Malaysian Journal of Computer Science, Vol. 15 No. 2, December 2002, pp. 34-42

A PERFORMANCE STUDY OF ATM MULTICAST SWITCH WITH DIFFERENT TRAFFICS

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ABSTRACT

The demand of multicast service in ATM networks such as video teleconferencing and large file transfer makes the multicast switch very important. Since the cell loss and delay will decrease the performance of an ATM multicast switch, this paper proposes a new architecture of the switch. To improve the performance, this paper classifies traffic into three categories with different requirements: real-time traffic, near real-time traffic and non real-time traffic. The proposed architecture with the above traffic classes is studied by developing appropriate simulation models. Subsequently, the effects of arrival rate and immediate rate on the switch performance are studied quantitatively and qualitatively. It is concluded that the proposed architecture can support different future types of multimedia traffic, where cell loss probability and delay requirement will be the main factors.

Keywords: ***Multicast switch, Performance, Simulation, Cell loss, Cell delay, Real time, Near real time, Non real time.***

1.0 INTRODUCTION

Since the past few years, ATM or Asynchronous Transfer Mode has come out as a leading data transmission technique for high-speed networks [9]. Transmitting and receiving information in ATM networks and the determination of how to forward the cell are performed by the ATM switch. The use of switches is an effective technique to increase the performance of the network. An ATM switch contains a set of input ports and output ports and it is connection oriented. It is responsible to transmit the ATM cell or information from an incoming logical ATM input port to an appropriate outgoing logical ATM output port that takes the cell to its intended destination.

In today's multimedia era, ATM-based technology is capable to transmit and support services with both constant and variable bit rates where the services could be a combination of voice, data, picture and video. However, the services, which are provided in a wide variety of communications types, are transmitted with different transmission requirements. Most importantly, they should be able to be provided in multipoint communication in addition to point-to-point connection. Hence, to make the network capable of providing such flexible communication, a multicast switch is absolutely necessary.

A multicast switch is a very important component for multicast services which copy cells or packets from a single input port to a selected number of output ports [4]. This type of switch, which is capable of cell replications and switching is usually accomplished by a copy network (CN) and followed by a point-to-point routing network (RN) [10, 12]. The CN of both multicast switches replicate input cells from various sources and then the RN routes all the copies to their final destination. Most of the ATM multicast switches that have ever been proposed have either operated with only a single priority or two priorities of traffic class. The two traffics, which have been dealt with in many papers, are real-time traffic and non real-time traffic [3, 5, 7, 10, 12].

For the purpose to enhance the multicast switch performance, this paper proposes a new architecture, which describes several improvements to Endo's multicast switch architecture, which is referred as the basic architecture. In a previous related study, the cell loss of real-time traffic is not really dealt with but large loss may reduce the quality of the communication. In order to avoid large loss to happen in real-time traffic, this paper splits this type of traffic into real-time traffic and near real-time traffic. This is because, although the near real-time traffic is quite close to real-time traffic, it can tolerate a little delay. The classification of those three traffic types is very important to get the best improvement of ATM switch [2].

This paper also considers the use of efficient input buffering and scheduling scheme to decrease the cell loss. A buffer is necessary when two or more cells arrive at the same time and are destined to the same output. The output here is meant for the routing network because this paper evaluates mean cell delay and cell loss probability before the routing network. This new N×N multicast switch uses a separated input buffer for each input port in each route. To ease the decision regarding the cell to be dropped in the case of overflow, the cells are classified as:

- highest priority (real-time cell),
- second priority (near real-time cell) and
- lowest priority (non real-time cell).

The new architecture will serve the highest priority first until the number of ports, while the residual copy requests of other cells will be buffered if they are not served in a time slot. However, in this case, the real-time cell is the only cell that is served without being buffered. This is due to the fact that it is stringent to delay.

2.0 MODELLING TECHNIQUE

The performance modelling is studied via computer simulation. The proposed switch system consists of two different routes: real-time route (RT Route – for real-time and near real-time cell) and non real-time route (NRT Route – for non real-time cell) followed by a routing network (RN). Each route has its own buffer, cyclic running adder network (CRAN), copy network (CN) and trunk number translators (TNT) as shown in Fig. 1.

