Flow Aggregated Traffic-Driven Label Mapping in Label Switching Network

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ABSTRACT

Label switching technology enables high performance, flexible, layer-3 packet forwarding based on the fixed length label information mapped to the layer-3 packet stream. A Label Switching Router (LSR) forwards layer-3 packets based on their layer-3 address information or their label information mapped to the layer-3 address information.

This paper evaluates the required number of labels under traffic-driven label mapping policy using the real backbone traffic traces. The evaluation shows that the label mapping policy requires a large number of labels. In order to reduce the required number of labels, we propose a label mapping policy which is a traffic-driven label mapping for the packet stream toward the same destination network. The evaluation shows that the proposed label mapping policy requires only about one tenth as many labels compared with the traffic-driven label mapping for the host-pair packet stream, and the topology-driven label mapping for the destination network packet stream.

Keywords: ATM, LSR, Router, IETF

1. INTRODUCTION

The data networks applying the TCP/IP technology, i.e., the Internet and intranet, are growing both in geographical and numerical scale, as well as in traffic volume. Also, recent and upcoming applications often require a specific quality of service (QoS) or a class of service (CoS) rather than the conventional best-effort service. Label switching technology will satisfy these requirements, i.e., high speed and large processing capability while providing QoS and CoS, with reasonable implementation cost. A Label Switching Router (LSR) forwards layer-3 packets using either their layer-3 address information or their label information mapped to the layer-3 address information.

Several architectures for LSR, including ARIS (Aggregate route-based IP switching),[7] CSR (Cell Switch Router),[3] IP Switch[1] and TSR (Tag Switch Router),[5] have been proposed with their own protocol designs. The protocol to establish the mappings between a packet stream and a corresponding label is generally called a LDP (Label Distribution Protocol) by the IETF (Internet Engineering Task Force) MPLS (MultiProtocol Label Switching) Working Group.

From the view points of the scalability and the implementation feasibility of LSR, it is important to evaluate the required number of labels in label switching networks. The number of required labels depends on a label mapping trigger, which is an event to invoke the label mapping, and on the granularity of a packet stream.

Two kinds of label mapping triggers have been proposed. One is a traffic-driven mapping, where the label is mapped to a packet stream according to the actual packet arrival. The other is a topology-driven mapping, where the label is mapped, in advance, to a packet stream using the network topology information regardless of actual packet arrival to the LSR.

Several kinds of granularity for a packet stream can be defined. The typical definitions for the packet stream are a host-pair packet stream and destination network packet stream. The host-pair packet stream is defined as a set of packets having the same source and destination layer-3 addresses. The destination network packet stream is defined

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as a set of packets having the same destination network prefix. Other packet stream definitions will be discussed in a later section.

Two typical label mapping policies have been proposed. One is specified in IFMP (Ipsilon Flow Management Protocol)[2] and FANP (Flow Attribute Notification Protocol),[4] where the LSR uses the host-pair packet stream as the granularity of the packet stream definition and applies traffic-driven label mapping. Lin and Mckeown[10] have evaluated the number of required labels using actual traffic traces on the Internet, and show that a large number of labels is required on the Internet backbone. The other label mapping policy is specified in TDP (Tag Distribution Protocol),[6] where LSR uses the destination network packet stream as the granularity of the packet stream definition and applies topology-driven label mapping. With this label mapping policy, the number of required labels becomes as large as the number of routing table entries maintained by the LSR.

This paper evaluates the required number of labels under each of the above two label mapping policies using the real traffic traces on a wide area Internet backbone. The required number of labels with the traffic-driven mapping for the host-pair packet stream is quite large, and the required number of labels with the topology-driven mapping for the destination network packet stream is also large.

In order to reduce the required number of labels, we propose a label mapping policy, which is a combination of the above label mapping policies. The label is mapped to the packet stream toward a specific destination network triggered by the arrival of its traffic. The required number of labels with the proposed label mapping policy is evaluated using the real wide area Internet backbone traffic.

