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SR-TE Path Midpoint Protection
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Abstract

Segment Routing Traffic Engineering (SR-TE) supports the creation of explicit paths using segment lists containing adjacency-SIDs, node-SIDs, anycast-SIDs, and binding-SIDs. When the segment list defining an SR-TE path contains a node-SID, and the node fails, the network may no longer be able to properly forward traffic on that SR-TE path. [[I-D.bashandy-rtgwg-segment-routing-ti-lfa](#)] and [[I-D.hegde-spring-node-protection-for-sr-te-paths](#)] describe a mechanism that allows local repair actions on the direct neighbors of the failed node to temporarily route traffic to the node immediately following the failed node on the SR-TE path segment list. However, once the IGP shortest paths have converged, the local repair mechanism is no longer sufficient to continue forwarding traffic using the original segment list of the SR-TE path, since the non-neighbors of the failed node will no longer have a route to reach the failed node. This document describes a mechanism that allows traffic to continue to be forwarded on an SR-TE path for an extended period of time after the failure of a node used in the path's segment list.

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC 2119](#) [[RFC2119](#)].

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1. Introduction

Segment Routing Traffic Engineering (SR-TE) is a technology that implements traffic engineering using Segment Routing. SR-TE supports the creation of explicit paths using adjacency-SIDs, node-SIDs, anycast-SIDs, and binding-SIDs. A node-SID in the segment list defining an SR-TE path indicates a loose hop that the SR-TE path should pass through. When a particular node fails, it would be useful to be able to continue to send traffic on an SR-TE path that uses the node-SID of the failed node for an extended period of time, without having to immediately modify the segment list used at the ingress to the SR-TE path.

The first step to achieve this objective is to make the rest of the routers in the network continue to forward traffic using the node-SID of the failed node. If we don't do anything special, once the IGP converges to take into account the failed node, a given router will no longer maintain a route corresponding to the node-SID. Any traffic that arrives at the router with the node-SID of the failed node as the active segment will be dropped. This document addresses this problem by having each neighbor of the failed node advertise its SR proxy forwarding capability. This indicates that the neighbor (the Proxy Forwarder) will forward traffic on behalf of the failed node. A router receiving the SR Proxy Forwarding capability from neighbors of a failed node will send traffic using the node-SID of the failed node to the nearest Proxy Forwarder.

Once the affected traffic reaches a Proxy Forwarder, the Proxy Forwarder sends the traffic on the post-failure shortest path to the node immediately following the failed node in the segment list. [[I-D.bashandy-rtgwg-segment-routing-ti-lfa](#)] and [[I-D.hegde-spring-node-protection-for-sr-te-paths](#)] describe how the immediate neighbors of a failed node can accomplish this by forwarding based on the first two segments in the segment list. The forwarding described in these drafts was originally intended to be used for only a short period of time, to provide fast-reroute protection until the IGP converges. The current document proposes to extend this behavior on the Proxy Forwarder until well after the IGP has converged.

If the faulty node is a label adhesion node, the Binding-SIDs cannot be exchanged to the label stack for its identity, and the traffic will be lost before it reaches the faulty node.

In this document, the proxy mechanism is provided in the neighbor node of the faulty node of the forwarding path to implement traffic forwarding after the node with the label adhesion fails on the SR-TE loose path.

2. Extensions to IGP for Proxy Forwarding

When a node has segment routing proxy forwarding capability, it advertises this capability. The capability indicates that the node has the ability to do proxy forwarding for the global SID of each of its neighbors. When an neighbor in a SR-TE path fails, the traffic can be forwarded to the proxy node, which fast re-routes the traffic to the node immediately following the failed node on the SR-TE path.

2.1. Extensions to OSPF

2.1.1. Advertising Proxy Forwarding

When a node P has the capability to do a SR proxy forwarding for all its neighboring nodes for protecting the failures of these nodes, node P advertises its SR proxy forwarding capability in its router information opaque LSA, which contains a Router Functional Capabilities TLV of the format as shown in Figure 1.

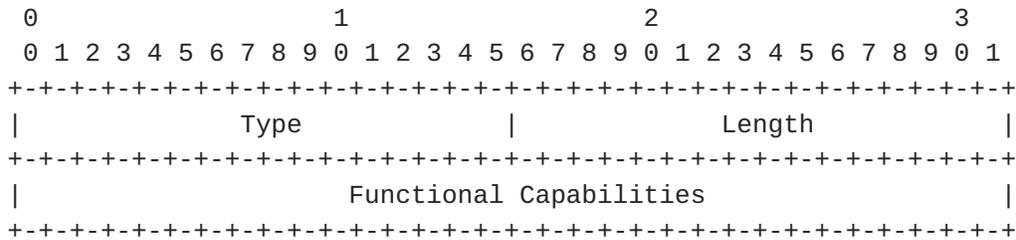


Figure 1: Router Functional Capabilities TLV

One bit (called PF bit) in the Functional Capabilities field of the TLV is used to indicate node P's SR proxy forwarding capability. When this bit is set to one by node P, it indicates that node P is capable of doing a SR proxy forwarding for its neighboring nodes.

