Efficient label distribution mechanism for bidirectional paths in MPLS-TP networks

Zongpeng Du (杜宗鹏), Yueming Lu (陆月明), and Yuefeng Ji (纪越峰)*

Key Laboratory of Information Photonics and Optical Communications, Ministry of Education,
Beijing University of Posts and Telecommunications, Beijing 100876, China

**Corresponding author: jyf@bupt.edu.cn*

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Transport network paths are typically bidirectional and symmetrical. In multi-protocol label switching (MPLS) and generalized MPLS (GMPLS) mechanisms, independent labels are distributed for bidirectional paths. Thus, the requirement of the MPLS transport profile (MPLS-TP), which is a new transport technology, could not be satisfied efficiently. A novel label distribution mechanism for bidirectional paths in MPLS-TP networks is proposed. Labels distributed by the mechanism are symmetrical and can reflect the pairing relationship of the forward and backward directions of the transport path.

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With the increase of internet protocol (IP) based network services, such as voice over IP (VoIP) and IP television (IPTV), transport technology is moving from time-division multiplex schemes to packet transport network (PTN). One of the promising solutions for PTN is multi-protocol label switching transport profile (MPLS-TP)[1,2].

Over the past two decades, historical optical transport infrastructures, i.e., synchronous optical network/synchronous digital hierarchy (SONET/SDH) and optical transport network (OTN), have provided carriers with a high benchmark for reliability and operational simplicity[3,4]. To achieve this, MPLS-TP defines additional requirements and functions based on MPLS. One requirement is for the nodes on a bidirectional path in MPLS-TP networks to be aware of the pairing relationship of the forward and backward directions of the path so that they can be used as end points to protect all or part of that path[3].

Existing bidirectional path setup mechanisms in MPLS and generalized MPLS (GMPLS)[5−7] cannot satisfy this requirement efficiently. Labels distributed in these two mechanisms are independent and cannot reflect the pairing relationship of the forward and backward directions of the transport path. As a result, additional memory is needed in the nodes along the transport path to record the pairing relationship.

This letter proposes a symmetrical label distribution mechanism based on the bidirectional path setup scheme in GMPLS, which has been widely studied[8−10]. The symmetrical labels in the proposed mechanism indicate identical labels for both directions. This mechanism needs no additional memory because labels for the forward and backward directions of a bidirectional path are symmetrical.

A method, particularly for MPLS-TP networks, is proposed in this letter. Both associated bidirectional point-to-point paths and co-routed bidirectional point-to-point paths are supported in MPLS-TP, and the proposed method is applied to the latter. Simulations demonstrate that the proposed mechanism is an efficient way to establish bidirectional paths in MPLS-TP networks.

The standard protocol for managing MPLS-TP paths is RSVP-TE, an extension of the resource reservation protocol (RSVP) for traffic engineering[5]. The three mechanisms introduced in the current study are all based on this scheme.

RSVP is originally a protocol for establishing quality of service (QoS) enabled connections through the use of Path and Resv messages. The messages are extended in RSVP-TE so that they can piggyback label distribution information.

Paths in transport networks often need to be bidirectional. In MPLS, this is done by setting up two unidirectional label switched paths (LSPs). Also available in MPLS-TP, this process is called the MPLS mechanism in the current study.

However, this mechanism is not efficient for bidirectional paths. It requires two signaling processes and cannot ensure that both LSPs are routed along the same route. In addition, the higher layers are required to coordinate on the virtual binding of the two LSPs.

The two signaling processes are shown in Fig. 1(a). There are four label switching routers (LSRs) in the transport path. LSRs 1 and 4 are the initiator and the terminator, respectively.

In the first signaling process, the label carried in the Resv message is stored in the label information base (LIB) of a LSR as the outgoing label for the downstream LSP. Subsequently, similar operations take place in the second signaling process. Finally, the two LSPs form a bidirectional path.

