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Multicast ATM Switches : Survey and Performance Evaluation*

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Abstract

In the past twelve years or so, many designs for multicasting ATM switches are proposed. It seems about time to do a historical survey. It is hoped that by learning from the wisdom of the previous authors, new spark or angle can be found and exploited to design new multicasting ATM switches. Without easy and inexpensive multicasting, all the exciting services may become unaffordable. This will in turn lead to the diminishing of customer bases and finally will hinder the full-scale deployment of high speed networks.

1. Introduction

Asynchronous Transfer Mode, commonly known by the slightly unfortunate acronym of ATM (Automatic Teller Machines or Another Technical Mistake), is the most widely studied and implemented form of high speed networks. Its standards are defined by ITU-T, formerly CCITT, and some interim standards are being developed by a user and vendor group known as the ATM Forum. ATM is the underlying transmission system for CCITT's next-generation ISDN, Broadband ISDN. BISDN is designed to provide subscriber communication services over a wide range of bit rates from a few megabits to several gigabits. Among the services emerged are video-on-demand, distant learning, video conference, and so on. Many of these services are characterized by point-to-multipoint communication. To support this capability in an ATM network, the ATM switch must be able to transmit copies of an incoming cell to different outlets. In doing so, there are many problems to be solved. For example, where is the cell copying to be done? How to handle the output port conflicts resulting from multicasting cells? How can cell ordering sequence be kept? The solutions to all the above problems require nontrivial modification to the original point-to-point ATM switches.

In principle, an ATM switch shall perform two basic functions: switching and queueing. Switching is to transport the information from an incoming logical ATM channel to an outgoing logical channel ATM channel. This logical channel is characterized by:

- A physical inlet/outlet pair indicated by physical port number
- A logical channel on the physical port, characterized by a virtual channel identifier (VCI) and/or a virtual path identifier (VPI).

When more logical channels contend for the same link or switching element in the internal of an ATM switch, blocking would occur. Since it is usually unwise to discard cells randomly, queueing, the second basic function of an ATM switch, is necessary. According to inhere the queues are provided in a switch, three types of switches can be identified: input queueing switches with buffers at the input ports; output queueing switches with the buffers at the output ports; and shared buffer switches with buffers inside a switch to be shared by the entire traffic. Examples of switch designs are abundant in the literature. Please refer to [1] for an extensive survey.

Multicasting for ATM switches means that an incoming cell is destined for more than one output port in the switch. If an ATM switch does not include the cell replicating function, it is not a multicast switch - since it can not do multicasting. Therefor, in studying multicast ATM switches, cell replicating is a very important operation that needs special attention.

In cascaded multicast switch architectures, the interconnection networks of the switch fabric can be decomposed into several subfunctions, and each subfunction is accomplished by one subnetwork component. A number of cascading design techniques

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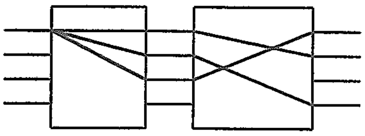

Fig. 1: A multicast packet switch consists of a copy network and a point-to-point switch.

for multicast connectivity has been previously described in the literature [2-19]. Fig 1 shows the basic architecture for a multicast switch. It is usually a serial combination of a copy network followed by a point-to-point (unicast) switch. The copy network replicates input cells from various sources simultaneously, and then copies of multicast cells are routed to their final destination by the point-to-point switch.

Copy network, as it is named, is a special kind of functional networks for replicating cells. That is, it is used to duplicate a multicast cell into many corresponding unicast cells. If there is a copy network doing cell replicating in a ATM switch, then the switch can be regarded as a multicast switch.

In fact, the copy network is not absolutely necessary for a multicast switch. If a switch does not have a copy network but somehow manages for the cell replicating operation in itself, it is still a multicast switch. Often in this kind of switches there is no particular switch element which is in charge of cell replicating. More or less, the cell duplication is just a sub-function in some components in the switch such as routing elements.

From starlite in 1984 [12], various multicast ATM switches are explained and examined in this paper. The purpose is to take a snapshot of the current status quo. Since multicasting is expected to be more important and common place. It is our sincere hope that this paper will arouse new enthusiasm and entice new design directions.

