論文 94-19-6-11

Traffic Flow Control of B-NT for Prevention of Congestion in B-ISDN UNI

Soong Hee Lee[*], Heung Moon Choi[**] *Regular Members*

B-ISDN UNI에서 폭주를 예방하기 위한 B-NT의 트래픽 흐름 제어

正會員 李 崇 熙[*] 正會員 崔 興 文[**]

ABSTRACT

We propose a traffic flow control scheme of B-NT with temporary cell buffering and selective cell discarding to prevent congestion state of the network nodes in B-ISDN UNI. The scheme is designed for the B-NT systems to reduce or suppress output cell streams towards T_B interface. We define the states of the network nodes as *normal*, *pre-congestion*, and *congestion*. In a pre-congestion state, the loss-sensitive traffic is temporarily buffered to slow down the rate of the output traffic streams. In a congestion state, the delay-sensitive traffic is selectively discarded to suppress the output traffic streams as possible in addition to the cell buffering. We model the input cell streams and the states of the network nodes with Interrupted Bernoulli Process and 3-state Markov chain to analyze the performance of the proposed scheme in the B-NT system. The appropriate size of the cell buffer is explored by means of simulation and the influence on the performance of the proposed scheme by the network node state is discussed. As results, more than 2,000 cells of buffer size is needed for the control of medium or lower than the medium degree of congestion occurrence in the network node while the control of high degree of congestion occurrence is nearly impossible.

要 約

본 논문에서는 망 노드에서의 폭주를 B-ISDN UNI에서 예방하기 위해 B-NT에서 일시적인 셀 저장 및 선택적 셀 폐기를 수행하는 트래픽 흐름 제어를 제안하였다. 제안된 구조는 B-NT 시스템에서 T_B 접속을 향하는 출력 셀 흐름을 감소 또는 억제시키도록 구성하고, 인접 망 노드의 상태를 정상, 준폭주, 폭주의 세 상태로 정의하였다. 준폭주 상태에서는 손실에 민감한 트래픽은 일시적으로 저장되어 출력 셀 흐름의 속

---

[*] 韓國電子通信研究所 廣帶域通信方式研究室
Broadband Communication Systems Sect., ETRI
[**] 慶北大學校 電子工學科
Dep't of Electronics, Kyungpook National Univ.

論文番號 : 9416
接受日字 : 1994年 1月 15日

도를 저하시키고, 폭주 상태에서는 손실에 민감한 트래픽의 셀 저장과 더불어 지연에 민감한 트래픽의 셀이 선택적으로 폐기되어 최대한 출력 트래픽 흐름을 억제시킨다. 입력 셀 흐름과 망 노드 상태의 변화를 IBP와 3 상태 마르코프 체인으로 모델링하여 B-NT 시스템에서 제안된 구조의 성능 분석을 위한 시뮬레이션을 수행하여 적당한 버퍼 사이즈를 구하고 망 노드의 상태에 따른 제안한 구조의 성능 변화를 조사한 결과 망 노드에서의 폭주 정도가 극심한 경우에는 제안한 방법으로 제어가 거의 불가능하지만, 그 외의 경우에는 2,000 셀 이상의 버퍼 사이즈로 제어가 가능함을 알 수 있었다.

Ⅰ. Introduction

Since the emergence of ATM as the key technology for the construction of B-ISDN, congestion control has been one of the hot issues in the research for the construction of the ATM-based B-ISDN [1][2][3]. The phenomenon of congestion has been discussed in packet networks which have bursty sources. For providing better qualified services to the user, any possible congestions due to fluctuations of input traffic, which cause packet loss and delay resulted from buffer overflow, should be resolved.

Congestion problems in B-ISDN are considerably different with those in traditional packet-switched networks [4]. First, the presence of various traffic types, which have their own QoS and performance requirements, requires different schemes for each types to result a complexity in real implementation. Second, the high speed of the broadband capabilities makes the implemetation of the feedback mechanism to "slow down" traffic sources so difficult. Third, the mechanism based on software is too slow to be used for such a high speed while hardware implementation is expensive when its complexity is too high. For the first item, *segregation* of bandwidth to the traffic of each class is presented to satisfy multiple performance requirements [5]. A procedure for the feedback control before a congestion occurs must be considered from the second item. Implementation of the preventive control function should be as simple as possible for the last item.

