

# Quality Control Scheme for ATM Switching Network

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In an ATM network, there are many kinds of calls which require various qualities. A method is required to control the connection and cell administration according to the required Quality of Service (QoS) for each connection. In this paper, we propose the Quality Control Path (QCP) concept to control the qualities of the established connections in the ATM switch. With this method, the buffers and the capacities of the physical links in the switch are each divided into logical paths. We also described a control scheme to maintain a required QoS for each connection.

## 1. Introduction

Six years have passed since the basic recommendations on ATM (Asynchronous Transfer Mode) have been frozen in the ITU-T. There have been a few field trials using ATM switching systems over the past two years.<sup>1)-3)</sup> Recently, ITU-T is going to define the bearer capabilities for an ATM network. These are the ATM transfer capabilities, including definitions such as Deterministic Bit Rate (DBR) for circuit emulation and Statistical Bit Rate (SBR) for variable bit rate (VBR) traffic. They will help to allow an ATM network to provide for high bandwidth multimedia services.<sup>4)</sup>

To use an ATM network as a flexible infrastructure for multimedia services, the ATM switch has to provide various QoS (Quality of Service) levels which the end user can request. However, various QoS requirements could imply a complicated and expensive infrastructure from the view points of ATM switching system manufacturing and of network operation. Therefore, this paper discusses the "minimum set" of ATM QoS control mechanisms which should be implemented in advance for the coming multimedia age.

The approach in this paper is different from the QoS control mechanisms in previously proposed ATM switching systems, even though the goal may be the same.<sup>5)-7)</sup> These proposed to change the priority to store cells based on the ac-

tual queue length. In our approach, the key controlled object is the internal/output bandwidth of the ATM switching system. That is, the scheduling mechanism for reading cells from a number of buffer spaces allocated to each QoS class is significant.

In Chapter 2 of this paper, we introduce Quality Control Paths (QCPs), which provides the capability of the minimum bandwidth guaranteed by the ATM switching system for each QoS classes. Chapter 3 will cover candidates for buffer scheduling to realize QCP, then evaluate the performance of each scheduling mechanism.

## 2. Quality control in ATM network

### 2.1 Quality of service (QoS) in ATM network

In the ATM network, various traffic such as data, video and voice are handled for various applications, such as data transfer between LANs, distance learning, video on demand, etc. Different applications may request different quality of services (QoSs) to the ATM network. For example, voice and interactive video applications require low transfer delay, but a data communication application for distributed computing may not stringently require so low delay.

In the ATM Forum, five ATM layer service categories which are CBR (Constant Bit Rate), rt-

VBR (real time Variable Bit Rate), nrt-VBR (non real time VBR), ABR (Available Bit Rate), and UBR (Unspecified Bit Rate) are defined.<sup>8)</sup> And the attributes of required QoS for each service are defined. The concrete objective values on Cell Loss Ratio (CLR) will be specified for CBR, rt-VBR, nrt-VBR and ABR. The objective values on maximum Cell Transfer Delay (CTD) will be specified for CBR and rt-VBR.

Further, charging policy will be related to QoS provided in the ATM network. For example, if objective value of QoS and negotiated bandwidth can fairly be guaranteed in the network, the network can charge the bandwidth of the connection based on the holding time. However, in the case that many connections share the common bandwidth, it is natural that the network charges the number of cells actually carried in the service category.

In summary, to make ATM network to be a flexible infrastructure for multimedia communication, the ATM switching system should have a basic mechanism to provide various QoSs.

## 2.2 Traffic control in ATM switching system

To maintain QoS objectives, the ATM switching system has a set of traffic control function. The ATM switching system usually determines whether the new connection set-up can be accepted or rejected. It uses a CAC (Connection Admission Control) algorithm, which can judge whether the required QoS for every connection can be maintained after the acceptance of the new connection or not. The Usage Parameter Control (UPC) then checks whether the actual user transmission cell rate is compliant with the CAC negotiated cell rate.

However, even the combination of both CAC and UPC is not enough to differentiate QoS levels and efficiently use the network resources. To allocate many connections to a common bandwidth for the economical service class, such as a UBR service, a per-connection-based CAC and UPC will

not be done, because the available bandwidth during silent periods of connections should allow for an any connection in active state to be used. However, for the service class requiring a stringent QoS, interference by traffic from the economical class must be avoided. Therefore, a kind of priority scheme is necessary. To provide a flexible QoS class menu, the ATM switching system should differentiate how to store and forward cells due to the requested QoS class of the ATM connection.