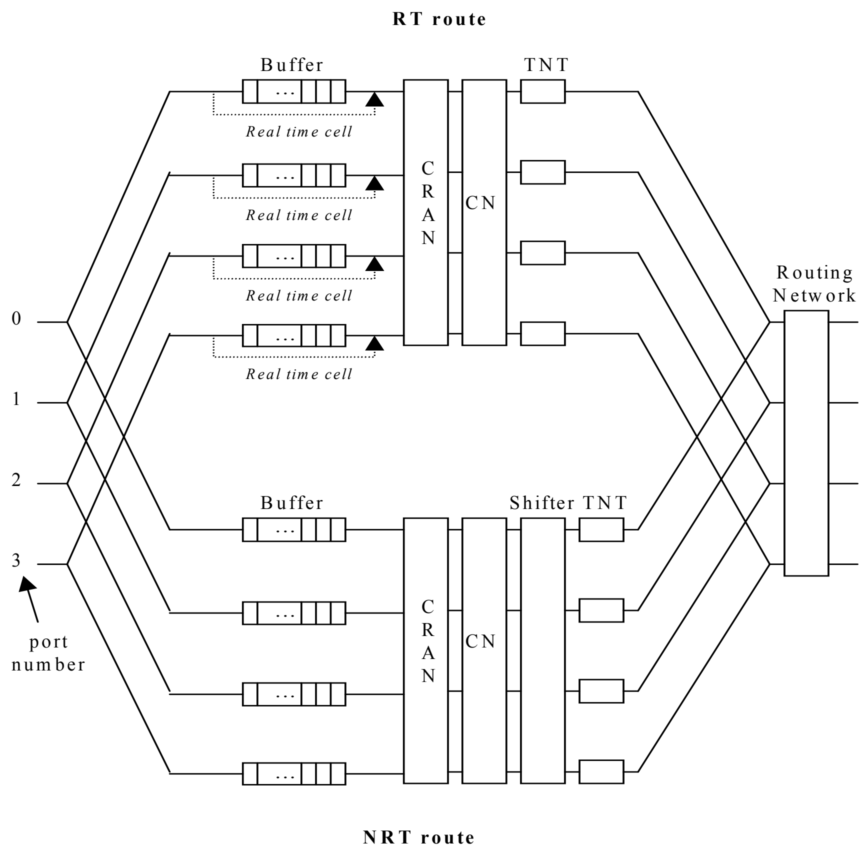

Fig. 1: Proposed multicast switch model

The function of each component is described as below:

- Buffers, which exist before a CN are required for every port to store cell requests in order to prevent cell loss.
- CRAN is used to calculate the running sums of requested copy number (RCN) of the incoming cell in any input port. The RCN is basically specified in the headers of input cells [8].

- The function of CN in this paper is the same as that of CN proposed by other researchers of multicast switches where it is responsible to make copies of broadcast cells from various inputs ports as they pass through and passes the copies to TNT.
- The TNT determines the destination address of each replicated cell based on its copy index and broadcasts the channel number. The copies are then passed to the RN to be routed to their final destination.

The difference between RT Route and NRT Route is the existence of a shifter after a CN. The shifter is used to shift served copy requests from CN to the port that is not used at the RN. A served copy of incoming cell means the cell has been replicated by CN.

The improvement of the basic architecture allows the switch to achieve lower losses and delay of real-time and near real-time cell since a buffer is added at each port of RT route. In this model, the RealTCs and NearRCs are routed through the RT route while the non real-time cells (NonRCs) are routed through the NRT route.

In this paper, two quality of service (QOS) parameters have been defined; 1) cell loss probability and 2) mean cell delay. The cell loss means the amount of lost copy request, which is obtained when more copy requests compete for the buffer and those copy requests loss due to buffer overflow. This cell loss probability has to be kept within limits to ensure high reliability of the switch. Let:

$$\text{Cell loss probability (of each cell type)} = \frac{\Sigma \text{ copy requests loss}}{\Sigma \text{ RCN}} \tag{1}$$

The delay is defined as the number of clock cycles a requested copy spends in the switch from the instant it enters the switch until it leaves the switch. Since this paper evaluates the mean cell delay before the RN in the switch model, the mean cell delay means the average number of time slots a copy request spends from the time it joins the buffer until it departs from the TNT.

$$\text{Mean cell delay} = \frac{\Sigma (T_D - T_A)}{\Sigma \text{ copy request departed}} \tag{2}$$

where;

T_D : The time a copy request of specific buffer departs from the switch
T_A : The time a copy request arrives in the switch