There have been discussions about two categories of congestion control in ATM-based networks, *reactive control* and *preventive control* [4]. In [4], the former is regarded as a last resort for emergency situations to protect network integrity while the latter is rated as best for attaining fair congestion control when applied at the access node, namely *access control*. The access control admits the traffic flow into the network at the access node, which permits the customer premises to access the public B-ISDN via UNI(User Network Interface).

The access control includes every actions in B-ISDN UNI for preventing congestion, such as route control, admission control(e.g., CAC), bandwidth enforcement(e.g., UPC), etc.. However, congestion may occur from the traffic uncertainties, and the incorrect modeling of the statistical behavior of the traffic sources, which leads to the necessities of acknowledgement of the network status. It is shown that congestion management based on the network state in the case of LAN makes very good results even with its slowness [5]. Thus, a congestion control strategy with the care of the network status has been discussed in [2]. The control mechanism in [2] is proposed for rate control of end to end transport with assuming very short feedback time of the network state between end to end. The method uses the notification of the congestion state derived from the buffer state of the destination node. This function cannot prevent the congestion but react against it, which just follows the concepts of the reactive control. In addition, the propagation delay may not be negligible so that the reaction may not be so efficient in flow control for end to end transport. Therefore, it is required to consider such a scheme that prevents the congestion at a network access point, which may be regarded as a combination of preventive access control and flow control based on the network status. For the preventive control, we must consider a method which controls the traffic flow before detecting a congestion state in the network using indication of *pre-congestion* state.

In fact, information of user side cannot be preserved safely in the network node after transmission during the congestion state of the node with the reactive control methods [3]. It means that any actions after the congestion occurred may not resolve the bad influences of the congestion and its prevention might be more effective if possible. Loss-sensitive traffic (e.g., LAN data) has no other way besides retransmission or connection release after loss of information. It requires very stringent cell loss tolerance ($10^{-9\sim-12}$) while has loose cell delay tolerance (10 ms~100 s). Then, we can figure out several methods to preserve loss-sensitive traffic in B-ISDN UNI as follows: i) buffering in source terminals, ii) buffering in terminal adaptors, or iii) buffering in network terminating points, while the network is congested. The first has no way of checking states of network nodes in source terminals and the second is not efficient rather than the last in the view of buffer utilizations in systems.

In this paper, a scheme for more efficient and simple traffic flow control which helps to prevent congestions of the network nodes with suppression of the output cell streams on T_B interface of B-NT, while preserving loss-sensitive traffic information as described before, is proposed. For this scheme, we define three states of the network node interconnected with B-NT which functions according to the proposed scheme. We assume that the network node has OAM function for sending alarm messages indicating its state to the B-NT system. The B-NT system must have the function for OAM procedure with the network node. We locate the function into the control module of the B-NT system. We also classify input traffic streams into two types of flows. Separated input traffic streams are processed independently in the B-NT system. In the next section, we give the more specific description of these definitions and system structure for the proposed scheme. We present a description of the mechanism in the proposed scheme and a model for the performance evaluation of our proposed scheme in the third section. Simulation results are shown and discussed in the fourth section and finally we give conclusions in the last section.

Ⅱ. System description

A. System description of B-NT

The phenomenon of congestion has been discussed in packet networks which have bursty sources. The instantaneous aggregate rate of packet generation can exceed the link bandwidth of the network while the sum of the average rates of the sources is less than the bandwidth. Buffers are provided per link for congestion control. After the shortage of the link capacity to the input traffic, this buffer stores the input traffic information. For prevention of buffer overflow, access control is needed at network access point in UNI (here, in B-NT) as described before.