For example, an ATM switching system can accommodate two types of connections, one with strict QoS requirements for delay and another with not so strict requirements, by using two cell buffers. When there are cells in the buffer of the strict requirements-class for delay, the switch reads-out the cells for the higher priority strict QoS class. The cells of the not so strict delay class are read-out when there are no cells in the higher priority delay class buffer.

## 2.3 Quality control path<sup>9)</sup>

### 2.3.1 QCP concept

First, let us suppose that a network provides an economical ATM transfer capability such as an Unspecified Bit Rate (UBR) service (defined the ATM Forum). In this service, a statistical multiplexing gain is desired but the QoS objective value need not be specified. If every end-user were satisfied with this kind of economical services, all ATM network resources, such as bandwidth and buffer spaces, could be shared. However, for a multimedia infrastructure, the ATM network has to simultaneously provide other ATM transfer capabilities, including DBR in which a QoS objective value needs to be specified. In this situation, all network resource cannot be shared due to the potential negative impact of the other ATM transfer capabilities degrading the QoS.

The simplest method to protect the QoS between various ATM transfer capabilities is segmentation of bandwidth, referred to as the deterministic bandwidth scheme. That is, some deterministic

bandwidth is allocated to an ATM transfer capability and is guaranteed by deterministic readout scheduling. Of course, bandwidth allocation, i.e., readout frequency for ATM transfer capability, may be rearranged. Considering that it seems impossible to design a credible integrated CAC algorithm for all traffic types shared with the total bandwidth without segmentation, the deterministic bandwidth scheme provides a realistic and credible CAC solution. In this system, some deterministic bandwidth is given to the transfer capability which handles similar types of traffic and provides similar QoS requirements, independent of the others. Furthermore, deterministic bandwidth will be convenient when ATM switching system provides ABR (Available Bit Rate) transfer capabilities. In an ABR service, some available bandwidth will be shared among ABR connections. Therefore, the available bandwidth for the ABR in the switching system must first be determined and should be guaranteed especially when calculating the allowed cell rate for each ABR connection.

On the other hand, the deterministic bandwidth scheme may waste network resources. For example, some stored cells in a buffer space for the transfer capability cannot be read until the next scheduling time, even though there are no stored cells in other buffer spaces for other transfer capabilities. Furthermore, if the number of classes is large and only a few bandwidth slots can be allocated to each class, the cell queuing delay could be extremely large because the equivalent frequency to serve becomes lower. Similarly, statistical multiplexing gain must be small for bursty traffic because the probability that the sum of Peak Cell Rate (PCR) for the many simultaneous traffic sources exceeding available bandwidth would be relatively large.

We propose Quality Control Path (QCP) for an ATM switching system to maintain required QoS levels (see **Fig. 1**). The goal is to utilize the internal/external bandwidth of the switching system efficiently, while guaranteeing some 'minimum' bandwidth in order to prevent QoS inter-

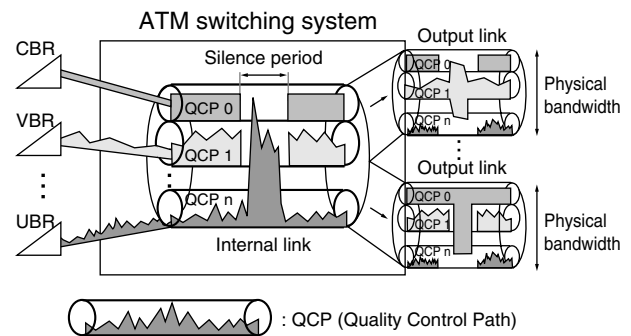


Fig.1– Concept of QCP.

ference between services. This basic aim is the same as the deterministic bandwidth scheme. The following scheduling rule is added to the basic deterministic bandwidth scheme in order to enhance resource efficiency. Stored cells for a class can be read out whenever there is no stored cells in other buffer spaces for other classes even before it is time for scheduling classes. That is, the stored cell need not wait its next scheduled time interval. Figure 1 shows the schematic diagram configuration for QCP. The unified ATM switching system with QCPs performs as if there were multiple virtual switch areas for QoS classes. The switching system allocates one QoS class to one QCP. If there are several QCPs which can read out by the added scheduling rule, a reading priority between QCPs is determined.