The remainder of this paper is organized as follows. Section 2 surveys various switches for multicasting. Performance evaluations are conducted on some of the switches on Section 3. Finally, conclusions and future research directions are given in Section 4.

2. Survey of Multicast ATM Switches

Before dwelling on details, historical developments of some multicast switches are shown in Fig. 2. Starlite switch [12] is the earliest architecture which discussed the multicasting traffic. It builds on the combination of two simple switch architecture, crossbar network and Batcher-Banyan network. Sunshine switch [13] is a modified version of Starlite switch to improve the performance. Knockout switch [7] is built only on crossbar network. It is an output queueing switch and is regarded as having the best performance. Gauss ATM Switching Element (ASE) [9] is a switch which is very similar to Knockout switch and which is output queueing also.

Turner proposed the first broadcast switch based solely on Batcher-Banyan network in 1988 [16]. At the same year, Lee presented another switch for multicasting traffic. After these harbinger works, many new designs for multicast switches followed.

Shared Concentration and Output Queueing Multicast (SCOQ) switch [4] is a switch with shared concentration and output queueing. It is modified from Knockout switch. Recursive Multistage Structure [6], a switch based on Link-Grouped Multistage Interconnection Network (LGMIN) [19], and Multinet switch [13] are both improved from Turner's or Lee's switch.

Besides the above switches, another switches design directions are based on the Clos network. Growable Packet Switch [8] and Ring Sandwich Network [17] are examples of this kind of switches.

Guo and Chang developed an ATM multicast switch from another point of view in 1995 [11]. They tried to make the total switch cycles needed as few as possible to transmit the incoming cells (including unicast cells and multicast cells). The way adopted is prescheduling the incoming cells so that the cells going through the followed multicast switch at the same "time" (switch cycle) will need no recirculation and will cause no internal or output port conflicts in the switch. Due to the limitations of space, we omit the presentation of details for every switch fabric mentioned in the paper.

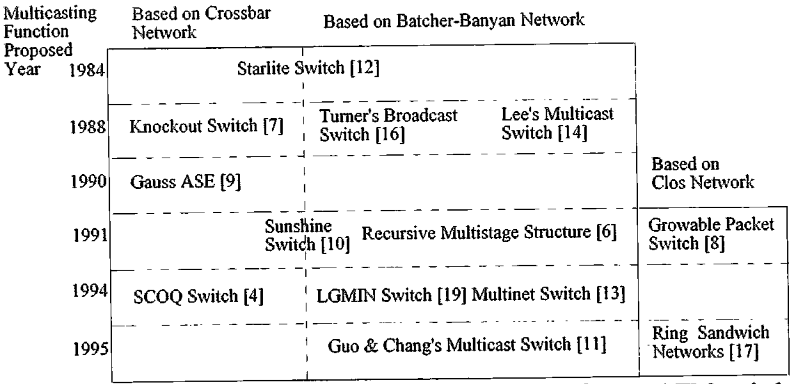

Fig. 2: The relationships in time and basic architecture of some ATM switches.

