ENSC 833-3: NETWORK PROTOCOLS AND PERFORMANCE

CMPT 885-3: SPECIAL TOPICS: HIGH-PERFORMANCE NETWORKS

FINAL PROJECT

Backbone: FDDI, ATM or Gigabit Ethernet?

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1. ABSTRACT

To get a better understanding on what we learnt from the lectures, we investigate several widely-used LAN backbone technologies, such as FDDI, ATM and Gigabit Ethernet. We use OPNET to do the simulation. We design experiments to compare the performance of several backbone technologies, as well as performance of LANs interconnected by 10Base-T(without backbone), Fast Ethernet (100 Base-T), ATM backbone, FDDI backbone, and Gigabit Ethernet backbone. By running these experiments with variant types of traffics, we collect a great deal of statistics, and reach some conclusions on the advantages, disadvantages of these backbone technologies.

2. INTRODUCTION

2.1 Backbone Technology

In the recent years, LAN services have evolved from simple file printing, service sharing to applications that include large files, multimedia, and Internet access. Size of data, number of network users are also growing rapidly. As the volume of LAN traffic increases, typical 10 Mbps shared Ethernet backbones are becoming insufficient to handle the traffic.

This has led to the deployment of faster technologies into LAN backbone. This allows for 10Mbps desktop connections and 100Mbps in the backbone. However, since the introduction of backbone technology, its importance is increasing dramatically, and people start to demand even higher bandwidth at the desktop, thus causes an even greater demand for bandwidth on the backbone.

The growing pressure on backbones over the years has first led to the deployment of faster shared-media LAN technologies such as FDDI, and, more recently, to the use of switched high-speed LAN technologies including fast Ethernet and ATM. Gigabit Ethernet, since it's applied into backbone technology, seems to become a strong competitive to ATM, however recently more and more people realized that these two technologies should be viewed as more complementary than competitive.

2.2 Earliest Backbones: FDDI and Fast Ethernet

Being the first high-speed (100-Mbps) LAN technology, FDDI saw great success in enterprise LAN backbones because of its two attributes: First, its dual-ring topology provides a high degree of fault tolerance. Second, FDDI's token-passing access scheme provides deterministic performance, which means, as the number of end stations on an FDDI ring increases, performance will not degrade fast.

Fast Ethernet is another LAN backbone which can deliver 100Mbps bandwidth. It has same frame format and frame length as Ethernet, which makes it can easily be integrated with traditional Ethernet. Due to its low cost and high performance, Fast Ethernet has once gained widespread acceptance over FDDI for client and server connectivity.

2.3 ATM Backbone Technology

With the emerging of ATM, people found it a more attractive technology, because it has these properties:

- Scalable amounts of bandwidth. ATM can supply a wide rage of bandwidth, from OC-1 of 51.84Mbps up to OC-24 of 1.244Gbps, and OC-48 which has 2.5Gbps is also being introduced.

- Traffic Integration: ATM can deliver data, video and voice simultaneously across the same medium. ATM accomplishes this by ascribing a Quality of Service marker to each cell transmitted. Video and voice traffic cells, which are extremely sensitive to delay, are granted priority over data cells, which are more sensitive to bit errors than to delay.

- Network Scalability: ATM spans the entire network from the desktop, throughout the workgroup and campus, onto the enterprise backbone and across the carrier or private WAN.

- Preserving Infrastructures: ATM's LAN Emulation offers a way to bring existing Ethernet LAN users into an ATM environment so that users can enjoy the benefits of ATM interworking through existing UTP-5 and Ethernet NICs.

2.4 Gigabit Ethernet Backbone Technology

Gigabit Ethernet, also known as the IEEE 802.3z standard, is an extension of the IEEE 802.3 standard. It addresses the need for a high-speed technology at the backbone level. The design objectives of the IEEE 802.3z standard are listed as follows:

- Offers high bandwidth of 1,000 Mbps.
- Uses the IEEE 802.3 Ethernet frame format, with the addition of carrier extension field.
- Employs the same MAC operation schemes as the predecessors.
- Addresses backward-compatibility with 10 Mbps and 100 Mbps Ethernet technologies.
- Supports all existing network protocols.

For Physical Layer, three types of wavelengths are included in the IEEE 802.3z standard (known as 1000Base-X standard) :

- 1000Base-SX: Short wavelength 850 nm laser on multi-mode fiber.
- 1000Base-LX: Long wavelength 1300 nm laser on single-mode and multi mode fiber.
- 1000Base-CX: wavelength of 800nm on shielded copper cable.

The MAC Layer of Gigabit Ethernet contains all capabilities that exist in other Ethernet technologies, as well as additional features and functions that older Ethernet technologies do not have. Examples of some of the new features specific for Gigabit Ethernet operations are carrier extension and frame bursting.

2.5 Project Proposal

We make these comparisons in our experiments:

1) LANs with 10Base-T link vs. LANs with ATM OC-1 link as backbone
2) LANs with Fast Ethernet vs. LANs with FDDI backbone
3) LANs with ATM OC-3 vs. LANs with FDDI backbone
4) LANs with Gigabit Ethernet backbone vs. LANs with ATM OC-24 backbone

The applications we use in our project include:

1) Client-server applications: FTP, Telnet, HTTP, Email.
2) Client-client applications: Video Conferencing and Voice Application.

And we collect three sets of results as following:

1) Global Statistics: LAN Delay, Application Response Time, Application End-to-end Delay, etc.
2) Node Statistics: Traffic Sent and Received.
3) Link Statistics: Utilization, Queuing Delay, Point-to-point Throughput, etc.

We also get some conclusions on the applicability of each backbone technology based on statistics we collected.

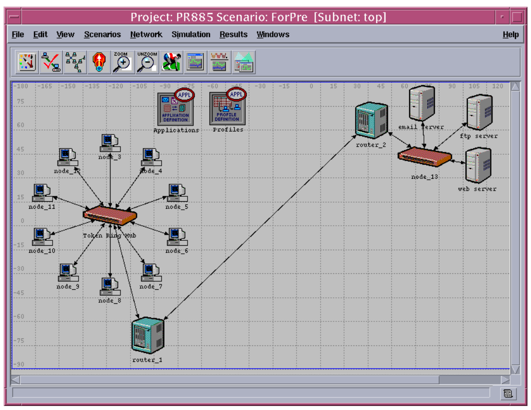
3. PROJECT IMPLEMENTATION

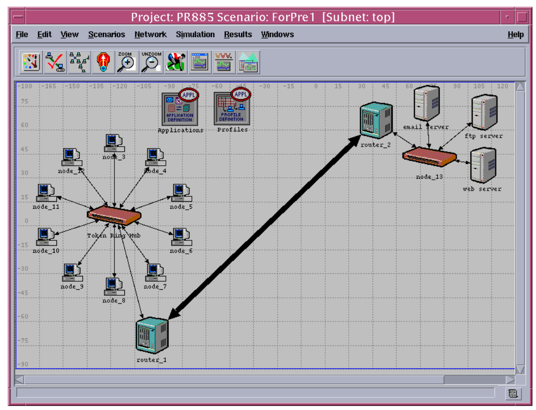
Based on what we've learnt about backbone technology, our project is aimed at doing some experiments to compare the performances of various backbone technologies on different network environments , discovering their own advantages and discussing their respective applicability.
To avoid confusion on terms, we're going to substitute the word "experiment" for "project" in OPNET.

