause significant throughput degradation. When a segment is dropped from a TCP connection, the sender does not get an acknowledge(ACK) of the dropped segment from the receiver, so the sender cannot advance its sending window. After sending all the data in the sending window, and without being able to advance the widow, the sender remains idle until the lost-segment's retransmission timer expires. Then the sender retransmits the first segment in the window whose ACK was not received, and restart the a window with size of one segment in the slow-start mode. Thus the sender recovers the normal window size from a segment loss with long afterward period using the fast-retransmit mechanism, where the third duplicate ACK triggers the retransmission.

If multiple segments are dropped from a same TCP window caused by ATM cell losses in a congested ATM switch, it takes a long time to recover from the congestion. Because TCP can only recover fast by fast-retransmit with high probability only if less than 3 segments are lost within the same window[6].

In [6], with small windows size, even a ATM cell loss might result in a timeout. However for long transfers and reasonable loss rates, *cwnd* is not so small most of the time. Keeping the number of losses from the same window less than 3 is sufficient in order to minimize the probability of a timeout. To limit the number of segment losses from the same window less then 3, we should include some additional functions to UBR+ algorithm.

Ⅲ. The Enhanced UBR+ Scheme

In the proposed enhanced UBR+(EUBR+) scheme, we limit the loss of segment less than three to reduce the probability of the delayed retransmission by timeout[6]. The basic idea is to protect VC that has lost a TCP segment recently. To protect multiple segment losses, the proposed scheme reserves buffer space, which is called *recovery_zone*. Fig. 1 shows the flow chart of this algorithm.

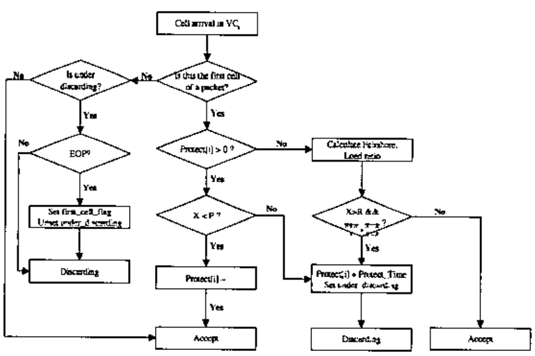


Fig. 1 Flowchart of Enhanced UBR+ Algorithm

Since the EUBR+ algorithm is an extension of UBR+ algorithm, UBR+ algorithm uses the selective discarding and the fair buffer allocation to support the fairness and to improve the efficiency. EUBR+ also supports fairness among the TCP connections and other non-TCP connections. But this scheme addresses the timeout problem additionally.

In order to minimize the occurrence of timeouts, our scheme aims at preventing multiple segment losses from the same TCP window. The buffer has two thresholds: one for EPD, another for *recovery_zone*. When the first cell arrives, the UBR+ algorithm is activated to guarantee the fairness and to avoid global synchronization. If this cell is discarded by UBR+ algorithm, this VC is marked as *damaged_VC*. The damaged_VC is a VC that has lost a cell recently. If the following cell arrives, and if it is belong to the damaged_VC_i, we give a chance for the *damaged_*VC_i to use the reserved buffer space, *recovery_zone*.

When the current buffer occupancy (X), exceeds the EPD threshold (R), UBR+ scheme is applied. If UBR+ scheme drops a cell, all subsequent cells and the related cells in the buffer are discarded as in the EPD scheme, the VC is marked *damaged_VC* and allowed a higher priority over the non-damaged VCs. Because this damaged_VC has a chance to use the recovery zone, between R and P, it is protected from the multiple cell losses in a statistic view. In EPD scheme, if a cell is dropped from a VC i, there is probability for VC i to drop the next cell which may cause multiple cell losses from the same TCP window. In the proposed scheme, EUBR+, using the recovery zone that prevents multiple contiguous cell discards and reduces this probability. The damaged_VC uses the recovery zone for a certain time period that is defined as *guaranteed period*.

