A New Architecture for Transmission of MPEG-4 Video on MPLS Networks

Geng-Sheng (G.S.) Kuo* and C. T. Lai**
National Chengchi University*
Taipei, Taiwan 11623
e-mail: gskuo@ieee.org
National Central University**
Chung-Li, Taiwan 32054

Abstract - Due to insufficient network bandwidth on Internet, multimedia-oriented applications are still not popular now. The traffic on Internet often causes congestion in routers. Therefore, Internet must overcome these challenges and bottleneck to provide more multimedia-oriented applications. In this paper, we study the transmission of MPEG-4-based video traffic in MPLS networks. We propose a better architecture, coined Actively Reserved Bandwidth Architecture, for improving CR-LDP in MPLS networks. The architecture is designed to overcome the bottleneck of router in MPLS networks. And, this approach is beneficial to the transmission of MPEG-4-based video traffic.

1. INTRODUCTION

Bandwidth is the most scarce and precious resource in Internet. The transmission of multimedia traffic needs stable network bandwidth [29], which is achieved by reservation. RSVP is used by a host to request specific QoS for particular application streams on Internet [2] [26] [27]. Although the concept of QoS provides stable bandwidth for multimedia traffic, the bottleneck of transmission is often in the routers. The router is responsible for forwarding each packet to the next hop. In conventional routing, the router extracts each packet header first, then uses routing algorithm to forward this packet to the next hop. When the traffic is increasing, this approach will lead to forwarding packets inefficiently, especially for multimedia traffic.

The main purpose of this paper is to propose a better architecture for improving CR-LDP in MPLS networks for efficiently transmitting MPEG-4-based video. The rest of this paper is organized as follows. In Section 2, we describe the differences between the conventional routing and MPLS. In Section 3, we propose an architecture, coined Actively Reserved Bandwidth Architecture, for improving CR-LDP in MPLS networks and discuss its advantages. Finally, some conclusions are made.

2. SURVEY

A. Conventional Routing

Routing is in the network layer of OSI 7-Layer Reference Model. Transmitting a packet to the destination may require many hops at intermediate routers along the path. To finish the process, the network layer must know the topology of subnets and choose a suitable path through it. When choosing a path, the routers avoid the paths and routers with heavy load. Because the state of network is highly changeable, the routers often update their routing table information using RIP [39] or OSPF [40].

In general, the bottleneck of transmission is in routers. In the conventional routing, each packet is forwarded hop-by-hop using routing table and algorithm in each router. Each packet is forwarded independently in every router [21] [22]. This approach is unreasonable and inefficient for multimedia traffic [24]. As network technologies evolve, Internet has invented and improved many applications. While the traffic is increasing with the conventional routing, congestion often happens in the router. It is not wise that each packet is forwarded independently in the router, especially for multimedia traffic. We can treat one video object plane (VOP) in MPEG-4 as one unit of multimedia traffic or one unit of transmission and give this VOP a high priority for transmission in Internet. This way is more reasonable and efficient than the conventional routing in Internet.

B. MPLS

MPLS proposed by IETF is one of the latest network technologies, which transmits traffic effectively and supports QoS on the Internet. It is expected that MPLS improves the performance of routing in the network layer [3] [4] [5] [30] [47] [48]. However, based on MPLS, there are many reasons supporting the desire of using explicit routing instead of hop-by-hop one [5] [6]. The Label Distribution Protocol (LDP) is a set of procedures by which one Label Switching Router (LSR) informs another LSR of the meaning of labels used to forward traffic between and through them. And, LDP uses TCP for session communications to ensure that LDP messages are reliably delivered across MPLS networks [33] [36].

Constraint-based routing using LDP (CR-LDP) offers the
opportunity to extend the information used to setup paths beyond what is available for the routing protocol [7] [8] [33]. A Constraint-based Routed Label Switched Path (CR-LSP) can be setup based on explicit route constraints, QoS constraints, and other constraints to support the transmission of real-time multimedia traffic [8]. In recent years, some research efforts emphasized the traffic engineering of MPLS [8] [9] [45], the advantages of traffic engineering [10], and the differentiated services [35] [46]. [8] compared two MPLS signaling protocols, CR-LDP and RSVP in many aspects, such as transport mechanism, failure notification, and so on. It concluded that CR-LDP is superior to RSVP particularly due to using TCP [8]. Hence, the MPLS is suitable for transmitting real-time multimedia traffic.