For a node X in the network, it learns the prefix/node SID of node N, which is originated and advertised by node N. It creates a proxy prefix/node SID of node N for node P if node P is capable of doing SR proxy forwarding for node N. The proxy prefix/node SID of node N for

node P is a copy of the prefix/node SID of node N originated by node N, but stored under (or say, associated with) node P.

In normal operations, node X prefers to use the prefix/node SID of node N. When node N fails, node X prefers to use the proxy prefix/node SID of node N. Thus node X will forward the traffic targeting to node N to node P when node N fails, and node P will do a SR proxy forwarding for node N and forwarding the traffic to its destination without going through node N. After node N fails, node X will keep the proxy prefix/node SID of node N for a given period of time.

If node P can not do a SR proxy forwarding for all its neighboring nodes, but for some of them, then it advertises the node SID of each of the nodes as a proxy node SID, indicating that it is able to do proxy forwarding for the node SID.

A new TLV, called Proxy Node SIDs TLV, is defined for node P to advertise the node SIDs of some of its neighboring nodes. It has the format as shown in Figure 2.

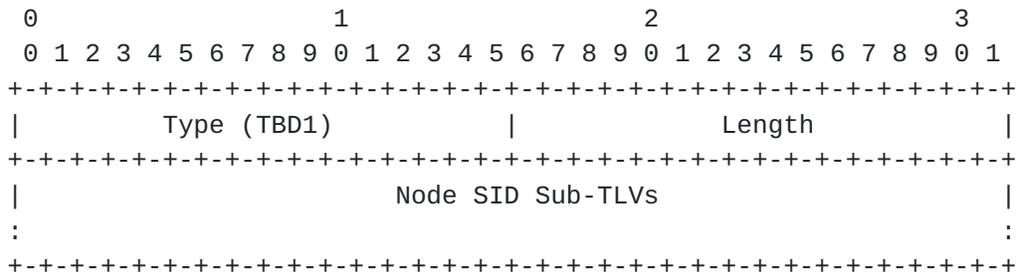


Figure 2: OSPF Proxy Node SIDs TLV

The Type (TBD1) is to be assigned by IANA. The TLV contains a number of Node SID Sub-TLVs. The Length is the total size of the Node SID Sub-TLVs included in the TLV. A Node SID Sub-TLV is the Prefix SID Sub-TLV defined in [[I-D.ietf-ospf-segment-routing-extensions](#)].

A proxy forwarding node P originates an Extended Prefix Opaque LSA containing this new TLV. The TLV includes the Node SID Sub-TLVs for the node SIDs of some of P's neighboring nodes. For each of some of P's neighboring nodes, the Node SID Sub-TLV for its prefix/node SID is included the TLV. This prefix/node SID is called a proxy prefix/node SID.

A proxy forwarding node will originate an Extended Prefix Opaque LSA, which includes a Proxy Node SIDs TLV. The format of the LSA is shown in Figure 3.

For a proxy forwarding node P, having a number of neighboring nodes, P originates and maintains an Extended Prefix Opaque LSA, which includes a Proxy Node SIDs TLV. The TLV contains the Prefix/Node SID Sub-TLV for each of some of the neighboring nodes after node P creates the corresponding proxy forwarding entries for protecting the failure of some of the neighboring nodes.