GMPLS is the control protocol for MPLS-TP[11]. It extends MPLS and supports multiple types of switching, such as lambda and fiber switching[6,12]. The process of label request is also changed in GMPLS. An upstream label (ULabel) is introduced for the bidirectional LSP setup mechanism in GMPLS signaling[6,7].

Figure 1(b) shows the process of the GMPLS mechanism. The ULabels carried in the Path messages in step 1 are used as the outgoing labels for the upstream path. The downstream path is set up by the same procedure

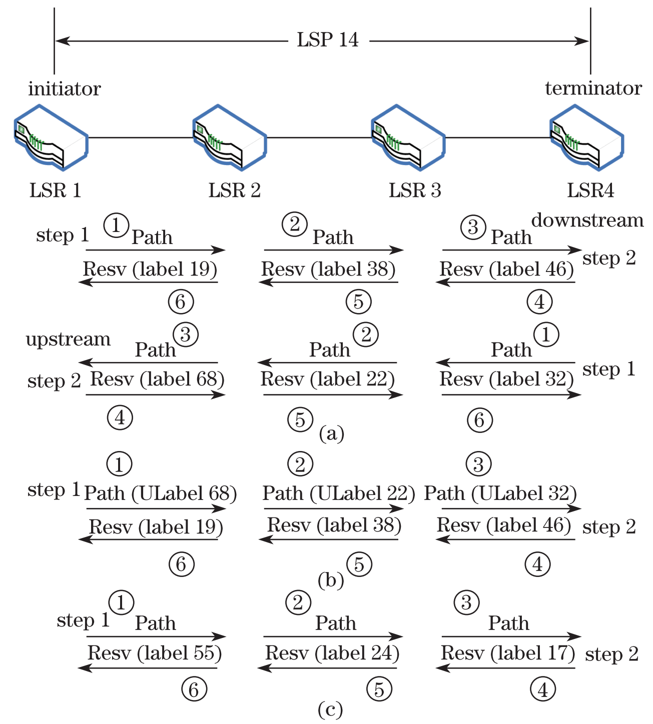

Fig. 1. (a) MPLS bidirectional path establishing process, with two unidirectional paths established independently; (b) GMPLS bidirectional path establishing process; (c) symmetrical bidirectional path establishing process.

as the MPLS mechanism.

The downstream and upstream paths are built together using a single set of signaling messages in this mechanism. The mechanism reduces the setup latency to one initiator–terminator round-trip time and limits the control overhead to the same number of messages as a unidirectional LSP[6].

MPLS is further extended to MPLS-TP, which is a technology for transport networks. This standard fulfills a large number of traditional transport network requirements and will be a success similar to IP/MPLS[13].

The proposed mechanism needs only one round-trip time, as shown in Fig. 1(c), similar to that of the GMPLS mechanism. The difference is that the ULabel is not needed in the proposed mechanism because labels from the downstream nodes can be used for the LSPs of both directions.

Figure 1(c) shows that the Path message does not need to carry label information. The label carried in the Resv message is stored in the LIB of a LSR as the outgoing label for the downstream path and, at the same time, the incoming label for the upstream path. If the label carried in Resv message is accepted when it reaches the initiator node, the establishment of the bidirectional path is complete. The result is shown in Fig. 2(b).

The forward and backward labels distributed by traditional mechanisms are independent, as shown in Fig. 2(a). In comparison, the labels distributed by the new mechanism are symmetrical, as shown in Fig. 2(b).

Nevertheless, the new mechanism also brings up a problem. If the label provided by the downstream node is already occupied in the upstream node, there will be a label distribution conflict. Fortunately, the problem can be solved by existing schemes.

If there is a label distribution conflict in an upstream node, the node will generate a PathErr notification message with an "unacceptable label value" indication for the downstream node. The downstream node is required to resend another label chosen at random from the available label space[6]. This loop will continue until the upstream node receives an acceptable label. The maximum admissible loop time can be restricted to avoid an infinite loop. Moreover, an acceptable label set object[6] can be included in the PathErr message to indicate which labels are acceptable. It is useful for the node to receive an acceptable label.