3.1 LAN Performance with or without Backbone

The following experiment is just a simple illustration about how backbone can improve the performance of LANs.

Experiment Topology:





This experiment has two scenarios.

Scenario 1:
two token ring LANs:

- One has 10 workstations of node model tr_wkstn;
- The other has three servers of node model tr_server supporting email, ftp and http services;

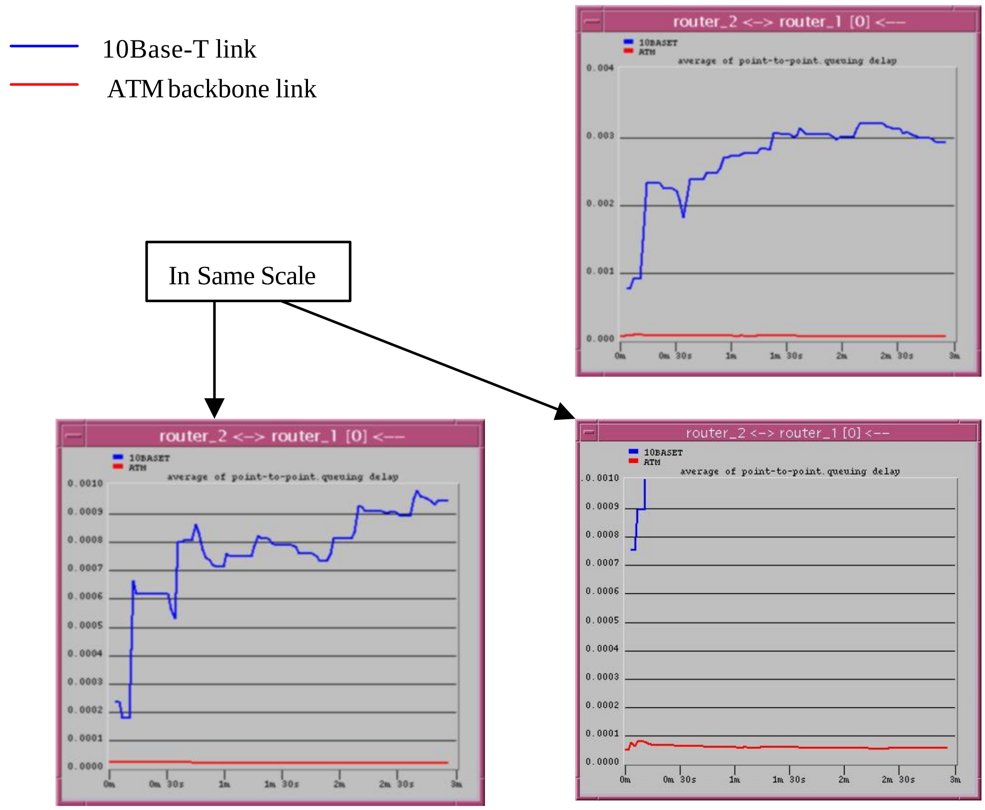
Interconnected by 10Base_T link, with the speed of 10 Mbps;
Two routers (ethernet_tr_gtway) work as gateway between the LAN and the link;

Scenario 2:
Same as Scenario 1, except:
Interconnected by ATM OC-1 link, with the speed of 51.84Mbps;

Experiment Configuration:

We run simulations on these two scenarios for 3 minutes. The first time, we set the background traffic utilization of the link from router1 to router2 as 60%. Next, increase it to 90% to see the deference of queuing delay .

Simulation Result:



Average of queuing delay on the link utilization = 60%

Average of queuing delay on the link utilization = 90%

From the graphs we can see:

1) 10Base-T link causes much larger delay between two LANs than ATM backbone.
2) When the network becomes more congested (link utilization increases from 60% to 90%), the queuing delay on the 10Base-T link increases sharply, while the queuing delay on ATM backbone just increases a little.

We also got some other statistics about the link point –to-point throughput, token ring delay, email response time, which all prove that backbone has improved the performance of the network.

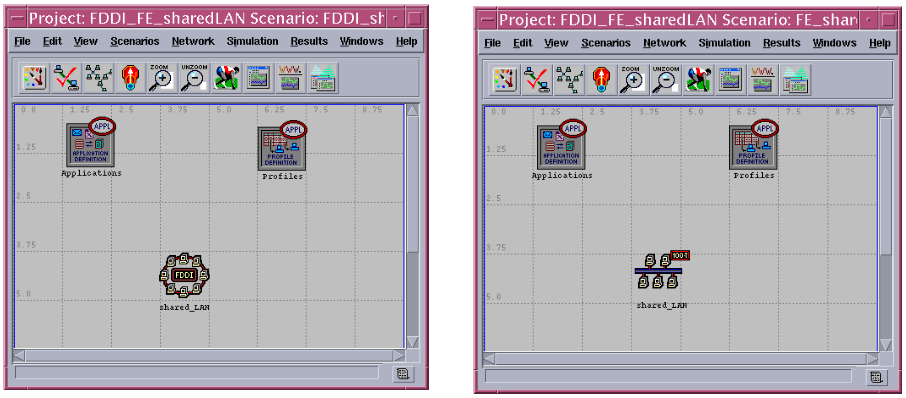
Conclusion:

This experiment gave us a rough concept that how backbone can bring much less delay on information transmission between LANs.

3.2 FDDI vs. Fast Ethernet

The following experiment is to compare FDDI backbone with Fast Ethernet Backbone.

Experiment Topology:



This experiment has four scenarios.

