COMPARATIVE PERFORMANCE ANALYSIS of MPLS over ATM and IP over ATM METHODS for MULTIMEDIA TRANSFER APPLICATIONS

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ABSTRACT

This paper presents fundamental aspects of MPLS over ATM method, IP over ATM method and multimedia application traffics with different quality of service (QoS) needs. Using a simulation program, the MPLS over ATM method providing ABR, CBR & VBR QoS support, and the IP over ATM method providing UBR QoS support for transferring data, voice and video traffics are modeled. Having simulated the models under varying loads, simulation results obtained and comparisons of the results are presented. Comparing the average delay and delay variation graphs, not only does MPLS over ATM method provide improved results for all of the multimedia applications but also overcomes the worst disadvantage of the IP over ATM method producing similar and erratic results for the data, voice and video application traffics.

I. INTRODUCTION

With the advent of the World Wide Web (WWW), the Internet has seen enormous growth, from its roots as a network of modest proportions mostly used by the research and academic community, to a large public data network [1]. The ever-increasing demands of Internet users have been forcing the Internet Service Providers (ISPs) to improve the provided service quality. Especially with the recent advances in real-time multimedia applications, a number of needs for example high bandwidth, fast routing and QoS support remains still unresolved. Regardless of the type of the application traffics, simple routing algorithm of the IP provides only a Best Effort service best suited to the data transfer applications. Therefore, especially voice and video traffics have to be transferred using other methods such as MPLS over ATM and IP over ATM, where QoS support advantages of the ATM are exploited in particular. ATM can handle the network delay, allocating its bandwidth to different application traffics fairly and differentiating the real time and non-real time multimedia traffics. As a result, optimum performance can be obtained from the network resources for all sorts of multimedia applications [1, 2, 15].

The paper describes ATM, IP, MPLS over ATM, and IP over ATM briefly in Section II. Multimedia Applications and Quality of Service are explained in Section III. Sections IV and V present the computer modeling of the MPLS over ATM and IP over ATM methods for transferring multimedia traffics followed by the simulation results, and comparative performance analysis of both models, respectively.

II. MPLS over ATM and IP over ATM Methods

ATM (Asynchronous Transfer Mode)

ATM technology is an ITU-T standard for broadband services supporting voice, video, data and real-time traffics effectively. It is a connection-oriented type of data transfer protocol, where information is transferred in fixed-size cells. As shown in Figure 1 each ATM cell consists of 53 bytes. The first 5 bytes contain the cell header information, and the remaining 48 bytes contain the "payload" (user data).

Header	Payload
5 bytes	48 bytes

Figure 1. ATM cell format

ATM can provide end-to-end connections for different multimedia traffics with required QoS. QoS describes the needs of a data traffic, which may have different kinds of characteristics depending on the nature of the user application. For example, voice, video and data traffics all belong to a different service class. ATM supported service classes (CoS) are called CBR, VBR (rt-VBR, nrt-VBR), ABR and UBR.

Constant Bit Rate (CBR) service is mostly appropriate for voice and video conferencing service category. The types of applications supported by the rt-VBR service category are voice traffic with bandwidth compression and silence suppression, and some types of real-time multimedia applications. Non-real-time Variable Bit Rate (nrt-VBR) service category is intended for non-real-time, bursty applications that require some level of service guarantee. Typical applications supported are critical response time transaction processing applications. Available Bit Rate (ABR) service category is intended for non-real-time bursty applications. It supports applications that adapt to network feedback. Unspecified Bit rate (UBR) service category is designed for data traffics that are insensitive to end-to-end delay and end-to-end delay variation (lowest priority).

IP (Internet Protocol)

Internet consists of numerous independent computer networks connected with routers and gateways. With its backbone structures it is used to connect public and local networks, providing high bandwidth links and rapid routers. Internet employs the IP which is a network layer protocol where data is sent as datagram with a connectionless approach.

IP-based networks only provide Best Effort service (ATM-UBR equivalent), which implies that there is no guarantee as to delay margins or actual delivery times. The problem with today's generic IP is that it only provides point-to-point connectivity, operates on a first-come-first-served basis, and is subject to variable and unpredictable queuing delays as well as congestion losses. Neither is it possible to share band-width on a particular link between applications with different performance requirements [6, 7, 14].