2.1 Switch Operation

The switch operation and the input traffic pattern is described as follows :

- Each input port of the switch has a buffer associated with it. The size of each input buffer is finite and denoted by Bsize where the buffer can hold up to Bsize copy request.
- An arrival process is defined as follows:
  λ_{in} is to be the input rate and *pim* indicates the rate of the real-time cell against all arriving cells (i.e. immediate rate).
  Therefore, the input rate of real-time cell is given by:
  $$\lambda_s = \lambda_{in} \ x \ pim \tag{3}$$
  while the input rate of NonRC is given by:
  $$\lambda_t = (1 - pim) \ x \ \lambda_{in} \tag{4}$$
- Due to three traffic types, where the real-time cell is split into RealTC and NearRC, this paper introduces *pr* to indicate the rate of the RealTC against all arriving real-time cells. As the result, the input rate of RealTCs is represented by λ_r where:
  $$\lambda_r = \lambda_s \ x \ pr \tag{5}$$
  while the input rate of NearRc is represented by λ_n where:
  $$\lambda_n = (1 - pr) \ x \ \lambda_s \tag{6}$$
- The number of copies that is requested by each multicast cell, copy, is independent of the arrival process. In this case, the cell is replicated copy number of times and is sent to copy distinct output ports. This means, each copy of the original cell is sent to exactly one output port.

3.0 RESULTS AND DISCUSSIONS

The simulation experiments are undertaken to evaluate the performance of the proposed multicast switch. The two subsections below present the results for studying the effects of varying the arrival rate and real-time (RealTC) class traffic on the near real-time (NearRC) traffic performance.

3.1 Effect of Varying the Arrival Rate

In this paper, five parameters are taken into consideration, namely the arrival rate λ_{in}, the input buffer size Bsize, the copy number requested by each incoming cell copy, the immediate rate *pim* and the RealTC rate *pr* (Table 1).

Table 1: Simulation Parameters under Varying the Arrival Rate

Parameter	Value(s)
λ_{in}	0.05 – 0.95
Bsize	20
copy	4
pim	0.6
pr	0.5

To investigate the accuracy of the three-traffic model, this subsection firstly compares the results of a new model with the basic model. Fig. 2 to Fig. 5 plot the cell loss probability versus the arrival rate obtained from the simulation of the basic and the proposed model. Fig. 6 to Fig. 7 show the results of mean cell delay versus the arrival rate for the two different models.

For convenience of illustration, this paper uses the naming convention below to represent the different types of traffic shown in all figures.

- Old Real - real-time traffic of the basic model
- Old Non - non real-time traffic of the basic model
- New Real - real-time traffic (RealTC) of the proposed model
- New Near - near real-time traffic (NearRC) of the proposed model
- New Non - non real-time traffic (NonRC) of the proposed model

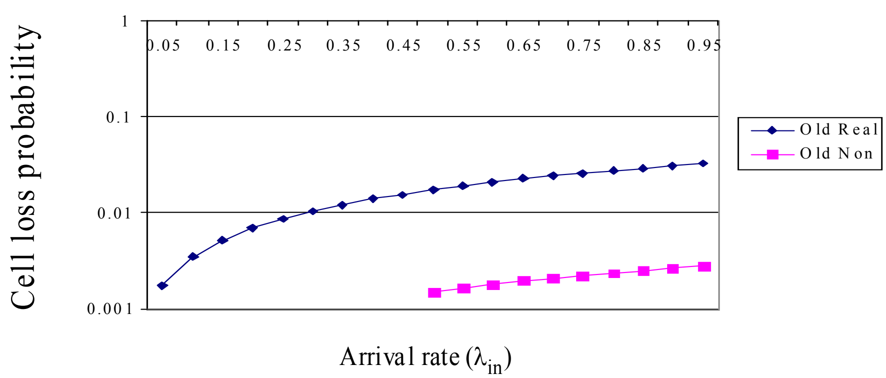

Fig. 2: Cell Loss Probability versus Arrival Rate for Two Traffic Models

Fig. 2 shows the cell loss probability of the basic model with two curves representing the loss probability of real-time cell and non real-time cell. It shows that, as the arrival rate increases, the cell loss probability also increases for both the traffics. This happens as when arrival rate increases, more cells arrive. As the result, the cells dropped more frequently due to lack of free port at RN. However, the loss probability of non real-time cell is lower than that of real-time cell since the cell loss of the non real-time cell is decreased by the input buffer.