Scenario 1: Campus LAN with FDDI backbone (model name FDDI_Shared_LAN), with 10 workstations;

Scenario 2: Campus LAN with Fast Ethernet backbone (100BaseT_Shared_LAN), with 10 workstations;

Scenario 3: Same as Scenario 1, except the LAN having 100 workstations;

Scenario 4: Same as Scenario 2, except the LAN having 100 workstations;

Experiment Configuration:

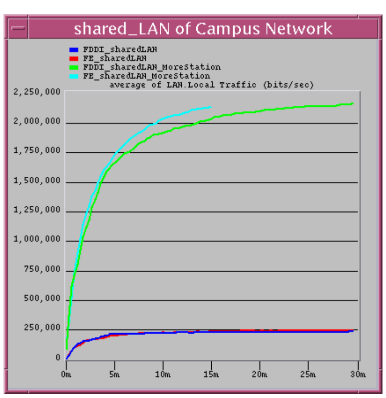
We configure these three attributes for these shared LAN models:

Application – Client Supported Profiles : Database (Entire LAN)

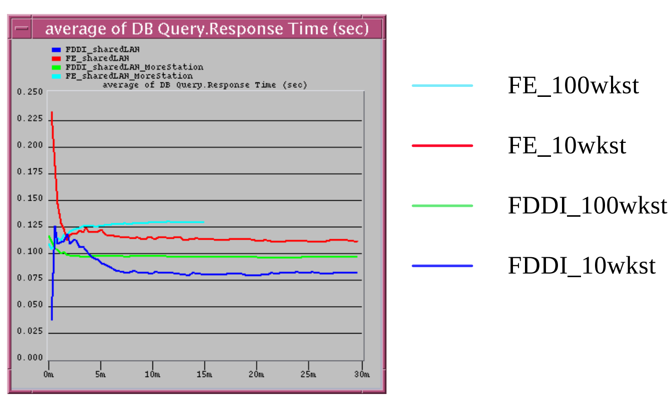
Application – Server Supported Profiles : Database Access (heavy)

Number of Workstations : 10 or 100.

Simulation Result:



Average of LAN Local Traffic



Average of DB Query Response Time

From the left graph we can see:

- The traffic of the networks with same number of workstations are same, whatever kind the backbone is.
- The traffic of the networks with 100 workstations are almost 10 times of that of with 10 workstations, which just correctly resembled what we set up in the network.

The right graph tells us:

- With similar amount of traffic, FDDI has shorter response time than Fast Ethernet.
- Even the response time in FDDI with 100 workstations is lower than FE with only 10 workstations.

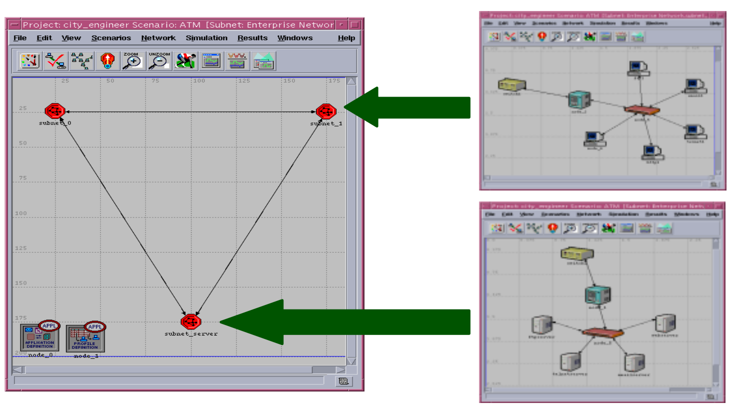
Conclusion:

FDDI backbone has better performance and better scalability than fast Ethernet backbone.

3.3 FDDI vs. ATM

3.3.1 Performance of FDDI vs. ATM on Client-server Applications

Experiment Topology:



This experiment has two scenarios.

Scenario 1:

Enterprise network (200km * 200km), with three Token Ring LANs as subnets;
Subnet1 and Subnet2: showed on the right upper figure .There are five workstations (tr_wkstn) connected to a token ring hub (tr16_hub).The hub is connected to an FDDI backbone switch (fddi16_switch) via a gateway (fddi_tr_slip8_gtwy);
Subnet3: showed on the right lower figure. The same hub, switch and gateway as other subnets. Four token ring servers (tr_server) supply Email, FTP, HTTP, Telnet services respectively;
FDDI backbone connects three subnets via FDDI switches (fddi16_switch).

Scenario 2:

Same as Scenario 1, except that : ATM OC-3 backbone connects three subnets via ATM switches (atm4_crossconn), and gateways of atm4_fddi_slip8_gtwy.

Experiment Configuration:

Attribute configurations:

Token Ring Station Latency(fddi_tr_slip8_gtwy): 4 bits
Switch BPDU Service Rate(fddi16_switch): 500,000 pkts/sec
Switch Packet Switching Speed(fddi16_switch): 500,000 pkts/sec
ATM Switching speed (atm4_crossconn): infinity
IP Forwarding Rate (subnet router): 50,000 pkts/sec
IP Ping traffic (subnet router): None

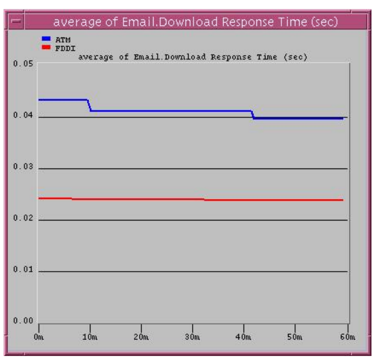
We set applications running as: Email (heavy), File Transfer (heavy), Telnet Session (heavy), Web Browsing (heavy). To do this,

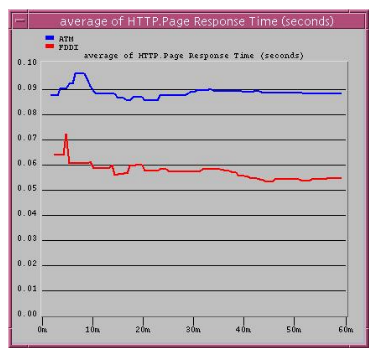
In Profile configuration:

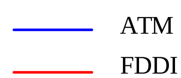
Start time: Exponentially Distributed, Mean Outcome 100 seconds
Start time offset :Exponentially Distributed, Mean Outcome 10 seconds.
Operation mode: Simultaneously
Duration : end of Profile.

Some workstations in susbnet1 and 2 are clients of the applications supplied by the four servers on the subnet3. We ran simulation for 60 minutes, and collected statistics such as service Response Time, Token Ring Delay and Token Ring MAC Delay.

