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A Study on Collision Avoidance and Priority Control Scheme for Cells in Frames

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Abstract

This paper proposed a collision avoidance scheme to improve the network performance and priority control scheme to support real-time ATM applications in CIF(Cells in Frames), which carries ATM cells over existing Ethernet interfaces. The proposed scheme has optimized for the two nodes Ethernet, that is a typical CIF network, and doesn't require any hardware modification of existing Ethernet interface card. The collision avoidance scheme gives fair access opportunities with minimized contention to the nodes by assigning different inter-frame gap to each element of CIF network. The priority control scheme guarantees preemptive transmission of real-time frames to the medium by exchanging queuing status information between two nodes. Therefore in this paper it is shown that CIF network which has both the collision avoidance scheme of MAC layer and the priority control scheme of CIF layer has a improved network performance and supports real-time ATM applications efficiently.

요 약

본 논문은 기존의 이더넷 인터페이스를 통하여 ATM 셀을 전송하는 CIF(Cells in Frames)에서 네트워크 성능을 향상시키기 위한 충돌 회피(collision avoidance) 방안과 실시간 ATM 응용을 지원하기 위한 우선 제어 방안을 제안한다. 제안된 방안은 전형적인 CIF 네트워크인 두개 노드를 가진 이더넷에 적합하며, 기존 이더넷 인터페이스 카드에 대한 어떠한 하드웨어적인 수정을 필요로 하지 않는다. 충돌 회피 방안은 CIF 각 요소에 서로 다른 프레임간 간격(inter-frame gap)을 할당함으로써 출동을 최소화하면서 그 노드들로 공평한 액세스 기회를 제공한다. 우선 제어 방안은 두 노드간 큐잉 상태 정보를 교환하므로 써 매체로 실시간 프레임을 우선적으로 전송하는 것을 보장해준다. 그러므로 본 논문에서는 MAC 계층의 충돌 회피 방안과 CIF 계층의 우선 제어 방안을 모두 갖춘 CIF 네트워크가 향상된 네트워크 성능을 가지며 실 시간 ATM 응용을 효율적으로 지원한다는 것을 보여준다.

1. Introduction[1]

The Ethernet is the most popular LAN technology and one of the most cost effective communication network in a local area[1][2]. The Ethernet has an advantage of easy wiring and management, reliable and robust protocol, low cost, and several wiring options according to the coverage of the network. The Fast Ethernet, which has raised Ethernet speed to 100Mps through only minimal modification of the existing cable structure, is also standardized in 1994.

In the near future, BISDN(Broadband Integrated Service Digital Network) based on ATM(Asynchronous Transfer Mode) will support new and diverse applications. These

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applications require unique traffic characteristics and different QoSs(Quality of Service) from network. As ATM is based on the statistical multiplexing technique, it not only use network's resources (e.q., bandwidth and buffer) efficiently, but also can support the different types of traffic with different QoS[3][4].

To keep the cost of ATM to the desktop low, the Cornell has proposed the CIF protocol [5][6][7] that carries ATM cells over existing Ethernet interfaces. ATM cells will be carried in ordinary Ethernet frames using a new value of the Ethernet type field. The CIF has two components: an attachment device(CIF-AD), which takes place of an existing Ethernet hub, and low-level end system(CIF-AD) software, which has the functions of SAR(Segmentation and Reassembly), AAL5 CRC calculation and ABR(Available Bit Rate) traffic management[5][6].

The Ethernet shows relatively low medium utilization because it uses contention based medium access protocol generating collision and capture effect in which one sender transmits a sequence of its queued frames before the other can gain control of the Ethernet and transmit any frame. The capture effect is caused by binary exponential backoff algorithm, which calculates the deferring time of a frame transmission after collision detection. Therefore, it is recommended that a collision avoidance mechanism should be implemented to improve the low medium utilization and access unfairness at the CIF-AD. One of the best point of ATM network is that it can transport various kind of traffic with different QoS(Quality of Service). The CIF, which is a part of ATM network, should support not only data oriented applications but also real time applications. Therefore, some mechanisms for supporting the ATM traffic with different QoS are required in the CIF-AD and CIF end system.