Ⅳ. Simulation and Analysis

In order to evaluate the proposed scheme, we implemented a simulation program with the OPNET network simulation tool [7]. OPNET supports ATM and various network functional modules. Since OPNET version 6.0.L does not support intelligent cell dropping schemes such as PPD or EPD scheme yet, we also implemented these schemes to compare the performances. The compared performance metrics are as follows:

- TCP Connection Congestion Windows Size [bytes]
- TCP Retransmission Timeout[second]
- Buffer size and Lost cell size
- Received traffic by the Server node

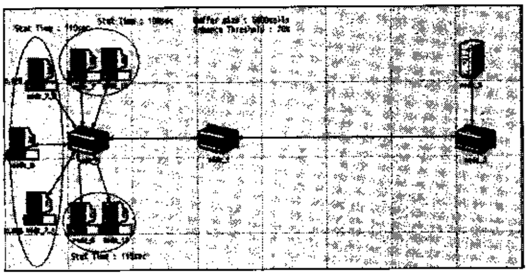
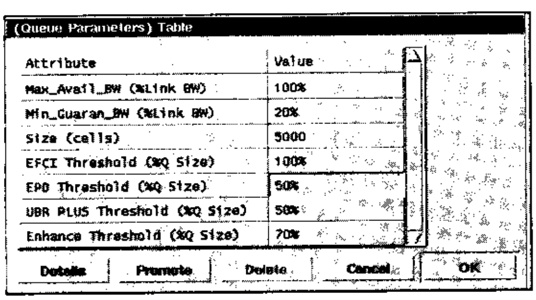


Fig. 2 Test Network Topology

Fig. 2 depicts the test network topology. It consists of three ATM switches with intelligent cell dropping schemes, seven nodes that produce network traffic, and one server that receives the traffic from the seven nodes. The capacities of all links are 2Mbps, except just the congested link, which is 1.5Mbps.

All nodes generate TCP(FTP) traffic but start at different time. Two nodes start at 100sec, three nodes begin at 110sec and the rest start at 120sec until the end of the simulation time. The simulation duration is set to 10 minute. Three switches have 50,000 cell queue capacity. The EPD threshold is set to 50%, UBR+ threshold to 50%, and EUBR+ threshold to 70% of the queue capacity. Fig. 3 shows the ATM switch buffer configuration of the congested switch.

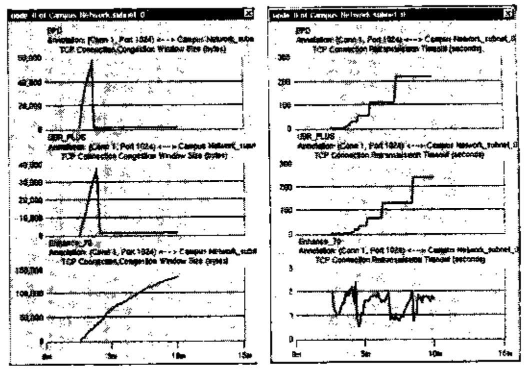
In order to analyse the packet discarding schemes's performance under the same traffic, we generate the same traffic with same seed value and evaluate the TCP congestion window size that restricts the upper bound of transmission. Fig. 4 show the node_13's congestion window size and retransmission timeout value.


(Queue Parameters) Table

Attribute	Value
Max_Avail_BW (%Link BW)	100%
Min_Guaran_BW (%Link BW)	20%
Size (cells)	5000
EFCI Threshold (%Q Size)	100%
EPD Threshold (%Q Size)	50%
UBR PLUS Threshold (%Q Size)	50%
Enhance Threshold (%Q Size)	70%

Details | Promote | Delete | Cancel | OK

Fig. 3 ATM Buffer Configuration



(a)TCP Congestion Window Size (b) TCP Retransmission Timeout

Fig. 4 TCP Congestion Window Size(bytes) and Retransmission Timeout(sec)

The congestion window size of the EPD and UBR+ shows that it is dropped suddenly because of the congestion in the network. This makes the retransmission timeout value to be increased as shown in (b). But the proposed scheme's congestion window size is not decreased and the retransmission timeout values is below the 3 second. These fact show that the EUBR+ scheme reduces the timeout probability and also reduce the probability of multiple packet losses that makes the TCP performance be delegated.

A buffer utilization of a congested ATM switch is shown in Fig 5. In EPD the buffer utilization falls to zero frequently as we expected. This continuous zero buffer size is cased by the TCP congestion control algorithm which may raise the probability of multiple cell losses. In UBR+ scheme, the zero queue size is not frequently shown. But it is shown 4 time zero queue size. In EUBR+ there is only one time zero queue size which show that the probability of the multiple cell losses has been reduced and the TCP performance has been enhanced as well.