Section 2 describes an overview of LSR, the label mapping triggers for LSP and the granularity of the packet stream. Section 3 describes the evaluation of the required number of labels with the conventional two label mapping policies; the traffic-driven mapping with host-pair packet stream and the topology-driven mapping with destination network packet stream. Section 4 describes the evaluation of the proposed label mapping policy with various granularities of the packet stream. Section 5 presents a brief conclusion.

2. OVERVIEW OF LABEL SWITCHING ROUTER

2.1. Architectural Overview

The label switching concept enables layer-3 packets to be forwarded either using the layer-2 label (e.g., VPI/VCI) or using the shim label[9] between the layer-2 header and layer-3 header. The label is used as information to forward the packets without analyzing the layer-3 address (e.g., IP address). This means that the label represents the destination address of the layer-3 packets. By using the label instead of the layer-3 address for packet forwarding, the LSR does not need to look up anything in the best match policy based routing table, whose search key is the layer-3 address.

The packet forwarding at the LSR is shown figure 1. The LSR has a layer-3 forwarding engine and layer-2 forwarding engine. It is connected with two LSR-edge routers (Edge1 and Edge2).

LSRs are connected with two types of VC. One is the Default VC, another is the Label Switched VC.

The Default VC is used for conventional packet forwarding. For example, when Edge1 sends a packet to Edge2 using conventional packet forwarding, Edge1 sends the packet through the default VC. LSR receives it and transmits it to the layer-3 forwarding engine through the layer-2 forwarding engine. The layer-3 forwarding engine of the LSR looks up the routing table according to the destination of the packet and sends it through the default VC. Then, Edge 2 receives it. LSR forwards the packets using the layer-3 engine.

The Label Switched VC is used for cut-through packet forwarding. For example, when Edge1 sends a packet to Edge2 using the cut-through packet forwarding, Edge1 sends the packet through the label switched VC. LSR receives it and forwards it using only the layer-2 forwarding engine to send it through the Label Switched VC. LSR forwards these packets faster than with the conventional forwarding because LSR doesn't need to look up the layer-3 packet. The conjunction of the Label Switched VC is called the Label Switched Path (LSP).

A relationship between the label and the packet stream needs for LSR to forward packets using the label. Label Distributed Protocol (LDP) establishes the mapping between the label and the packet stream.

One of major applications of LSR is ATM-LSR, that contains the ATM switch module as a layer-2 forwarding engine. ATM-LSR has to allocate a reassemble buffer space for each label. Therefore, each ATM-LSR has the maximum number of labels to be able to provide for the packet stream. From the view points of the scalability and

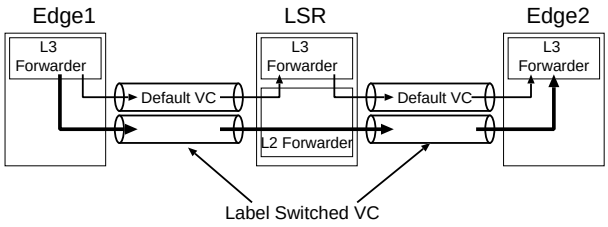

Figure 1. LSR

the implementation feasibility of LSR, it is important to evaluate the required number of labels in a label switching network. The required number of labels depends on the following two parameters.

- Label mapping triggers
- Granularity of packet stream

2.2. Label Mapping Triggers

There are two types of triggers to control the LSPs, which are traffic-driven label mapping and topology-driven label mapping.

With the traffic-driven mapping, the LSP is established on demand according to the appearance of data packets at a node. The LSP is maintained as long as packets are forwarded through the LSP. When the node recognizes that the LSP is not active any more, it is released.

With the topology-driven mapping, the LSP is established in advance according to the routing protocol information. For example, the LSP is established when a routing entry is injected to a node by the routing protocol. The LSP is maintained as long as the corresponding routing entry exists. It is released when the routing entry is deleted.

The advantage of the traffic-driven mapping is that the required amount of label space is smaller than that for the topology-driven mapping, since the LSP in the topology-driven mapping is established in advance even if a data packet isn't forwarded through it at all.