MPLS over ATM

Recently, as Internet and its services grow rapidly, a new switching mechanism, Multi-protocol Label Switching (MPLS), has been introduced by IETF [2]. MPLS by overlying IP and simplifying backbone of wide-area IP networks is a high speed technology [3]. It substitutes conventional packet forwarding within a network, or a part of network, with a faster operation of label look-up and switching [4].

ATM cell switching mechanism and label switching in MPLS networks are very similar to each other. In order to send packets rapidly, MPLS decreases complexity by integration of Layer-2 switching and Layer-3 routing for complete integrated solutions [5, 6]. Integration of IP routers and ATM switching mechanisms provides IP scalability over ATM networks, where packet forwarding and path controlling are provided with routers [5, 6].

MPLS uses the control-driven model to initiate the assignment and distribution of label bindings for the establishment of Label Switched Paths (LSPs). An LSP is created by concatenating one or more label switched hops, allowing a packet to be forwarded from one label-switching router (LSR) to another LSR across the MPLS domain. The MPLS network architecture consists of label switching routers (LSR) in the core of the network, and label-edge routers (LER) at the edge. The label-edge routers have the task of analyzing the IP header of each packet arrived, in order to find the corresponding forwarding equivalence class (FEC) and label-switched path, which facilitates the label swapping function in the LSR nodes (Figure 2) [6].

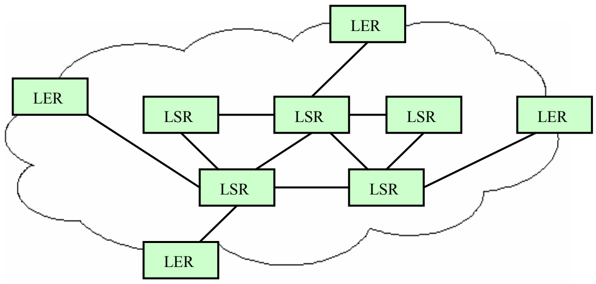

Figure 2. Label-edge routers and label-switch routers

Inside an MPLS domain, packet forwarding, classification and QoS are determined by the labels and the class of service (CoS) fields. This makes core LSRs simple. Each MPLS packet has a header that contains a 20-bit *label*, a 3-bit *Experimental field*, a 1-bit *label stack indicator* and an 8-bit *TTL field* in a non-ATM environment, and holds only a label encoded in the VCI/VPI field in an ATM environment (Figure 3) [8].

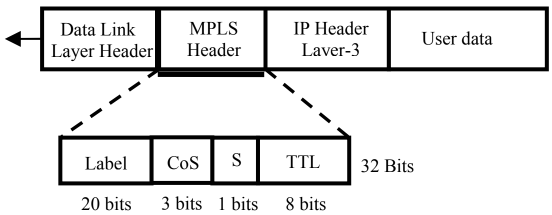

Figure 3. MPLS Header

Different MPLS headers may be used depending on the environment employed for data transferring. For example, in a solution utilizing an ATM backbone, data in the MPLS header is forwarded in the ATM header. On the other hand, for label based forwarding process whatever the data format is, additional labels and information to packets is necessary through MPLS Encapsulation [8, 9].

IP over ATM

In large scale environments, core networks usually use switch-based technologies. Routers are also operated in these networks at certain points. IP over ATM overlay model occurs by using these two technologies together [10]. As a secondary technology, ATM or Frame Relay both with overlay traffic management capabilities provides the IP backbone system with virtual circuits (VC) [7, 10]. IP over ATM networks widen design space and permit determinate arbitrary virtual topologies. IP over ATM model has also a few disadvantages. While layer-2 switching provides high speed connectivity, IP routers in the network edges need to be connected with each other using layer-2 virtual circuits. This increases the complexity of network architecture and network design. While IP routing protocols run on ATM, IP routers in the network are connected together using Permanent Virtual Circuits (PVCs) across an ATM cloud. The number of adjacencies in the overlay model generally increases quadratically with the number of routers. This creates neither a scalable nor a manageable network, primarily because all routers on the ATM cloud become IP neighbors [7, 10, 11].