Label distribution conflict rarely occurs, unless the number of labels is quite limited. MPLS and MPLS-TP have a very large number of available labels (approximately 2^{20}). Therefore, the probability of label distribution conflict is very low in a certain network layer if every label is chosen at random from its label space.

We use the topology in Fig. 3 to further explain the adopted scheme, in which nodes 1–7 are configured to be MPLS-TP nodes. It is assumed that there are two bidirectional paths in the topology. One is the path between nodes 0 and 8, while the other is the path between nodes

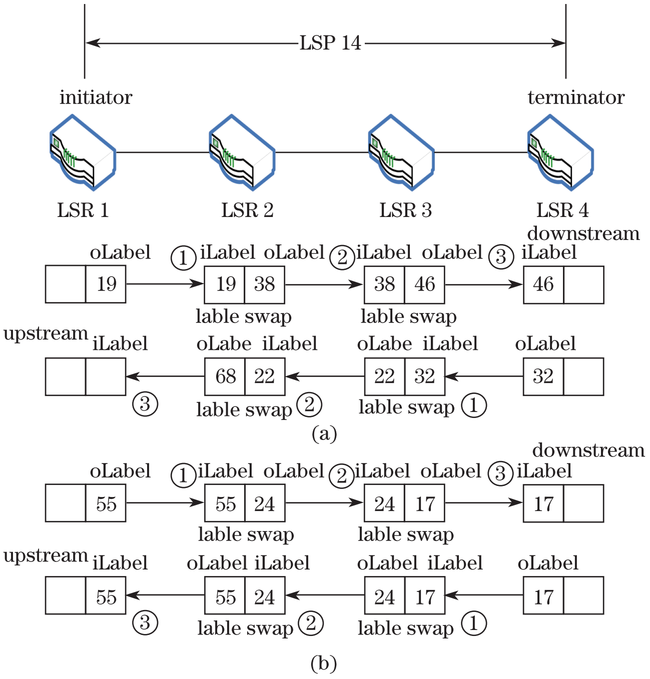

Fig. 2. (a) Label swaps of MPLS and GMPLS; (b) label swaps of symmetrical label distribution mechanism. iLabel=incoming label; oLabel=outgoing label.

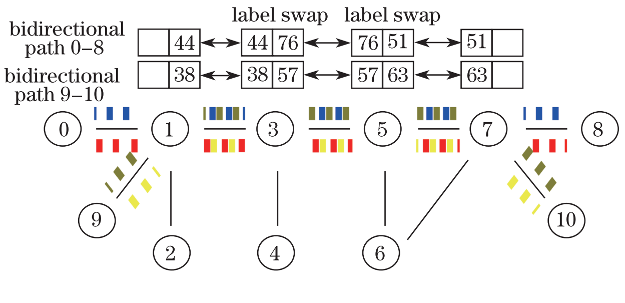

Fig. 3. Example of a simple symmetrical label distribution.

9 and 10.

The detailed label distribution results for the topology are shown in Table 1. For example, the labels for the forward direction of the path between nodes 0 and 8 are 44, 76, 51, and 0.

Table 1 shows that the labels distributed by the proposed mechanism in LSRs 3 and 5 are symmetrical. It is easy to find the pairing relationship of the forward and backward directions of a bidirectional path from the labels.

In the current study, we verify whether or not the mechanism is available in practice by computer simulations based on network simulator version 2 (NS2)[14]. We implement the proposed method by extending the codes about MPLS in NS2, which is an event-driven network simulator; the trace file produced in the simulation can be used to analyze the simulation time of each event.

We use the topology of the NSF network with 14 nodes and 21 edges to perform the simulation for performance evaluation. The connections in the simulation are added one by one in the configure process, and all the paths are established concurrently after that. The final connection setup time recorded by the time stamps in NS2 is mainly decided by the longest one in the paths. Therefore, a step for a low number of established paths can be seen in Fig. 4 because the paths selected in the first few simulations may not include the longest path in the topology.

