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PAPER

Cell Flow Control by Stop and Release Credit Method in ATM Networks

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SUMMARY Broadband Integrated Services Digital Network (B-ISDN) is intended to provide various services in telecommunications like voice, video, and data communication. For realizing the B-ISDN network, Asynchronous Transfer Mode (ATM) is one of several data transfer technologies that are proposed and currently being developed. Several flow control methods have been proposed for data cell traffic in ATM network. One of the feedback control mechanisms is credit-based flow control that is proposed to handle an Available Bit Rate (ABR) traffic [1]. The credit based mechanism is applied in Local Area Network (LAN) and usually uses static buffer allocation method. When the conventional credit-based algorithm is applied in the LAN system, the problems such as low utilization of node buffer and large delay of source data will occur. In this paper, we propose a new algorithm that is called stop and release credit method to make credit-based flow control more effective. According to simulation results, proposed method will make high utilization of node buffer and small delay of source data.

key words: *flow control, credit-based, ABR traffic, stop and release method, LAN, ATM network*

1. Introduction

Broadband Integrated Services Digital Network (B-ISDN) is intended to provide various services in telecommunications like voice, video, and data communication. For realizing the B-ISDN network, ATM is one of several data transfer technologies that are proposed and currently being developed. In the ATM network, information is divided into a fixed length of data block, called cell. The ATM technology can provide high speed and high efficiency of the network because simplicity of data transfer protocol and wide bandwidth of optical fiber media are used in the network [11], [13].

There are several kinds of cell flow control that are proposed in the ATM network. The cell flow controls are rate-based and credit-based mechanisms [1], [2]. The rate-based mechanism is applied in the Wide Area Network (WAN), because the WAN has a wide geographical area. Long distance area means a large propagation delay and propagation delay in fact be greater than queueing delay in the node of WAN. On the other hand, the credit-based mechanism is applied in the LAN, because the link distance of LAN is modest and the queueing delay is larger than the propagation delay [3].

The controls use feedback control method. The control mechanisms are designed to manage "best effort" traffic that includes ABR traffic. The ABR service is the economical support of applications without tight quality of service requirements. However ABR traffic has a bursty or unpredictable data traffic that is difficult to manage. When the small packet loss rate is required by existing application in the LAN, credit-based flow control is an appropriate control mechanism to manage ABR traffic [3].

In the conventional credit-based mechanism, when a credit is generated for a sender, certain area of a node buffer is allocated to the sender [1], [11]. The allocated space of the node buffer makes inefficient of buffer utilization while the senders do not use simultaneously. According to our estimation, the utilization of the conventional method as described in Sect. 3, is low at the node buffer and it induces large delay of the source data. To overcome the problems, we propose a new algorithm called *stop and release credit* method to improve performance. The proposed method does not calculate current credit distribution, distributes credits as all of the empty space of the node buffer, and prevents buffer overflow by a cancel signal. Comparing to the conventional method, the proposed method becomes a simple algorithm. When the proposed method is applied in the system, the utilization of node buffer becomes high and it makes transferring data faster and small delay of the source data.

In the next section we describe the flow control mechanism. In Sect. 3 we discuss several problems and solutions around credit-based flow control and propose a new algorithm. We discuss network model for evaluating proposed method, then we discuss the performance results of conventional and proposed method in Sect. 4. Finally the conclusion and future works are stated in Sect. 5.

2. Flow Control

Flow control refers to the set of actions taken by the network to avoid congestion conditions. Congestion is defined as a state of network elements in which the network is not able to meet the negotiated performance objectives for already established connections [13]. Sev-

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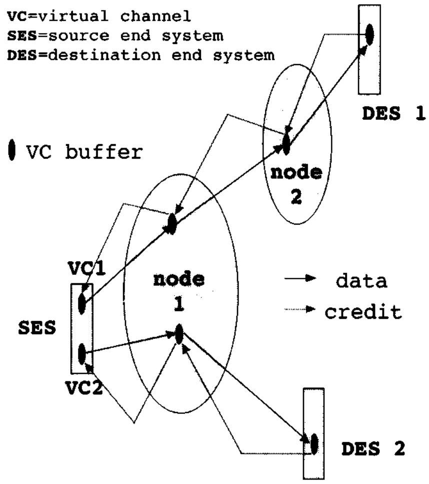

Fig. 1 Credit-based flow control scheme.