III. MULTIMEDIA APPLICATIONS AND QUALITY OF SERVICE

QoS is an end-to-end system architecture. It refers to the ability of a network to provide improved service to a certain type of application traffic over various underling links. QoS signaling is used for coordinating QoS for end-to-end delivery between network nodes. QoS policing and management functions control and handle end-to-end traffic across the network [12].

One class of data applications has no requirements beyond that of the traditional "best effort" IP network. However, other classes of applications introduce new requirements (Table 1) [13].

Table 1. Different user applications have different QoS requirements.

Voice	Data	Video	Interactive Video
Low delay	High delay	Higher delay than voice	Requires low delay and low loss for control but can accept greater delay variation for control
Low delay variation	High delay variation	Data loss may have noticeable effects	
Tolerant to some data loss	Tolerant to varying bandwidth		

IV. MODELING and SIMULATION

For MPLS over ATM and IP over ATM models studied a simulation program (COMNET III) is used. Both models shown respectively in Figures 4 and 6 are independently obtained. Two similar nodes running a voice, a video and a data traffic application requiring different service classes are presented on the network. In the models, CrossComm XL5 Multiprotocol Routers (5000 Mbps) and Xylan Omni-9Wx (13200 Mbps) ATM Switches are employed. The links used to connect the routers and the ATM switches in the MPLS clouds are chosen as OC-3 (150 Mbps) due to their reliability and huge bandwidth capacity. The links between the routers and the nodes are IEEE 802.3z Gigabit Ethernet with CSMA/CD.

MPLS over ATM SIMULATION MODEL and SIMULATION RESULTS

Voice1, Video1 and Data1 message sources at Node1 introduce 5000─50000 bytes of information at an Exp(1.0) seconds interarrival time to be transferred across the ATM network to the Node2, and vice versa. Each traffic is carried over the MPLS cloud with a different service required, i.e., with CBR, VBR and ABR, respectively. LSR1 (LSR2) ingress edge router adds 4-byte MPLS labels to all Voice1, Video1 and Data1 packets before entering the MPLS cloud. Then these packets are transferred over ATM connections with required QoS that is realized using AAL1, AAL2 and AAL3/4 ATM Adaptation Layers for CBR, VBR and ABR respectively (Table 2). MPLS labels are removed at the LSR4 (LSR3) egress router, completing the Node1 to Node2 multimedia traffic transfer over MPLS cloud.

Table 2. ATM network parameters.

	ABR (packets)	CBR (packets)	VBR (packets)	UBR (packets)
PCR	10000	943	11792	10000
MCR	500	-	10613	1
ICR	2500	-	-	1
SBR	-	-	10613	-

PCR: Peak Cell Rate **MCR**: Minimum Cell Rate
ICR: Initial Cell Rate **SBR**: Sustained Bit Rate

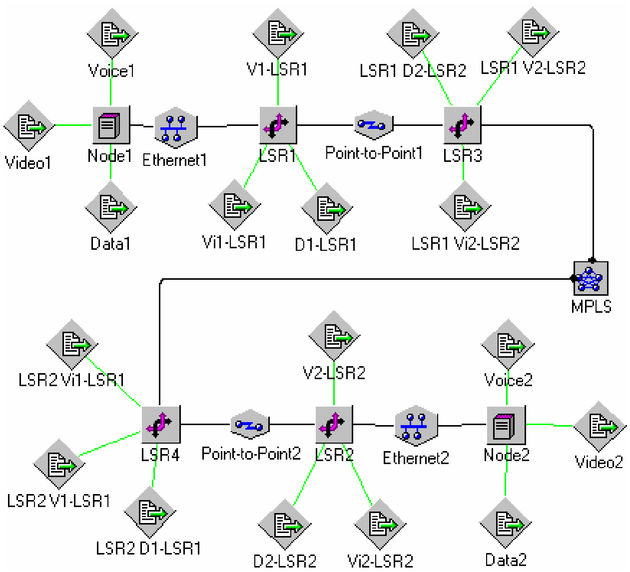

Figure 4. MPLS over ATM simulation model.