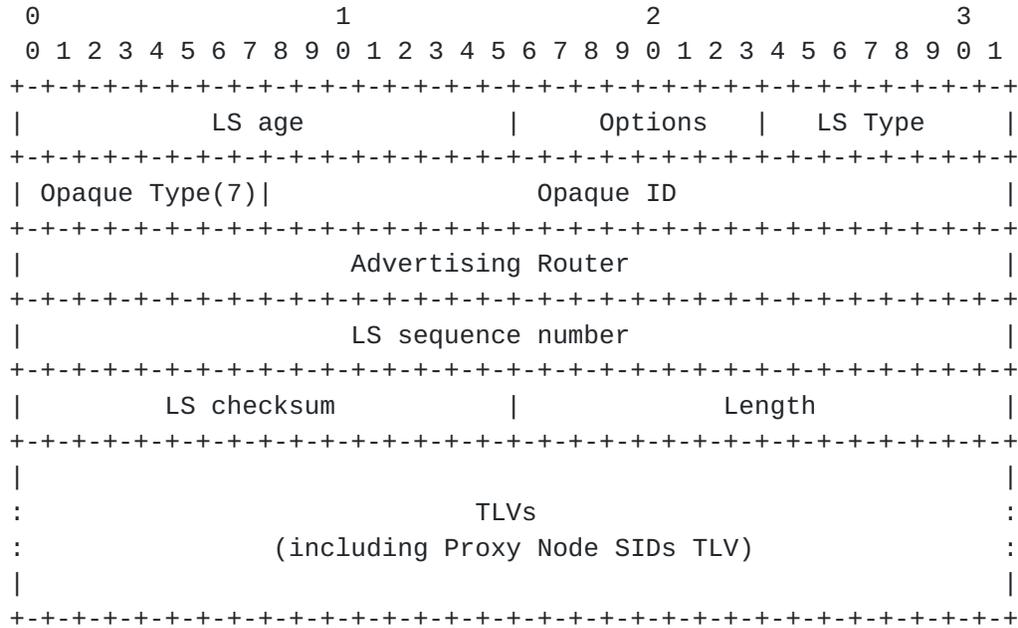


Figure 3: OSPFv2 Extended Prefix Opaque LSA

When an neighboring node fails, P maintains the LSA with the TLV containing the Prefix/Node SID Sub-TLV for the neighboring node for a given period of time. After the given period of time, the Prefix/Node SID Sub-TLV for the neighboring node is removed from the TLV in the LSA and then after a given time the corresponding proxy forwarding entries for protecting the failure of the neighboring node is removed.

For a node X in the network, it learns the prefix/node SID of node N and the proxy prefix/node SID of node N. The former is originated and advertised by node N, and the latter is originated and advertised by the proxy forwarding node P of node N. Note that the proxy Prefix/Node SID Sub-TLV for node N does not contain a prefix of node N, and the prefix is the prefix associated with the prefix/node SID of node N originated by node N.

In normal operations, node X prefers to use the prefix/node SID of node N. When node N fails, node X prefers to use the proxy prefix/node SID of node N. Thus node X will forward the traffic targeting to node N to node P when node N fails, and node P will do a proxy

forwarding for node N and forwarding the traffic to its destination without going through node N.

2.1.2. Advertising Binding Segment

For a binding segment (or binding for short) on a node A, which consists of a binding SID and a list of segments, node A advertises an LSA containing the binding (i.e., the binding SID and the list of the segments). The LSA is advertised only to each of the node A's neighboring nodes. For OSPFv2, the LSA is a opaque LSA of LS type 9 (i.e., a link local scope LSA).

A binding segment is represented by binding segment TLV of the format as shown in Figure 4.

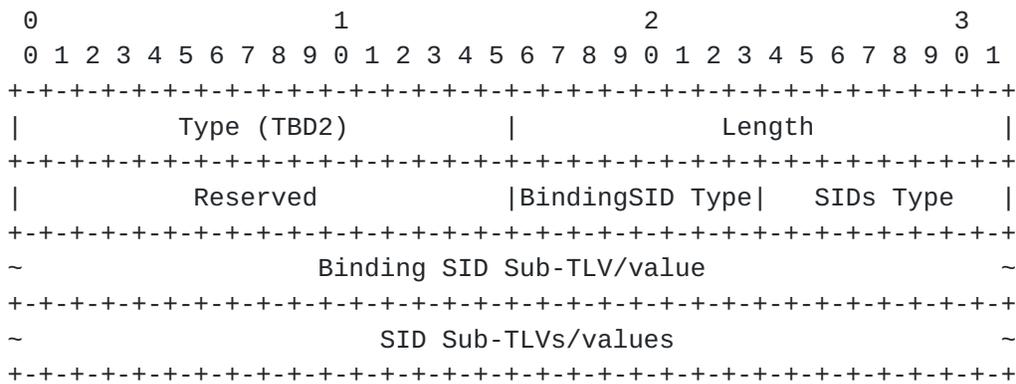


Figure 4: OSPF Binding Segment TLV

It comprises a binding SID and a list of segments (SIDs). The fields of this TLV are defined as follows:

- Type: 2 octets, its value (TBD2) is to be assigned by IANA.
- Length: 2 octets, its value is (4 + length of Sub-TLVs/values).
- Binding SID Type (BT): 1 octet indicates whether the binding SID is represented by a Sub-TLV or a value included in the TLV. For the binding SID represented by a value, it indicates the type of binding SID. The following BT values are defined:
 - o BT = 0: The binding SID is represented by a Sub-TLV (i.e., Binding SID Sub-TLV) in the TLV. A binding SID Sub-TLV is a SID/Label Sub-TLV defined in [\[I-D.ietf-ospf-segment-routing-extensions\]](#). BT != 0 indicates that the binding SID is represented by a value.
 - o BT = 1: The binding SID value is a label, which is represented by the 20 rightmost bits. The length of the value is 3 octets.

o BT = 2: The binding SID value is a 32-bit SID. The length of the value is 4 octets.