Several attempts were made to reduce a collision of the CSMA/CD(Carrier Sense Multiple Access/ Collision Detection) protocol based on hybrid method combined the best properties of Ethernet and token passing protocols[8] or based on time synchronization among nodes on the network[9][10][11]. Also Previous works in the area of supporting real-time traffic on the Ethernet were made based on channel reservation [11] or based on timed-token[12][13]. However, They are unrealistic for the two nodes because they require quite complicated functions[11] or sophisticated synchronization overhead[9]. Also some of them require hardware modification of existing Ethernet interfaces[8][9][10][11][13].

This paper has proposed a collision avoidance scheme for CIF-AD by assigning different inter-frame space of CIF-AD from the end systems. This scheme requires slight modification of MAC hardware of CIF-AD but CIF end system uses existing Ethernet hardware and Ethernet driver without any modification. Also this paper has proposed a priority control scheme for real-time applications. The scheme can be implemented by software because it is applied to the CIF layer of the CIF-AD and CIF end system instead of MAC layer. The CIF network which combines the collision avoidance scheme of MAC layer with the priority control scheme of CIF layer shows a improved network performance and supports real-time ATM applications efficiently.

2. CIF Protocol

ATM technology allows transmission of cells over diverse media, from optical fiber to spectrum radio. ATM is not coupled to any particular physical medium. Since July of 1994, Cornell has studied the concept of carrying ATM over Ethernet hardware, an approach which we call "Cell In Frames" or CIF. To standardize protocols, conduct interoperability tests, and promote the concept, Cornell has established the Cells In Frames Alliance[5][6]. Figure 1 shows the typical CIF configuration. It is a star topology network with a CIF-AD, which has the function of ATM cell switching between ATM interface and multiple Ethernet segments, and multiple CIF-ESs, which are connected to the CIF-AD through point-to-point Ethernet cables. Each Ethernet segment has a CIF-ES but sometimes it may have multiple CIF-ESs.

In CIF, ATM traffic will be carried in ordinary Ethernet frames, using a new value for the ethernet type field that denotes CIF traffic. However, ATM payloads will be aggregated, with only one header for up to 31 cell payloads.

There is ATM functions that have high overhead or strict timing requirements: formation of individual cells, calculation of AAL5 CRC, and management of ABR traffic[5][6].

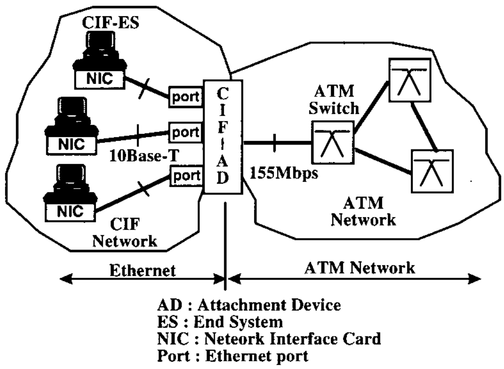

Figure 1. CIF network configuration

- Cell creation

Most of the function of conversion to/from ATM cells will be done in the CIF attachment device, not in the end system. For traffic from the network to the end system, the CIF attachment device will gather cells into frames. In general, low-bandwidth but delay-sensitive traffic such as voice will have only one cell per frame, while high-bandwidth but delay-tolerant traffic will have maximum filled frames. Figure 2 shows an AAL5 PDU carried in CIF frames. A frame begins with a CIF header of 8 octets. The CIF header includes a cell header template that carries the information required to construct a cell header on these payloads. Higher layer framing is carried in the AAL payload just as with any other ATM interface. After CIF header comes data in multiples of 48 octets. The Ethernet frame may be filled with any number of these up to 21 cells.

- AAL CRC calculation

Since Ethernet CRC protects Ethernet traffic, data from Ethernet does not need to be protected at AAL layer. Therefore, AAL5 CRC calculation and validation can optionally be done in the CIF attachment device on behalf of the end system. For traffic to the end system the attachment device can accumulate the CRC as the cells of an AAL5 CS-PDU are places in an Ethernet frame for transmission. When the last cell is placed in a frame, the attachment device can set flags to indicate

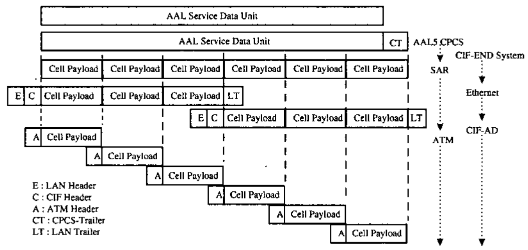

Figure 2. An AAL5 PDU carried in CIF frames

whether the CRC is valid or not for the PDU.