Varying the Voice1-2, Video1-2 and Data1-2 message source traffics between 5000─50000 byte/sec at the Node1-2, end-to-end delay and delay variations for the end user applications are provided and explained. As shown in Figure 5, average and delay variation results for the voice traffic are well around 20 ms. until the load is 45000 byte/sec, which is quite acceptable for real-time voice communication tolerable to less than 50 ms. end-to-end delay. In addition, this traffic is carried with the least delay as result of ATM CBR support, compared to the video and data traffics. The data traffic experiences the worst delay and delay variation of all since it is carried over ATM ABR connections.

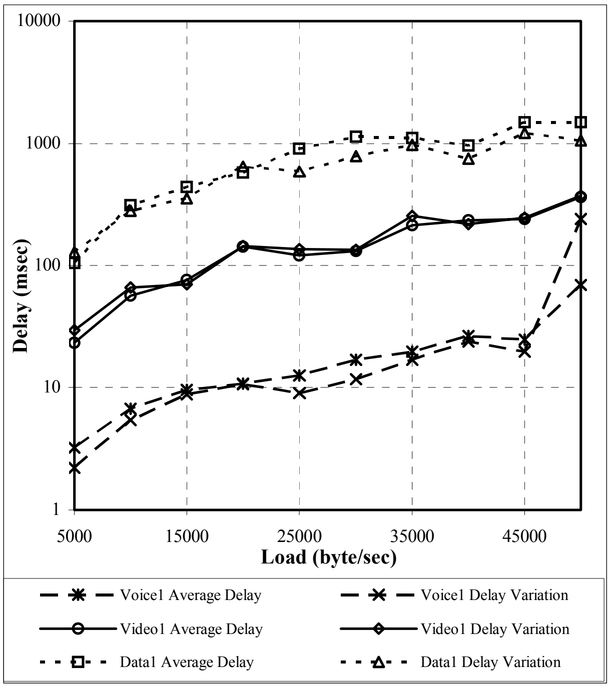

Figure 5. Average message delays and delay variations for MPLS over ATM

IP over ATM SIMULATION and SIMULATION RESULTS

This simulation model seen in Figure 6 differs from the MPLS over ATM model in that it uses the basic IP over ATM overlay approach. IP packets carrying all of the multimedia traffic are transferred over the ATM cloud with only UBR service (equivalent of IP Best Effort service) support realized using AAL5 ATM Adaptation Layer (Table 2).

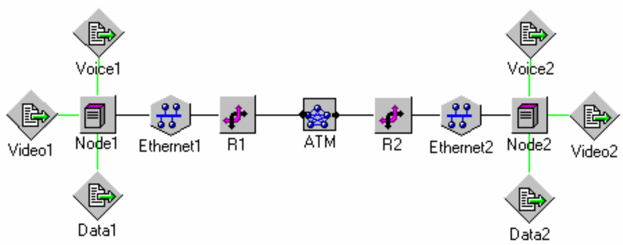

Figure 6. IP over ATM simulation model.

Analogous to the MPLS over ATM model, varying the Voice1-2, Video1-2 and Data1-2 message source traffics between 5000─50000 byte/sec at the Node1-2, end-to-end delay and delay variations for the end user applications are presented in Figure 7. As using only ATM UBR connections for all multimedia application traffics, the IP over ATM approach produced similar delay and delay variation results above 10000 ms without any differentiation among voice, video and data traffics. These results are unacceptable for the voice and video communication especially.