SIDs Type (ST): 1 octet indicates whether the list of segments (SIDs) are represented by Sub-TLVs or values included in the TLV. For the SIDs represented by values, it indicates the type of SIDs. The following ST values are defined:

o ST = 0: The SIDs are represented by Sub-TLVs (i.e., SID Sub-TLVs) in the TLV. A SID Sub-TLV is an Adj-SID Sub-TLV, a Prefix-SID Sub-TLV or a SID/Label Sub-TLV defined in [\[I-D.ietf-ospf-segment-routing-extensions\]](#). ST != 0 indicates that the SIDs are represented by values.

o ST = 1: Each of the SID values is a label, which is represented by the 20 rightmost bits. The length of the value is 3 octets.

o ST = 2: Each of the SID values is a 32-bit SID. The length of the value is 4 octets.

The opaque LSA of LS Type 9 containing the binding segment (i.e., the binding SID and the list of the segments) has the format as shown in Figure 5. It may have Opaque Type of x (the exact type is to be assigned by IANA) for Binding Segment Opaque LSA.

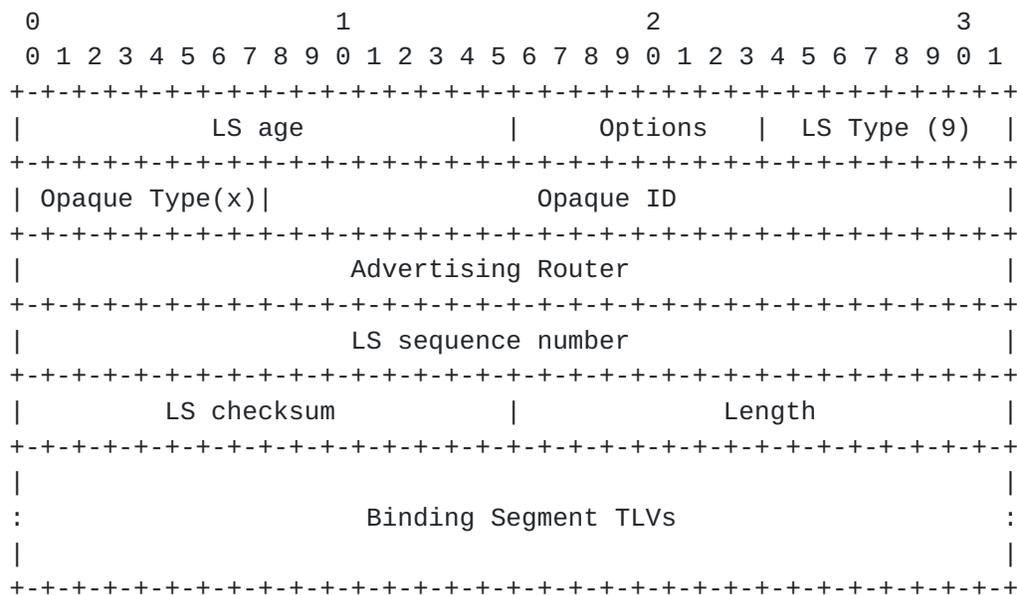


Figure 5: OSPFv2 Binding Segment Opaque LSA

For every binding on a node A, the LSA originated by A contains a binding segment TLV for it.

For node A running OSPFv3, it originates a link-local scoping LSA of a new LSA function code (TBD3) containing binding segment TLVs for the bindings on it. The format of the LSA is illustrated in Figure 6.