In the simulation of the proposed method with a large label space, no label distribution conflict is found, as expected. Therefore, the time taken by the symmetrical mechanism in Fig. 4 is the same as that of the GMPLS mechanism, whereas the MPLS mechanism needs more time to establish the paths.

Figure 5 shows the number of label information messages that are piggybacked by the Path or Resv messages of RSVP-TE in the three label distribution mechanisms.

Table 1. Label Information of the Symmetrical Mechanism

LSR	Destination	iIface	iLabel	oIface	oLabel
1	0	3	44	0	0
	8	−1	−1	3	44
	9	3	38	9	0
	10	−1	−1	3	38
3	0	5	76	1	44
	8	1	44	5	76
	9	5	57	1	38
	10	1	38	5	57
5	0	7	51	3	76
	8	3	76	7	51
	9	7	63	3	57
	10	3	57	7	63
7	0	−1	−1	5	51
	8	5	51	8	0
	9	−1	−1	5	63
	10	5	63	10	0

iIface=incoming interface; oIface=outgoing interface

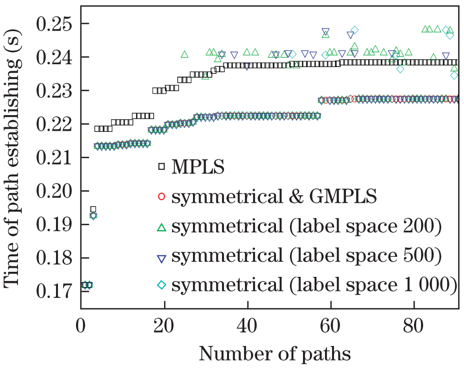

Fig. 4. Time taken for the path establishing of the three label distribution mechanisms.

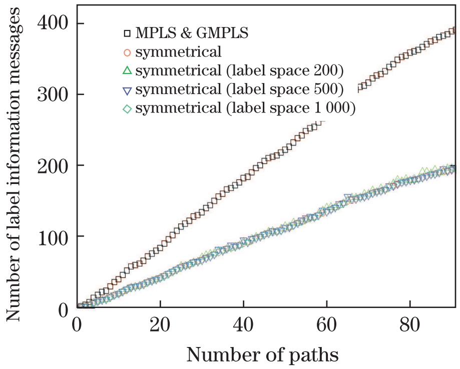

Fig. 5. Number of label information messages piggybacked by the RSVP-TE of the three label distribution mechanisms.

The traditional mechanisms need twice as many messages compared to the symmetrical mechanism.

Some simulations with limited label spaces are performed to further explore the performance of the proposed method in more realistic scenarios. The label spaces are limited to 200, 500, and 1 000, respectively. Expectedly, some conflicts occur. In the simulations, we simply add a suggested label[6] in the PathErr message to resolve these conflicts.

Figure 4 shows that the conflicts are more likely to happen when the label spaces become more limited. Although the maximum times of path establishing with limited label spaces are higher than that of the MPLS scheme, the average times of the formers are less than that of the later. Figure 5 shows that there are few differences in the simulations with limited label spaces due to the small number of conflicts.

Although GMPLS, as a control plane for MPLS-TP, has done a great job, the proposed method can enhance the performance of the solution to the label pairs. Additionally, the simulations demonstrate that the symmetrical mechanism can efficiently establish bidirectional paths in MPLS-TP networks.

In conclusion, PTN is generally regarded as a connection-oriented transport network technology, in which paths are typically symmetrical. However, MPLS is not designed as a connection-oriented technology, and MPLS-TP needs to define additional functions for transport networks. We propose an efficient mechanism for establishing co-routed bidirectional point-to-point paths in MPLS-TP networks. In this mechanism, the nodes along a bidirectional path can be used as the end points for path protection without the need to record the pairing relationship of the forward and backward directions of that path. In addition, the compression of LIBs becomes possible because of the existence of symmetrical elements.

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