C. CR-LDP and ER-LSP

CR-LDP is used to setup CR-LSP. CR-LDP is a simple, scalable and open signaling protocol for MPLS networks. It provides mechanisms in establishing explicitly routed label switched paths (ER-LSPs). And, it is defined for the specific purpose of establishing and maintaining ER-LSPs [7] [37]. Because LDP is a peer-to-peer protocol based on the establishment and maintenance of TCP sessions, it has two advantages mainly. First, CR-LDP messages are reliably delivered by the TCP. Second, CR-LDP messages are flow-controlled through TCP. In addition, CR-LDP is designed to support the different medium types, which are supported by MPLS. Hence, it works equally well for multi-service switched networks, router networks, and hybrid networks [37] [38].

A CR-LSP is a path through a MPLS network like any other LSP. The difference is that other paths are setup solely based on information in routing tables and the constraint-based route is calculated and setup once at the edge-LSR based on criteria. ER-LSP is setup by explicit routing, which is a subset of the constraint-based routing. CR-LDP supports ER-LSP in two modes, strict and loose modes [7]. In the strict mode, the ER-LSP is established by identifying each single hop along the explicit path. Besides, the setup of ER-LSP only happens at the originating node, such as the edge-LSR. In the loose mode, the edge-LSR does not need to specify each single hop along the path. Each ER-hop may identify and select a group of nodes in the constraint-based route in the loose mode. Here, we call each group of nodes an abstract node. Thus, the loose ER-LSP is established by selecting the constraint-based route among abstract nodes according to IP forwarding tables and constraint information, such as bandwidth requirement. In this paper, we only discuss the strict mode of ER-LSP establishment.

D. Establishment of Strict ER-LSP Using CR-LDP

First, the edge-LSR, LSR1, generates a Label Request Message including four ER-hops. In other words, the Label Request Message includes the requested path. Each core-LSR of LSR2, LSR3, and LSR4, pops the ER-hop information, then determines the next hop and forwards the updated Label Request Message to the next hop. LSR3 is the last LSR of the Label Request Message. Then, it will generate a Label Mapping Message to LSR4 when it receives the Label Request Message. A similar procedure occurs at each LSR of the strict ER-LSP. When LSR1 receives the Label Mapping Message, the establishment of strict ER-LSP will finish.

We think that the process of strict ER-LSP establishment has some drawbacks. First, the ingress LSR probably has heavy load. The ingress LSR needs some information to calculate for the Label Request Message, and the provisioning of the strict ER-LSP only happens at the originating node. As traffic is increasing, the load of the ingress LSR is heavier. Second, the processes of label request and label mapping are inefficient. Many real-time multimedia applications need stable network resources, such as bandwidth. If the ER-LSP with sufficient resources cannot be established, the process of label request will fail. Then, the ingress LSR will generate a Label Request Message again. This is very inefficient for real-time multimedia applications. If we can inform the ingress LSR about the available network resources for each route, the ER-LSP will be established quickly and the chance of failure in establishing ER-LSP will decrease. Besides, the load of ingress LSR will be lightened.

3. NEW ARCHITECTURE

ACTIVELY RESERVED BANDWIDTH ARCHITECTURE

A. Operation

The MPLS architecture has some shortcomings. First, it will lead to the heavy load of edge-LSRs due to calculating the path of traffic in the MPLS domain, when traffic is increasing considerably. Second, it spends time to establish a path. When network resource is insufficient, it will cost more time to re-establish a path. Therefore, we propose a new architecture, coined Actively Reserved Bandwidth Architecture, to improve the original MPLS architecture.

In the Actively Reserved Bandwidth Architecture, each core-LSR reserves some bandwidth for every edge-LSR. These core-LSRs construct a path that occupies the bandwidth for the edge-LSR. While a traffic flow requests an edge-LSR for transmission, the edge-LSR can quickly find a path with sufficient bandwidth to transmit it without calculating and establishing the path in the MPLS domain. This reduces the chance of failure in establishing a path and decreases the load in edge-LSR. Therefore, this approach is good for transmitting multimedia traffic due to the serious delay limitation.

Sometimes, an edge-LSR requests the bandwidth exceeding the reserved capacity. The edge-LSR uses the original architecture in calculating and establishing a path to
transmit the traffic flow in the MPLS domain. This may use other edge-LSR's reserved bandwidth in some core-LSRs. When the situation occurs, these core-LSRs signal the edge-LSR whose reserved bandwidth is occupied. And, the core-LSRs cut down the reserved bandwidth for the edge-LSR.