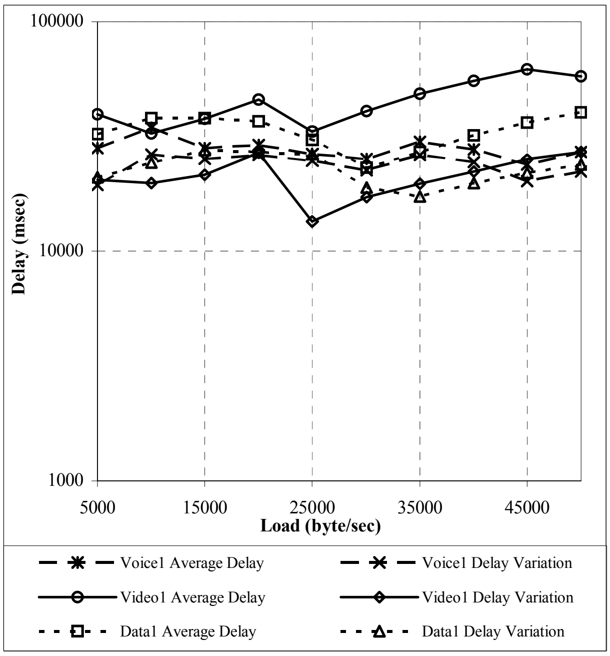

Figure 7. Average message delays and delay variations for IP over ATM

V. COMPARISON OF THE SIMULATION RESULTS OF THE MODELS

All of the multimedia traffic loads in the both models are chosen to be equal so that the justification of the MPLS over ATM and IP over ATM can easily be done with comparisons. Figure 8 shows the average delay graphs of the voice, video and data traffics for assessing suitability of the MPLS over ATM and IP over ATM approaches for multimedia applications. It can be seen from the figure that MPLS over ATM model average delay results outweigh the other model average delay results about 10 times for data traffic, 100 times for video traffic and 1000 times for voice traffic. Moreover, the latter model has produced exceedingly high average delays making it unsuitable for all of the multimedia application traffics.

MPLS over ATM model has yielded not only better and lower average delay and delay variation results than those of IP over ATM model but also it has differentiated the multimedia traffics according to their required QoS. Therefore, voice, video and data traffics experience different end-to-end average delay and delay variations due to fair and efficient use of ATM backbone resources offered with AAL1, AAL2 and AAL3/4 connections.

As a concluding remark, the simulation results illustrate that IP over ATM approach is insufficient for multimedia application traffics whereas MPLS over ATM provides these applications with end-to-end connections with guaranteed bandwidth and required priority, leading to low average delay and delay variations.

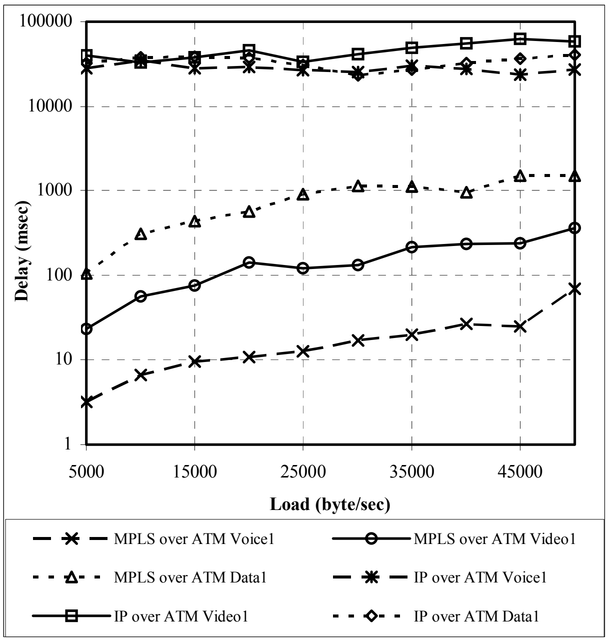

Figure 8. End-to-end average delay comparison of MPLS over ATM and IP over ATM models.

VI. CONCLUSION

Unpredictable and high end-to-end delay and delay variation results have been the most significant problem in the deployment of IP over ATM networks for multimedia applications. It is neither adequate nor acceptable to use the IP Best-Effort service for the most demanding real-time voice and video traffic transfer due to its simple and connectionless routing protocol approach. Similarly, IP over ATM traffic does not provide sufficient QoS guarantees for these applications either. MPLS increases scalability of the routing and forwarding by facilitating the traffic engineering in IP networks. The simulation results presented concludes that by using QoS support, which is provided by the underlying ATM network, MPLS over ATM method grants a much more suitable infrastructure for multimedia traffic transferring compared to the IP over ATM method.

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