Proc. Natl. Sci. Counc. ROC(A)
Vol. 22, No. 5, 1998. pp. 627-635

(Scientific Note)

The Strategies of Address Resolution Model and Traffic Control for Multimedia Data Transmission with QoS Guarantees between ATM and Ethernet

YU-CHANG CHEN*, CHEIN-CHIH CHANG**, ANN-YO JENG*, WEN-SHYONG HSIEH*,†, AND CHU-SING YANG*

**Institute of Computer and Information Engineering*
National Sun Yat-Sen University
Kaohsiung, Taiwan, R.O.C.
***Institute of Electrical Engineering*
National Sun Yat-Sen University
Kaohsiung, Taiwan, R.O.C.

(Received September 27, 1997; Accepted February 23, 1998)

ABSTRACT

This paper proposes efficient strategies for address resolution and QoS (Quality of Service) guarantees between a huge network contained ATM(Asynchronous Transfer Model) and Ethernet. To fulfill these purposes, first, we have to solve the "addressing problem". The classical IP(Internet Protocol) over ATM, LAN(Local Area Network) Emulation, Peer Model, Next Hop Resolution Protocol (NHRP) and Multiprotocol Over ATM (MPOA) have been proposed, but there are some limitations to these methods. The Peer Leader Address Resolution Protocol (PLARP) will be introduced to reduce these limitations. To attain the QoS guarantees between an ATM and traditional network (such as Ethernet), a new connection admission control engine named the "Edge-device Connection Admission Control (ECAC) Server" is proposed for multimedia data transmissions. The ECAC server takes the responsibility of auditing connection requests and flow control. The performance evaluation results show the advantages of the strategies proposed in this paper.

Key Words: ATM, QoS, classical IP over ATM, LAN emulation, peer model, next hop resolution protocol, multiprotocol over ATM, Edge-device Connection Admission Control (ECAC), Peer Leader Address Resolution Protocol (PLARP)

I. Introduction

Because of the rapid growth of multimedia data transmission, there is an urgent need to find a suitable method for dealing with the huge amount of multimedia data transmissions. The Asynchronous Transfer Mode (ATM) is a good choice for multimedia data transmission having the characteristics of high bandwidth and Quality of Service (QoS) guarantees. However, it is still very difficult to find a seamless method to build interconnections between ATM network and Ethernet. In the paper, we treat multimedia data as real time data, such as voice, video etc. QoS means the quality of multimedia data transmission, considering minimal delay and delay jitter (variation) and proper bandwidth allocation. To reduce data transmission delay, we must build an end-to-end connection from the source to destination. In other words, it is better to eliminate intermediate systems between the source and destination. When data is transmitted from an ATM network to a router, it must be converted from cells to packets to get the routing path. Then, the packets must be converted to cells again for transmission from the router to the ATM network. This process will cause huge data transmission delay. This paper will reveal how to improve the addressing model and will propose the Peer Leader Address Resolution Protocol (PLARP) method to improve the efficiency of data transmission.

†To whom all correspondence should be addressed.

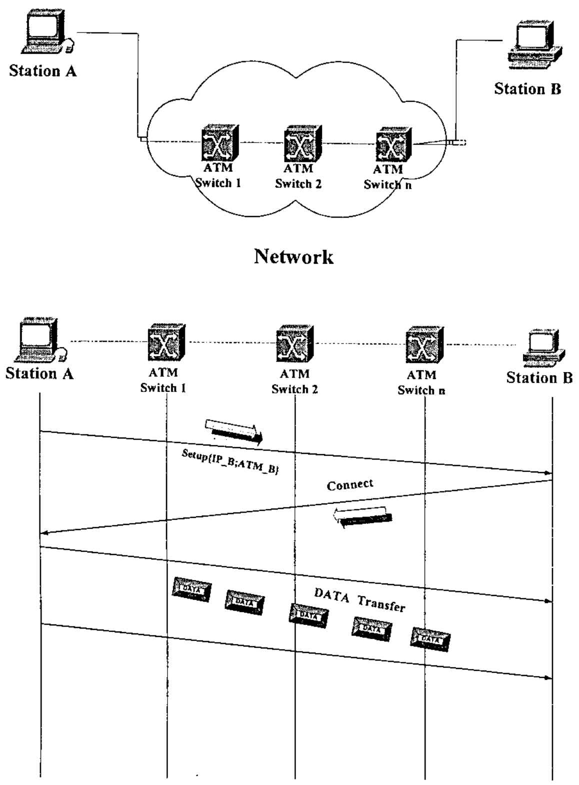

Fig. 1. End-to-end connection.

Additionally, it is not true that higher bandwidth transmission is better. For example, the bit rate of voice data is constant and a constant bit rate connection is needed. With a transmission bandwidth higher than the voice connection demand, data will be dropped. Furthermore, this will cause voice distortion and increase the voice data loss rate. For the same reason, this will happen in video data transmission. This is the reason why we propose the ECAC (Edge-device Connection Admission Control) Server to control connection requests and monitor traffic admitted by the ECAC Server.