The available bandwidth used by CAC is the guaranteed bandwidth allocated to a QCP. That is, when the switching system receives a new connection set-up request, it will determine whether the request can be accepted or should be rejected. If the available bandwidth, i.e., the QCP bandwidth, is large enough for the QoS objectives of the QCP to be maintained for all connections—including the new request—the request is accepted. The actual QoS provided in the switching system must be better than the request because the actual bandwidth could be larger than the QCP bandwidth by the scheduling rule described above. That is, when there are no cells in the QCPs having reached the next scheduled time, the other QCPs having not reached the next scheduled time

can read out their cells.

### 2.3.2 QCP control method

**Figure 2** shows the QCP structure. At the input to system, a new proprietary header are attached to each cell. The new special header includes not only routing information for the switching system, but also an appropriate QoS class number based on the user request. The cell is then sent to the QCP class buffers, where it is written to the buffer that corresponds to the QoS class number. The cell readout rates from the buffers are scheduled according to each QCP bandwidth in the physical bandwidth of the output link. The QoS for each QCP class can be controlled by adjusting the scheduler.

## 3. Evaluation of proposed scheme

### 3.1 Comparison objects

In this section, the proposed scheme described the previous section is evaluated by using comparisons. We will compare the following ATM allocation schemes:

- 1) our new method
- 2) deterministic bandwidth
- 3) simple priority

**Figure 3** shows a representation of each allocation method. The mechanism of each method is as follows:

- 1) our proposed scheme (QCP mechanism)

The scheduler allocates cell readout times to each priority class periodically (minimum bandwidth). If there is no cell in the buffer of the allocated class, a cell in other class is read out from

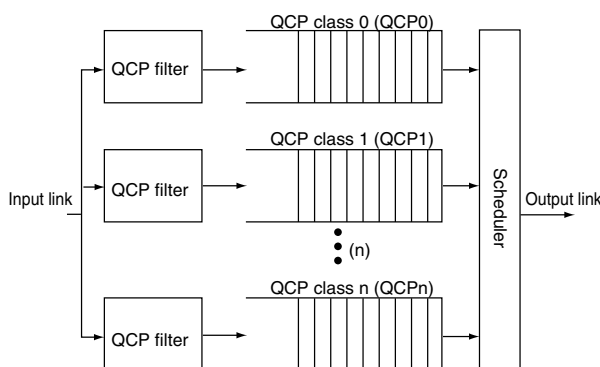
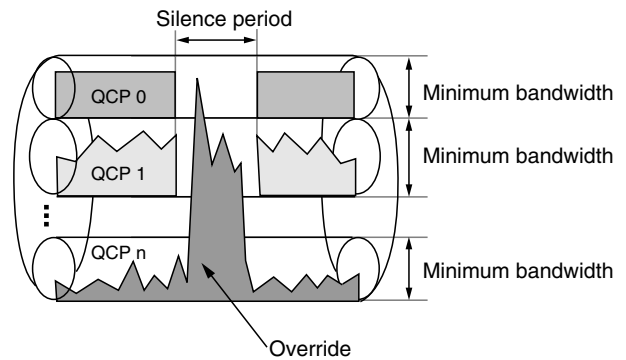
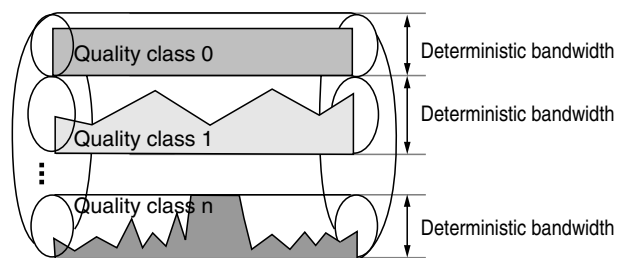


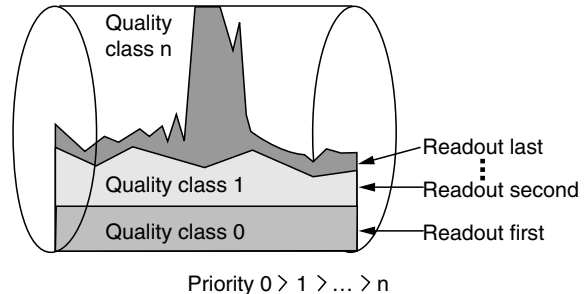
Fig.2– QCP structure.



a) Our proposed scheme (QCP)



b) Deterministic bandwidth scheme



c) Simple priority scheme

Fig.3– Comparison objects.

the buffer. In other words, a cell in the buffer can readout if there are no cells in the other classes which can readout {Fig. 3 a) }.