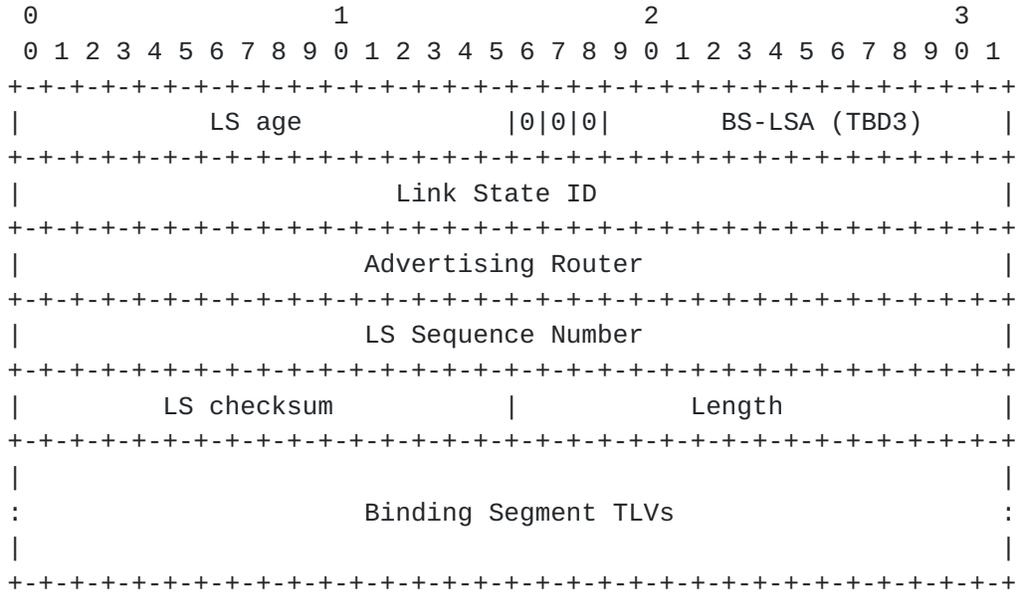


Figure 6: OSPFv3 Binding Segment Opaque LSA

The U-bit is set to 0, and the scope is set to 00 for link-local scoping.

2.2. Extensions to IS-IS

2.2.1. Advertising Proxy Forwarding

When a node P has the capability to do a SR proxy forwarding for its neighboring nodes for protecting the failures of them, node P advertises its SR proxy forwarding capability in its LSP, which contains a Router Capability TLV of Type 242 including a SR capabilities sub-TLV of sub-Type 2.

One bit (called PF bit as shown in Figure 7) in the Flags field of the SR capabilities sub-TLV is defined to indicate node P's SR proxy forwarding capability. When this bit is set to one by node P, it indicates that node P is capable of doing a SR proxy forwarding for its neighboring nodes.

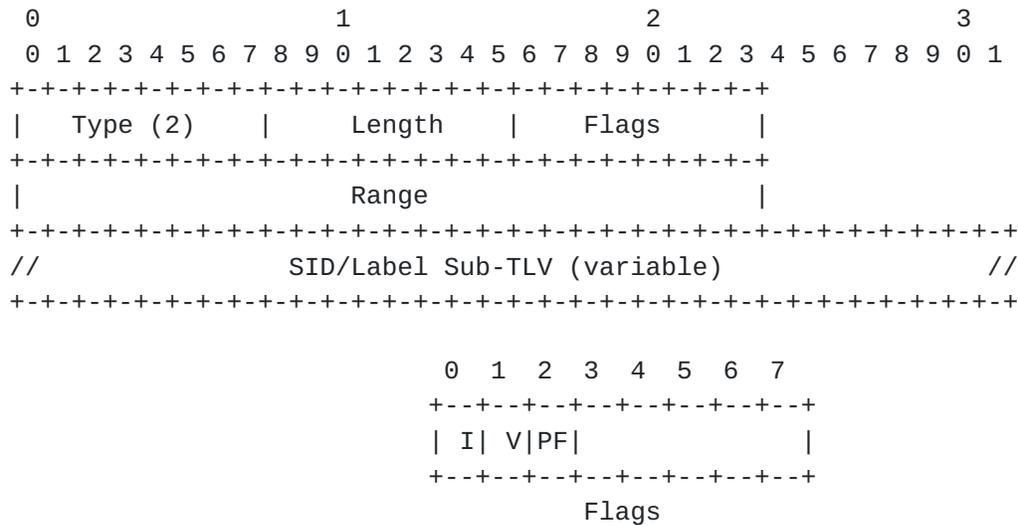


Figure 7: SR Capabilities sub-TLV

If node P can not do a SR proxy forwarding for all its neighboring nodes, but for some of them, then it advertises the node SID of each of the nodes as a proxy node SID, indicating that it is able to do proxy forwarding for the node SID.

The IS-IS SID/Label Binding TLV (suggested value 149) is defined in [[I-D.ietf-isis-segment-routing-extensions](#)]. A Proxy Forwarder uses the SID/Label Binding TLV to advertise the node SID of its neighboring node. The Flags field of the SID/Label Binding TLV is extended to include a P flag as shown in Figure 8. The prefix/node SID in prefix/node SID Sub-TLV included in SID/Label Binding TLV is identified as a proxy forwarding prefix/node SID.

advertised in IS-IS Hello (IIH) PDUs, LSPs, or in Circuit Scoped Link State PDUs (CS-LSP) [[RFC7356](#)]. Its format is shown in Figure 9.

