行政院國家科學委員會專題研究計畫成果報告

未來高速多媒體導向 Internet 之
下一代寬頻 MPLS 路由器架構與性能研究
Research on Architecture and Performance of Next-Generation Broadband MPLS Router in Future High-Speed Multimedia-Oriented Internet

計畫編號：NSC 89-2416-H-004-101
執行期限：89 年 8 月 1 日至 90 年 10 月 31 日

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一、中文摘要

本計畫之主要目的是研究下一代寬頻 MPLS 路由器之架構與性能。MPLS 路由器係現今全世界之標準規格，從此主題去研究其改進，深具價值。

關鍵詞：路由器、寬頻、MPLS、網際網路

Abstract

The main purpose of this project is to study the architecture and performance of the next-generation broadband MPLS router. Label switching router (LSR) is the MPLS standard. To improve LSR can achieve significant value.

Keywords: Router, Broadband, MPLS, Internet

二、緣由與目的

下一代寬頻路由器絕對是未來高速多媒體導向網際網路之瓶頸，而下一代寬頻路由器之架構已很清楚地定義為 Label Switching Router，其重要性不言可喻，全世界均須依照。本計畫之主要目的就是為了探討此主體，提出具體之改進，產生實質之貢獻。

三、研究報告

Introduction

Currently, the Internet is widely used and the applications on it are increasing rapidly. The crucial bottleneck of overall Internet performance is the router. It is a must to design and develop the so-called next-generation broadband router for future multimedia-oriented broadband Internet. IP label switching technology is one of the most attractive approaches to achieve the expected goal. IP label switch uses the Routing Information Binding technique which maps the routing information in Layer 3 to the switching table in Layer 2, so that it can process packets rapidly in order to provide better performance and QoS support. In short, label switching is the state-of-the-art technology in the IP over ATM (IPOA) area. Four major IP label switching models are Ipsilon's IP Switch, Toshiba's CSR, Cisco's Tag Switch, and IBM's ARIS [1]. After comparing the four label switching technologies, we obtain that both traffic-data driven and control-data driven technologies have their own strengths and weaknesses [2] [3]. VC explosion and control message overhead are the main drawback of label switching technology [2] [3]. The purpose of this paper is to study the performance of label switching technology first, then based on the analysis result to propose new improvement on the IP label switching technology to achieve better efficiency.

The rest of the paper is organized as follows. In Section 2, we analyze the performance of label switching technology. Based on the analysis result, we figure out some new design consideration, and make new improvement on the label switching technology. The architecture of Active Label Switching Router (ALSR) is proposed in Section 3. Finally, conclusions are made.

Performance of Label Switching Technology

For conventional routing method, the basic unit that a router notices is a packet. A router processes each packet arriving from its neighbor and finds a route for the packet. Each packet needs to be decomposed at the network layer. Very important, label switching technology changes this conception. Label switch treats the packet flow as a unit of the traffic. It pries the characteristics of flow. If it perceives the existence of long duration flow, it establishes a dedicated virtual channel automatically in order to speedily switch all packets belonging to the flow by label switching mechanism. Because this dedicated virtual channel is not dedicated from the source node and the router classifies the flow, the routing time may not be improved notably.

Assume that a packet flow contains n packets and the average time to route a packet using conventional routing method is Tc. The total routing time T1 is nTc.

$$T_1 - n \cdot T_c \tag{1}$$

By using label switching technology, the classifier decides to set up the dedicated channel. After the flow classifier in label switch watches m packets all matching a specific flow, it will establish a dedicated channel for the flow. Before the dedicated channel is set up, the packets are routed by conventional network layer routing method. Setting up a dedicated channel spends time T. During the time period T, no more than k packets belonging to the flow arrive at the router, i.e. k=T/Tc, and these packets will be routed by conventional routing method. We assume that the average time of switching a packet by label switching method is Ts after the dedicated channel has been established. Hence, the total time to route the flow by label switching technology T2 is:

$$T_2=\begin{cases} n\cdot T_c \\ m\cdot T_c+T \\ m\cdot T_c+T+(n-m-k)\cdot T_s \end{cases}$$

$n<m$ (2.1)

$m\le n<m+k$ (2.2)

$n\ge m+k$ (2.3)

In Equation 2, we discuss the performance of label switching technology in three conditions. First, when a flow contains only n packets and n is less then m, label switch does not activate the label switching mechanism due to no discovery of the flow. All packets belonging to the flow are routed by the conventional method, and the total routing time is equal to nTc. Second, when n is equal to or larger than m but less than m+k, label switch initiates the label switching mechanism. The classifier notifies the flow and starts to set up a dedicated virtual channel. Because n is less than m+k, no packet can be switched through layer 2, and the dedicated channel has not been set up yet. In order to study the performance issue, we define the efficiency G = T1/T2. G can be expressed as Equation 3.