II. Addressing Model

The best connection model from a source to a destination is a direct end-to-end connection without any intermediary system, as shown in Fig. 1. When station A intends to build a connection with station B to transmit data, the data can go directly through from station A to station B without any intermediate system, and this will be an efficient address resolution model. As a result, data transmission delay will be decreased and will reach the minimum range. For multimedia data transmission, this will be more suitable, and this is the goal of PLARP model proposed in this paper.

There are many address resolution models such as the Classical IP over ATM (Laubach, 1994), LAN Emulation (John, 1997), Peer Model (Iwata *et al.*, 1995), NHRP (Iwata *et al.*, 1995) and MPOA (Multiprotocol over ATM) (Andre, 1997). This section will present our proposed address resolution model – PLARP.

1. Peer Leader ARP (PLARP) Model

Considering the Classical IP over ATM, LANE, Peer Model, NHRP and MPOA, none is favorable for multimedia data transmission. Accordingly, we propose the PLARP model to improve the efficiency of the connection setup and data transmission processes. In the PLARP model, as shown in Fig. 2, we can see that each LIS has one or more Local ARP (LARP) servers, and that the network manager selects a leader from LARPs, which we call the "Peer Leader ARP" (PLARP) server. The election policies state that the network manager constructs a PLARP server and assigns a backup PLARP server. All ARP servers have a **linked table**, including PLARP and LARP server hierarchical structures. The PLARP server has to set up a permanent virtual channel (PVC) or switch virtual channel (SVC) connected to other PLARP and LARP servers. Figure 3 shows the hierarchical structure of PLARP model shown in Fig. 2. For example, as Fig. 3 shows, PLARP 2 makes PVC or SVC connections to PLARP 1, PLARP 3, PLARP 4, LARP 2-1 and LARP 2-2. The responsibility of PLARP / LARP is to exchange **the variation ARP tables** with other ARP servers. Base on the same rule, the LIS Group (LISG) is composed of many LISs. The network manager also selects a leader from the PLARP servers within the LISG and assigns a backup PLARP server for them in the initial state. It has a hierarchical structure. A bigger LISG is composed of many smaller LISG.s. Because

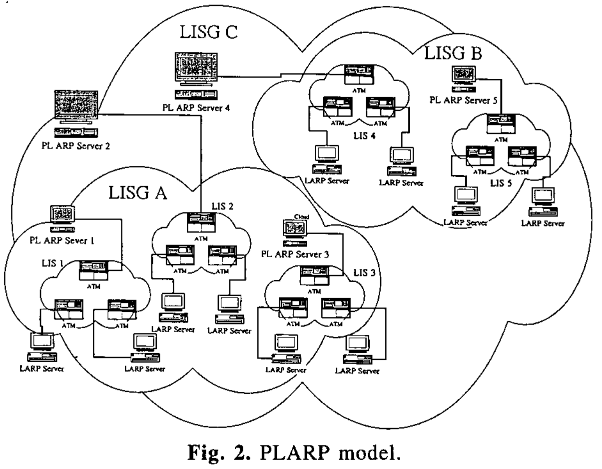

Fig. 2. PLARP model.

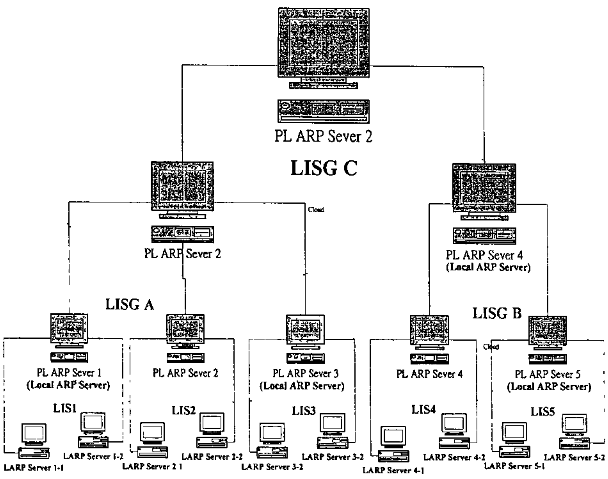

Fig. 3. Hierarchical structure of PLARP model.

a PLARP server will exchange[1] a ARP tables with other PLARP servers, the ARP table of the LAPR server in a LIS is unlimited within a LIS.

There is a fault-tolerance mechanism: when the master PLARP server crashes, the backup PLARP server will replace it automatically. It will set up a SVC to other PLARP / LARP servers using its **linked table** of PLARP / LARP servers hierarchical structure and retrieve the ARP tables to reconstruct its own ARP table. Then, it has to send a new linked table of the PLARP and LARP server hierarchical structure to the other ARP server. Moreover, if the backup PLARP server breaks down, the other LARP servers will compare their own ARP tables and re-elect a LARP server, which has the biggest ARP table, to be the new PLARP server automatically. If more than two LARP servers have the same size ARP table, then the LARP server which survives longest will be elected to be the new PLARP server.

The LARP table will include the ARP tables of other LISs, so the sender can set up an end-to-end connection, and data transmission processes will be more efficient.