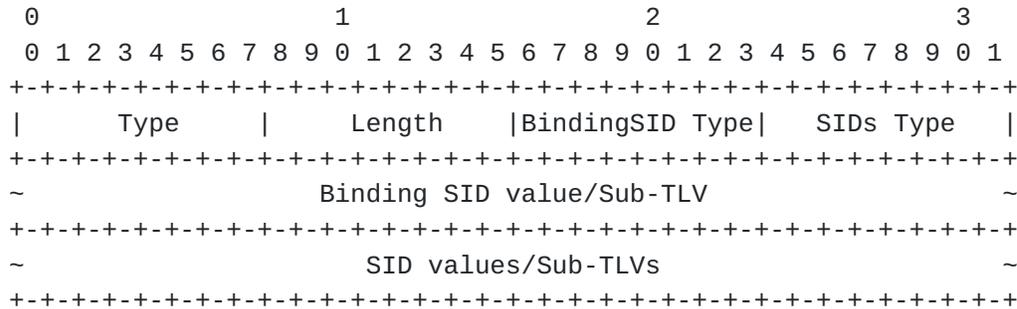


Figure 9: IS-IS Binding Segment TLV

The fields of this TLV are defined as follows:

Type: 1 octet Suggested value 152 (to be assigned by IANA)

Length: 1 octet (2 + length of Sub-TLVs/values).

Binding SID Type (BT): 1 octet indicates whether the binding SID is represented by a Sub-TLV or a value included in the TLV. For the binding SID represented by a value, it indicates the type of binding SID. The following BT values are defined:

- o BT = 0: The binding SID is represented by a Sub-TLV (i.e., binding SID Sub-TLV) in the TLV. A binding SID Sub-TLV is a SID/Label Sub-TLV defined in [[I-D.ietf-isis-segment-routing-extensions](#)]. BT != 0 indicates that the binding SID is represented by a value.
- o BT = 1: The binding SID value is a label, which is represented by the 20 rightmost bits. The length of the value is 3 octets.
- o BT = 2: The binding SID value is a 32-bit SID. The length of the value is 4 octets.

SIDs Type (ST): 1 octet indicates whether the SIDs are represented by Sub-TLVs or values included in the TLV. For the SIDs represented by values, it indicates the type of SIDs. The following ST values are defined:

- o ST = 0: The SIDs are represented by Sub-TLVs (i.e., SID Sub-TLVs) in the TLV. A SID Sub-TLV is an Adj-SID Sub-TLV, a Prefix-SID Sub-TLV or a SID/Label Sub-TLV defined in [[I-D.ietf-isis-segment-routing-extensions](#)]. ST != 0 indicates that the SIDs are represented by values.

- o ST = 1: Each of the SID values is a label, which is represented by the 20 rightmost bits. The length of the value is 3 octets.
- o ST = 2: Each of the SID values is a 32-bit SID. The length of the value is 4 octets.

3. Building Proxy Forwarding Table

Figure 10 is used to illustrate the SR proxy forwarding approach. Each node N has SRGB = [N000-N999]. RT1 is an ingress node of SR domain. RT3 is a failure node. RT2 is a Point of Local Repair (PLR) node, i.e., a proxy forwarding node. Three label stacks are shown in the figure. Label Stack 1 uses only adjacency-SIDs and represents the path RT1->RT2->RT3->RT4->RT5. Label Stack 2 uses only node-SIDs and represents the ECMP-aware path RT1->RT3->RT4->RT5. Label Stack 3 uses a node-SID and a binding SID. The Binding-SID with label=100 at RT3 represents the ECMP-aware path RT3->RT4->RT5. So Label Stack 3, which consists of the node-SID for RT3 following by Binding-SID=100, represents the ECMP-aware path RT1->RT3->RT4->RT5.