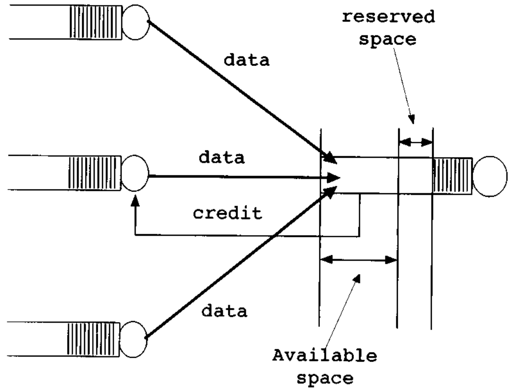

Fig. 2 Conventional credit method scheme.

eral flow control methods have been proposed. A well-known algorithms are rate-based mechanism and credit-based mechanism. In the long distance network, propagation delay is greater than queueing delay in the node buffer. The buffer sizes that is required to support credit-based mechanism are impractical because of the propagation delay of the long distance network. Then rate-based mechanism is usually implemented in the WAN and credit-based mechanism is applied in the LAN [3]. We focus the research to credit-based mechanism.

Credit-based flow control is usually implemented on node by node per VC connection basis. As shown in Fig. 1, before transmitting data to a node, a source needs to receive credits for the VC from the node. When data exist in the source, the source requests the credits to the node. On the other hand, the node sends credits to the source after calculating availability of buffer space for receiving data. When the source receives the credits, it is allowed transferring some number of data cells. The credit will be reduced by one, if one cell is forwarded to the node [1], [3], [11].

Credit-based flow control is an appropriate traffic control for ABR traffic in the LAN, when the applications that generate the ABR traffic are required a small packet loss rate. The traffic is bursty or unpredictable data traffic and credit system is suited to handle the traffic. The credit system prevents cell loss, and makes high throughput in the network. Static buffer allocation of credit-based flow control is always used, because it has simple mechanism to manage a credit control [3], [11].

3. Problems and Solutions

3.1 Conventional Credit Method

The credit-based mechanism manages credit distribution to each Source End System (SES), and allocates an area in a node buffer. Commonly credit-based flow control uses static buffer allocation scheme for credit distribution. Before the SES sends some data, the SES must request the credit to the node. The node checks its own buffer capacity and calculates an available space. According to the static buffer allocation scheme, if there are some available space, the fixed value of credits will be distributed to the SES. After having received the credits, the SES is eligible to send some data to the node according to the received credit information [1], [3], [11].

When the credit is generated and distributed to the SES, certain area of the node buffer is allocated to the SES. The allocated area cannot be used by the other SES, because the area is reserved as a distributed credit value to the SES. Therefore the allocated area means a reserved space of the node buffer.

The node distributes credits to the SES after calculates available space. The available space is an empty space of the node buffer. The empty space is calculated by subtracting current number of queueing cell and reserved space from all capacity of the node buffer. The node can distribute credits to the SES if there is any empty space in the node buffer. Furthermore the node must record current credit distribution for calculation of the reserved space in the node buffer. In this scheme, the reserved space of the node buffer exists as shown in Fig. 2. The reserved space is released when the SES used all of the distributed credit value.

According to our estimation, when the conventional credit-based algorithm is applied in the LAN system, the following problems will occur: low utilization of node buffer, large delay of SES data.

3.2 Proposed Credit Method

Now we try to manage the credit distribution for achieving high utilization of node buffer and small delay at the SES. Utilization is defined as percentage of node buffer occupancy and delay is defined as waiting time of packet data in the SES buffer.

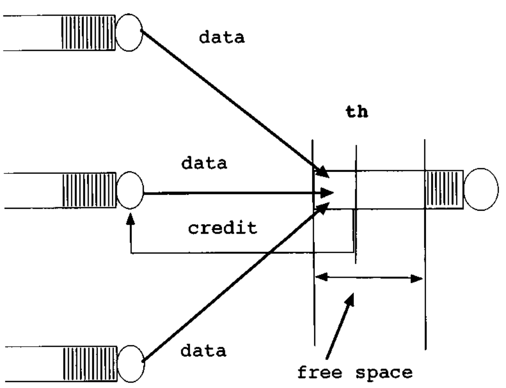

Fig. 3 Proposed credit method scheme.