A comparison on cell loss probability among three traffic types of the proposed model is shown in Fig. 3. In the case that λ_{in} is small, the cell loss probabilities of the RealTC, NearRC and NonRC are small. As the λ_{in} is increased, the cell loss probabilities of these three traffics increase. As seen in the figure, the cell loss probability of the RealTC is the smallest compared to those of the NearRC and NonRC. This is because the arriving cell of RealTC is assigned a higher priority over the other two traffics. This means, the copy requests of RealTC are the first to be served.

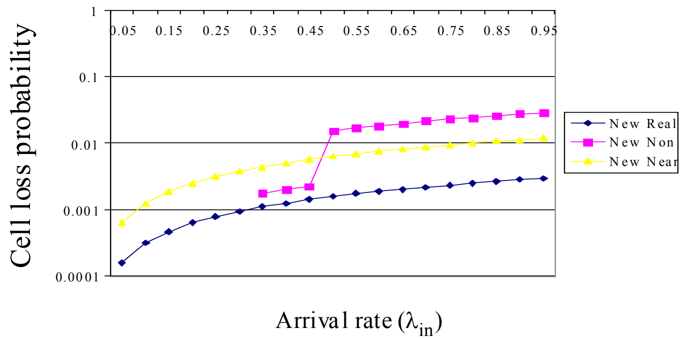

Fig. 3: Cell Loss Probability versus Arrival Rate for Three Traffic Models

In the case that λ_{in} is less than 0.45, the cell loss probability of NonRC is smaller than that of the NearRC since the number of arriving NonRCs is small and the overflow of the NearRCs at the input buffer occurs more frequently. However, in the case that λ_{in} increases beyond 0.45, the cell loss probability of NonRC rises drastically. The loss probability now seems the largest since many copy requests of RealTC and NearRC are served and few NonRC copy requests can be served. In addition, the NonRC is given the lowest priority in service.

Fig. 4 plots a comparison on cell loss probability of real-time traffic for two different models. It shows that the cell loss probability of RealTC in the proposed model is smaller than the cell loss probability of real-time cell in the basic model. It also shows the low cell loss probability of NearRC in the proposed model. When the cell loss probabilities of the RealTC and NearRC in the proposed model are totaled up, the loss probability is still much smaller than the probability of real-time cell in the basic model. Thus, it can be concluded that by separating the real-time cell into two different cells, RealTC and NearRC, it can reduce the loss probability of copy requests. This is because, the ratio of arriving RealTC becomes smaller and the residual copy requests of NearRC can be kept in the buffer whenever there is no idle port at RN to serve them.

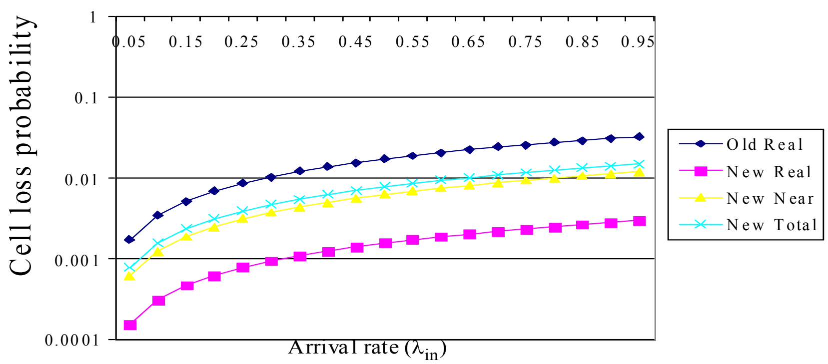

Fig. 4 : Cell Loss Probability of Real-time Traffic versus Arrival Rate for Two Different Models