Simulation Result:

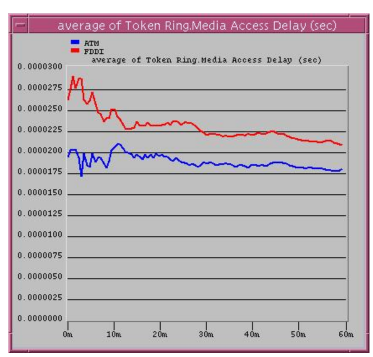






Average of Email Download Response Time

Average of HTTP Page Response Time



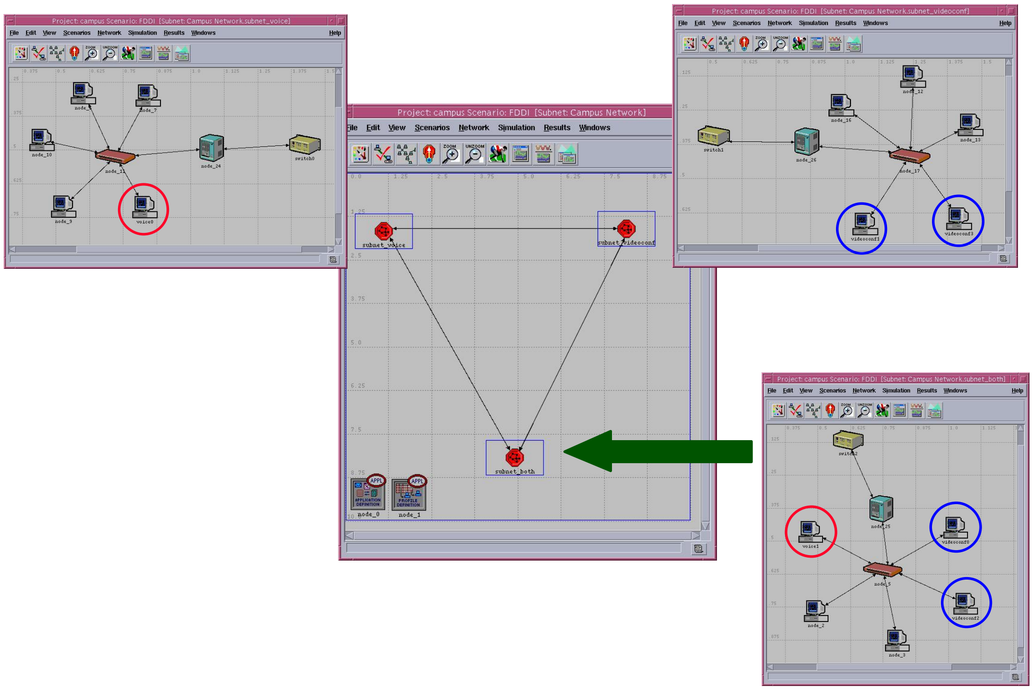
Average of Token Ring Delay

Average of Token Ring MAC Delay

We can see that for email, FTP, HTTP and Telnet applications, ATM has longer response time than FDDI, while for the token ring delay and MAC delay, ATM is shorter than FDDI.

3.3.2 Performance of FDDI vs. ATM on Multimedia Applications

Experiment Topology:



This experiment has two scenarios. The models used here are all the same as in last experiment.

Scenario 1:

Campus network (10km * 10km);

Three Token Ring LANs as subnets;

Almost the same topolo gy as previous experiment The only difference is there’s 5 token ring workstations instead of four servers in subnet3 .

FDDI backbone connects subnets.

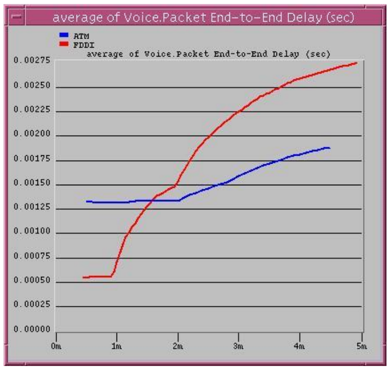
Scenario 2:

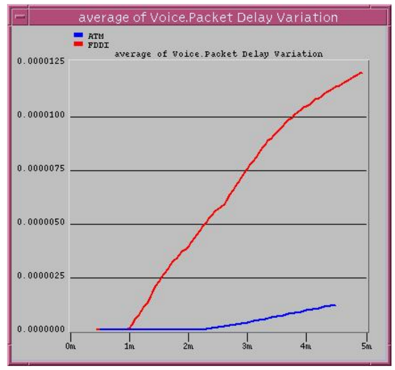
Same as Scenario 1 except that: ATM backbone connects subnets.

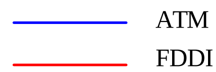
Experiment Configuration:

We choose the “video conferencing (light)” and “voice over IP call (PCM Quantity)” in the profile configuration. Other attributes of start time, operation mode and duration are same as previous settings. We configured a pair of workstations in these LANs to transmit voice data mutually (these workstations are marked by red circles), and another two pairs of workstations to transmit video conferencing data (these workstations are marked by blue circles), and we collected following statistics.

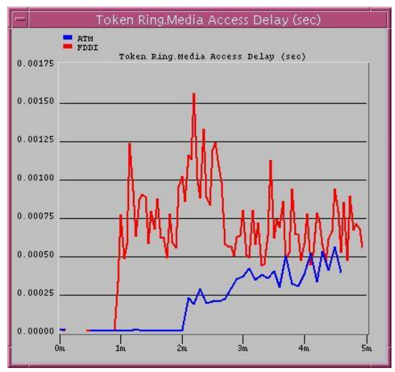
Simulation Result:







Average of Voice Packet End-to-End Delay   Average of Voice Packet Delay Variation



Token Ring Delay   Token Ring Token Ring MAC Delay

For Voice applications,

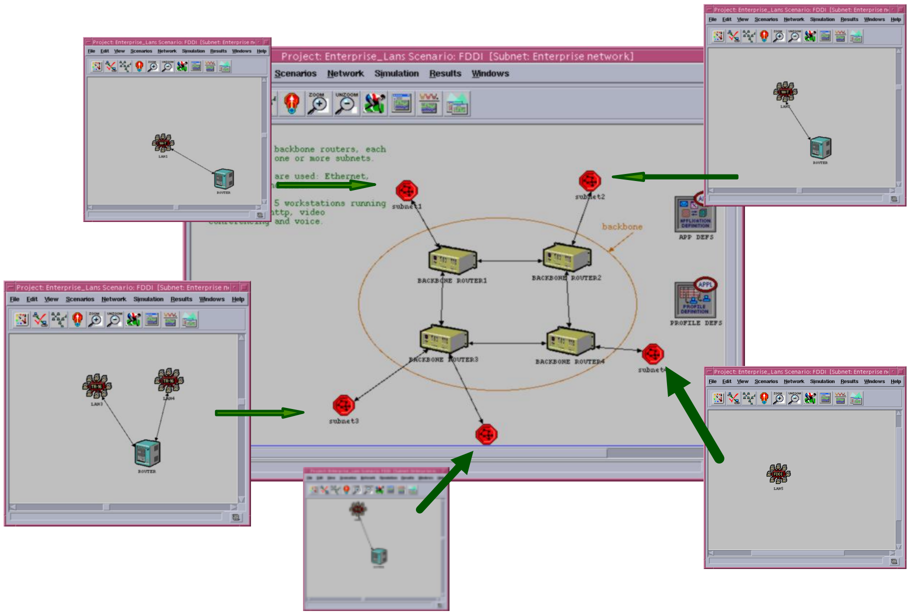
i) ATM has lower service response time than FDDI;

ii) ATM has lower Token Ring Delay and MAC delay than FDDI.