For the construction of B-ISDN, the establishment of local ATM access network is considered to be preceded in the customer side. The B-NT system is a component of the ATM access network which interconnects user terminal or Customer Premises Network (CPN) with the public access B-ISDN at B-ISDN UNI. Before considering congestion control in B-NT, we survey the whole structure of the B-NT system. The system consists of five parts, which are S_B Interface Module (SBIM), Multiplex and Demultiplex Processing Module (MDPM), B-NT Control and Processing Module (NCPM), T_B Interface Module (TBIM) and Traffic Flow Control Module (TFCM) as shown in Figure 1.

SBIM performs SDH-based physical transmission functions with the rate of 155.52 Mbps, ATM layer functions including header translation, and simple UPC functions (just tagging for

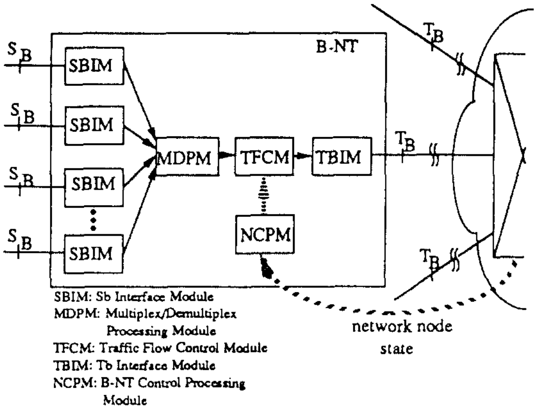


Figure 1. The B-NT system

violated traffic) for S_B input streams. MDPM performs multiplexing and demultiplexing of multiple ATM connections using translated VPI/VCI numbers from SBIM and TBIM and scheduling algorithm in it. NCPM performs functions of control and management plane to cope with the management actions of the network. Especially, NCPM takes a role of exchanging OAM information with the network node for the proposed scheme. TBIM performs SDH-based physical transmission functions with the rate of 155.52 Mbps and ATM layer functions including header translation for T_B input streams. The B-NT system can perform functions under normal situation without TFCM. However, under the network congestion, QoS of user traffic cannot be guaranteed without some methods for preserving or others, and the network node also endures a heavy loaded state without some methods at user side. Hence, we present a method locating a traffic flow control function between ATM multiplexing point and T_B interface (here, we call TFCM) for the suppression of traffic output flow under the network congestion. In addition, the B-NT system we develop has no method of cell discarding in S_B interface function for UPC. TFCM performs a part of UPC function by discarding cells with lower cell loss priority to complete UPC functions in B-NT.

TFCM is a module for the preservation of information from the customer premises into the network node under the emergent situation of network congestion. TFCM can preserve the precious user information temporarily and release the stored information when the network changes to normal condition. The proposed scheme does not affect the traffic flow to guarantee complete transparency of the information transfer under the normal situation.

We classify input traffic into two types, Type-A and B, for *segregation* of bandwidth for independent processing to each traffic with different requirements [5]. For simplicity in real implementation, we just separated into these two types. Delay-sensitive traffic such as voice and video is classified to Type-A traffic while loss-sensitive traffic such as LAN data is classified to Type-B traffic. We do not consider traffic flow control per virtual connections as we assume the network node has shared buffer scheme in which the node buffer is shared by multiple connections.

We also present a definition of the state in the network node for the proposed scheme. We define *pre-congestion* state as the state at which sum of input traffic amounts exceeds the capacity of the input links in network node to result input cells buffered in the buffer of the node, *congestion* state at which the input traffic of the node cannot be transferred to the destination due to overflow of the node buffer, and *normal* state which is the case other than these two states. More specifically, *pre-congestion* state is assumed to be detected at which the buffer level exceeds its threshold level in the shared buffer of the network node. The threshold level can be adapted not to lose stored data in the node buffer due to long transmission delay for alarm message transfer. It also must attain more buffer utilization as possible. The detailed criteria for the detection of the network state is needed for analyzing the behavior of the network node which is for further study.