To see the number of cells discarded under the network congestion, we add additional statistic

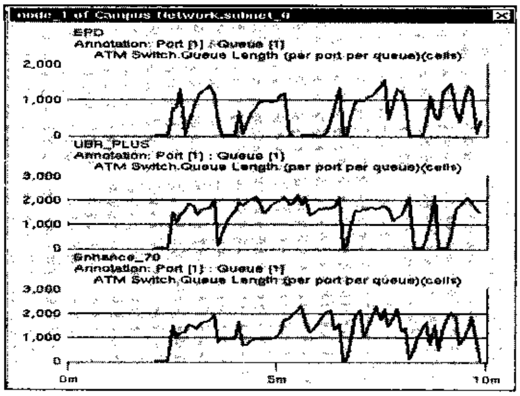
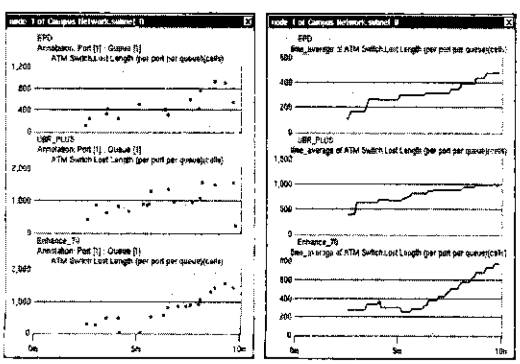


Fig. 5 Buffer Length of a Congested ATM Switch(cell)

probe, lost cell size, to the ATM switch module.

Fig. 6 depicts the lost cell size and the average value in the congested ATM switch. The lost cell size is the accumulated value. In EPD, because it stops transmitting traffic when the buffer size exceeds the EPD threshold, the lost cell size is lower than those of other two scheme. The constant value of lost cell size means that the congested ATM switch drops no or a little of cells. Although the average value of the EUBR+ is increasing, the lost cell size is less than that of UBR+ algorithm. It also does not mean continuous cell loss. With the buffer length value, we can see that the EUBR+ reduce the multiple cell loss probability and supports acceptable performance in the TCP layer.

Fig. 7 shows the average UBR Cell Loss Ratio(CLR). It represents the probability of cell loss. If the average UBR CLR is low, it means



(a) Lost Cell Size (b) Average lost cell size

Fig. 6 Lost Cell Size(cells)

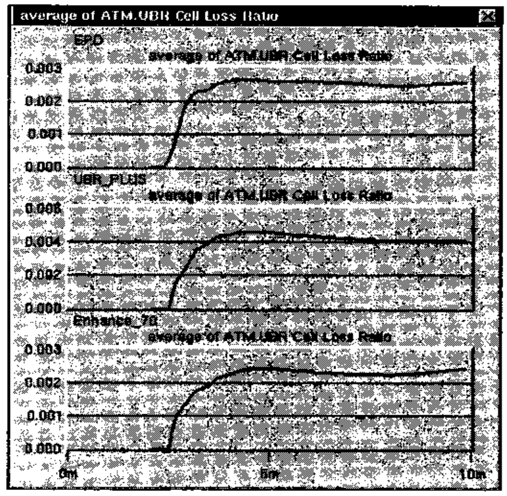


Fig. 7 Average UBR Cell Loss Ratio(CLR)

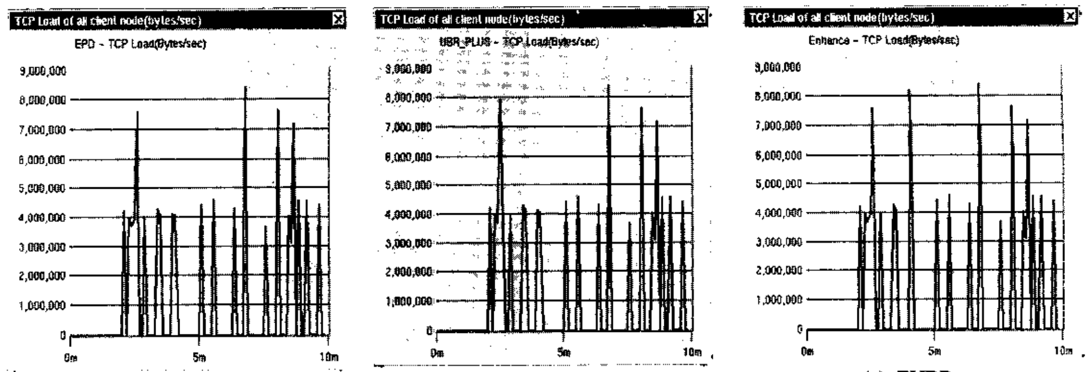
that the multiple cell loss probability is also low. Because the EPD scheme prevents the TCP from transmitting more traffic when the buffer size exceeds the threshold, it shows the low CLR. It can be seen in Fig. 5. The buffer size of EPD is shrank and the TCP can not send more traffic. The proposed scheme also shows the low CLR but does not prevent transmitting traffic.