We propose an algorithm called *stop and release credit* method. This algorithm is based on credit-based flow control and modified as follows (see Fig. 3):

- threshold value: We set a threshold value in the node buffer. If the number of queueing cells in the node buffer exceeds the threshold value, the credit distribution is stopped even if any SES requests some credits. Although the credit distribution is stopped, the SES can send cells to the node if the SES has some credits. When the number of queueing cells becomes under the threshold value, the node restarts credit distribution.

- credit distribution: In the conventional method when the SES requests credits, a fixed amount of area of the node buffer must be allocated for credit value, and then credits can be distributed. The allocated area cannot be used by the other SES. However, in the proposed method we distribute credit without allocating certain area of the node buffer. If the requested credit value is larger than the free space of the node buffer, all the free space is distributed as a credit value. Otherwise, the value of credit is the same as the SES's requested value. We remove the operation of allocating area of the node buffer, thus the mechanism of credit distribution becomes simple. Since the SES can receive credits earlier than the conventional method, the SES can send cells to the node earlier.

- credit management: We do not record current value of credit distribution in each SES. Then we can distribute credits as soon as requested credit coming. Without calculation of current value of credit distribution in each SES, the mechanism of the proposed method becomes a simple algorithm.

- cancel signal: If the number of queueing cells is equal to the capacity of the node buffer, then the node sends *cancel signal* to each SES for deletion of all credits. Cancel signal prevents buffer overflow at the node buffer. When the cancel signal comes to the SES, the SES saves its own data cell and prepares to request a new credit in the next term. In this situation, no cell loss occurs at the node buffer. The cancel signal is a newly proposed mechanism in the present paper.

Most data of the ABR traffic, for example, the real-time TCP/IP applications are bursty and sensitive to the cell loss. As described above, the proposed algorithm can take care of the ABR traffic properties by avoiding cell loss. If the node buffer is full, the node generates cancel signal to all the SES's and then the algorithm can prevent cell loss. Moreover the proposed algorithm makes a utilization of the node buffer higher than the conventional method, because the free space of the node buffer can be used as a credit value of each SES.

When the utilization of the node buffer is high, cells are stored in the node buffer rather than in the SES buffer. The cells move from the SES to the node faster than the conventional method. Commonly the transmission speed of the node is higher than the SES, so the cells are stored up in the fast speed equipment. When the cells can be transferred fast, packet data can be re-assembled fast in the destination. Consequently the transfer of packet data becomes fast. Since the cells from the SES come early, the utilization of the node buffer is mostly high and the node buffer is used effectively.

However not only the utilization of the node buffer but also the average delay at SES should be measured to show a good performance of the proposed method. We expect that the proposed method does not make throughput of the system lower than the conventional method. When transferring of cells can be fast, packet data can be transmitted fast too. Therefore packet data are not stored up in the buffer, then we expect that the delay of packet data is small.

4. Simulation

We make a simulation model to analyze that the proposed method has a better performance than the conventional method. We design two types of simulation models, cell level and packet level simulation models. The cell level simulation model is used to evaluate the utilization of the node buffer and delay of SES data. The packet level simulation model is used to evaluate total transmission delay of packet data in the system.

4.1 Cell Level Simulation

4.1.1 Model

As shown in Fig. 4, the cell level simulation model consists of SES and LAN node with speed of transmission 10 Mbps and 150 Mbps, respectively. Several SES are connected to the LAN node and the output cells of the

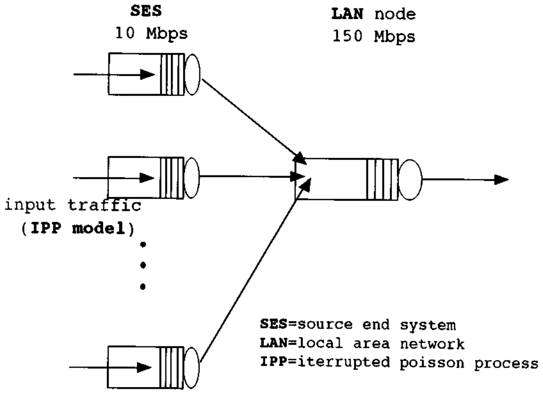

Fig. 4 Cell level simulation model.