3.3.3 Performance of FDDI vs. ATM on connecting different LANs

In this experiment, we build a more complicated model: enterprise network model to compare the performance of FDDI and ATM backbone in depth .We have applications of Email, FTP, HTTP, Telnet, voice and video conferencing in this experiment.

Experiment Topology:



This experiment has two scenarios.

Scenario 1:

Enterprise network;

Five subnets of three different kinds:

Subnet1 : A 100base-T LAN with 5 workstations, an ethernet_fddi_slip8_gtwy as router, and 100Base-T link between the router and the LAN.

Subnet2 : A 100base-T LAN with 5 workstations, an ethernet_fddi_slip8_gtwy as router, and 100Base-T link between the router and the LAN.

Subnet3 : Two TR16_LANs ,each has 5 workstations, an fddi-tr-slip8-gtwy-int as router, and TR16 link between each TR LANs and router.

Subnet4 : A TR16_LANs with 5 workstations, an fddi-tr-slip8-gtwy-int as router, and TR16 link between TR LAN and router.

Subnet5 : An FDDI LAN with 5 workstations;

Backbone:4 fddi16_switches as backbone routers, connected by FDDI (100Mbps)link.

Scenario 2:

Same as Scenario 1, except :

Subnet1 and 2:an atm4_ethernet2_slip8_gtwy as subnet router;

Subnet3 and4: an atm4_tr2_slip8_gtwy as subnet router.

Subnet 5:an atm4_fddi2_slip8_gtwy as subnet router.

Backbone:4 atm4_crossconn as backbone routers, connected by ATM OC-3 (155.52Mbps)link .

Experiment Configuration:

In scenario1:

Switch BPDU Service Rate(Backbone Router): 500,000 pkts/sec

Switch Packet Switching Speed(Backbone Router) : 500,000 pkts/sec

FDDI Requested TTRT(Ethernet_fddi_slip8_gtwy) : 0.008 sec

Token Ring hop Propagation Delay(Ethernet_fddi_slip8_gtwy): 3.3E-06 seconds

Token Ring THT Duration(fddi_tr_slip8_gtwy): 0.01 seconds

FDDI link: 100Mbps duplex

In scenario2:

ATM switching Speed (Backbone Router): infinity

IP Forwarding Rate (subnet router) : 50,000 pkts/sec

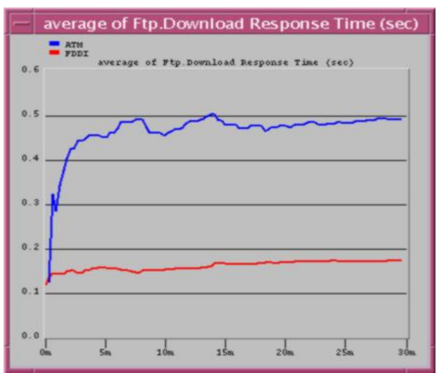
IP Ping traffic (subnet router) : None

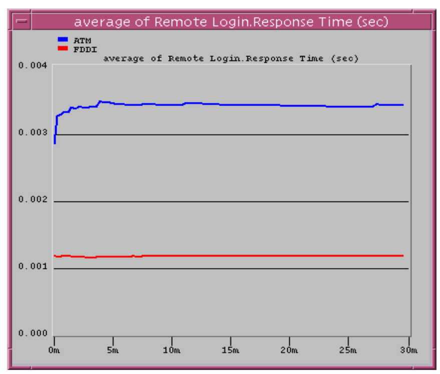
Applications we run are:

Email (heavy), File Transfer (heavy), Telnet Session (heavy), Web Browsing (heavy).
Video Conferencing (light), Voice over IP call (PCM Quantity).

Simulation Result:

As to the service Response Time and Token Ring Delay, we got the similar results as before. Here are some other information from this enterprise network model:



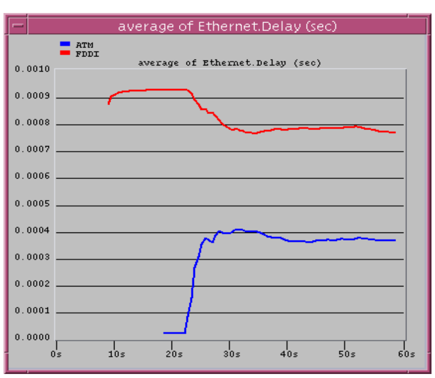


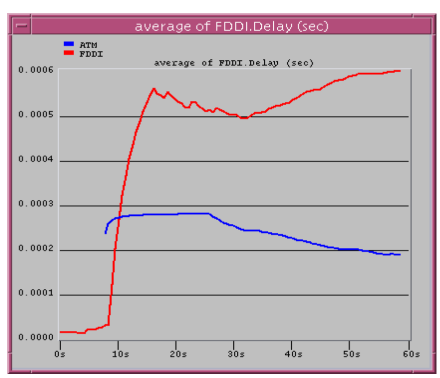
ATM

FDDI

FTP Response Time   Remote Login Response Time

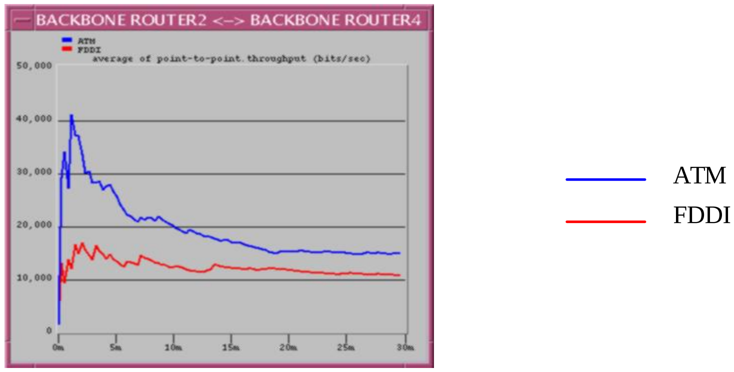
Same as the result in campus network, ATM backbone performs poorer than FDDI backbone.





Average of Ethernet LAN Delay   Average of FDDI LAN Delay

Here ATM backbone shows it’s advantages on having less delay on LANs.



Average of Point-to-point Throughput on backbones

Obviously, ATM has achieved higher throughput speed than FDDI when transferring video conferencing and voice.