The advantage of the topology-driven mapping is that all data packets are forwarded through the LSP.

2.3. Granularity of Packet Stream

The followings definitions of the packet stream are discussed in this paper.

- set of the packets which have the same source and destination addresses. It is denoted as (src, dst).
- set of the packets which have the same source address and destination network prefix. It is denoted as (src, dstnet).
- set of the packets which have the same source and destination network prefixes. It is denoted as (srcnet, dstnet).
- set of the packets which have the same destination address. It is denoted as (*, dst).
- set of the packets which have the same destination network prefix. It is denoted as (*, dstnet).

3. EVALUATIONS OF CONVENTIONAL LABEL MAPPING POLICY

3.1. Traffic Condition for Evaluations

This subsection briefly describes the traffic conditions used for the performance evaluations in this paper.

- Traffic monitoring point
  Figure 2 shows a traffic monitoring point. A traffic monitoring host is attached to the Ethernet segment which is located between the WIDE (Widely Integrated and Distributed Environment) project internet backbone network in Japan and the U.S. The host traces and records the traffic using the tcpdump application on the host. The measurement was been performed for around two hours (7437 seconds), from 14:08 JST November 4 1997 to 16:11 JST November 4 1997. The traffic traces are recorded for each direction, separately.

- Packet forwarding rate
  Table 1 shows the average packet transfer transmission speed, in megabits per second and in packets per second, at the monitoring point for both directions. The average packet transfer rate was 1.225 Mbps and 329 pps, for the traffic incoming into the AS (WIDE project backbone network), while it was 0.926 Mbps and 564 pps for the traffic outgoing from the AS.

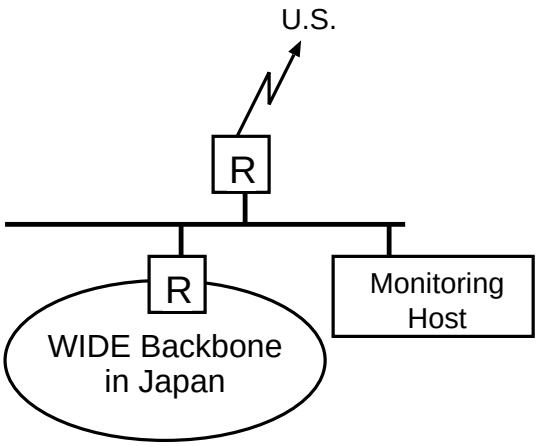

Figure 2. Traffic Monitoring Point

Direction	Transfer Rate [Mbps]	Transfer Rate [pps]
to the AS	1.225	329
from the AS	0.926	564

Table 1. Average Transfer Rate

3.2. Evaluations for Conventional Traffic-Driven Mapping

In this subsection, we evaluate the number of required labels for the conventional traffic-driven mapping, that using the host-pair packet stream. The parameters applied in the LSR are assumed as followings.

- The label-established trigger is invoked when the HTTP/FTP/TELNET/NNTP packets are sent.
- The label-released trigger is invoked when no packet is sent during the Disconnect Timer Interval. The value of the Disconnect Timer Interval is selected from 10,30,60,120,240,300 and 600 seconds.

- The delay of LDP is 100 ms. The packets are transmitted using the conventional layer-3 forwarding function for 100 ms, after the label-established trigger is invoked.

We evaluate the number of required labels and the cut-through ratio. Here, the cut-through ratio is defined as the number of packets transferred through the LSP divided by the number of all packets transferred both through label switching and through the conventional layer-3 forwarding function.

Figure 3 shows the number of the required labels and cut-through ratios for the outgoing traffic from the AS. Figure 4 shows those for the incoming traffic into the AS itself.

In both figure 3 and 4, the cut-through ratio is almost the same when the disconnect timer interval is more than 60 ms. This result indicates that the value of the disconnect timer interval should be 60 ms. Therefore, the number of required labels and the cut-through ratio, when the disconnect timer interval is 60 ms, are shown.

The number of labels with the host-pair packet stream outgoing from the AS is 1131 and the cut-through ratio is 68 %. The required number of labels incoming into the AS itself is 365 and the cut-through ratio is 61 %.