2. PLARP Model Performance Simulation

We have build a huge simulation structure for the PLARP model, as illustrated in Fig. 4, to prove that the variation of the ARP table exchanging traffic will not flush the network bandwidth. The structure has 200 LIS clouds[2] and each cloud has 500 stations. In other words, the total amount of stations in the simulation structure is 100000 (stations). We assume that one entry in the ARP table is 24 Bytes (20-byte ATM Address + 4-byte IP Address), and that the average ARP table variation frequency is up to 1%~5% **per second**. That is to say, about 1000~5000 stations of ARP table entries change **per second**[3,4]. This is a terrible variation frequency. Therefore, this paper adopts the result as the worse case to prove that the variation ARP tables exchanging traffic will not let the bandwidth become congested. We have built a PVC or SVC among ARP Servers (PLARP and LARP) in which the bandwidth is just 1 Mbps to transfer the variation ARP table entries. We monitor the traffic of ARP table variation

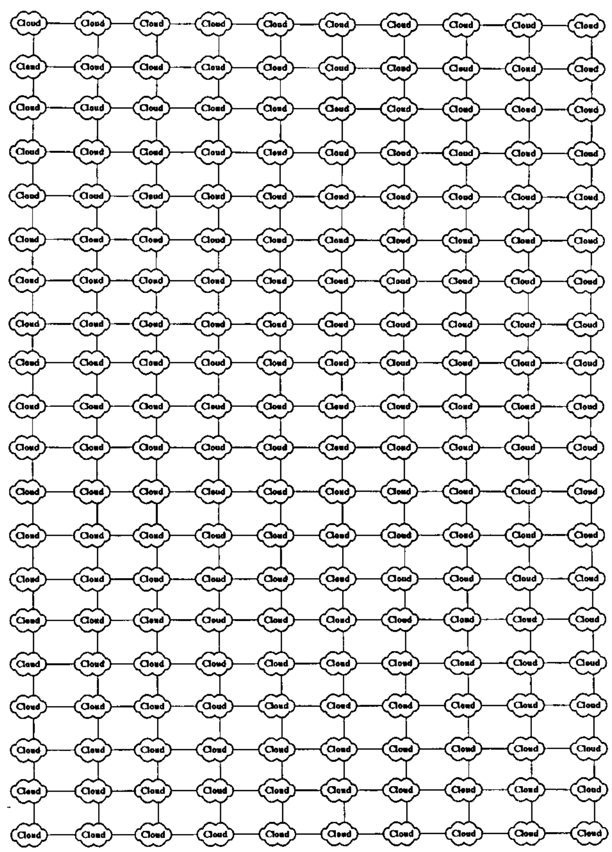

Fig. 4. The structure of ARP table swapping traffic simulation in the PLARP model.

[1] There is a PVC or SVC link between the PLARP and LARP servers. The bandwidth of the link is 1 Mbps. We adopt a "best effort" way to exchange the variation ARP tables. That is to say, 1 Mbps is the upper bound.

[2] There are two ARP (LARP or PLARP) servers in each cloud.

[3] If a station power is on or shut down, it should notify LARP Server to modify the ARP table.

[4] Stations within a LIS should send "alive acknowledge" to LARP Server regularly (ex: 300 seconds). If a station halts abnormally, it will not send an alive acknowledge to the LARP Server; therefore, its ARP table entry will be deleted.

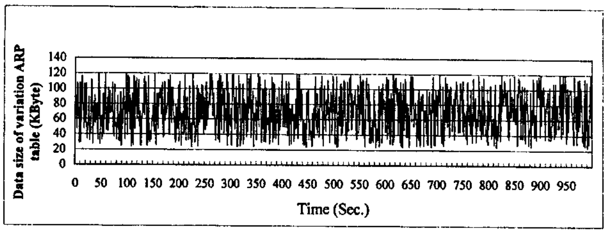

Fig. 5. Monitor the average data size of variation ARP table per second.

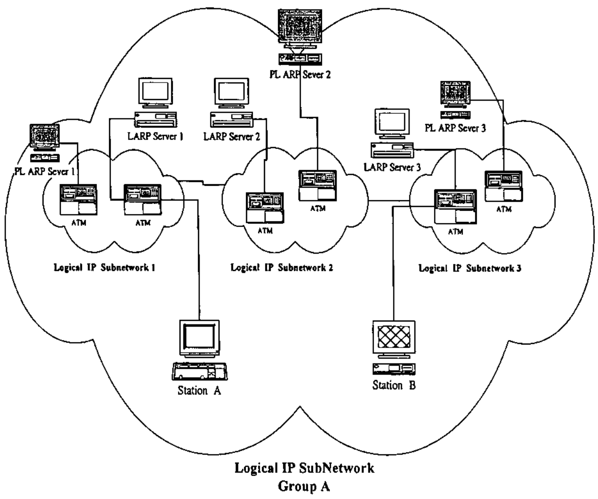

Fig. 6. Station A wants to establish a connection with station B.

in each ARP (LARP and PLARP) server. Figure 5 shows the variation ARP tables exchanging traffic per second. We can learn that the required bandwidth is under 1 Mbps (128 Kbytes/sec). From the result, we know that the traffic is limited and under control.