3.3.4 Conclusions about FDDI vs. ATM

1. FDDI backbone provides less response time for email, FTP, HTTP and Telnet services.

2. ATM has less LAN delay when working as backbone than FDDI.

3. ATM performs better when transferring voice for it can provide much lower voice delay and delay variation compared to FDDI.

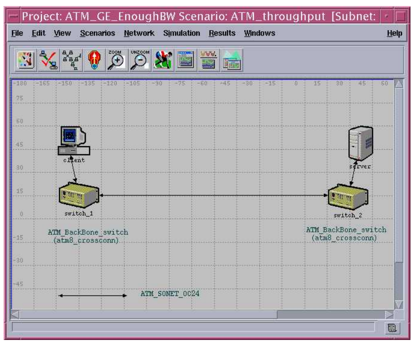
4. ATM can achieve higher throughput speed than FDDI.

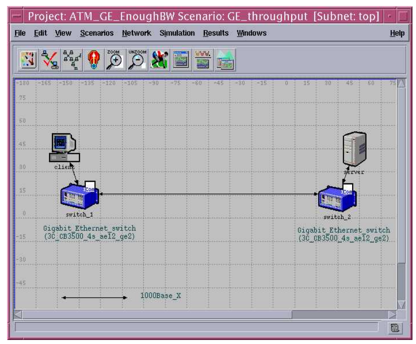
3.4 Gigabit Ethernet vs. ATM

3.4.1 Overhead

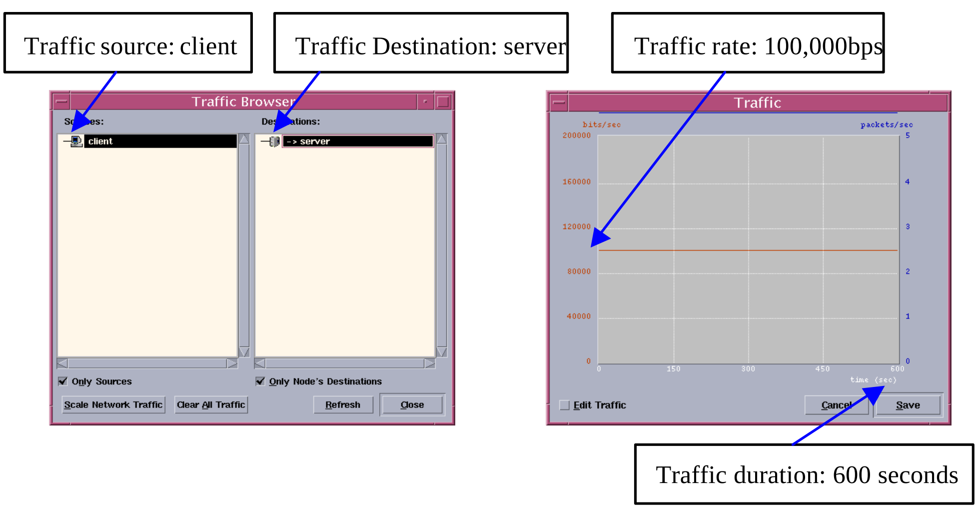
In order to carry traffic, both ATM and Gigabit Ethernet must encapsulate that traffic, thus they need to add the overhead to the traffic stream. Following experiment will be used to compare the overhead cost of this two technologies.

Experiment 1:



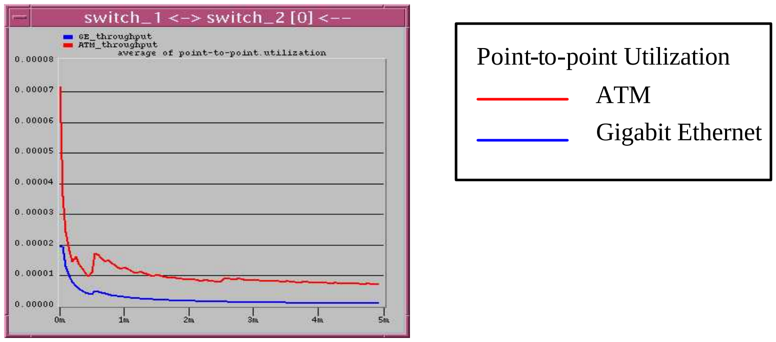


There are two scenarios in this experiment. In these two scenarios, ATM backbone (ATM-OC24) or Gigabit Ethernet backbone(1000Base-X) is used to connect a client and a server, and we apply the same traffic between the client and server. As following figures indicate, the traffic we use is defined in traffic browser.



Here, the traffic duration is 600 seconds and the rate is 100,000 bps. And the traffic source and destination are the clients and servers in the above scenarios.

Following is the statistics of “point-to-point utilization” collected in this experiment.



From the result we can find although these two scenarios used the same traffic, the utilization of ATM backbone is higher than Gigabit Ethernet, which means when encapsulating the data, ATM add more overhead than Gigabit Ethernet. So Gigabit Ethernet has higher bandwidth efficiency than ATM.

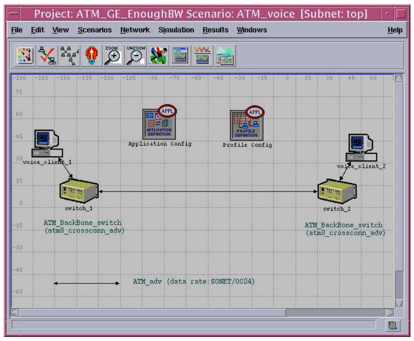
3.4.2 Quality of Service

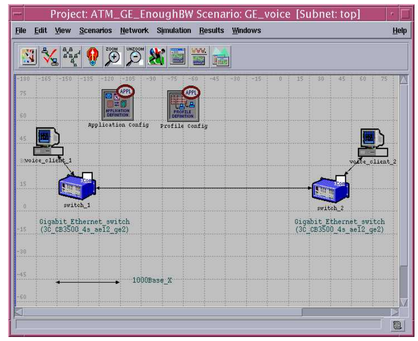
ATM has a multiplexing architecture which is designed to appropriately provide Quality of Service for different types of traffic, this point makes it capable of handling multimedia applications, especially voice and video, which are sensitive to delay. But how about Gigabit Ethernet ? Following two experiments will compare the performance of this two technologies when running voice application.
The voice application used is PCM Quality Speech, which belongs to the category of CBR. We set its attributes as following:

Silence Length (seconds) : exponential (0.65)
Talk Spurt Length (seconds) : exponential (0.325)
Symbolic Destination Name : Voice Destination
Encoder Scheme : G.711
Voice Frames per Packet : 1
Type of Service : Interactive Voice(6)

Here the most important attribute is Type of Service, it defines the priority level of the application for allocating the resource. Here I set this attribute to 6, which is a higher priority than common data traffic.