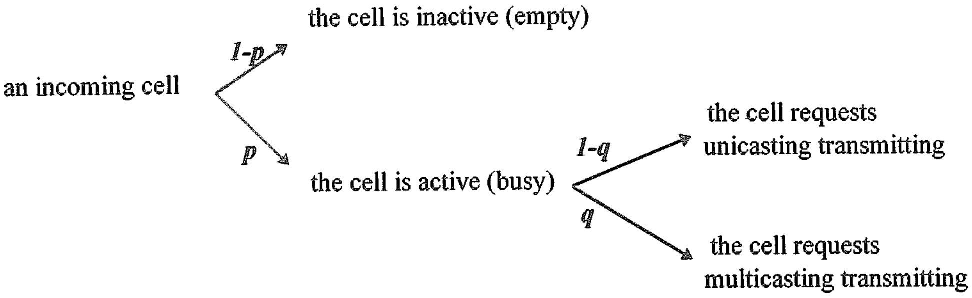

Fig. 3: The decision tree used in the simulation

3. Performance Evaluation

3.1 Simulation Assumptions

In this section, simulations are conducted to test three multicast switches. They are the SCOQ switch in [4], the Lee's switch in [14], and Guo and Chang's switch in [11]. Let A represents the event that an incoming cell is active or inactive, and let B represents the event that an active cell requests unicasting or multicasting transmitting. In the simulation, assume $Pro(A = active) = p$, $Pro(B = multicasting\ transmitting) = q$ and these two events are all *Bernoulli processes*. Fig. 3 depicts the relationship of these two events and the decision tree used in the simulation. Furthermore, assume that every output port in the switch has the same probability of being chosen.

3.2 Simulation Results

Four types of output port selection criteria are used in our simulation. They are: (1) All output ports can be chosen as the destination. (2) Only upper half of the output ports can be chosen. (3) Only odd numbered output ports can be chosen. (4) Same as (1), but all output ports in a multicast should be consecutive.

By using $p = 1$ (every input port is active), Fig. 4 to Fig. 8 are the results of total cycles needed for different q among three switches under the above four types of output patterns. Some conclusions from these figures: (1) When there are not many multicasting patterns in the switch traffic (for example, $q \leqq 0.5$), the SCOQ switch works better than the other two switches. But when there are more and more multicasting patterns in the switch traffic ($q \geqq 0.6$), the performance of the SCOQ switch degrades more than the other two switches. The reason is because of the restriction of the copy network in the SCOQ switch. The copy network will replicate less and less cells if there are more and more multicasting patterns in the traffic. (2) Our multicast switch model needs less cycles than Lee's switch, especially for output port traffic (4). It indicates that prescheduling multicast cells before copying indeed works. Besides that, the performance degradation of Lee's switch and our multicast switch is not so unstable as the SCOQ switch when there are more and more multicasting patterns in the traffic.

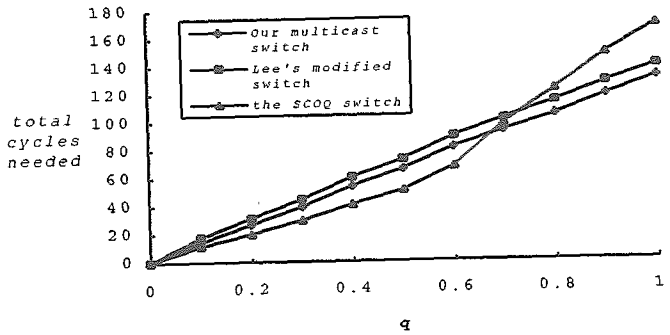

Fig. 4: Comparison of total cycles needed for different q among three switches under output port pattern (1) ($N = 256, p = 1$)

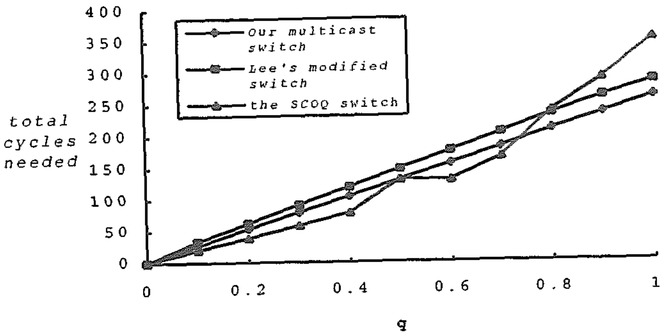

Fig. 5: Comparison of total cycles needed for different q among three switches under output port pattern (1) ($N = 512, p = 1$)

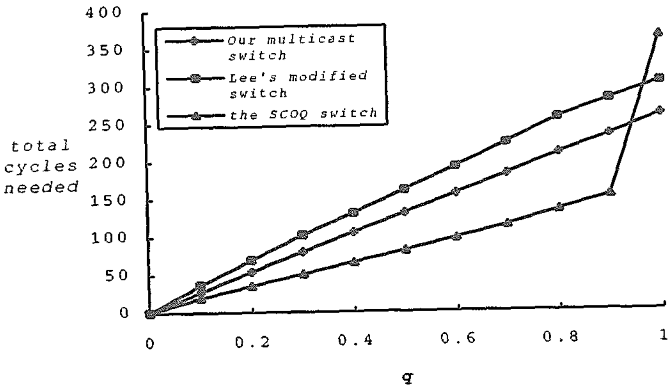

Fig. 6: Comparison of total cycles needed for different q among three switches under output port pattern (2) ($N = 512, p = 1$)