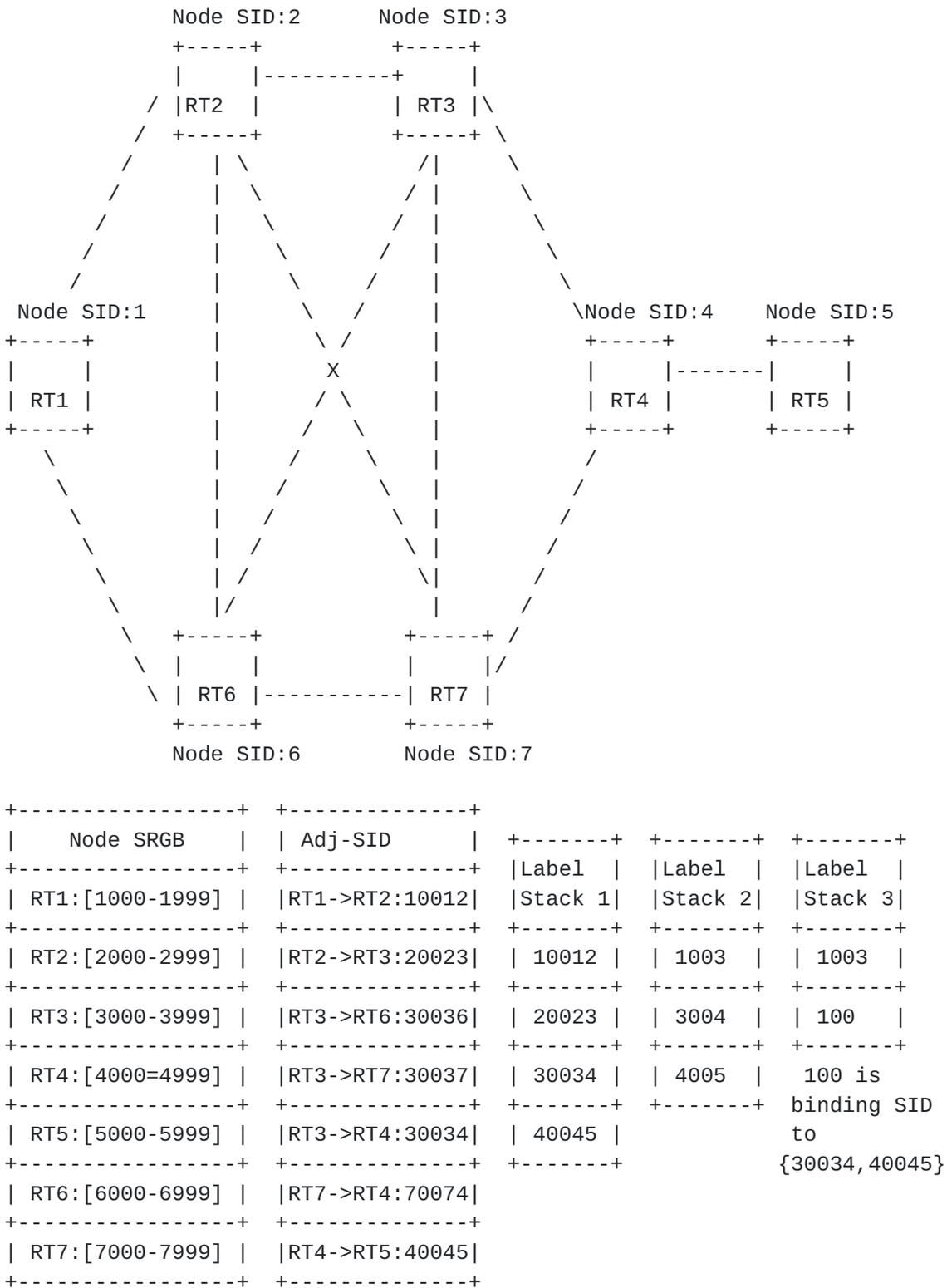


Figure 10: Topology of SR-TE Path

3.1. Advertising Proxy Forwarding

If the Point of Local Repair (PLR), for example, RT2, has the capability to do a SR proxy forwarding for all its neighboring nodes, it must advertise this capability. If the PLR can not do a SR proxy forwarding for all its neighboring nodes, but for some of them, for example, RT3, then it uses proxy Node SIDs TLV to advertise the prefix-SID learned from RT3. The TLV contains the Sub-TLV/value for the prefix/node SID of RT3 as a proxy SID. When RT3 fails, RT2 needs to maintain the Sub-TLV/value for a period of time. When the proxy forwarding table corresponding to the fault node is deleted (see [section 3.2](#)), the Sub-TLV/value is withdrawn. The nodes in the network (for example, RT1) learn the prefix/node SID TLV advertised by RT3 and the proxy Node SIDs TLV advertised by RT2. When RT3 is normal, the nodes prefer prefix/node SID TLV. When the RT3 fails, the proxy prefix/node SIDs TLV advertised by RT2 is preferred.