- Available Bit Rate

If CIF-AD acts as an ABR VS(Virtual Source) / VD(Virtual Destination) on behalf of its end systems, both end system process and the interaction between the CIF attachment device and the end system can be simplified. The CIF-AD can optionally act as a VS/VD for ABR VC(Virtual Connections), and only a small trickle of RM cells need pass to and from the end system.

3. Proposed CIF Protocol

The maximum utilization of Ethernet is greatly changed according to the traffic condition and the number of nodes on the network and the contention based access protocol does not guarantee a fair share of link bandwidth. Also, there is no priority access mechanism for providing bounded access delay for real-time traffic. Therefore the access protocol of the Ethernet is required some modification for providing guaranteed bandwidth and bounded access delay. But the protocol should not require any hardware modification of CIF-AD because one of the basic requirements of CIF is the use of existing Ethernet interface for low cost ATM cell transmission.

This paper assumes the CIF network as a group of Ethernet segments, which has only two nodes, CIF-AD and CIF-ES. It can allow applying bandwidth guarantee and priority access scheme to the CIF network easily.

3-1. Collision Avoidance Scheme

All of the nodes using CSMA/CD protocol have same inter-frame spacing, which is intended to provide inter-frame recovery time for other CSMA/CD sublayers and for the physical medium. Because each Ethernet segment of a typical CIF network has only two nodes, CIF-AD and CIF-ES, it is easy to reduce the collision by assigning different inter-frame space to the CIF-AD from that of CIF-ES. The node having shorter inter-frame space transmits its frame first and the other node detects the busy state of medium before initiation of frame transmission. To guarantee fairness of frame transmission between CIF-AD and CIF-ES, the value of the CIF-AD inter-frame space should be changed according to the node state.

Figure 3 shows the state transition diagram of CIF-AD. The state H means that the inter-frame space of CIF-AD is shorter than that of CIF-ES and state L stands for assigning longer inter-frame space to the CIF-AD. The CIF-AD changes its state to state L at the starting point of its transmission and changes it to state H at the starting point of a frame reception from the CIF-ES. This algorithm greatly reduces the collision and gives fair access opportunities to the nodes. Also this algorithm reduces collisions even in the Ethernet segment with multiple CIF-ESs when large portion of traffic is concentrated to the CIF-AD.

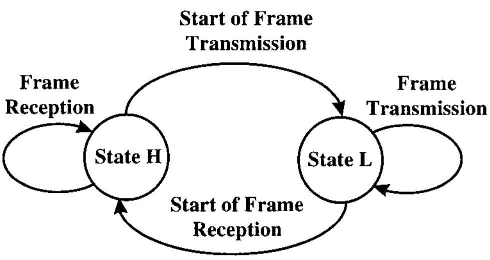

Figure 3. State transition of CIF-AD

3-2. Priority Control Scheme

We classified the traffic into multiple classes according to the delay priorities. The CIF layer of each node has multiple buffers for each class and the frames in the highest class buffer are transmitted first. Figure 4 shows the buffer configuration of the CIF and the MAC layer. The CIF layer determines whether it transmits the frames in the buffers according to the status of the other node. The QS(Queued Highest Priority) field is assigned in the CIF frame header in order to exchange the queuing status to the other side. Whenever CIF layer of sender node delivers a frame to the MAC layer for transmission, it assigns the highest class of remaining frames queued in the buffers as a QHP value. The receiver node saves the QHP value of the received frame and the node transmits only the frames of same or higher priority than that of received QHP value.

4. Simulation

To verify the performance of the suggested scheme, the result of simulation is compared with that of the Ethernet. The network model has two nodes connected through a 10 Mbps link with the length of 100m. As CIF limits packet size to 1500bytes like Ethernet[6], each node generates variable length frames with the distribution[14] as shown in Table 1.