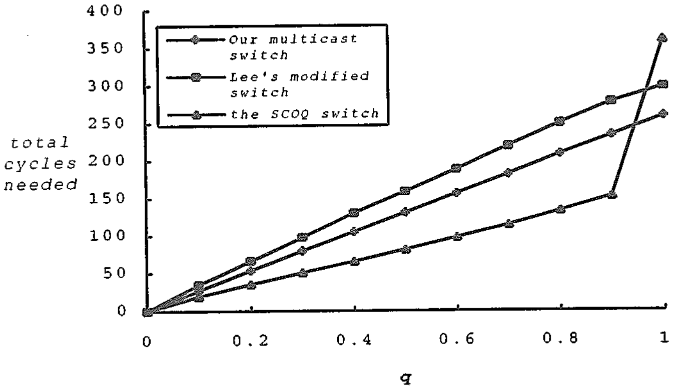

Fig. 7: Comparison of total cycles needed for different q among three switches under output port pattern (3) ($N = 512, p = 1$)

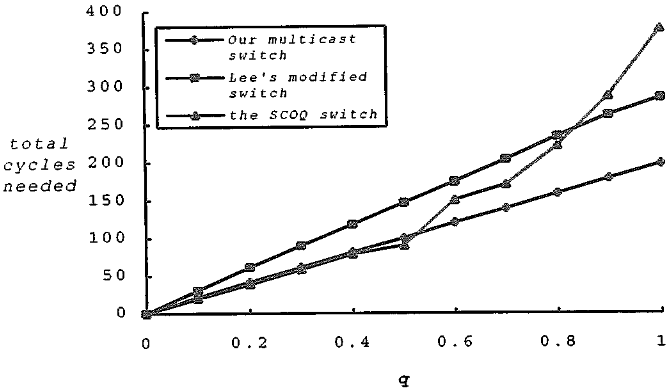

Fig. 8: Comparison of total cycles needed for different q among three switches under output port pattern (4) ($N = 512, p = 1$)

To further test the prescheduling concept, Fig. 9 and Fig. 10 show the total cycles needed for our switch model under four types of output port selection patterns with $N = 512$ and $N = 1024$ respectively. Fig. 11 to Fig. 12 show the same testing for Lee's modified switch and the SCOQ switch respectively.

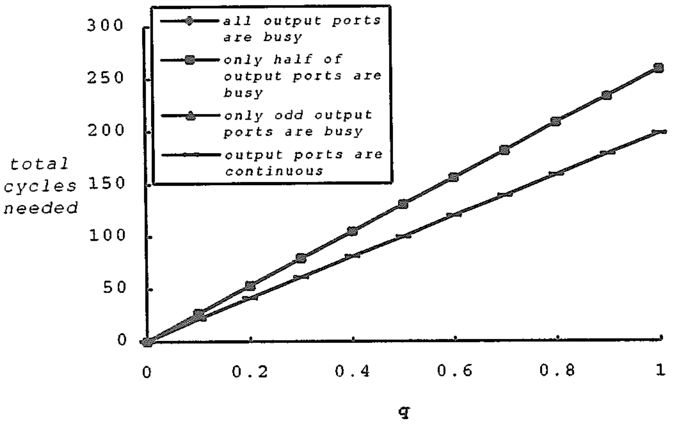

Fig. 9: Total cycles needed of our multicast switch under four types of output port patterns ($N = 512, p = 1$)