The result shows that a large number of labels is required for the conventional traffic-driven mapping with the host-pair packet stream in the Internet backbone area.

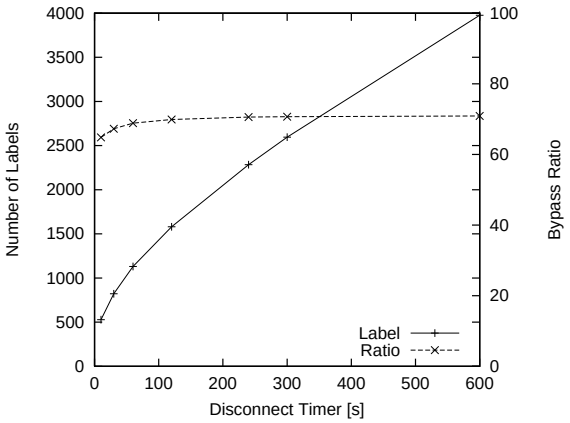

Figure 3. Number of labels and cut-through ratio directed outside of AS

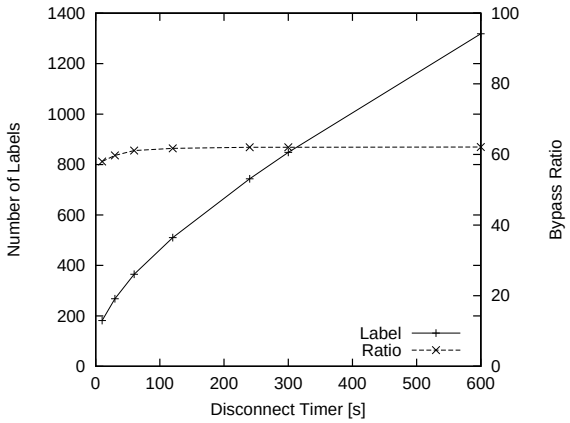

Figure 4. Number of labels and cut-through ratio directed inside of AS

4. FLOW AGGREGATED TRAFFIC-DRIVEN LABEL MAPPING POLICY

4.1. Flow Aggregated Traffic-Driven Label Mapping Policy

In a previous section, we show that the conventional label mapping policies require a large number of labels. In order to reduce the required number of labels, we propose a new label mapping policy. The label is mapped to the packet stream toward a specific destination network triggered by the actual packet arrival of its traffic. This policy is traffic-driven label mapping with the flow aggregated packet stream. In this section, the required number of labels with the proposed flow aggregated traffic-driven policy is evaluated using the real Internet backbone traces.

4.2. Evaluation of Flow Aggregated Traffic-Driven Policy

The flow aggregated traffic-driven label mapping policy is evaluated using the same Internet backbone traffic traces used in the previous section. The performance of the proposed policy is evaluated comparing with the topology-driven mapping and is evaluated with different granularities of the packet stream.

4.2.1. Evaluations with Granularity of Packet Stream

We evaluate the required number of labels and the cut-through ratio for the proposed label mapping policy with several packet stream granularities. The parameters of the traffic-driven mapping in the LSR are the same as in section 3. Five granularities of packet stream, which are (src, dst), (src, dstnet), (srcnet, dstnet), (*, dst) and (*, dstnet), are evaluated.

Figures 5 and 6 show the number of the required labels and the cut-through ratio for the outgoing traffic from the AS. Figures 7 and 8 show the number of the required labels and the cut-through ratio for the incoming traffic to the AS. The horizontal axis shows the value of the Disconnect Timer Interval. These analyses use the routing table in the AS.

As shown in figure 6 and 8, the cut-through ratios for both incoming and outgoing packets are almost the same when the disconnect timer is more than 60 ms. Therefore, the disconnect timer value should be 60 ms. The number of labels and the cut-through ratio when the disconnect timer is 60 ms are shown in tables 3 and 2.