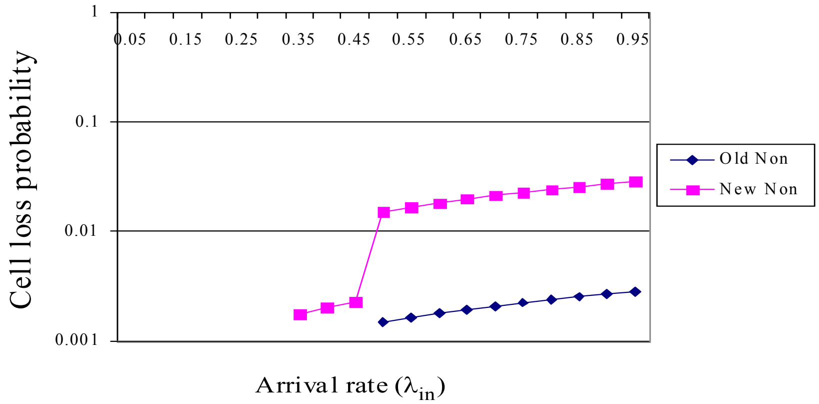

Fig. 5: Cell Loss Probability of Non Real-time Traffic versus Arrival Rate for Two Different Models

Fig. 5, however, shows that the loss probability of NonRC is larger than that of the non real-time traffic of the old system. Thus, it can be concluded that, the more we protect the RealTC and NearRC traffics, the smaller the loss probability of these traffics but the larger the loss probability of NonRC. From all the figures, it can be seen that the cell loss probabilities of all three traffics increase as λ_{in} increases.

Mean cell delay of the near real-time (NearRC) and non real-time (NonRC) of the proposed model versus arrival rate is plotted in Fig. 6. Due to the copy request of this type of traffic served first without being queued in the buffer, the delay of RealTC does not occur. The NearRC buffers are managed by *First In First Out with Ordinary Blocking* (FIFO-BL) buffering scheme to guarantee the delay of NearRC cells within a small-predetermined value [11].

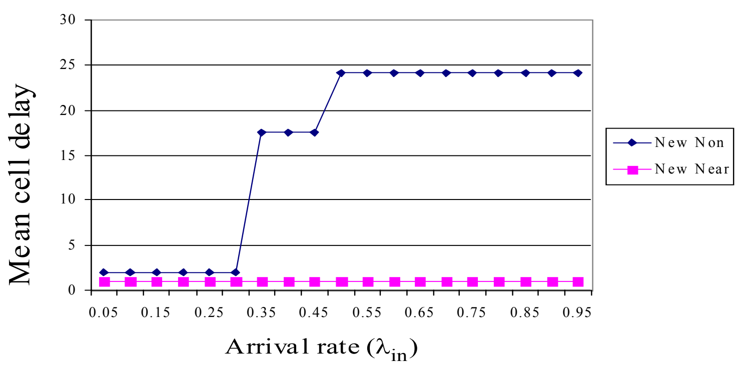

Fig. 6: Mean Cell Delay versus Arrival Rate for Three Traffic Models

As λ_{in} increases, the mean cell delay of NearRC is nearly unchanged because each queued copy request has been assigned a maximum waiting time. In this case, the copy request exceeds the time dropped from the system. Thus, it maintains the delay of this type of traffic. On the other hand, the mean cell delay of NonRC increases as λ_{in} increases. The delay rises quickly as λ_{in} increases beyond 0.25. This is because the load of the switch becomes higher which means the number of cell arrivals at the input buffer increases accordingly. As a result, the buffers get used up quickly and the copy requests of NonRC have to wait at the input buffer for a longer time.

Fig. 7 shows a comparison of the performance in terms of mean cell delay of non real-time traffic between the basic model and the proposed model. It shows that the mean cell delay of NonRC in the proposed system is higher than that of the basic model. It is due to the fact that the larger the λ_{in}, the less we protect the NonRC traffic. Therefore, it can also be concluded that the more we protect the NearRC traffic, the smaller the mean cell delay of this traffic but the larger the mean cell delay of NonRC.

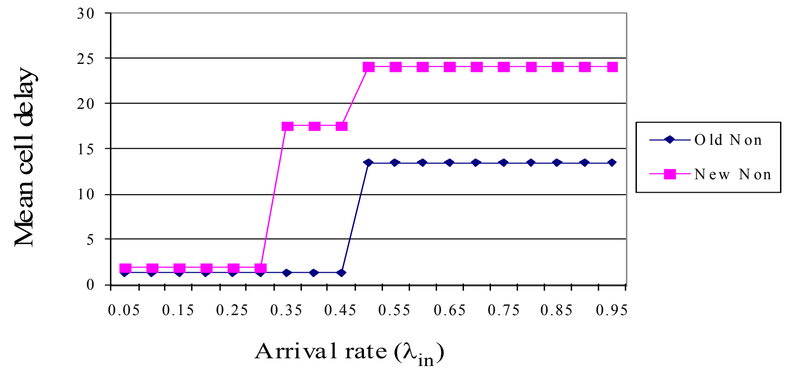

Fig. 7: Mean Cell Delay of Non Real-time Traffic versus Arrival Rate for Two Different Models

3.2 Effect of Real-time (RealTC) Class Traffic on the Near Real-time (NearRC) Traffic Performance

This subsection presents a result that shows the effect of RealTC rate, *pr,* against all arriving real-time cells including the NearRC so that it can provide the answer to help us compare the relative performance. The simulation is conducted using the values of input parameters as given in Table 2.