B. Satructure of TFCM

TFCM consists of five blocks, which are Input Traffic Classification Block (ITCB), Type-A Processing Block (TAPB), Type-B Processing Block (TBPB), Output Traffic Processing Block (OTPB), and Network Status Receiving Block (NSRB) as shown in Figure 2.

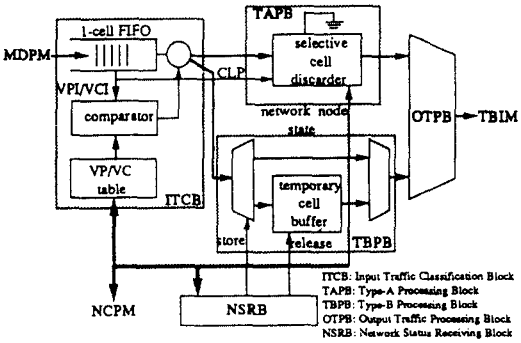


Figure 2. The TFCM in the B-NT system

ITCB classifies input cells with their VPI/VCI values according to the VP/VC table inside of it and forwards the classified cells into the streams of each types. In this block, segregation of bandwidth to the traffic of each class is attained to satisfy different performance requirements [5]. TAPB receives Type-A cells from ITCB and information of the network node state from NSRB, and discards cells with CLP = 1 or passes according to the state of the network node. TBPB receives Type-B cells from ITCB and information of the network node state from NSRB and stores or passes the cells according to the state of the network node. OTPB collects cells from TAPB and TBPB, and transfers them to TBIM. NSRB interfaces with NCPM for accepting the information about the state of the network and generates control signals to other blocks. The decision on the network node state in TFCM is attained only by hardware signal from NCPM to NSRB caused by alarm message from the network node.

An input cell is stored temporarily in 1-cell FIFO and VPI/VCI field in cell header is compared with the specified VPI/VCI values in VP/VC table at ITCB. According to the results of comparison, cell information is guided into one of two ports at the end of ITCB. VP/VC table updates its values with the aid of NCPM which has roles of connection management. TAPB receives Type-A cells from ITCB and passes or selectively discards cells according to the information of the network node state given by NSRB. TAPB performs a part of UPC functions in B-NT by discarding cells with a lower cell loss priority. TBPB receives Type-B cells from ITCB and passes or stores the cells into the cell buffer during *pre-congestion* state and releases them when it changes to *normal* state. Newly arrived Type-B cells are buffered after the cells already stored while cells in the buffer are released. Too long durations of *pre-congestion* states may cause cell loss due to buffer overflow. Hence, the evaluation of the appropriate size of the buffer is needed and discussed in the fourth section. OTPB collects cells from TAPB and TBPB and delivers them out to TBIM. With the collected cells, OTPB serves on the First Come First Served (FCFS) basis.

Ⅲ. Traffic flow control mechanism

We need to evaluate the performance of the proposed scheme under *pre-congestion* state before the actual implementation of the scheme. For the evaluation, we need to model the input traffic pattern and the variation of the state of the network node connected with B-NT. The procedure for the proposed scheme must be also described to be analyzed. We describe a control procedure for the proposed traffic flow control as follows :

1. Inspect the VPI/VCI value of input cells and separate into two types of cell streams. If Type-A, go to step 2, otherwise go to step 3.

2. If the network state is *normal or pre-congestion*, just pass Type-A cell flow without discarding and go to step 1. If *congestion*, discard cells with CLP = 1 and go to step 1.

3. If the network state is *pre-congestion* or *congestion*, store Type-B cells in the cell buffer temporarily and go to step 1. If *normal*, go to step 4.

4. Just pass Type-B cell flow if the TFCM buffer is empty. Release stored Type-B cells in the buffer while newly arrived Type-B cells are buffered if the buffer is not empty. Then go to step 1.

According to the description, the queue model of the B-NT system with the proposed scheme can be drawn as shown in Figure 3.