Experiment 2:





ATM Gigabit Ethernet

In this experiment, since voice application is client-to-client application, so I used a pair of workstations as the voice application clients, in network elements for this two scenarios is:

ATM Network:
- Workstation: atm_uni_client_adv
- Backbone switch: atm8_crossconn_adv
- Backbone link: atm_adv with the rate attribute of SONET/OC24

Gigabit Ethernet Network:
- Workstation: ethernet_wkstn
- Backbone switch: 3C_CB3500_4s_ae12_ge2
- Backbone link: 1000Base_X

In order to provide QoS in the ATM, some attributes of the nodes need to be set.
Firstly, the "traffic contract" attribute of "atm_uni_client_adv" should be set as following:

1. Category: CBR
   This attribute specifies the service category used by the application. Here since we use voice application, so the category should be CBR
2. Requested Traffic Contract: PCR: 0.12Mbps ; MCR: 0 Mbps ; SCR: 0 Mbps
   MBS: 10 cells
   This attribute specifies the traffic parameter settings for the connection. Here we set the peak cell rate (PCR) to 0.12Mbps, the minimum cell rate (MCR) and sustainable cell rate (SCR) to 0 Mbps, and mean burst duration (MBS) to 10 cells.
3. Requested QoS: ppCDV: CBR (3 msec); maxCTD: CBR (400 msec);
   CLR: CBR (3E-07)
   This attribute specifies the application's requested Quality of Service. During call admission control, these requested values will be compared to the supported parameters on all intermediate nodes.

Secondly, we should set the "ATM Port Buffer Configuration" attribute of all the nodes along the path through which the CBR traffic(voice application) is transferred to provide the QoS in the ATM network. Following is the attribute values:

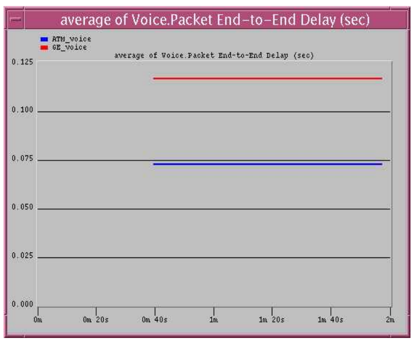
Queue Number: Q1

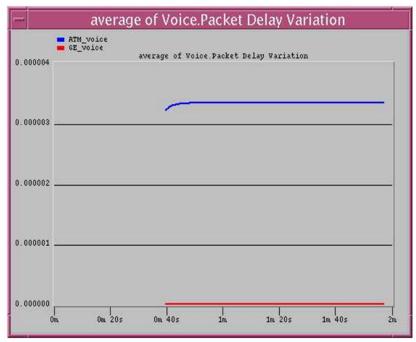
Category : CBR

QoS Parameters: CBR

After setting this attribute, an End-to End path which can provide the QoS guarantee will be established.

For this experiment, since there are only one pair of clients attached to the network, the bandwidth is enough and there is no congestion in the network. Now let's see the results:





Gigabit Ethernet

ATM

Packet End-to-End Delay　　　　　Packet Delay Variation

From the result we can see that End-to-End Delay of ATM (0.075 sec) is lower than that of Gigabit Ethernet (about 0.110 sec), but the Delay Variation of Gigabit (about 0) is lower than that of ATM (about 0.000003).

So for the End-to-End Delay, we can say the ATM is better than Gigabit Ethernet, while for the Packet Delay Variation, Since the value is very small, so we can think there is no obvious difference for these two technologies.

Experiment 3:

In this experiment, we just use the same scenarios as in experiment 2, the only difference is that we set the background utilization of two backbones to make the bandwidth be insufficient.

For ATM_OC24, we set the background utilization to 99.992%, so the bandwidth left is :

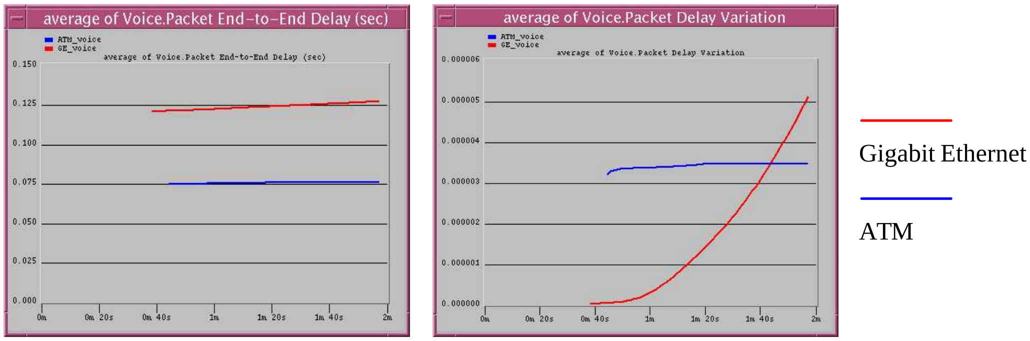
1244*(1-99.992%)=0.1Mbps

For 1000Base-X, we set the background utilization to 99.99%, so the bandwidth left is :

1000*(1-99.99%)=0.1Mbps

In the experiment 2, we have set the PCR to 0.12Mbps in the traffic contract, now in this experiment the available bandwidth is 0.1Mbps, so the network should have the congestion.

Following is the result when the bandwidth is insufficient:



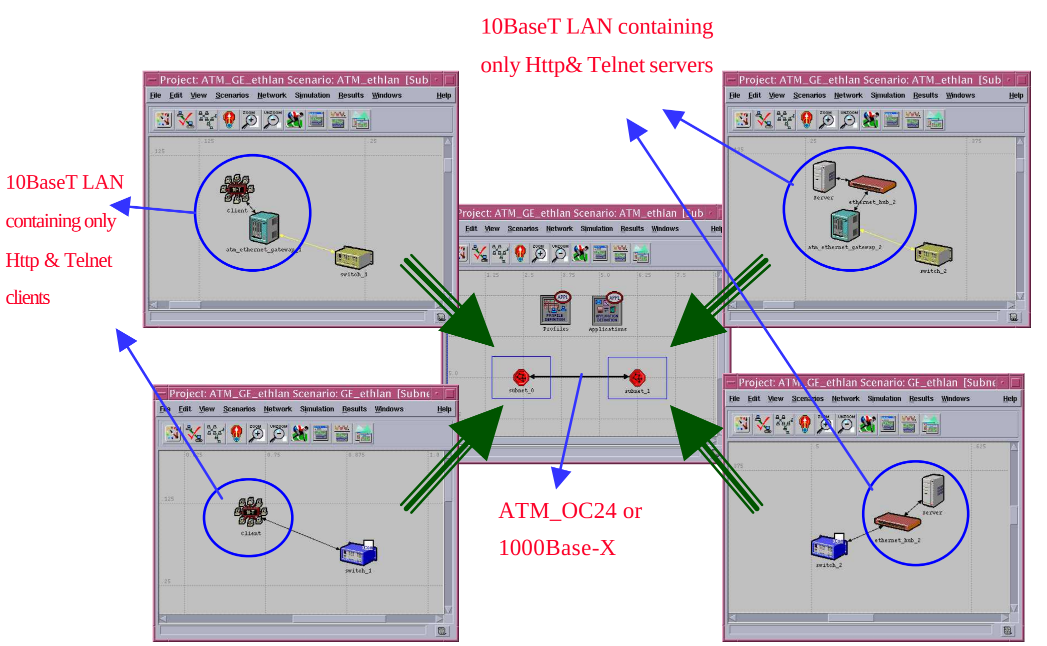
Packet End-to-End Delay Packet Delay Variation