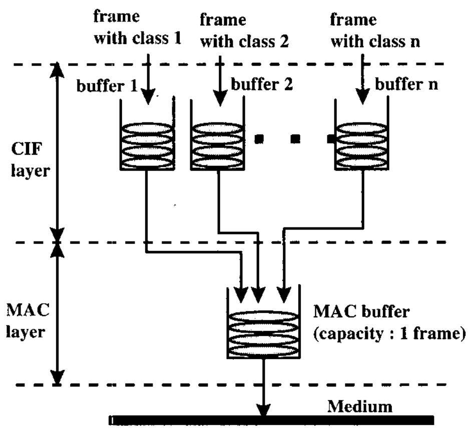

Figure 4. Buffer configuration of a node

Table 1. Frame Length Distribution

Frame length (bytes)	Probability	Probability Distribution	Cell Number (AAL3/4//AAL5)
64	0.304	0.304	2//2
144	0.083	0.387	4//4
220	0.080	0.467	5//6
576	0.100	0.567	13//14
1072	0.250	0.817	23//25
1500	0.183	1.000	32//35

4-1. Collision Avoidance Scheme

Simulations according to two different load conditions are conducted to evaluate the performance of proposed collision avoidance scheme and to compare it to that of standard Ethernet protocol. The first load condition is a balanced load case, in which two nodes generate same amount of traffic. The second one is an unbalanced load case, in which the CIF-AD and the CIF-ES generate 70% and 30% out of total load respectively.

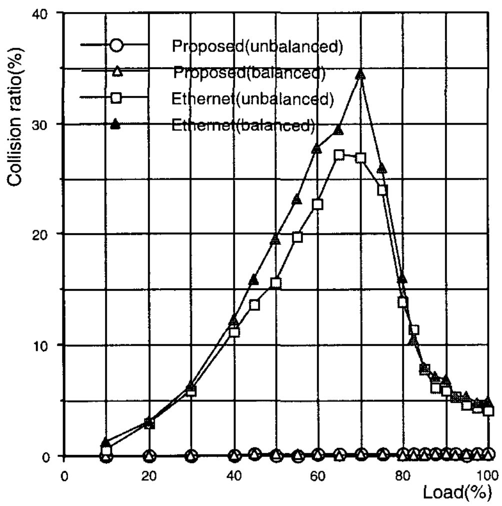

Figure 5. Collision ratio of proposed scheme and Ethernet protocol

Figure 5 shows the collision ratio according to the amount of load. The collision ratio is defined a proportion of the number of collisions to the total number of transmitted frames. The proposed scheme keeps the collision ratio under maximum 0.2% because the collision is only occurred when the frames are generated on both nodes during the round-trip delay between the nodes. However peak collision ratio of Ethernet is over 30% around 70% of load and it sharply decreases as the load increases over 70%. This phenomenon result from capture effect that the backoff waiting delay of a node is much longer than that of the other node at heavy load. It allows a node to send frames continuously without collisions and results severe access unfairness between two nodes.

Figure 6 and Figure 7 shows the access delay of the nodes on the balanced and the unbalanced load conditions respectively. The access delay is defined the time between the point of frame generation and the starting point of frame

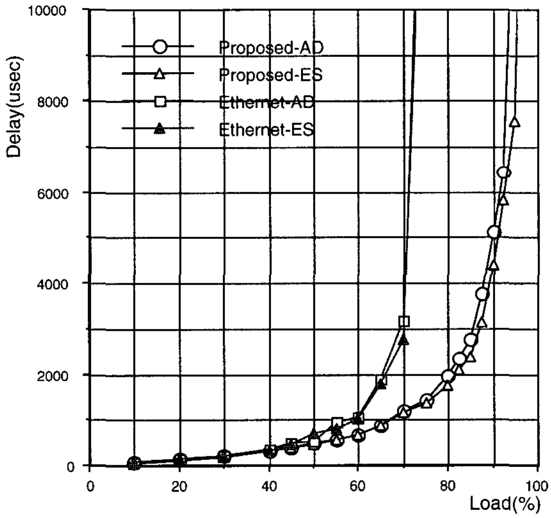

Figure 6. Access delay on balanced load condition

transmission on the medium. In both cases, the proposed scheme shows lower access delay than that of Ethernet because it has much lower collision probability. However there is unfairness on access delay in the unbalanced load case. The CIF-ES generating 30% of the load gets a lower delay compared to that of the AD because the scheme assigns same access opportunities to the both nodes without consideration of traffic unbalance. On the contrary, the CIF-ES has higher access delay in the Ethernet protocol. The higher collision