SES are multiplexed to the LAN node buffer. Cells are generated in the SES buffer and the generation cells are assumed to be Interrupted Poisson Process (IPP) model. The cells are processed by First In First Out (FIFO) method.

We assumed LAN applications which use existing protocol stacks (e.g., TCP/IP, UDP/IP, IPX, etc) for describing ABR traffic and Variable Bit Rate (VBR) traffic. The ABR and VBR traffic can be represented by IPP (On-Off) traffic model [4], [5]. We use mixed input traffic for approximating a multimedia traffic. The VBR traffic has a higher priority than the ABR traffic when those data are processed in the LAN node.

4.1.2 Model

For the conventional method, if some SES requests some credits, the LAN node may allocate at most 2 cells. We set threshold value as 70 cells in the LAN node buffer for the proposed method. The LAN node buffers length are 80 cells both in the conventional and the proposed methods. The other conditions of cell level simulation are shown in Table 1.

In the Table 1, $\frac{1}{r_{10}}$ is the on interval length, $\frac{1}{r_{01}}$ is the off interval length, and λ_0, λ_1 are average cell arrival rate at on and off interval respectively. At the 150 Mbps transmission speed, the average load of one SES is 0.02. When the multiplexed number of SES is increased from 1 to 50 SES's, the load of the LAN node will increase from 0.02 to 1.

4.1.3 Simulation Results

In the cell level simulation as shown in Fig. 5 to Fig. 7, a good performance is obtained when we apply the proposed method. Figure 5 shows the utilization of the LAN node buffer. If the load of LAN node is low we get the same performance for either the conventional method and proposed method. However, when the load of LAN node is high the proposed method has better performance than conventional method with high buffer utilization of the LAN node buffer.

Table 1 Cell level simulation condition.

Node	SES	LAN
Buffer	∞	80 cells
Traffic model	IPP	-
Traffic class	VBR and ABR	-
$\frac{1}{r_{10}}$	60 cells	-
$\frac{1}{r_{01}}$	100 cells	-
λ_0	0.8	-
λ_1	0	-
Average load ($\bar{\lambda}$)	0.3	0.02 to 1.0
Mux number	1 to 50	-
Speed	10 Mbps	150 Mbps
Threshold value	-	70 cells

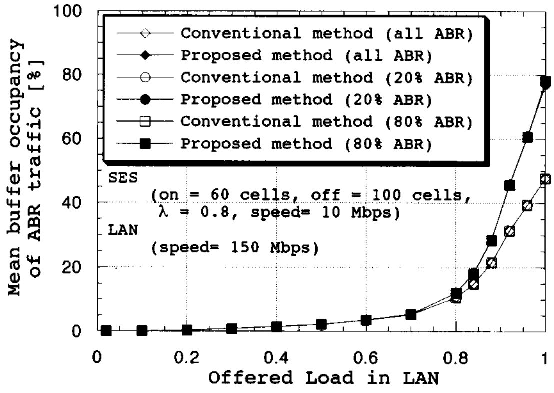

Fig. 5 Average LAN buffer occupancy.

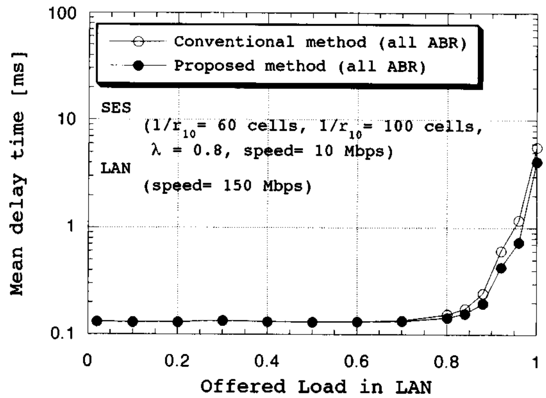

Fig. 6 Delay time in SES buffer when all ABR input traffic.