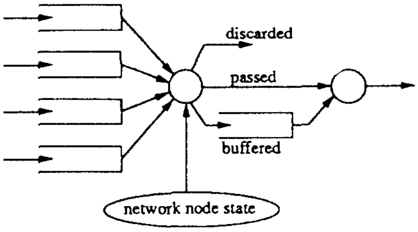


Figure 3. Queue model of the B-NT with the proposed scheme

After multiplexing the input traffic in four queues, the multiplexed traffic pattern is served according to the proposed scheme. We consider this queue model for the simulation to evaluate the performance of the proposed scheme. Hence, we first model the input traffic of the queues at the multiplexer as described in [6].

Cell arrival and departure occur in a discrete time unit for cell transmission called slot. The traffic is modeled by an Interrupted Bernoulli Process (IBP). An IBP has ON and OFF state alternatively. A cell arrives in a Bernoulli fashion when the process is in the ON state. No cell arrives when it is in the OFF state. Assuming the process is in the ON state. No cell arrives when it is in the OFF state. Assuming that at the end of slot i the process is in the OFF (or ON) state, it will remain in the OFF (or ON) state with probability q (or p), or it will change to the ON (or OFF) state with probability $1-q$ (or $1-p$). If the process is in the ON state, then a cell will arrive during a slot with probability α.

The characteristics of each traffic is specified by following parameters : peak arrival rate α, average burst length T, and burstiness β. Here, we define the burstiness as the ratio of peak arrival rate to average arrival rate. The average burst length T and average arrival rate ρ are related to the IBP parameters (p, q, and α) as follows :

$$T = \frac{1}{1-p}$$

$$\rho = \frac{\alpha(1-q)}{2-p-q}$$

For the performance evaluation of the proposed scheme, we need a model to describe the characteristics of the varying state of the network node. The state of a network node is intrinsically probabilistic. In addition, the state is correlated with the action of UNIs resulted by the proposed scheme here. It is much difficult to model such phenomena consequently. For simplicity and conveniences in analyzing the proposed scheme, we vse a simple model as explained below. We neglect the correlated effects by the proposed scheme

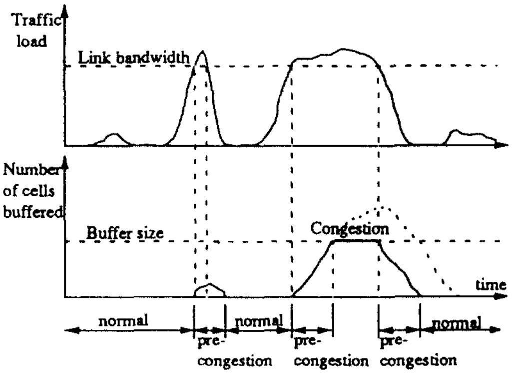


Figure 4. Three states of the network node

into the network node, assuming that the node connects numerable UNIs so that the effect by a single UNI is negligible. We consider the changes of the state in the network node as a *normal*, *pre-congestion* and *congestion* transition as shown in Figure 4.

Hence, we regard the process as a 3-state Markov chain which may present a special case of the congestion state of the network nodes which also leads to the more conveniences in the performance evaluation. The varying state of the network may be described in discrete time units as in the case of input traffic arrivals. In addition, the state of the network node may stay or transit with a similar manner as in the ON and OFF transition of the input traffic arrival pattern. Assuming that at the end of slot *i* the process is in any state, it will remain in the original state with a certain probability, or it will change to another state with some probability. The transition between the *normal*, *pre-congestion*, and *congestion* state is shown in Figure 5.