As shown in the table 2, the number of required labels with the host-pair packet stream is 1131 for the outgoing packets from the AS. This corresponds to the case where the conventional topology-driven policy (evaluated in the previous section) is applied. In contrast, the number of required labels mapped to the same destination network (*, dstnet) granularity is only 99. It is more than 10 times less, compared with the case using the host-pair packet stream granularity. Also, the cut-through ratio increases from 68 % to 99 %.

Table 3 shows that the number of required labels with (*, dstnet) granularity, for the incoming packets to the AS, is 20 times less than that with (src, dst) granularity. Again, the cut-through ratio increases from 61%, to 95%.

Furthermore, we analyzed the number of the required labels using the full route routing table. Figures 9 and 10 show the number of the required labels and cut-through ratio for the traffic directed outside of the AS. Figures 11 and 12 show those for the traffic directed inside the AS. In the same way as when the routing table within the AS was used, the disconnect timer value is selected as 60 ms. The number of the required labels is shown in tables 5 and 4.

Table 5 shows the evaluation result for the incoming packets to the AS. The number of required labels with (src, dst) granularity, corresponding to the conventional traffic-driven policy, is 1131. in contrast, the number of required labels with (*, dstnet) granularity is 542. The number of required labels with (*, dstnet) granularity is about a half of that with (src, dst) granularity.

Table 4 shows the evaluation result for the outgoing packet flows from the AS. The number of labels for (src, dst) granularity, corresponding to the conventional traffic-driven policy, is 365. In contrast, the number of required labels with (*, dstnet) granularity is 16. The number of required labels with (*, dstnet) granularity is about 22 times less than that with (src, dst) granularity.

The results show that the traffic-driven mapping with the flow aggregation (e.g., aggregated packet flow with a destination network) significantly decreases the number of required labels, and also increases the cut-through ratio.

Granularity	Number of Labels	Cut-through Ratio
(src, dst)	1131	68
(*, dst)	859	73
(src, dstnet)	498	78
(srcnet, dstnet)	113	94
(*, dstnet)	99	99