From the results we can find that for Gigabit Ethernet, both End-to-End Delay and Delay Variation will increase with the time passing, while for ATM, these two statistics still remain at the same level as when bandwidth is enough.

3.4.3 Connectivity to legacy Ethernet LAN

Since Gigabit uses the same IEEE 802.3 LLC layer as standard Ethernet, when interconnecting the legacy Ethernet LANs, there is no need of slow emulations and translations. So it should have better performance than ATM in this situation. In the following experiment, we will compare the performance of ATM and Gigabit Ethernet for interconnecting the traditional Ethernet LANs.

Experiment 4:



This experiment has two scenarios.

Scenario 1:

Two subnets; (the two graphs on upper two corners)
One subnet is a 10BaseT LAN with HTTP and Telnet servers.
The other subnet is a 10BaseT LAN with workstations being clients;
ATM backbone (ATM_OC24) connecting subnets.

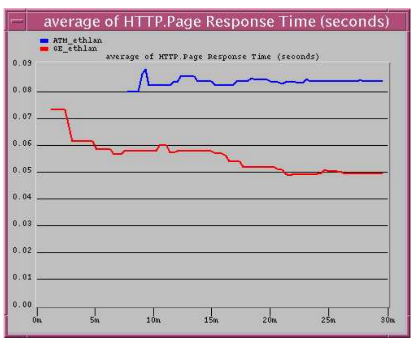
Scenario 2:

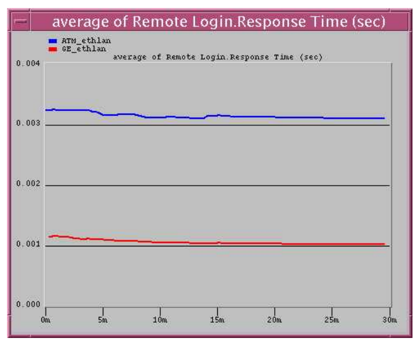
Two subnets; (the two graphs on lower two corners)
One subnet is a LAN with HTTP and Telnet servers.
The other subnet is a LAN with workstations being clients;
Gigabit Ethernet backbone (1000Base_X) connecting subnets.

Applications running over the network:

Web Browsing (Heavy HTTP1.1)
Telnet Session (Heavy)

Following is the statistics collected:





Gigabit Ethernet

ATM

HTTP Page Response Time

Telnet Response Time

In these two graphs, blue lines shows the response time of two applications for ATM backbone, while the red line shows the response time for two applications for Gigabit Ethernet backbone. It's clear that Gigabit Ethernet causes much shorter response time for both applications than ATM.

3.3.4 Conclusions about Gigabit Ethernet vs. ATM

In the long run, it will not be a question of people using only ATM or only Gigabit Ethernet, it is more a question of where do they fit. Each technology is appropriate for specific applications or environments. We can draw following conclusions from above several experiments:

1. Both Gigabit Ethernet and ATM have high bandwidth which fast Ethernet and FDDI can't provide. Because of ATM's high overhead cost, Gigabit Ethernet has higher bandwidth efficiency when transferring pure data traffic.

2. When transferring voice or other delay sensitive traffic, if the network resource is enough, Gigabit Ethernet will have similar performance as ATM, or even better than ATM in some aspects, such as Voice Packet Delay Variation. While if the network becomes congested, ATM will be much better than Gigabit Ethernet because of its QoS mechanism.

3. Gigabit Ethernet's technology is fully backward-compatible with existing Ethernet hardware standards, so when interconnecting legacy Ethernet LANs, it will be a better choice than ATM.

4. DISCUSSION AND CONCLUSIONS

In our project, we proved the advantage of using backbone technology, and we studied into several backbone technologies and did some experiments to compare their performance.

Based on our experiment results, these backbone technologies have following features:

FDDI:
Better performance and scalability than Fast Ethernet.
Short Response Time in applications like FTP, Email, HTTP, Telnet.

ATM:
Better performance in voice application than FDDI: shorter end-to-end delay and delay variation;
Achieve shorter delay in various types of LANs.
Quality of Service

Gigabit Ethernet:
High throughput;
Compatible with legacy Ethernet equipment.

We learned a lot from our experiments. Based on our knowledge on these major backbone technologies, we discussed the features they showed: FDDI's token–passing scheme provides deterministic performance, which is well showed on its scalability. Its property as a packet-switched network makes it possible to supply less response time for Email, FTP, HTTP, Telnet services, while for Virtual circuit-switched network as ATM, it takes time to establish a connection before transferring traffics.

However, ATM can provide higher throughputs to LAN users than FDDI due to its comparatively high speed. Furthermore, virtual circuit switched network ATM is good at transferring CBR traffic such as voice application, achieving much less packet delay and delay variation, which is very important for CBR traffic. Its better performance also can be seen from the obvious less LAN delay provided for LANs users. ATM's QoS keeps the delay and delay variation on a reasonable level even though the network is getting more congested. Under the same circumstance, the delay and delay variation of Gigabit Ethernet increase obviously. That's why we always say ATM is good at transferring voice.

Gigabit Ethernet's high bandwidth surpassed its opponents a lot. So the throughput on links is much higher. Gigabit Ethernet also shows more advantages on bandwidth efficiency because of ATM's comparatively larger overhead payload ratio .And since 80 % of LANs existing are Ethernet LANs, the migration to a backbone based on Gigabit Ethernet is more natural, painless, and cost-effective than migration to ATM.

We're also learnt from some reference books of some other features like the fault tolerance of FDDI, distance limitation of FDDI and Gigabit Ethernet, and ATM's fitness on large-ranged WAN or MAN. Since these features are unique to each technology, it's not comparable between different backbones, so we didn't design experiments to prove these characteristics of these technologies.

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