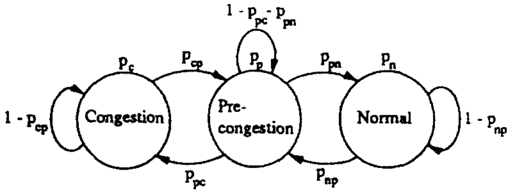


Figure 5. Transition between network node states

Then the characteristics of network node are specified by the following parameters : probability of staying at *congestion* state p_c, probability of staying at *pre-congestion* state p_p, probability of staying at *normal* state p_n, probability of transition from *congestion* state to *pre-congestion* state p_{cp}, probability of transition from *pre-congestion* state to *normal* state p_{pn}, and probability of transition from *normal* state to *pre-congestion* state p_{np}. In the steady state, these parameters are related as follows :

$$[p_c\ p_p\ p_n]\begin{bmatrix} 1-p_{cp} & p_{cp} & 0 \\ p_{pc} & 1-p_{pc}-p_{pn} & p_{pn} \\ 0 & p_{np} & 1-p_{np} \end{bmatrix} = [p_c\ p_p\ p_n]$$

$$p_c + p_p + p_n = 1$$

The probability to be busy in TFCM P_{BUSY}, which represents the degree of pre-congestion or congestion occurrence, is given as

$$P_{\mathrm{BUSY}} = 1 - p_n$$

The value of P_{BUSY} is changed to generate the values of p_p and p_c for simulating changing status of the network node.

Ⅳ. Simulation results and discussions

For an analysis of more actual cases, we assume four traffic inputs with different rates and required QoS as used in [6]. For simplicity, we adopt a set of traffic input as shown in Table 1, which was used for the analysis of scheduling algorithm in [6]. Input traffic of port 1, whose burstiness is unity, is to be classified to Type-A while those of the others to Type-B.

Table 1. Input traffic parameters

port no.	1	2	3	4
peak rate	20 Mbps	100 Mbps	50 Mbps	10 Mbps
normalized peak rate	0.134	0.668	3.34	1.34
burstiness	1	6.68	3.34	1.34
burst length	-	500 slots	100 slots	100 slots

We assume an STM-1 transmission line for the reference of slot time. Excluding overheads of SDH frame, it transferes cells at 149.76 Mbps. One service slot corresponds to the transmission time of one cell, 2.831 μs. We assume each size of the buffers before the multiplexer in the queue

Table 2. Cell loss rate of Type-B flow vs. buffer size in TFCM (90% Confidence Interval)

buffer size	Pp=0.09524, Pc=0.04762	Pp=0.15, Pp=0.075	Pp=0.2, Pp=0.1	Pp=0.25, Pc=0.125	Pp=0.3333, Pc=0.1667	Pp=0.5, Pc=0.25
100	0.010816±0.00184	0.0301±0.002362	0.059228±0.008837	0.1025±0.040039	0.199899±0.04644	0.679554±0.180589
500	0.0003±0.000037	0.002707±0.000329	0.009478±0.000996	0.022999±0.008217	0.066532±0.008696	0.312819±0.087086
900	0	0.000167±0.000073	0.001523±0.00071	0.005591±0.000722	0.024795±0.007056	0.200895±0.073014
1200	0	0	0.000363±0.0001	0.001934±0.000566	0.01326±0.005329	0.165152±0.068156
1500	0	0	0	0.000514±0.000083	0.006284±0.000577	0.132813±0.041949
2000	0	0	0	0.000181±0.000066	0.001716±0.000569	0.094204±0.02099
2500	0	0	0	0	0.000247±0.000045	0.092391±0.036166

Table 3. Mean Cell Delay of Type-B flow vs. buffer size in TFCM (90% Confidence Interval)

buffer size	Pp=0.09524, Pc=0.04762	Pp=0.15, Pp=0.075	Pp=0.2, Pp=0.1	Pp=0.25, Pc=0.125	Pp=0.3333, Pc=0.1667	Pp=0.5, Pc=0.25
100	22.27802±0.278391	36.723899±0.168769	53.062982±1.331141	67.225069±1.268248	94.012343±1.466858	294.917126±12.328315
500	39.168746±0.33628	81.770632±1.811875	135.457183±3.943712	199.504587±4.468363	335.484684±8.226351	1107.979366±36.495966
900	38.405242±0.333166	84.771652±1.205082	151.262339±2.352394	244.567357±3.624983	444.121485±3.697379	1850.645678±89.035415
1200	39.913198±0.281481	88.896597±4.202458	160.588277±3.770527	264.801426±4.144724	517.839666±5.031962	.
1500	37.924953±0.296942	84.941403±1.749228	154.402893±4.351544	261.21662±4.777665	564.099509±3.503702	.
2000	38.283648±0.294241	85.642577±1.527553	156.411377±3.56979	265.859975±3.939909	638.295202±11.503643	.
2500	39.489012±0.27417	87.025097±1.208988	158.881362±4.486293	272.786582±3.085656	663.919471±11.929117	.