Table 2: Simulation Parameters under Varying the RealTC Rate

Parameter	Value(s)
λ_{in}	0.4
Bsize	20
copy	4
pim	0.6
pr	0.05 – 0.95

Fig. 8 shows that when *pr* is small, the arriving cells of RealTC is much smaller than the arriving cells of NearRC. Therefore, the cell loss probability of NearRC is greater than that of RealTC since the large number of arriving cells of NearRC makes the overflow of the NearRC at the input buffer occur more frequently. However, it is noted that the loss probability of NearRC gets smaller as *pr* increases. This can be explained that as *pr* increases, the arriving cells of NearRC decreases. On the other hand, the arriving cells of RealTC increases.

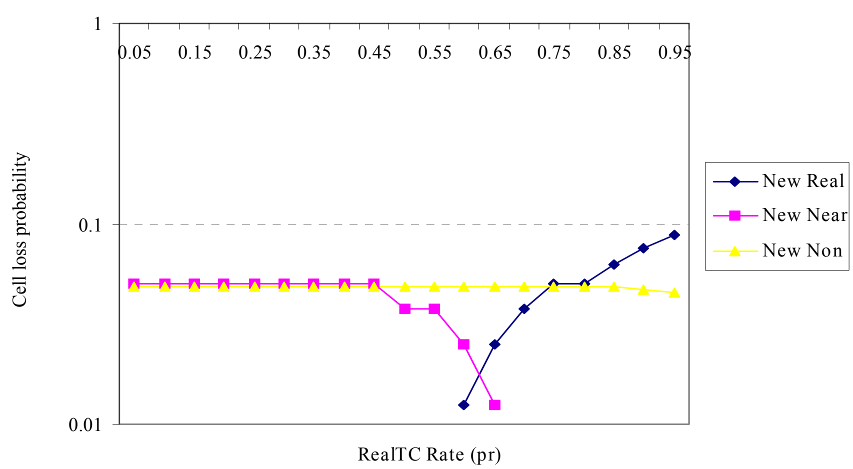

Fig. 8: Cell Loss Probability versus RealTC Rate for Three Traffic Models

As *pr* increases beyond half of the value, the cell loss probability of RealTC rises drastically. This is because, the higher values of *pr*, the more RealTC copy requests arriving. As a result, more copy requests cannot be served. Since the RealTC are not being buffered, these copy requests are lost from the system. From the figure, it also shows that pr = 0.6 gives the optimal cell loss performance with the given buffer sizes and RCN.

4.0 CONCLUSIONS

In this paper, the performance of a new ATM multicast switch under three different traffics with two separate routes has been studied. With the separate routes, this model is capable of handling different kinds of traffics, which are having different requirements of loss and delay probabilities. The simulation results clearly show that the proposed model, which separates the real-time cell into two different traffics achieves better performance than the basic model.

Furthermore, it has become clear that buffering copy requests of NearRC and NonRC end with a significant improvement in reducing their cell loss probability. Considering the results in the previous section, however, it shows that the more we protect real-time and near real-time traffic, the lower the performance of non real-time traffic.

The main contribution of this paper are the derivations of performance measures for three traffic types that take into account the influence of separating the real-time traffic into two other different traffics: real-time and near real-time, and the development of a simulation model. When the real-time class is decomposed with two sub-classes, the performance of the sub-classes was also derived. The decomposition approach is effective in the sense that the model can make the loss probability and mean cell delay of the RealTC and NearRC small.

5.0 FUTURE WORK

The investigation of ATM multicast switch architecture is only in an initial phase, where the performance for only three traffic types is presented. In future, the multicast operation across the switch for more types of traffic can be investigated. Finally, a more complete study of the influence of the various traffics on the maximum system throughput can practically help in designing more efficient multicast switch systems.

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BIOGRAPHY

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