B. Advantages

The advantages of Actively Reserved Bandwidth Architecture are pointed out as follows:

- To reduce the need of establishing a path.
  - If the reserved bandwidth is sufficient, the edge-LSR has no need to establish a path.
- To decrease the probability of failure in establishing a path.
  - When the reserved bandwidth is occupied by other edge-LSR, the core-LSRs will actively notify the edge-LSR.
- To be suitable for real-time multimedia traffic.
  - Establishing paths results in time delay.

C. Performance

We consider that the LSR spends one unit of time \( t_p \) for transmitting one packet. Assume that there are \( r \) LSRs. Let \( m_i \) denote the number of packets of the \( i \)-th VOP. Furthermore, let \( EST\_PATH_i \) denote the time of establishing a path in the MPLS domain. The edge-LSR needs \( CAL\_PATH_i \) units of time to calculate a path. If bandwidth is not sufficient enough, the \( REEST\_PATH_i \) units of time are needed to re-establish a path in the MPLS domain.

Let \( T_{ij} \) denote the transmission time of \( n \) VOPs in our proposed architecture.

\[
T_{ij} = \begin{cases} 
  t_p \sum_{i=1}^{r} m_i & \text{(1.1)} \\
  CAL\_PATH_i + EST\_PATH_i + t_p \sum_{i=1}^{r} m_i & \text{(1.2)} \\
  CAL\_PATH_i + EST\_PATH_i + t_p \sum_{i=1}^{r} m_i + REEST\_PATH_i & \text{(1.3)} 
\end{cases}
\]

The edge-LSR has one of three conditions while transmitting \( n \) VOPs in our proposed architecture. Condition (1.1) shows that the edge-LSR has no need to calculate and establish a path. In other words, the edge-LSR has sufficient reserved bandwidth to form a path.

And, we assume that the probability of Condition (1.1) is \( P_{i0} \).

Condition (1.2) denotes that the edge-LSR spends time to calculate and establish a path due to no sufficient reserved bandwidth. Although the edge-LSR does not have sufficient reserved bandwidth, it has sufficient network bandwidth for establishing a path. We assume that the probability of Condition (1.2) is \( P_{i1} \).

And, Condition (1.3) shows that the edge-LSR fails to establish a path due to insufficient network resource. It spends more time than that of Condition (1.2) on this process. We assume that the probability of Condition (1.3) is \( P_{i2} \).

Let \( T_{ij} \) denote the transmission time of \( n \) VOPs in the original MPLS architecture.

\[
T_{ij} = \begin{cases} 
  CAL\_PATH_i + EST\_PATH_i + t_p \sum_{i=1}^{r} m_i & \text{(2.1)} \\
  CAL\_PATH_i + EST\_PATH_i + t_p \sum_{i=1}^{r} m_i + REEST\_PATH_i & \text{(2.2)} 
\end{cases}
\]

The edge-LSR has two conditions while transmitting \( n \) VOPs. Condition (2.1) shows that the edge-LSR calculates and establishes a path when network bandwidth is sufficient. We assume that its probability is \( P_{2a} \). Under Condition (2.2), the edge-LSR uses more time than that of Condition (2.1) to re-establish a path due to insufficient network bandwidth. We assume that its probability is \( P_{2b} \).

Therefore, \( P_{i0} + P_{i1} = P_{2a} \) and \( P_{i1} = P_{2b} \).

The expected value of \( T_{ij} \) is as follows.

\[
E(T_{ij}^1) = t_p \sum_{i=1}^{r} m_i + \frac{CAL\_PATH_i + EST\_PATH_i + t_p \sum_{i=1}^{r} m_i}{P_{2a}} + \frac{CAL\_PATH_i + EST\_PATH_i + t_p \sum_{i=1}^{r} m_i + REEST\_PATH_i}{P_{2b}}
\]

The expected value of \( T_{ij} \) is as follows.

\[
E(T_{ij}^2) = \frac{CAL\_PATH_i + EST\_PATH_i + t_p \sum_{i=1}^{r} m_i}{P_{2a}} + \frac{CAL\_PATH_i + EST\_PATH_i + t_p \sum_{i=1}^{r} m_i + REEST\_PATH_i}{P_{2b}}
\]

Due to \( P_{i0} = P_{2b} \),

\[
\left( CAL\_PATH_i + EST\_PATH_i + t_p \sum_{i=1}^{r} m_i + REEST\_PATH_i \right) \cdot P_{2b} = \left( CAL\_PATH_i + EST\_PATH_i + t_p \sum_{i=1}^{r} m_i + REEST\_PATH_i \right) \cdot P_{2b}
\]

The new architecture spends less time than that of the original MPLS architecture in transmitting traffic. This improves the original architecture.