The seven client nodes generate almost same traffic profile as shown in Fig. 8. This makes us to evaluate the three discard schemes under same traffic condition.

Fig. 9 shows the received TCP traffic by the server. As shown in Fig. 9 the server cannot receive exactly the same traffic because of the packet discard scheme. There are three times and one time where a server node cannot receive the traffic in EPD and UBR+ respectively. However, there is no such case in EUBR+ scheme. This means that the EUBR+ scheme reduces the multiple cell loss probability in the same TCP window, and enhances the performance of TCP.

V. Conclusion

TCP-over-ATM internetworking architecture suffers low performance due to two major problems: partial packet loss and long-delayed retransmission by timeout problem. The partial



(a) EPD (b) UBR+ (c) EUBR+

Fig. 8 Total TCP Load

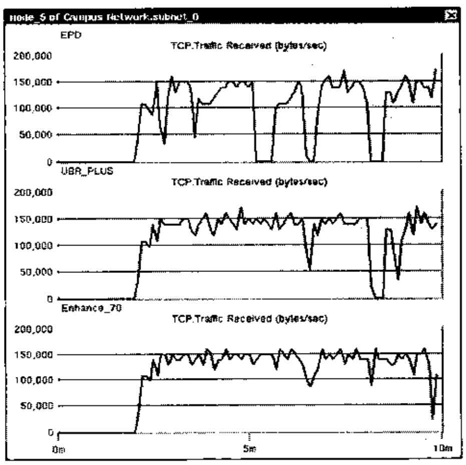


Fig. 9 TCP traffic received by a server node

packet problem has been figured out by PPD, EPD, UBR+, and other intelligent packet drop scheme to the extent. But the timeout problem is not considered by these packet drop schemes. Most of the packet drop schemes consider only the link utilization, and TCP efficient throughput; They do not consider the timeout problem.

In this paper we proposed an enhanced intelligent packet drop scheme, EUBR+, to solve the timeout problem. It reserves the buffer space for the damaged VC and protects the damaged VC from the successive packet dropping to the extent with reserved buffer space.

From the OPNET simulation results, we found that the proposed scheme reduces the cell loss rate compared to EPD and UBR+. Although its buffer length is fluctuated between two thresholds, it reduce the probability of multiple packet losses and the proposed EUBR+ scheme can support better performance and less timeout. It also reduces the probability of timeout than EPD and UBR+ scheme.

Reference

[1] G. Armitage and K. Adams, "Packet reassembly during cell loss," *IEEE Network Magazine*, Sept. 1993.

[2] Romanow. A and Floyd, S., "Dynamics of TCP Traffic over ATM Networks," *IEEE JSAC*, Vol. 13, No. 4, May 1995, p633 641.

[3] H. Tzeng C. Ikeda H. Li, K. Siu and H. Suzuki, "TCP Performance over ABR and UBR Services in ATM," Mar. 1996.

[4] R. Goyal, Raj Jain, Shiv Kalyanaraman, Sona Fahmy and Seong-Cheol Kim, "Performance of TCP over UBR+," Oct 1996.

[5] R. Goyal, R. Jain, S. Kalyanaraman, S. Fahmy and Seong-Cheol Kim, "UBR+ : Improving Performance of TCP over ATM-UBR Service," *Proc. of ICC97*, June 1997.

[6] Reuven Cohen and Yaniv Hamo, "Balanced Packet Discard For Improving TCP Performance in ATM network," *Proceeding of ICC* 1999.

[7] OPNET http://www.opnet.com.

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