$$G=\frac{T_1}{T_2}=\frac{n\cdot T_c}{m\cdot T_c+T}=\frac{n}{m+k} \quad (3)$$

Since n<m+k, G is between 0 and 1. Clearly, we wish k be as small as possible. And, it is determined by each label switching technology independently. Third, if n is equal to or greater than m+k, since Ts<Tc, then T2<T1 We obtain G as Equation 4.

$$G=\frac{T_1}{T_2}=\frac{n\cdot T_c}{m\cdot T_c+T+(n-m-k)\cdot T_s} \quad (4.1)$$

To make G larger is the critical issue we want to understand. Because T=kTc, Equation 4.1 can be expanded to Equation 4.2.

$$G=\frac{T_1}{T_2}=\frac{n\cdot T_c}{(m+k)\cdot T_c+(n-m-k)\cdot T_s} \quad (4.2)$$

Let p=m+k, we have

$$G=\frac{T_1}{T_2}=\frac{n\cdot T_c}{p\cdot T_c+(n-p)\cdot T_s} \quad (4.2.1)$$

Because

$$\frac{n\cdot T_c}{p\cdot T_c+(n-p)\cdot T_c}=1 \quad (4.2.2)$$

and Ts<Tc, we have

$$\frac{n\cdot T_c}{p\cdot T_c+(n-p)\cdot T_s}\ge\frac{n\cdot T_c}{p\cdot T_c+(n-p)\cdot T_c} \quad (4.2.3)$$

So, when n is equal to or greater than m+k (or n is equal to or greater than p), G is equal to or greater than 1.

If n>>p, we obtain

$$G=\frac{n\cdot T_c}{p\cdot T_c+(n-p)\cdot T_s}\cong\frac{n\cdot T_c}{p\cdot T_c+n\cdot T_s} \quad (4.3.1)$$

$$\frac{n\cdot T_c}{p\cdot T_c+n\cdot T_s}=\frac{1}{\frac{p}{n}+\frac{T_s}{T_c}}\cong\frac{T_c}{T_s} \quad (4.3.2)$$

Then,

$$G\cong\frac{T_c}{T_s} \quad (4.3.3)$$

When n is much larger than p, the efficiency G is the ratio of Tc and Ts. If we can make m and k as small as possible, the performance is the best. And, the proposed new IP label switching architecture is to achieve this expected goal.

m is the number of packets detected before a dedicated channel is established. If m is smaller, the efficiency will be better. But the less packets have to be seen before a dedicated channel is set up, the more dedicated channels have to be set up. This probably increases the router load and costs more VC setup time T. The choice of flow classifier affects the value of m.

k is the average number of packets in the flow arriving at a label switching router during dedicated channel establishment. The shorter setup time is, the better performance of label switching is. The parameters, which influence k, include dedicated-VC creation delay, dedicated-VC deletion period, VC space support by label switch, label switch processing time, and route change.

Active Label Switching Router (ALSR)

After carefully investigating the current IP label switching technologies, we propose our improved IP label switching technology, coined Active Label Switching Router (ALSR). ALSR binds the network layer information and data link layer information actively. It improves the VC setup time and ensures the efficiency of label switching. ALSR is based on data-traffic driven architecture but not control-traffic driven, because the control message overhead of control-traffic driven architecture is complex. It needs more tasks to manage and maintain the binding of routing information and VC information. Furthermore, the scalability and flexibility of data-traffic driven architecture is better than those of control-traffic driven one.

A. Terminology

ALSR is a switch/router which can conduct layer 2 switching and layer 3 routing independently and serve ALSR protocol (ALSRP). ALSRP manages and maintains the binding information in ALSR and provides loop detection by hop count filed rather than layer 3 TTL. Several ALSRs, which are connected one another, form an ALSR cloud. At the margin of an ALSR cloud, there are Ingress ALSRs (I-ALSRs) which perform flow classification. ALSR does not execute flow classification procedure beyond I-ALSR. This reduces the latency of flow classification and ensures the total efficiency of label switching technology.

Four kinds of VC are set up in an ALSR - default channel, control channel, dedicated channel, and unused channel. If packet traffic is not recognized as a flow and is not control traffic, the packets will be transmitted to next hop through default channel by conventional hop-by-hop routing method. IP control message, such as ICMP, IGMP, etc, is forwarded and received on control channel. The dedicated channel is used to forward packets of a flow which have the same routing requirement at data link layer. And, the unused channel is not used and is the candidate of dedicated channel. Both dedicated channel and unused channel are managed by Active Label Switching Router Controller (ALSRC). The architecture of ALSR is illustrated in Figure 1.

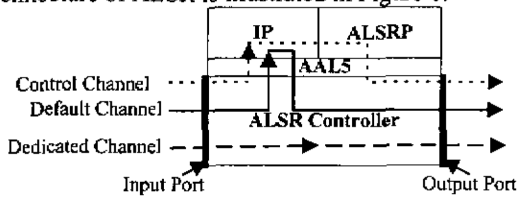

Figure 1. ALSR Architecture.