Figures 6 and 7 show average waiting time of cells in the SES buffer with ABR traffic. When the load of the LAN node is high, small delay in the SES buffer is obtained then the proposed method shows a good performance. We mix ABR traffic and VBR traffic to represent a multimedia traffic. The VBR traffic has high priority than ABR traffic, then generated cells from VBR traffic are processed earlier than ABR traffic.

According to the results, we see that the delay of ABR cells in the SES buffer increases when the VBR traffic is added to the input traffic. The LAN node buffer occupancies are the same for all the ABR in-

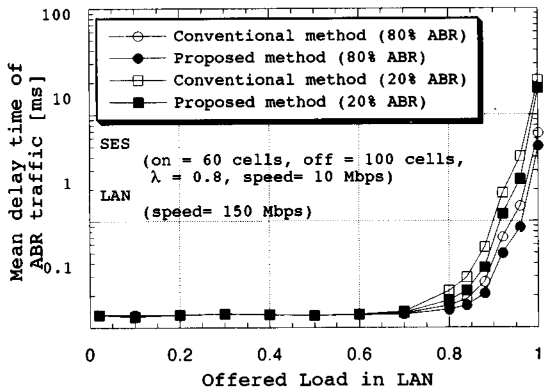

Fig. 7 Delay time in SES buffer when mixed ABR input traffic.

put traffic. However the proposed method yields better performance of delay in the SES and utilization in the LAN node than the conventional method. It is because the ABR traffic has a lower priority than the VBR traffic and then the ABR cells are queued in the SES buffer. With comparing Figs. 6 and 7 we know that average delay time at the SES which generates only ABR traffic, has a smaller value than the SES which generates mixed traffic. Moreover the VBR cells with higher priority occupy the node buffer and make the utilization of the node buffer high.

4.2 Packet Level Simulation

4.2.1 Model

As shown in Fig. 8, the configuration of the packet level simulation model consists of SES, LAN1 node, WAN node, LAN2 node and Destination End System (DES) with speed of transmission 10, 150, 150, 150, 10 Mbps respectively. The applications which use ethernet protocol are assumed for generating packet data in each SES. Packets from each SES are generated randomly with Poisson distribution. Packet data length is constant of 5 cells to represent average length of commonly data communication traffic about 200 bytes [5].

Using this model, we estimate the throughput and the transmission delay of the system. In the packet level, if one or more cells from a packet data are not received by the DES, the DES requests re-transmission of packet data to SES. When the SES receive re-transmission signal from the DES, the SES will destroy current transferring packet and restart to transfer the first cell of packet data. Then we can calculate the throughput of the system by comparing transferred data and success packet data. Propagation delay is defined by calculation time until transmission of packet data is successful.

Outgoing cells from each SES are multiplexed to the LAN1 node. Furthermore the LAN1 node output traffic is added to the WAN node with background (BG) traffic. We apply two state Markov Modulated Poisson Process (MMPP) model for BG traffic to describe the WAN traffic. A transfer rate of the LAN1 node to the WAN node is controlled by backward explicit congestion notification (BECN) rate-based control mechanism. The BG traffic affects the transfer rate of the LAN1 node. Depends on a condition of the WAN node traffic, the transfer rate of the LAN1 node is choked or not. If the WAN node is busy, the transfer rate of the LAN1 node is dropped to 50 Mbps. In this simulation, the busy condition is defined as the number of queueing cells in the WAN node is more than 30 cells. We set the length of the WAN node buffer in 40 cells.

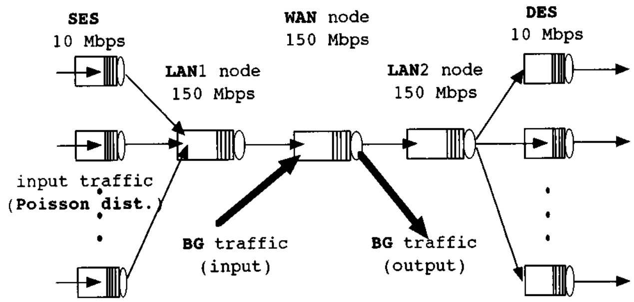

Fig. 8 Packet level simulation model.