model is 60 cells. For an analysis at more actual condition, we adopt a Queue Length Threshold (QLT) strategy, which shows the best results in [6], for scheduling in the multiplexer. The output of the multiplexer is assumed to be fed into TFCM. Threshold values of the buffers for the strategy are selected as 3, 50, 3, and 5 each [6].

We analyze the proposed scheme depicted in Figure 3 by simulation. The batch size is 24,000,000 slots and the number of batch is 10 in our simulation. We simulate about only Type-B flow and let Type-A flow, with CLP bits fixed to zero, not be affected by the changes of the network node state. CLP bits are fixed to zero when the traffic arrival in S_B interface does not violate the predefined traffic parameters and we assumed a condition of no violation in Type-A flow. Simulation results are shown in Table 2 and 3. Moreover, they are plotted in Figure 6 and 7.

Figure 6 shows the result of cell loss rates on Type-B flow vs. buffer size at TFCM varying probability of staying at *pre-congestion* or *congestion* state. Cell loss rate is approached to zero when the buffer size is larger than 500 cells at low degree of pre-congestion or congestion occurrence ($P_{\text{BUSY}}=0.14286$, $p_p=0.09524$, $p_c=0.04762$) while goes under 0.002 when the buffer size is larger than 2,000 cells at the medium degree of pre-congestion or congestion occurrence ($P_{\text{BUSY}}=0.5$, $p_p=0.3333$, $p_c=0.1667$). It is noted that buffer size larger than several thousands of cells has no way of prevention with a reasonable buffer size under the high degree of pre-congestion or congestion occureence ($P_{\text{BUSY}}=0.75$, $p_p=0.5$, $p_c=0.25$). It implies that its implementation is possible with a limited size(>2,000 cells) of memory chips for the buffer in TFCM under the network node state with a degree lower than medium of pre-congestion or congestion occurrence.