B. Basic Operation

The premise of operation for ALSR is that all unused channels on an input port of an ALSR are mapped to the ALSRC and several adjacent routers which serve ALSRP are connected each other to form an ALSR cloud. Flow classifier is only set at I-ALSR. The ALSR topology is illustrated in Figure 2.

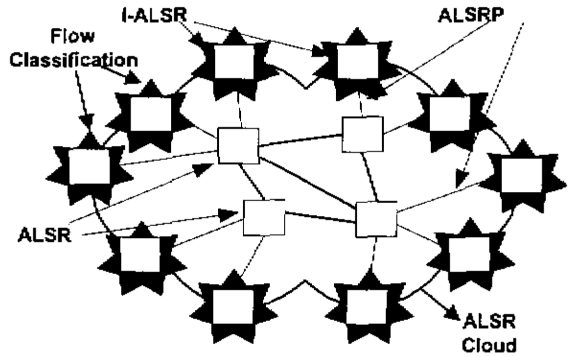

Figure 2. ALSR Topology.

When an I-ALSR receives a packet from a node beyond the ALSR cloud, flow classifier can classify whether there is a flow traffic. The flow classifier may be X/Y classifier, PORT classifier, or PROTOCOL classifier. If ALSR does not recognize the flow existence, it forwards the packet through default VC using conventional network layer routing in Figure 3.1. If ALSR discovers the existence of a flow, ALSRC selects an unused VC on an outgoing port as a dedicated VC for the flow. Then, ALSR directly forwards the first packet of the flow according to network layer routing information through the dedicated VC selected by ALSRC without any notification, which is illustrated in Figure 3.2. Because an ALSRC knows all unused VCs on an ALSR input port which it controls, any data received from unused VCs means the packet traffic in the VC has been classified as a flow by I-ALSR. The downstream ALSR selects a dedicated VC on outgoing port based on IP routing information and marks the unused VC as used. Simultaneously, ALSRC adds the entry {(input port, input VC), (output port, output VC)} in the VC table. The first packet of the flow is then forwarded to its next hop through the dedicated VC in Figure 3.3. The creation of dedicated VC stops at the boundary of ALSR cloud. Packets following the first packet are switched at data link layer rather than by conventional routing method illustrated in Figure 3.4.

There are two ways to release the dedicated VC. First, when I-ALSR closes the binding of dedicated VC, it sends a REMOVE message to its downstream ALSR through control channel. When downstream ALSR receives this message, ALSRC releases the binding information in the VC table and marks the dedicated as unused. Then, sends a REMOVE message to its downstream ALSR. Second, when no packet received in a refresh interval, ALSRC releases the binding information and marks the dedicated VC as unused. ALSR does not send any REMOVE message to its neighbor ALSR.

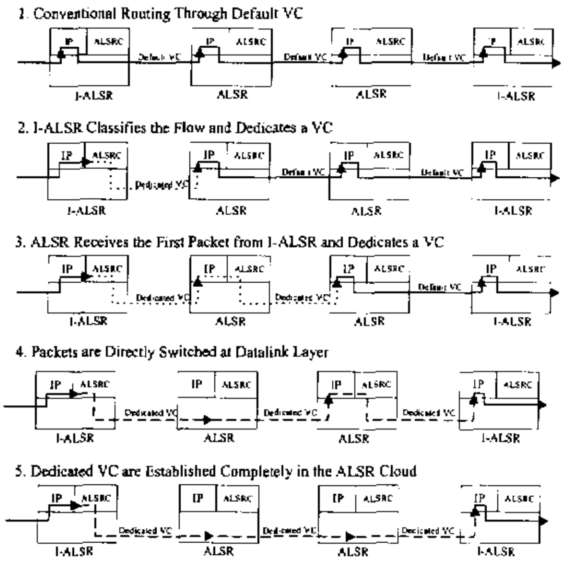

FIGURE 3. BASIC OPERATION OF ALSR.

ALSRC is the main processor in the ALSR architecture. Each port of a switch is assigned an IP interface. Incoming packets on all unused VCs are considered as a flow traffic and directed to the ALSRC. When a packet is received on an unused VC, the incoming VC and Port number information pair is recorded in the VC table by ALSRC. And, ALSRC keeps track of all unused VCs on each port, and maintains a VC which maps a flow to a switched path.

Conclusion

According to the results of simulation study, ALSR indeed improves the performance of the router. With limited number of VC space, ALSR can switch 0.5 - 12.1% more packets than IP Switch does, because ALSR improves the flow creation latency. And, the characteristics of network traffic influence the degree of improvement. Although ALSR reduces the channel establishment time and increases the number of packets switched, it does not decrease the number of VC usage. When poor VCs are available, the performance difference between ALSR and IP Switch is small. Conversely, when enough VCs are available, ALSR is definitely a better choice. In addition, only I-ALSRs perform flow classification in an ALSR cloud. This approach reduces the flow classification time.