- 2) deterministic bandwidth scheme

In this scheme, each priority class is assigned to a deterministic bandwidth according to a guaranteed QoS for connections. The scheduler allocates cell readout times to each priority class periodically. Even if there is no cell in the buffer of the allocated class, no cell is read out from the other buffers {Fig. 3 b) }.

### 3) simple priority scheme

In this scheme, a cell with a higher priority is read before cells with lower priorities at any time. The lower priority cell is read if there are no cells with the higher priority in the buffer. The scheduler selects the cell with the highest priority for readout (Fig. 3 c) ).

## 3.2 Simulations and results

We studied the characteristics of each scheme described in the previous subsection with simulations. We used a general simulation language<sup>10)</sup> and FORTRAN. The simulation model is showed in Fig. 4. In this simulation, the number of priority classes are three labeled QCP0, QCP1, and QCP2. The line speed of the output is 149.76 Mbit/s (353,207 cell/s). The cell buffer of each priority class is divided physically. The readout of cells from each priority class is determined by the scheduler. The buffer length is infinitely long.

QCP0 has poisson traffic that utilizes 90% of the QCP0 channel bandwidth. QCP1 has burst traffic that utilizes 60% of the QCP1 channel bandwidth. (A burst traffic model is shown in Fig. 5.) QCP2 has poisson traffic, where the utilization of

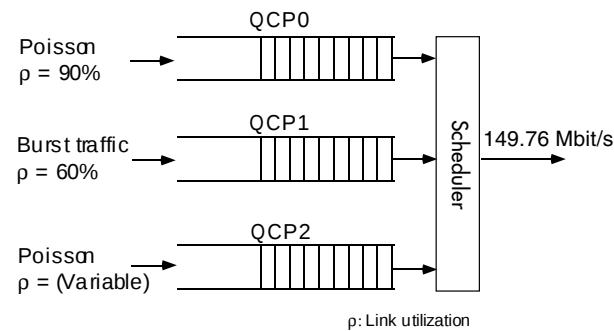


Fig.4- Simulation model.

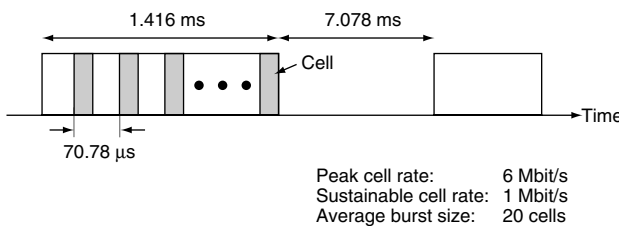


Fig.5- Burst traffic model.

QCP2 channel bandwidth is a variable parameter.

The simulation results are shown in Fig. 6.

In Fig. 6 a)-c), the results show that the delay time for the deterministic bandwidth scheme is longer than the others independent on the simulation conditions. The delay time of the deterministic bandwidth scheme is large because the scheduler does not utilize the bandwidth effectively when the other classes are idle. The delay time for QCP0 when using the simple priority scheme was smaller than all of the others because QCP0 always has the highest priority readout. As for QCP1, the delay time in our proposed scheme is not so large when the traffic load of QCPs is balanced (Fig. 6 b)). However, when the traffic load is imbalanced, the delay time of QCP1 in the simple priority scheme is larger than in our proposed