For example, in Fig. 6, station A residing in LIS1 wants to establish a connection and transmit data to station B in LIS3. Figure 7 shows the data flow chart of the connection between station A and station B. Five steps compose the data transmission behavior in Fig. 7:

Step 1: Station A sends an ARP request to LARP server1 residing in LIS1 to query the ATM address of station B residing in LIS3.

Step 2: LARP server1 finds the ATM address of station B in its ARP table and replies it to station A immediately.

Step 3 and 4: Station A sets up a direct end-to-end connection to station B.

Step 5: Station A transmits data to station B directly.

In PLARP model, any station just needs to send only one ARP request to LARP. Then it can find the ATM address of the destination station.

III. Edge-device Connection Admission Control (ECAC) Server

Another focus of this paper is the QoS guarantees (Park *et al.*, 1996) for multimedia data transmission between ATM networks and Ethernet. We designed the ECAC server (Sanjeev and Reeves, 1995) as a

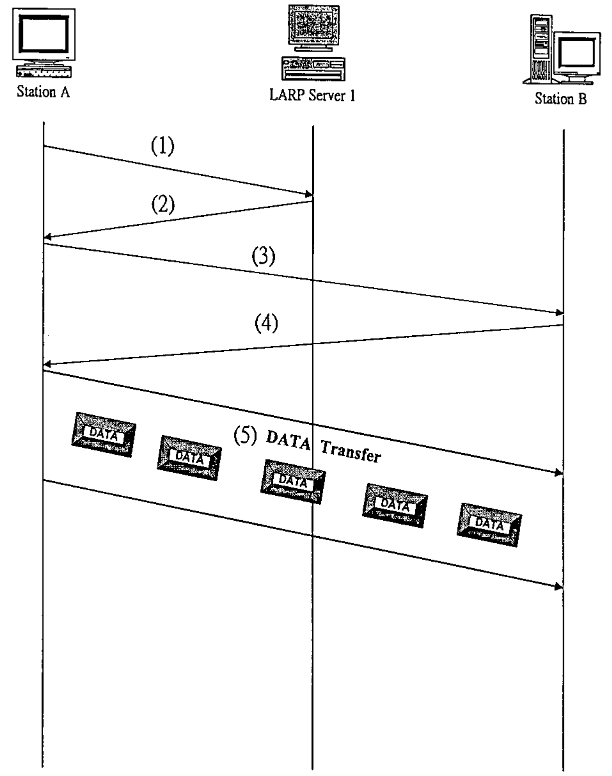

Fig. 7. Data flow chart of the connection between station A and station B.

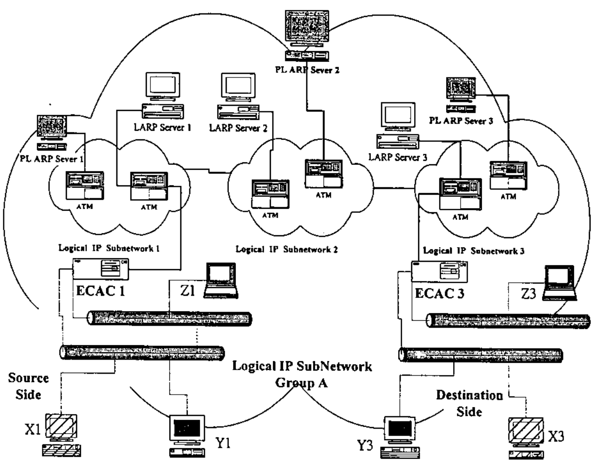

Fig. 8. ECAC phays the role of a bridge between an ATM network and an Ethernet.

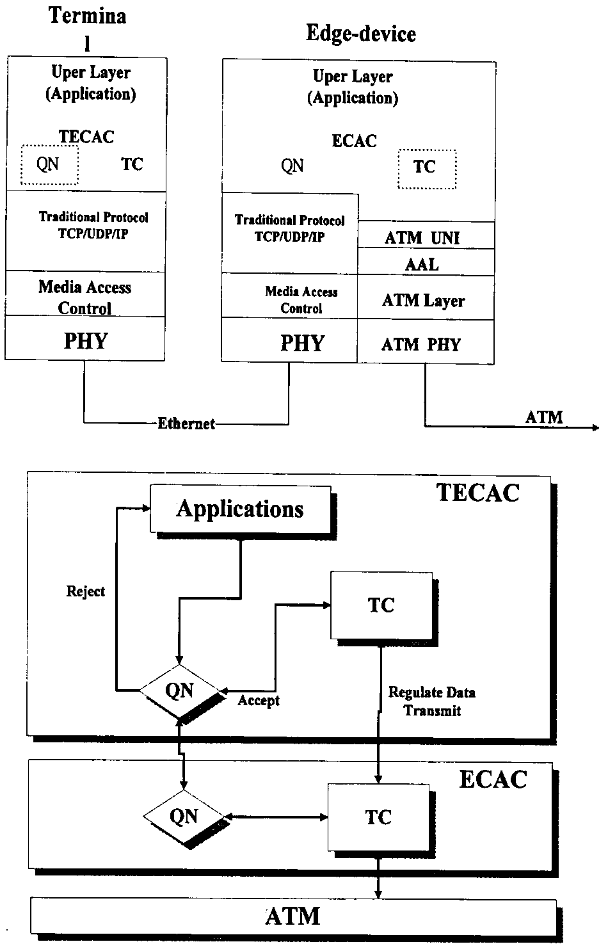

Fig. 9. Two roles of ECAC.