Table 2 Packet level simulation condition.

Node	SES	LAN	WAN
Traffic model	Poisson (packet)	-	MMPP (cell)
Average load (cell level)	0.3	0.02 to 0.4	0.6
High interval	-	-	1000 cells
Low interval	-	-	1500 cells
Buffer	∞	80 cells	40 cells
Mux number	1 to 20	-	-
Speed	10 Mbps	150/50 Mbps	150 Mbps
Threshold value	-	70 cells	30 cells

In the conventional method, we use static buffer allocation scheme. For distribution credits, the LAN1 node may allocate at most 5 cells if some SES requests some credits. We set threshold value as 70 cells in the LAN1 node buffer for the proposed method. The LAN1 node buffer length are 80 cells both in the conventional and the proposed methods. The other conditions of packet level simulation are shown in Table 2.

4.2.2 Simulation Results

In the packet level simulation, we try to have the performance of the throughput and the packet transmission delay in the system. We use ABR traffic for all SES input traffics. The packet level simulation results are shown in Fig. 9 to Fig. 12.

Figure 9 shows average packet delay time in the SES and the LAN1 buffer. In the SES buffer, average packet delay time of the proposed method is smaller than the conventional method, but in the LAN1 node

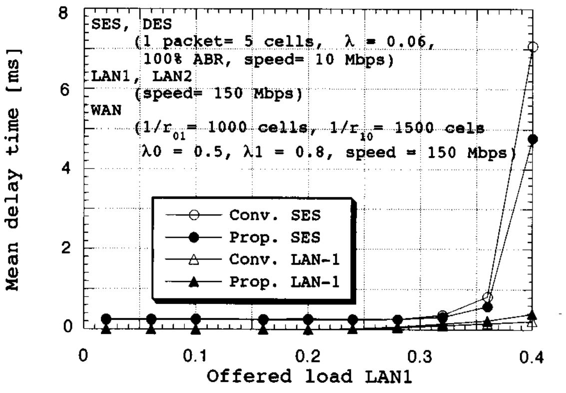

Fig. 9 Delay time in SES and LAN1 buffer.

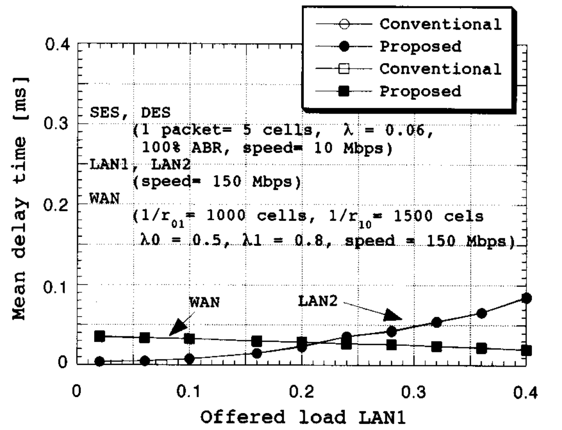

Fig. 10 Delay time in WAN and LAN2 buffer.

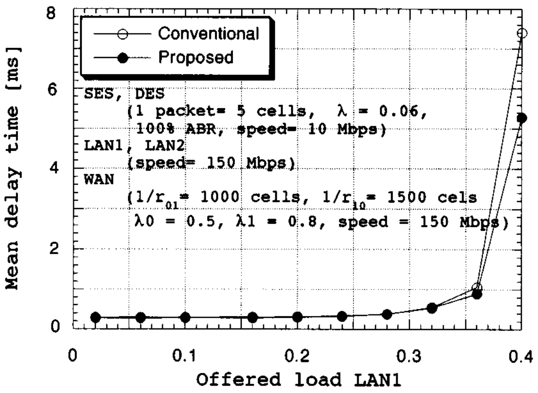

Fig. 11 Total delay time.