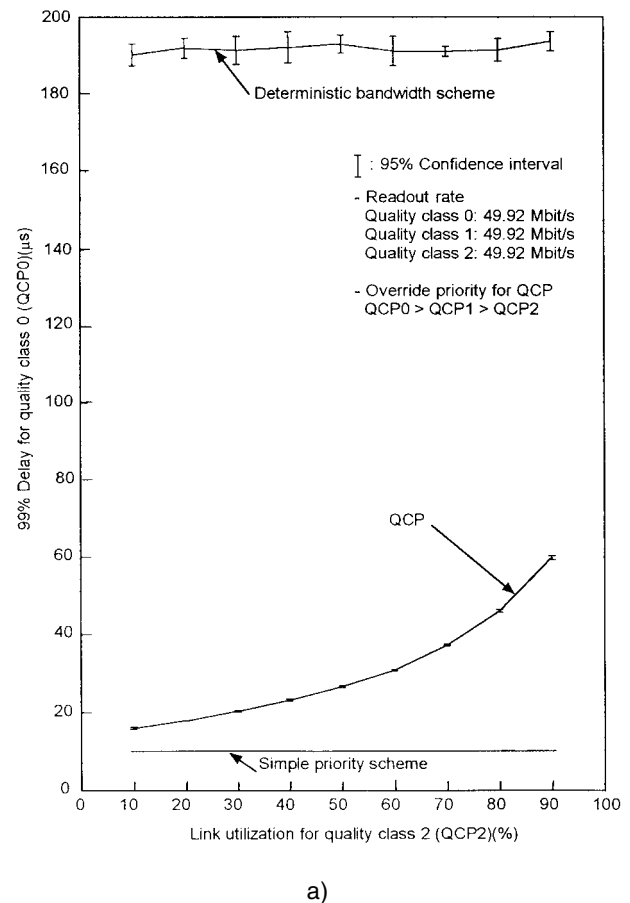


Fig.6- Simulation result.

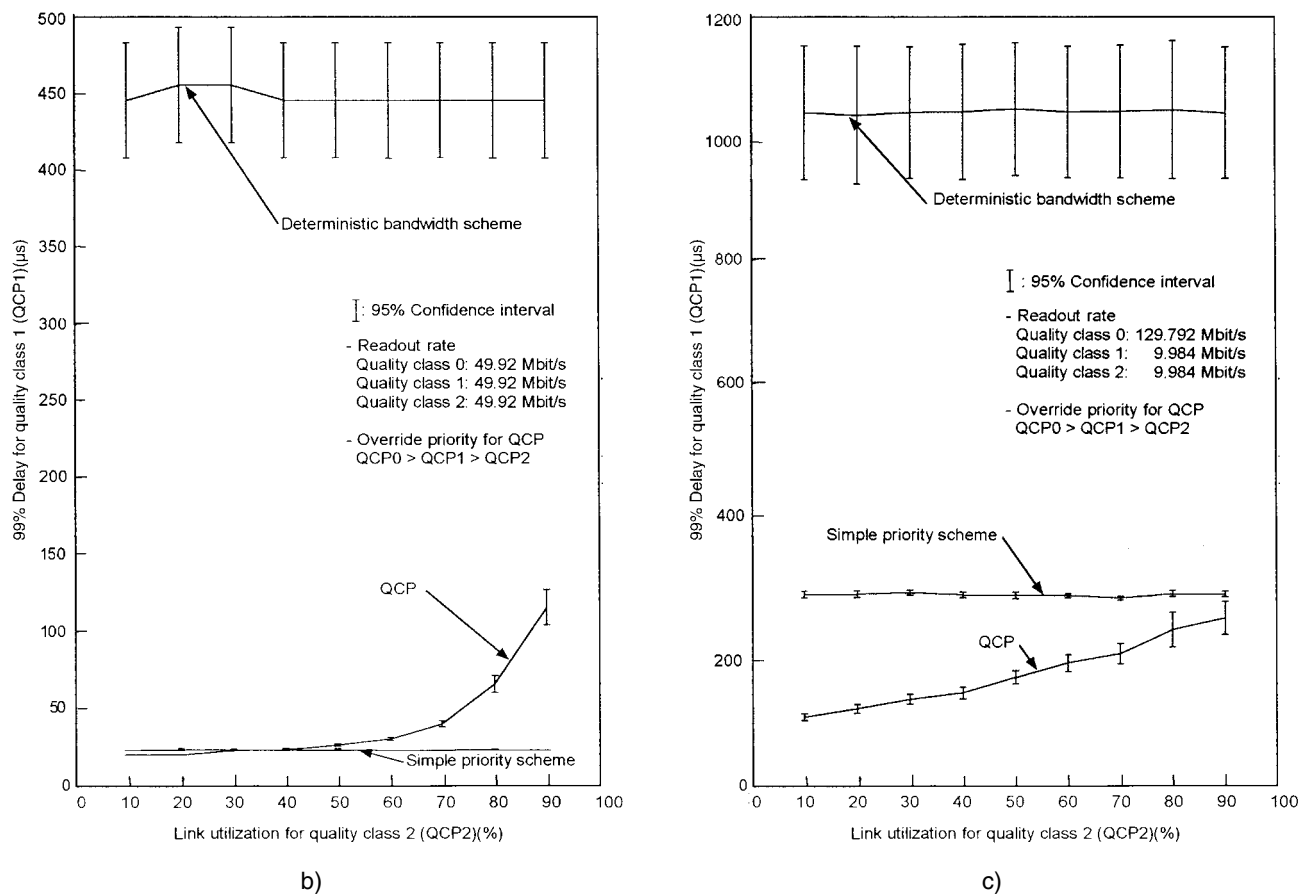


Fig.6— Simulation result.