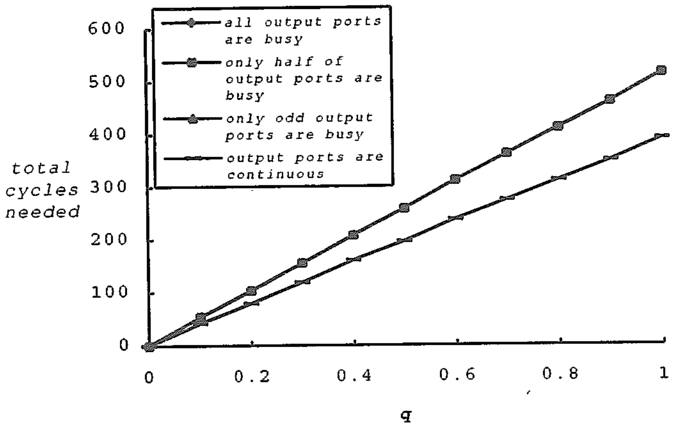

Fig. 10: Total cycles needed of our multicast switch under four types of output port patterns (*N = 1024, p = 1*)

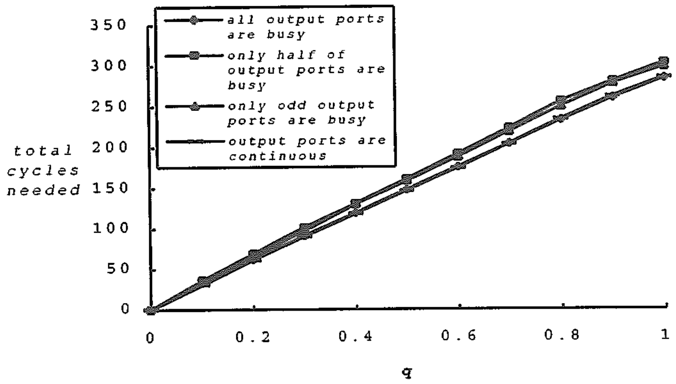

Fig. 11: Total cycles needed of Lee's modified switch under four types of output port patterns (*N = 512, p = 1*)

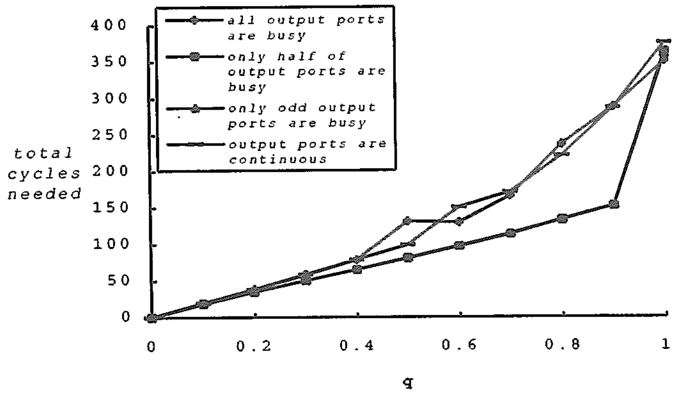

Fig. 12: Total cycles needed of the SCOQ switch under four types of output port patterns (*N = 512, p = 1*)

According to these figures the following conclusions can be drawn: (1) Our multicast switch model is robust with respect to output pattern variations. (2) Our multicast switch is the most stable among the three switches.

4. Conclusion

In this paper, various multicast ATM switches designed from 1984 to 1995 are examined. Performance Evaluations are conducted to test some of the switches. The results seem to indicate that the concept of scheduling before copying is not a bad idea. But, all of the switches have yet to be tested in a real multicasting service environment.

Computer networks are changing at a daunting speed. The killer application WWW (World Wide Web) has made the network (Internet) interesting and easily accessible. This will make the deployment of next generation high speed networks become more necessary and urgent. The users can not wait (WWW = World Wide Wait). So designing new, efficient, and cheap high speed network elements will be crucial to the development of networks. From the above surveys, several research directions can be identified:

- Combine the concept of prescheduling with the best features of other switches to design a new multicast switch.
- The scheduling produced multicasting cycles are not optimal. Is further improvement possible?
- Benchmarks for testing ATM switches in general (multicast switches in particular) have to be developed and standardized.
- Compatibility and interoperability problems between multicast ATM switches have to be addressed.

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