bridge to monitor and control the traffic contract between the source and destination, as shown in Fig. 8. The ECAC Server represents the stations on the Ethernet to attach to ATM switch. In other words, the ATM address of each station on the Ethernet will be the same as the ATM address of the ECAC server. As illustrated in Fig. 8, when station X1 wants to connect with station X3, X1 transmits data to ECAC1 first and then transmits data to ECAC3 directly. After that, ECAC3 will transmit the data to X3. We call the X1 and ECAC1 the "*source side*" X3 and ECAC3 the "*destination side*". We also treat ECAC1 as a *virtual source* and ECAC3 as a *virtual destination*. ECAC server will be the agent of the stations in the Ethernet. (It is attached to the ECAC.)

The ECAC server has two important roles, as shown in Fig. 9. One is as the QoS Negotiator (QN), and the other is as the Traffic Controller (TC). The duties of QN are to negotiate with demanders who request connection with QoS guarantees, to record the resource utilization and to determine if there are enough resources to support the requests from demanders. If the resources are not enough, QN will negotiate with demanders to decrease their QoS requests. If a demander agrees and accepts the QoS negotiation, a connection will be built; otherwise the connection request will be rejected.

We explain the negotiation policies by Fig. 10. Station A wants to set up a connection with station B.

(1) Station A sends a connection request and QoS demands to ECAC Server A.

(2) ECAC Server A estimates the free resources to decide whether the request should be accepted or rejected.

(3) If the request is rejected, ECAC Server A will renegotiate with station A and ask him to decrease the QoS degree.

(4) If the request is accepted, ECAC Server A will forward the request to the next switch to request the QoS guarantees.

(5) The request will be delivered to station B (destination).

(6) Finally, if the ECAC Servers and switches admit the request for QoS guarantees, the connection will be built.

IV. Traffic Control (TC)

If the QoS request is agreed to by QN then the connection will be built. After that, TC will be in charge of monitoring and controlling the traffic on both the *source side* and *destination side*. TC also needs to decide if the source and destination are in the same

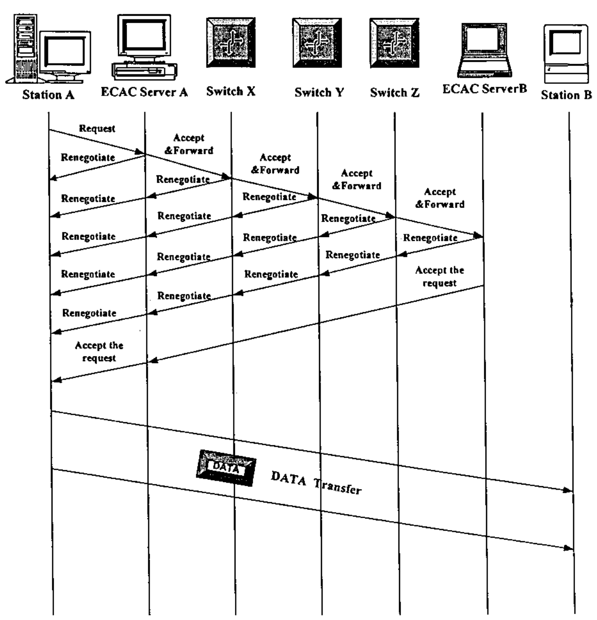

Fig. 10. QoS negotiation flow chart.

```
C= {c1, c2- - - - - cn} (Dedicated buffers for Constant Bit Rate Connections)
/* Guarantee PCR=SCR */
V= {v1, v2- - - - - vn} (Dedicated buffers for Variable Bit Rate Connections)
/* Guarantee SCR = Average Rate */
A= {a1, a2- - - - - an} (Dedicated buffers for Available Bit Rate Connections)
/* Guarantee Minimal Cell Rate */
T= { {C} , {V} , {A}}  ;  U= Buffers for Unspecified Bit Rate ;
SB = Shared Buffers  ; SBV = SB for V  ; SBA = SB for A  ;
SBU = SB for U ;

While ( (T≠empty ) or (SB≠empty))   do
 { if ( T≠empty)
   { if( C≠empty )
     {Select a source ci connection from C to transmit CBR data ;
      Remove ci from C; }
    else   Remove C from T if there is No CBR Data Arrival;
    if( V≠empty )
     { Select a source vi connection from V to transmit VBR data;
      Remove vi from V; }
    else if( (V = empty) and ( SBV≠empty ))
         { Transmit Peak Cell Rate for V ;
          Move SBV to V;
           SBV = empty;
           Select a source vi connection from V to transmit VBR data;
           Remove vi from V; }
     else   { Skip V if there is No VBR Data Arrival ;
             Remove V from T if there is No VBR Data Arrival; }
     if( A≠empty )
     { Select a source ai connection from A to transmit ABR data;
      Remove ai from A; }
    else if( (A = empty) and ( SBA≠empty ))
         { Transmit Peak Cell Rate for A ;
          Move SBA to A;
           SBA = empty;
           Select a source ai connection from A to transmit ABR data;
           Remove ai from A; }
     else   { Skip A if there is No ABR Data Arrival ,
             Remove A from T if there is No ABR Data Arrival; }
   }
  Refresh {C} ; {V} ; {A} in next round;
  T= { {C} , {V} , {A}} ;
 if( T = empty ) and (( U≠empty ) or ( SBU≠empty )))
  {No T data to send in this round ;
   move SBU to U to transmit UBR Data */
   Transmit U until T≠empty or U = empty ; }
}
```