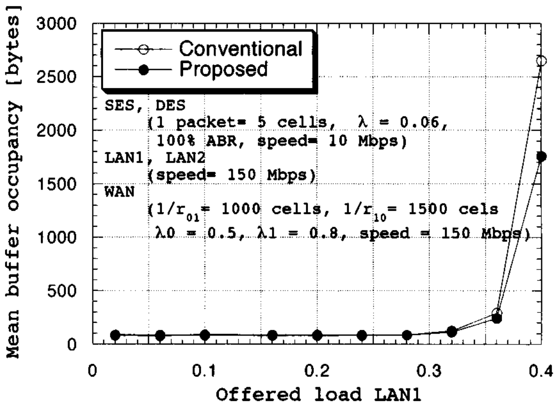

Fig. 12 Average SES buffer occupancy.

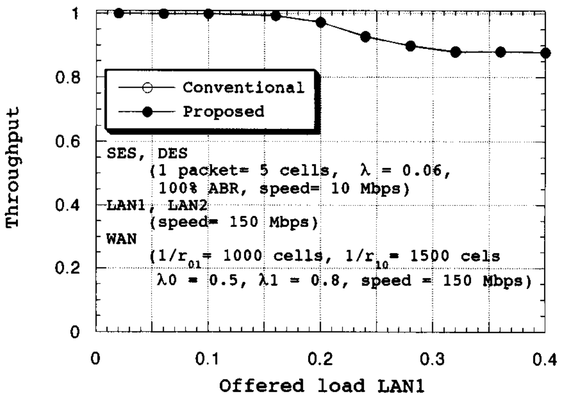

Fig. 13 Throughput of the system.

buffer, the proposed method gives a larger delay. In the WAN and the LAN2 buffer (see Fig. 10), the same delay are obtained by the proposed and the conventional method. It is because cells are queueing in the WAN and LAN2 buffer without accepted any congestion control.

Total transmission delay of packet data in the system is defined by the summation of delay in the SES, LAN1, WAN, and LAN2 buffers. As shown in Fig. 11, we obtain the total delay of the proposed method is smaller than the conventional method. Because the total delay is dominated by the SES buffer delay, the proposed method gives a smaller total delay than the conventional method.

As shown in Fig. 12, we obtained that the proposed method gives smaller SES buffer occupancy than the conventional method. When the offered load of the LAN1 node is 0.4, the difference of the SES buffer occupancy between the proposed method and the conventional method is about 2400 bytes. The proposed method provides low buffer occupancy in the SES and high buffer occupancy in the LAN1 node. Therefore the load of the SES is lighter than the LAN1 node.

In our model, the generated packets are first stored in the SES buffer. The packets or cells are assumed not to be discarded because the SES buffer length is infinity. A packet is transmitted to the DES if the DES does not request re-transmission signal and the previous packet is completely transmitted. The proposed method provides a fast cell transmission to the network. Consequently the number of transferred cells to the WAN node is larger than the conventional method. The performance of the throughput is the same for the proposed and the conventional methods. As shown in Fig. 13, at the high offered load of the LAN1, the values of the throughput are about 88%.

5. Conclusion and Future Works

In the ATM network, several kinds of traffic controls have been proposed. In the local network, credit-based flow control is one of the proposed control mechanisms that appropriates to handle ABR traffic.

When the conventional credit-based mechanism is applied in the network, we find several problems that make the network inefficient. We proposed a new algorithm to make the credit-based mechanism more effective. By the simulation, we have the following results: high utilization in the LAN node buffer, small delay for cell data in the SES buffer, small total delay for packet data transmission when the proposed method is applied. The performance of the proposed method is good, even if VBR traffics are mixed to the input traffic of SES. Hence we conclude that the proposed method also appropriates to manage ABR traffic.

For future works, we can predict that connecting local area to wide area of the network needs combination of credit-based and rate-based mechanism to make flow control more effective. The rule of credit-based mechanism must be transferred to rate-based mechanism and be a reference to make decision of flow control. Resource Management (RM) cells may be used to proceed information-exchange between credit-based in the LAN and rate-based in the WAN. We hope that the proposed method can be used in the system effectively.

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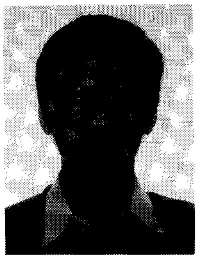

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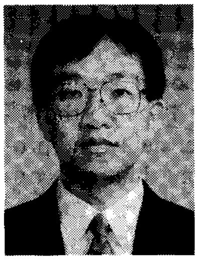

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