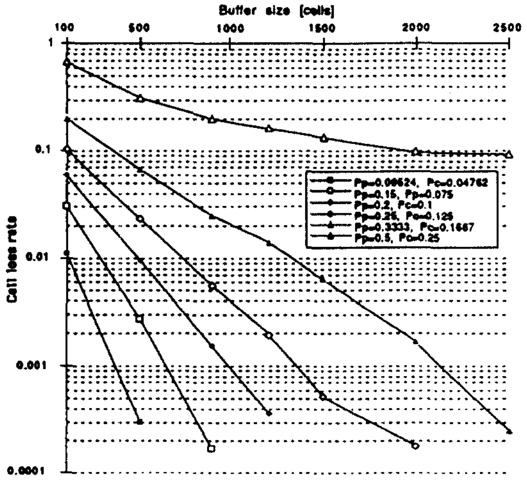


Figure 6. Cell loss rate of Type-B flow vs. buffer size in TFCM

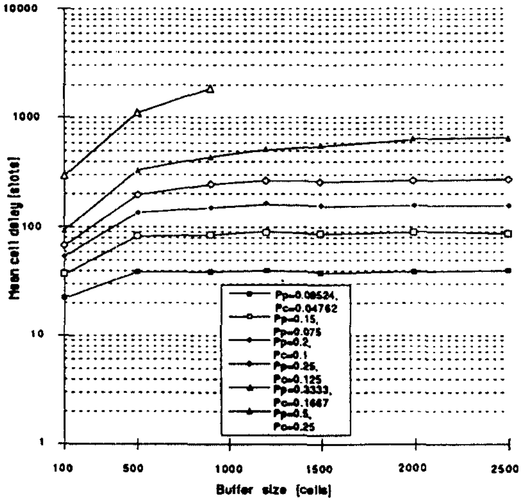


Figure 7. Mean cell delay of Type-B flow vs. buffer size in TFCM

Figure 7 shows the result of mean cell delay vs. buffer size varying probability of staying at *pre-congestion* or *congestion* state. Cell delay stays between 600 and 700 cell slots, which is equivalent to delay time of 1.6 ms~1.98 ms, after the buffer size is over 2,000 cells under the medium degree of pre-congestion or congestion occurrence. This result shows that the performance of cell delay is less significant compared with that of cell loss for the proposed scheme. It is also noted that buffer size larger than several thousands of cells has little effects on the performance of cell delay under low and medium degree of pre-congestion or congestion occurrence.

With additional information to these results, we can design the traffic flow control module which can efficiently prevent the medium degree of network node busy states. Besides the simulation results, we need to gather more meaningful information about the varying congestion state of the network node to design a more advanced scheme. With the deeper study on the characteristics about the congestion state, it also may be possible to analyze the actual performance of the proposed scheme.

V. Conclusions

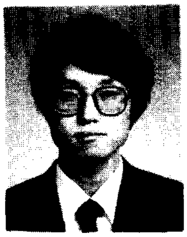
We proposed a traffic flow control scheme for prevention of congestion in B-ISDN UNI and analyzed the performance of the proposed scheme under assumed network congestion state. As results, the appropriate buffer size is evaluated and the possibility of actual implementation for the congestion flow control by the proposed scheme is discussed. We assumed a network node with a buffer shared by multiple connections for the evaluation. For the application of the proposed scheme in more general cases, considerations on the states of each links or virtual connections and nodes in the whole network are needed. We just confined the state of the network to the network node connected with B-NT system for convenience of analysis in this paper. More study and analysis based on the description of the state of the whole network are expected to be done. The procedure for end to end transport with more complete description and solution of congestion control issue also needs to be studied.

Acknowledgements

We would like to thank the division director Dr. Chul-Hee Kang, and department head Dr. Moon-Kee Choi at ETRI, for their encouragement and comments for this study. We also give thanks to Dr. Yong-Hee Jeon and Dr. Seok-Won Hong for the helpful discussions on this paper.

References

1. CCITT I.371, Draft, "Traffic Control and Congestion Control in B-ISDN," Jun. 1992.
2. H.I. Kwon, A. Tubtiang, G. Pujolle, "A Simple Flow Control Mechanism in ATM Network with End to End Transport," Proc. INFOCOM '93, Mar. 1993, pp. 654-661.
3. G.M. Woodruff, R.G.H. Rogers, P.S. Richards, "A Congestion Control Framework for High-speed Integrated Packetized Transport," Proc. Globecom 1988, pp. 203-207.
4. A. Bhargava, "Integrated Broadband Networks," Artech House.
5. ICC '93 Tutorial 2, "ATM Technology : Compatibility for Local, Wide Area, and Metropolitan Networks," May 1993.
6. J.S. Jang, K.S. Kim, Y.H. Park, H.J. Kim, "Design and Implementation of an ATM cell scheduler and router for B-ISDN," JC-CNSS '93, Jun. 1993.



李 崇 熙(Soong Hee Lee) 정회원
1961년 12월 8일생
1980년 3월 ~ 1987년 2월 : 경북대학교 전자공학과 졸업(공학사)
1988년 3월 ~ 1990년 2월 : 경북대학교 대학원 전자공학과 졸업(공학석사)
1990년 3월 ~ 현재 : 경북대학교 대학원 전자공학과 박사과정
1987년 2월 ~ 현재 : 한국전자통신연구소 선임연구원
※주관심분야 : 광대역 통신 시스템, 컴퓨터 네트워크

崔 興 文(Heung Moon Choi) 정회원
현재 : 경북대학교 전자공학과 교수 전자계산소 소상
제12권 2호 참조