Fig. 11. Algorithm of TC.

subnet. For the sake of efficiency, the source can transmit data to the destination directly under the TC control if they are in the same subnet. As Fig. 8 shows, station X1 can transmit data to station Y1 directly. If they are not in the same subnet, the TC of the *source side* on the Terminal ECAC (TECAC) will receive data from the upper layer (applications). As shown in Fig. 9, after that, TC on TECAC will transmit data to TC on ECAC with a regular transmission rate (X bits/sec). Because TC on ECAC admits one TC on TECAC to transmit data at the same time, collision in the Ethernet will be avoided. The contention among connections is shifted to the ECAC server, and the TC algorithm described below will solve it. As a result, efficiency on the Ethernet will be increased.

When the data are transmitted to ECAC, TC on ECAC will allocate bandwidth using its algorithm, as shown in Fig. 11. We describe the algorithm using Fig. 12 (Flavio and Kerry, 1995). The algorithm categorizes the buffers into dedicated buffers and shared buffers (as Fig. 12 shows). For constant bit rate (CBR) connections, we will provide dedicated buffers blocks (DBBs) to guarantee its bandwidth requirement. For variable bit rate (VBR) connections, we will also provide DBBs to guarantee its sustainable cell rate (average rate). If peak data arrive, we will allocate enough shared buffers blocks (SBBs) to buffer the data dynamically. Because TC recognizes the peak data under the QN admit, it will not disturb other connections to transmit data. For available bit rate (ABR) connections (Jain, 1996; Arulambalam, 1996), we will also provide DBBs to guarantee its minimal cell rate (MCR). If the peak data arrive, we will allocate SBBs, which are unused to buffer it. We do not guarantee that the SBBs will be large enough for their peak data because we do not guarantee the peak data of ABR connections will be transmitted under QN processes. For Unspecified Bit Rate (UBR) connections, we will just allocate some unused SBBs to them to transmit data, because we do not support the UBR connections any QoS guarantees under the QN processes.

Now, let us conclude the algorithm of TC: CBR connections have the highest priority to transmit data, so we give every CBR connection large enough DBBs to satisfy their data transmission. VBR connections have second priority to transmit data, but they have the highest priority to allocate SBBs to transmit their peak data. ABR connections have third priority to transmit data, and they have second priority to allocate SBBs to transmit their peak data. UBR connections have the lowest priority to allocate SBBs; after that, they only use the rest of the buffers (bandwidth) to transmit their data. ECAC will give a total of 10 Mbits buffers (dedicated buffers + shared buffers) to an Ethernet

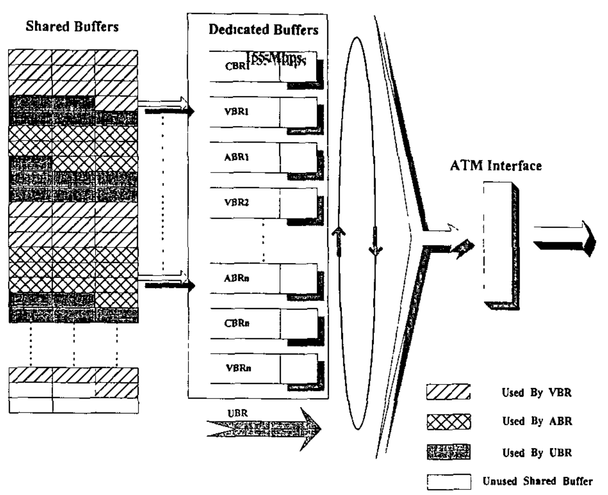

Fig. 12. Buffer (bandwidth) allocation of TC.

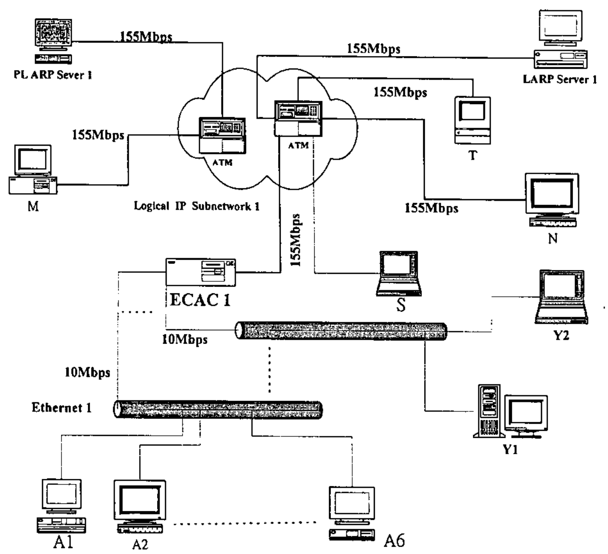

Fig. 13. Our simulation architecture.