Table 2. Number of labels and cut-through ratio directed outside of the AS

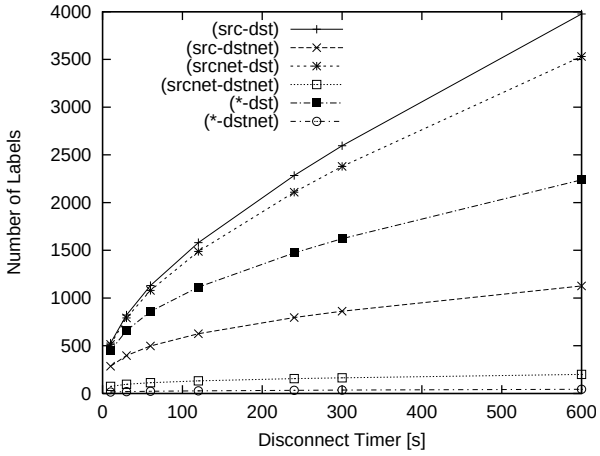

Figure 5. Number of labels directed outside of the AS

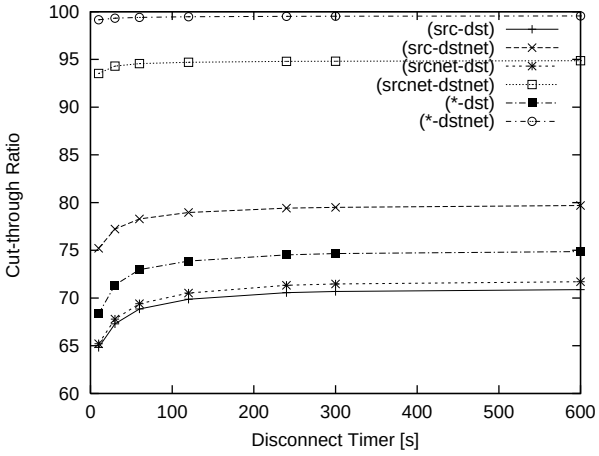

Figure 6. Cut-through ratio directed outside of the AS

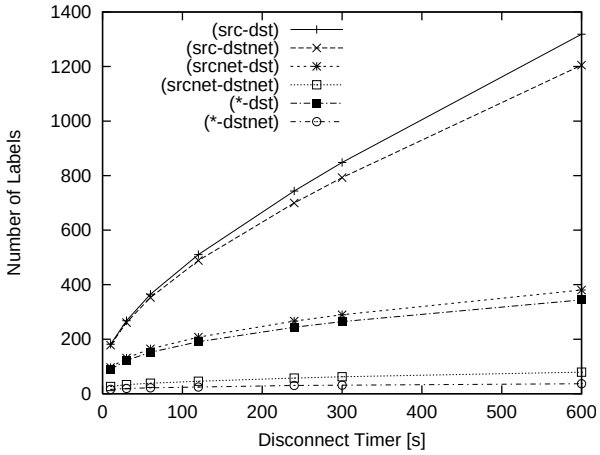

Figure 7. Number of labels directed inside of the AS

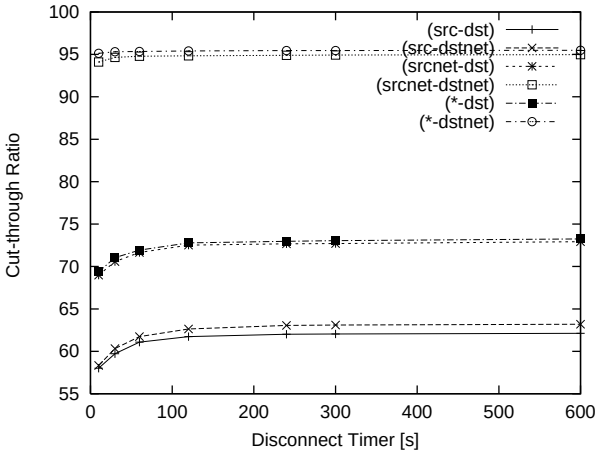

Figure 8. Cut-through ratio directed inside of the AS

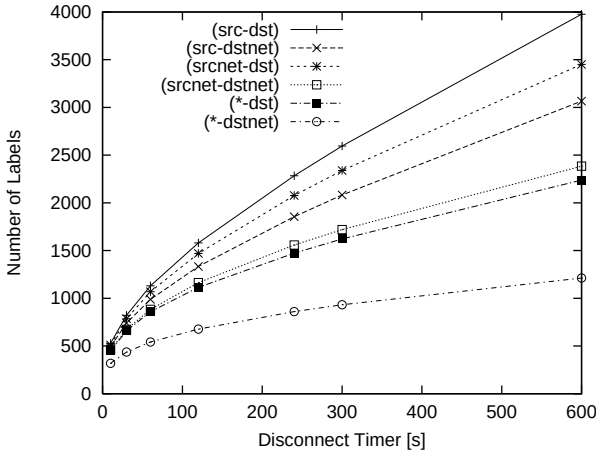

Figure 9. Number of labels directed outside of the AS using full route

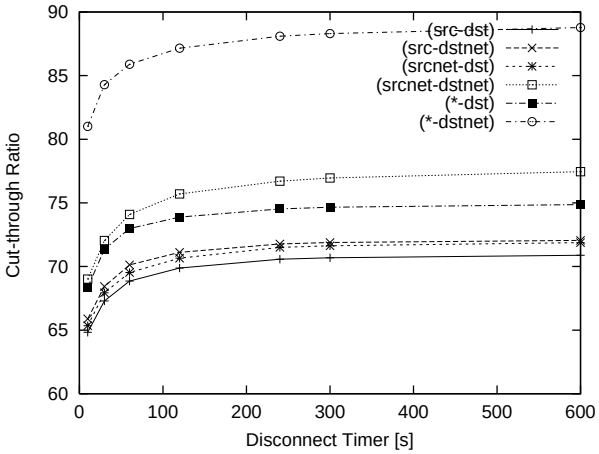

Figure 10. Cut-through ratio directed outside of the AS using full route

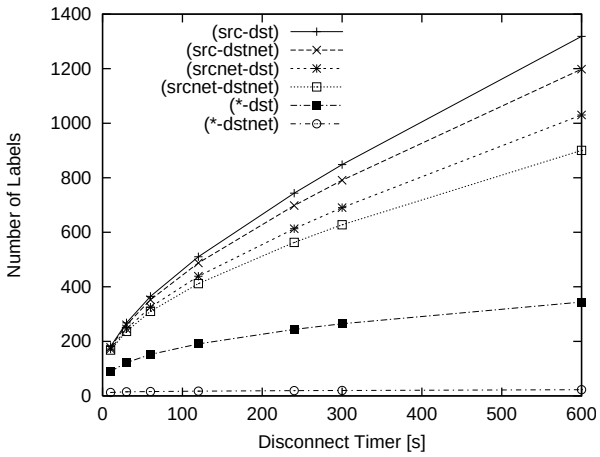

Figure 11. Number of labels directed inside of the AS using full route

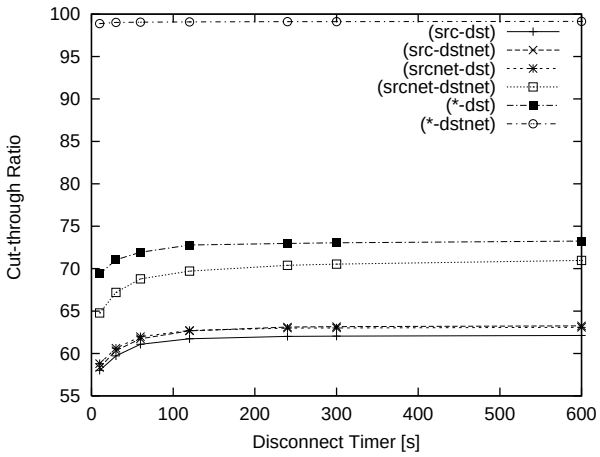

Figure 12. Cut-through ratio directed inside of the AS using full route

Granularity	Number of Labels	Cut-through Ratio
(src, dst)	365	61
(src, dstnet)	353	62
(*, dst)	152	72
(srcnet, dstnet)	38	95
(*, dstnet)	21	95

Table 3. Number of labels and cut-through ratio directed inside of the AS

Granularity	Number of Labels	Cut-through Ratio
(src, dst)	1131	68
(src, dstnet)	990	70
(*, dst)	859	73
(srcnet, dstnet)	883	74
(*, dstnet)	542	86

Table 4. Number of labels and cut-through ratio directed outside of the AS with full route

Granularity	Number of Labels	Cut-through Ratio
(src, dst)	365	61
(src, dstnet)	352	62
(srcnet, dstnet)	310	69
(*, dst)	152	72
(*, dstnet)	16	99

Table 5. Number of labels and cut-through ratio directed inside of the AS with full route

5. CONCLUSIONS

This paper evaluates the number of required labels and the cut-through ratio in the LSR, using actual Internet backbone traffic traces. The number of required labels depends on the label mapping triggers and on the granularity of packet streams. With the conventional label mapping policy, which is traffic-driven mapping with the host-pair packet stream, the required number of labels becomes quite large.

This paper proposes and evaluates a label mapping policy (i.e., flow aggregated traffic-driven policy) to reduce the required number of labels and to increase the cut-through ratio. The proposed policy uses label mapping with the aggregated packet stream toward a specific destination network, triggered by the actual packet arrival of its traffic. By the evaluations using the actual Internet backbone traffic traces, it is shown that the proposed label mapping policy will work well. For example, the required number of labels with the proposed label mapping policy is reduced to only one tenth of that with conventional policy; that is, 1131 labels with conventional policy is reduced to only 99 labels with the proposed policy. Also, the proposed policy increases the cut-through ratio from 68 % to 99 %.

These evaluation results indicate that, for LSRs in the internet backbone area, the proposed flow aggregated traffic-driven label mapping policy will be practically useful. The future work should include the evaluation of the required number of labels using other traffic traces and other flow aggregation policies.

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