In addition, let \( k_1 \) be \( t_p \sum_{i=1}^{r} m_i \), \( k_2 \) be \( CAL\_PATH_i \), and \( k_3 \) be \( EST\_PATH_i \).
Some conclusions are derived from (3.1). When \( f_{ji} + P_{za} \), Performance is much better for saving time in calculating and establishing the path. When both \( k_{z} \) and \( k_{3} \) are longer, Performance is better obviously. On the other hand, if \( k_{2} \) and \( k_{3} \) are less, the network condition is good and network traffic is less. Therefore, Performance is lower. The new architecture and original architecture have no obvious difference.

Let \( K \) denote \( \frac{(k_{2} + k_{3})}{(k_{1} + k_{2} + k_{3})} \). 0< \( K \) <1. \( K \) represents a "Traffic Condition Parameter". If \( k_{z} \) is fixed, Internet has heavy traffic while \( K \rightarrow 1 \). In other words, both path calculation time \( k_{z} \) and path establishment time \( k_{3} \) are larger.

Furthermore, let \( P \) denote \( \frac{P_{za}}{P_{za}} \). 0<P<1. So,

\[
\text{Performance} = K \cdot P
\]

In Fig. 1, when \( K \rightarrow 1 \), the performance is better obviously. In other words, when traffic is becoming much heavier, the performance is better. Conversely, when \( K \rightarrow 0 \), the performance is lower. The consequence is reasonable and valuable. In addition, when \( P \rightarrow 1 \), the edge-LSR can save much time in transmitting the flow. And, the performance is better. In Fig. 1, the slopes of lines are different. We change both \( K \) and \( P \) simultaneously, and observe the variation of performance in Fig. 2.

D. Time of Establishing One ER-LSP

The standard of MPLS has not been finished yet, especially [7] and [33]. Based on [7], we almost do not know the computing time of generating Label Request Message in the edge-LSR. So, it is very hard to estimate correctly the time of establishing one ER-LSP in the MPLS domain at this moment. To the best of our knowledge, it might be a good approach to assume the time includes the waiting time in all LSRs along the ER-LSP. According to [31], the mean waiting time for output queueing:

\[
W = \frac{P}{2(1-P)}
\]

where \( W \) denotes the mean waiting time, and \( P \) denotes the offered load (0<P<1). When an ingress-LSR establishes one ER-LSP, it includes the processes of Label Request and Label Mapping. The processes may let Label Request Message and Label Mapping Message pass through many LSRs.

According to Fig. 3, both Label Request Message and Label Mapping Message may result in some delay at each LSR during the process of establishing one ER-LSP. The offered load of each LSR is not affected by others. We assume both Label Request Message and Label Mapping Message pass through \( n \) LSRs, and the offered load of each LSR is the same. According to [33] and [34], both Label Request Message and Label Mapping Message need 4 bytes to store the related information. Therefore, the time in the processes of label request and label mapping is as follows.

\[
W = \frac{P}{2(1-P)} \cdot 2 \cdot n \cdot 4 = \frac{4nP}{(1-P)}, \text{ where } 0<P<1, n>0
\]

According to Fig. 4, the processes of label request and label
mapping may need some time to operate.

In this paper, according to the feature of MPEG-4 video, treating one VOP as a unit of transmission is more efficient than treating one packet as a unit of transmission. We proposed a new architecture, Actively Reserved Bandwidth Architecture, which improves CR-LDP in the MPLS domain. This architecture achieves better results and is more suitable for multimedia traffic, such as MPEG-4 video.

The future research on Actively Reserved Bandwidth Architecture is expected. Due to dynamic network traffic on Internet, the core-LSR hardly reserves definite bandwidth for the edge-LSR to handle all cases. Many studies emphasized the traffic engineering of MPLS, which is an important topic for further research. Besides, there is a trend in Internet router for differentiating the type of incoming network traffic. This makes flow-oriented control easier in LSR, and also supports QoS mechanisms. It is necessary to have an optimal design of bandwidth reservation in core-LSRs for the edge-LSR.

ACKNOWLEDGMENT

This work was supported by the National Science Council of the Republic of China under Grants NSC 89-2416-H-004-101 and NSC 89-2416-H-004-102.

REFERENCES