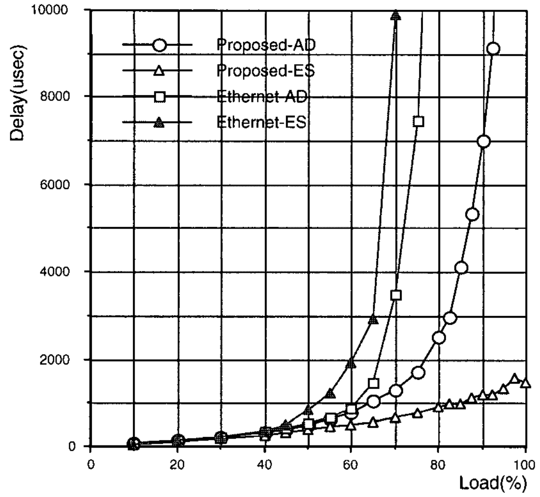

Figure 7. Access delay on unbalanced load condition

ratio per transmitted frame makes the ES longer average backoff delay even if it generates less amount of traffic.

Figure 8 shows the throughput according to the offered load. The saturation point is about 92% for the Ethernet and about 98% for the suggested scheme. In this case the 6% gain is obtained by the lower collision ratio. On both cases, there are no differences of throughput according to the condition of traffic generation.

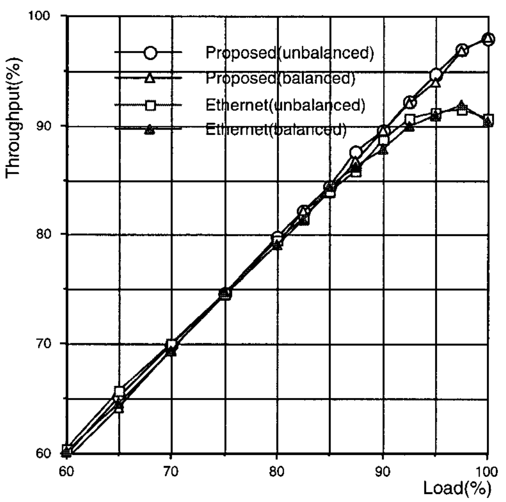

Figure 8. Throughput versus offered load

4-2. Priority access scheme

This paper has supposed each node has the access function of two level priorities. In the Ethernet model, standard Ethernet access protocol is applied to the MAC layer and the frame with highest priority is transmitted first in the CIF layer. In the proposed model, the collision avoidance scheme is applied to the MAC layer and the priority access mechanism is used in CIF layer. Two nodes generate same amount of traffic, while 70% and 30% of generated traffic on AD and ES respectively are the real-time traffic. The load up to 200% of the link capacity is offered to the network to see that the real-time traffic is served prior to the non-real-time traffic on an overload condition.