attached to it to guarantee that the total transmission rate from TC on ECAC to TC on TECAC will be accepted.

$$[\sum_{i=1}^{n} (ci + vi + ai) + SBV + SBA + SBU] < 10 \text{ Mbits}$$

ci: Dedicated buffers for CBR Connection

vi: Dedicated buffers for VBR Connection

ai: Dedicated buffers for ABR Connection

SBV: Shared buffers for VBR Connection

SBA: Shared buffers for ABR Connection

SBU: Shared buffers for UBR Connection

V. Simulation Results

Our simulation architecture is shown in Fig. 13. Stations A1, A2, A3, A4, A5 and A6 on Ethernet1 want to set up six connections to statiбns M, N, S, T, Y1 and Y2. We monitored and recorded the throughput on Ethernet1.

The simulation results are shown in Figs. 14 and 15. A data generator program (DGP) on the source was used to generate regular rate data (PCR is equal to SCR; X bits/sec that QN recognize) to simulate the CBR connection. For VBR and ABR connections, the DGP generated data at a regular rate (Y bits/sec, average rate) and then randomly generated Z bits as peak data to transmit under QN audit and TC control. Because the UBR connection was not suitable for multimedia data transmission, we eliminate it in Figs. 14 and 15. Connection1 was a VBR connection, which was requested by station A1 at 10 sec (time axis in Fig. 14), and its bandwidth demand was 1.5 Mbps (average rate). The QN on the ECAC recorded the bandwidth allocation. Connection2 was a CBR connection requested by station A2 at 10 sec, and its bandwidth demand was 640 Kbps (average rate). The QN agreed and recorded it. Connection3 was an ABR connection requested by station A3 at 20 sec, and its bandwidth demand was 1.0 Mbps (minimal transmission rate). The QN also agreed and recorded it. Connection4 was a VBR connection requested by station A4 at 20 sec, and its bandwidth demand was 2.0 Mbps (average rate). The QN agree and recorded it, too. Connection5 was a VBR connection requested by station A5 at 30 sec, and its bandwidth demand was 2.5 Mbps (average rate). The QN agreed and recorded it, too. The total bandwidth of the five connections is below the wired speed of the Ethernet (10 Mbps), so the QN on the ECAC agreed

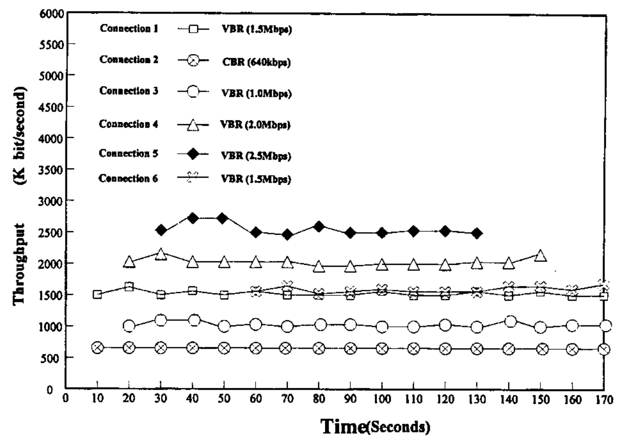

Fig. 14. Simulation result (1).

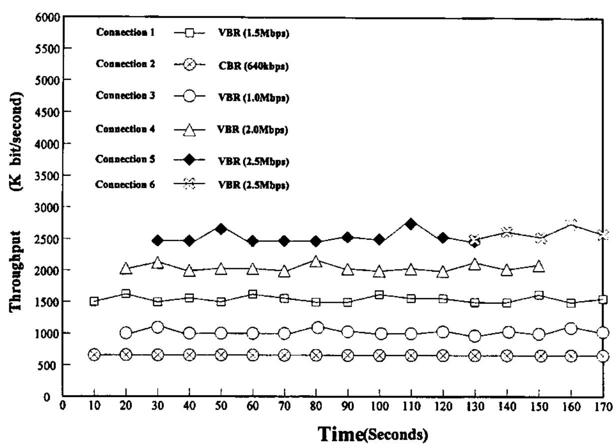

Fig. 15. Simulation result (2).

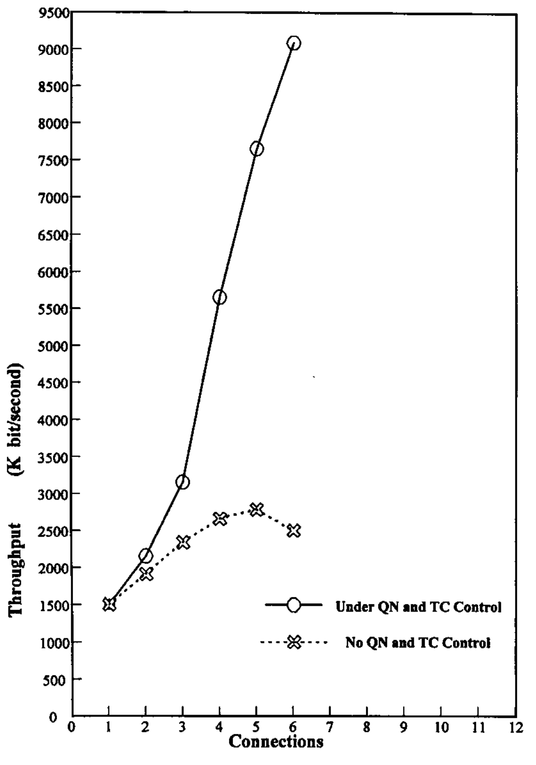

Fig. 16. Total throughput on Ethernetl.