scheme [Fig. 6 c)]. This reason is that much traffic load of QCP0 overrides QCP1 at any time in the simple priority scheme but the QCP1's minimum bandwidth is maintained in our proposed scheme. Our proposed scheme allows other classes to allocate the reading times properly, while serving the higher priority class.

### 3.3 Comparison of schemes

Here, our proposed scheme is compared with the simple priority scheme from other viewpoints.

From a viewpoint of hardware complexity, the proposed scheme needs the schedulers to allocate the minimum bandwidth for each quality class, but the simple priority scheme does not need the complex scheduler. It needs only a simple scheduler which selects a cell with the highest priority from the buffer. Therefore, our proposed scheme requires more complex hardware than the simple

priority scheme.

From a viewpoint of traffic control, the simple queuing model is applied to evaluations of delay and CLR (cell loss ratio) in the proposed scheme. In our proposed scheme, the upper limits of the maximum delay and maximum CLR of each priority class is evaluated approximately to use a G/D/1 model with the minimum bandwidth. And the evaluation is not influenced by the traffic load of other classes.

In the simple priority scheme, evaluation of quality is complex. The G/D/1 model is applied to evaluation only in the highest priority class. In the other classes, more complex queuing models are required, and the quality is influenced by the load of higher priority classes.

Therefore, a complex algorithm which includes the traffic and quality of the other priority classes is required for the CAC algorithm of the

Table 1. Comparison of two schemes

|                                | QCP                                                      | Simple priority scheme                                      |
|--------------------------------|----------------------------------------------------------|-------------------------------------------------------------|
| Delay of second priority class | Medium (balanced traffic)<br>Medium (imbalanced traffic) | Low (balanced traffic)<br>High (imbalanced traffic)         |
| Hardware complexity            | Complex scheduler for maintaining minimum bandwidth      | Simple Scheduler for selecting a highest priority cell      |
| Delay evaluation               | Simple queuing model (G/D/1)                             | Complex queuing model considers higher classes load (G/G/1) |
| CAC algorithm                  | Independent of other classes                             | Dependent on other classes                                  |

simple priority scheme.

**Table 1** shows a relative comparison of characteristics between our proposed QCP scheme and simple priority scheme.

#### 4. Conclusion

To make a viable ATM network for flexible multimedia services, end users will require various Quality of Service (QoS) levels. This paper discussed the “minimum set” of mechanisms, which should be implemented in the ATM switching system to provide a number of QoS classes while satisfying economical restriction.

We proposed Quality Control Paths (QCPs) for the internal link and output port of the ATM switching system. In QCP, a “minimum bandwidth” is guaranteed for each QoS class provided by the network, while available bandwidth during channel idle time can be allocated to other QCPs. The scheduler allocates cell readout times to each priority class periodically (minimum bandwidth). If there is no stored cell in a buffer for a class at the allocated time, a cell stored another buffer for another class is read out.

Our proposed QCP method was compared with the simple priority scheme in which the cell with the higher priority is read out prior to the cell with the lower priority at any time. The cell transfer delay (CTD) on the cells with the highest priority in the simple priority scheme is of course smaller than that our proposed QCP scheme. However, the CTD of the cells with second pri-

ty in the simple priority scheme could be larger than our proposed scheme, especially when the dominant traffic is the cells with the highest priority. From the viewpoint of traffic control, the conservative queuing behavior for any QCPs can independently be evaluated, based on the “minimum bandwidth” in the proposed QCP scheme. Conversely, in the simple priority scheme model, the queuing behavior of a lower priority class is influenced by the load of all higher-priority classes. When we consider that at least two other QoS classes (CBR and rt-VBR services) need to guarantee the CTD objective values, we concluded that the introduction of the QCP into the ATM switching system is a reasonable and feasible solution.

The QCP scheme has been implemented in the ATM switching system for four QoS classes. We have been studying the required number of QoS classes for the actual application demand in future.

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