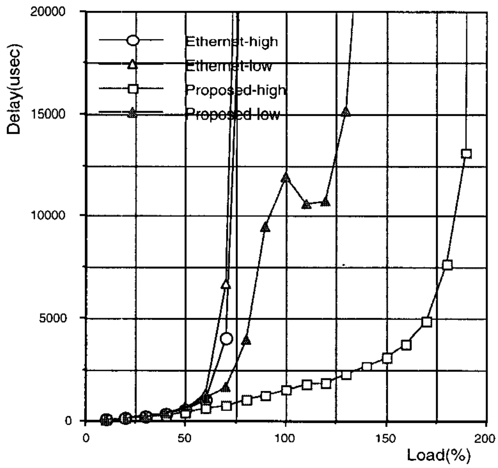

Figure 9. Access delay in CIF-AD

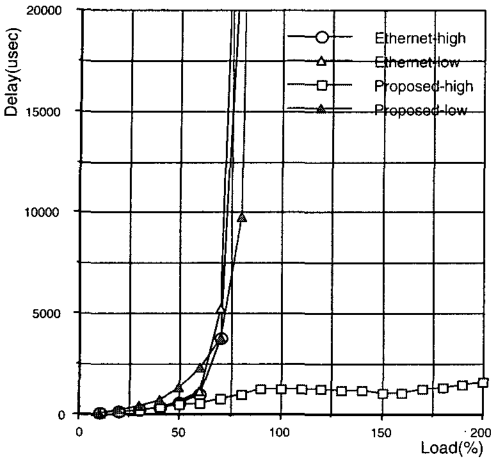

Figure 10. Access delay in CIF-ES

Figure 9 and Figure 10 show the delay of the AD and the ES respectively according to the offered load condition. In the Ethernet case, the access delay is increasing rapidly around the 70% load and is independent of its priority. However, in the suggested scheme, the delay of the real-time traffic is kept lower value even in the overload condition. The delay of real-time traffic of the ES is kept under 200 μsec even in the 200% of offered load, while that of AD is diverged around 175% because real-time traffic generated by the ES is much less under the condition of same access opportunity.

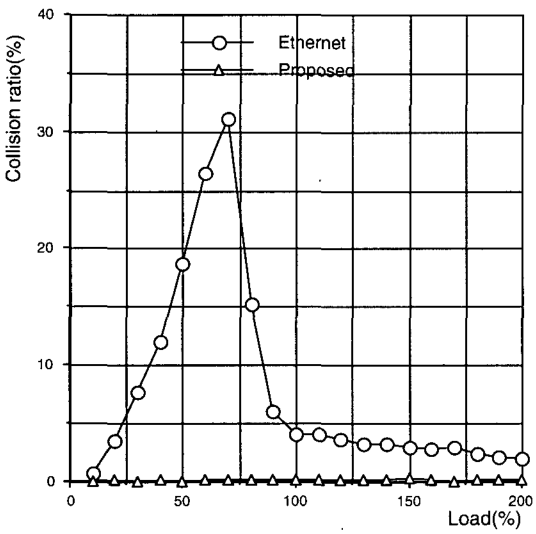

Figure 11. Collision ratio

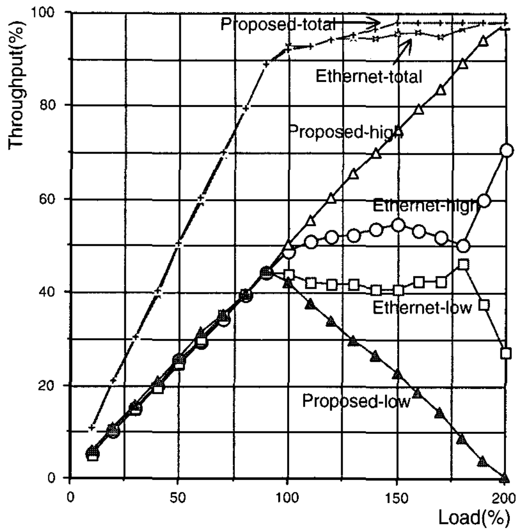

Figure 12. Bandwidth occupancy of each priority

Figure 11 depicts the collision ratio of the suggested scheme and the Ethernet. It shows almost same result as the case without priority access function. The maximum collision ratio of the Ethernet shows 31%, but the suggested scheme shows less than 0.22%.

Figure 12 shows the differences in bandwidth occupancy of each priority and total throughput. For the proposed scheme, the occupancy ratio of the non-real time traffic is decreasing from 100% of offered load and the only real-time traffic is transmitted at 200% load. It means the real-time traffic is transmitted prior to the non-real time traffic even on the overload condition. For the Ethernet case, the non-real-time traffic occupies over 40% of medium bandwidth over 100% of offered load. This means higher priority frames can not be served prior to the lower ones. This is because there is the unfairness of access opportunities under overload.

5. Conclusions

This paper has proposed a collision avoidance and priority control scheme for CIF without requiring hardware modification of CIF-ES. It reduces the collisions by assigning different inter-frame space to the CIF-AD from that of CIF-ES and gives the priority access function by controlling transmission of non-real-time frames according to the queuing status information of the other side node. Proposed collision avoidance scheme keeps the collision ratio under 0.22%, while standard CSMA/CD protocol keeps that over 30%. And it overcomes an access unfairness of Ethernet. Maximum throughput of proposed scheme reaches 98%, while that of existing Ethernet reaches 92%. Proposed priority control scheme provides guaranteed bandwidth to the frame of higher priority. Therefore it is shown that the CIF network with proposed scheme has an improved network performance and supports real-time ATM applications efficiently. In the future, the study on support of ABR service in CIF will be carried out.

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