those connections to be built. Connection6 was a VBR connection requested by station A6 at 60 sec and its bandwidth demand request was 2.5 Mbps (average rate). QN rejected the connection request to avoid congestion. Because the total bandwidth was over 10 Mbps, it would disturb other connections. QN negotiated with station A6 to decrease the bandwidth demand. If station A6 agreed to decrease its bandwidth demand to 1.5 Mbps, connection6 would be built immediately (as shown in Fig. 14), or it would be rejected, otherwise, it must wait until there was enough bandwidth to support connection6's demand (as shown in Fig. 15).

Base on the simulation results, the efficiency of transmission rate on the Ethernet increased under the QN and TC control. This structure also guarantees QoS for multimedia data transmission by controlling data transmission delay and bandwidth allocation.

The total throughput from Fig. 14 is shown in Fig. 16. We can compare the throughput with and without QN and TC control. Obviously, there will be a no collision architecture under QN and TC control (described in Section IV), so the environment controlled by QN and TC is much more efficient (illustrated in Fig. 16) than the native Ethernet environment (without QN and TC control). Once the number of connections increases, the probability of collision will also be increased in the native Ethernet environment. Unfortunately, bandwidth utilization will decrease when the connection is built after connection6. Without QN and TC control, the connection will keep on increasing. Finally, the traffic will crash down on the Ethernet1. We can see the better bandwidth utilization under QN and TC control.

VI. Conclusion

To guarantee QoS for multimedia data transmission, this paper has proposed the PLARP Address resolution Model between ATM Networks and Ethernet to increase the speed (efficiency) of connections setup processes, and we have designed the ECAC Server to audit and monitor the traffic between the source and destination. Most importantly, we have designed an architecture that avoids collision under QN and TC control for interconnection of an ATM network and an Ethernet. We have also increased the bandwidth utilization for the network architecture especially for an Ethernet. The total performance increases, and the QoS for multimedia data will also be guaranteed.

Acknowledgment

This research was supported by National Science Council, R.O.C., under grant NSC 86-2213-E-151-007.

References

Andre, N. (1997) *Multiprotocol over ATM Version 1.0.* AF – MPOA-0087.00, ATM Forum Technical Committee, Mountain View, CA, U.S.A.

Arulambalam, C. (1996) Allocating fair rates for available bit rate service in ATM networks. *IEEE Communications Magazine*, **34**, 92-100.

Flavio, B. and W. F. Kerry (March/April 1995) The rate-based flow control framework for the available bit.rate ATM service. *IEEE Network*, 25-56.

Iwata, A., N. Mori, C. Ikeda, H. Suzuki, and M. Ott (1995) ATM connection and traffic management schemes for multimedia internetworking. *Communication of the ACM*, **38**, 73-89.

Jain, R. (1996) Source behavior for ATM ABR traffic management. *IEEE Communications Magazine*, **34**, 50-55.

John, D. K. (1997) *LAN Emulation over ATM Version 2 – LUNI Specification.* AF-LANE-0084.00, ATM Forum Technical Committee, Mountain View, CA, U.S.A.

Laubach, M. (1994) *Classical IP and ARP over ATM.* RFC1577, Reston, VA, U.S.A.

Lee, W. C., M. G. Hluchyi, and A. H. Pierre (July/August 1995) Routing subject to quality of service constrains in integrated communication networks. *IEEE Network*, 46-55.

Park, C. Y., H. Chung, and C. K. Un (1996) Performance analysis of an output queuing ATM switch with heterogeneous traffic and multiple QoS. *IEE Proceedings Communications*, **143**, 356-362.

Sanjeev, R. and D. Reeves (1995) Routing and admission control algorithm for multimedia traffic. *Computer Communications*, **18**(10), 755-767.

QoS Guarantees between ATM and Ethernet

ATM網路與乙太網路連結並保證傳輸品質之策略

陳毓璋*　張建智**　鄭安佑*　謝文雄*　楊竹星*

*國立中山大學資訊工程研究所

**國立中山大學電機工程學系

摘　要

本文分成兩大部分來探討ATM網路與廣大的乙太網路結合並保證QoS的問題並提供解決方法。首先我們先解決位址的問題(Addressing Resolution Model)，對於Classical IP Over ATM、LAN Emulation、Peer Model、NHRP(Next Hop Resolution Protocol)、MPOA我們將探討其缺點並提出我們的解決方法PLARP(Peer Leader Address Resolution Protocol)；再來我們將設計出ECAC (Edge_device Connection Admission Control) Server來達成ATM網路與傳統網路連結的QoS保證，並監控連線的數量與交通流量。最後，提出此一架構的模擬結果並做一個總結。