3.2. Building Proxy Forwarding Table

A SR proxy node P needs to build an independent proxy forwarding table for each neighbor N. The proxy forwarding table for node N contains the following information:

- 1: Node N's SRGB range and the difference between the SRGB start value of node P and that of node N;
- 2: All adjacency-SID of N and Node-SID of the node pointed to by node N's adjacency-SID.
- 3: The binding-SID of N and the label stack associated with the binding-SID.

Node P (PLR) uses a proxy forwarding table based on the next segment to find a node N as a backup forwarding entry to the adj-SID and Node-SID of node N. When node N fails, the proxy forwarding table needs to be maintained for a period of time, which is recommended for 30 minutes.

Node RT3 in the topology of Figure 1 is node N, and node RT2 is node P (PLR). RT2 builds the proxy forwarding table for RT3. The structure of the table and how to build the table is a local implementation issue.

4. Node Protection for Segment List

Segment Routing Traffic Engineering supports the creation of explicit paths using adjacency-SIDs, node-SIDs, and binding-SIDs. The label stack is a combination of one or more of adjacency-SIDs, node-SIDs,

and binding-SIDs. This Section shows how a proxy node uses the SR proxy forwarding mechanism to protect traffic to the destination node when the next segment of label stack is adjacency-SIDs, node-SIDs, or binding-SIDs, respectively.

4.1. Next Segment is an Adjacency Segment

As shown in Figure 1, Label Stack 1 {10012, 20023, 30034, 40045} represents SR-TE strict explicit path RT1->RT2->RT3->RT4->RT5. When RT3 fails, node RT2 acts as a PLR, and uses next adj-SID (30034) of the label stack to lookup the proxy forwarding table built by RT2 locally for RT3. The path returned is the label forwarding path to RT3's next hop node RT4, which bypasses RT3. The specific steps are as follows:

- a. RT1 pops top adj-SID 10012, and forwards the packet to RT2;
- b. RT2 uses the label 20023 to identify the next hop node RT3, which has failed. RT2 pops label 20023 and queries the Proxy Forwarding Table corresponding to RT3 with label 30034. The Proxy Forwarding Table corresponding to RT3 returns an outgoing interface and label stack representing a path to RT4 that does not pass through RT3. In this case, outgoing interface to RT7 with label stack 7004, satisfies this requirement.
- c. So the packet leaves RT2 out the interface to RT7 with label stack {7004, 40045}. RT4 forwards it to RT4, where the original path is rejoined.
- d. RT2 forwards packets to RT7. RT7 queries the local routing table to forward the packet to RT4.

4.2. Next Segment is a Node Segment

As shown in Figure 1, Label Stack 2 {1003, 3004, 4005} represents SR-TE loose path RT1->RT3->RT4->RT5, where 1003 is the node SID of RT3.

When the node RT3 fails, the proxy forwarding TLV advertised by the RT2 is preferred to direct the traffic of the RT1 to the PLR node RT2. Node RT2 acts as a PLR node and queries the proxy forwarding table locally built for RT3. The path returned is the label forwarding path to RT3's next hop node RT4, which bypasses RT3. The specific steps are as follows:

- a. RT1 swaps label 1003 to out-label 2003 to RT3.

- b. RT2 receives the label forwarding packet whose top label of label stack is 2003, and searches for the local Routing Table, the behavior found is to lookup Proxy Forwarding table due to RT3 failure.
- c. RT2 uses 2003 as the in-label to lookup Proxy Forwarding table, and the query result is forwarding the packet to RT4.
- d. Then RT2 queries the Routing Table to RT4, using the primary or backup path to RT4. The next hop is RT7.
- e. RT2 forwards the packet to RT7. RT7 queries the local routing table to forward the packet to RT4.
- f. After RT1 convergences, node SID 1003 is preferred to the proxy SID implied/advertised by RT2.

4.3. Next Segment is a Binding Segment

As shown in Figure 1, Label Stack 3 {1003, 100} represents SR-TE loose path RT1->RT3->RT4->RT5, where 100 is a Binding-SID, which represents segment list {30034, 40045}.

When the node RT3 fails, the proxy forwarding SID implied or advertised by the RT2 is preferred to forward the traffic of the RT1 to the PLR node RT2. Node RT2 acts as a PLR node and uses Binding-SID to query the proxy forwarding table locally built for RT3. The path returned is the label forwarding path to RT3's next hop node (RT4), which bypasses RT3. The specific steps are as follows:

- a. RT1 swaps label 1003 to out-label 2003 to RT3.
- b. RT2 receives the label forwarding packet whose top label of label stack is 2003, and searches for the local Routing Table, the behavior found is to lookup Proxy Forwarding table due to RT3 failure.
- c. RT2 uses Binding-SID:100 (label 2003 has pop) as the in-label to lookup the Next Label record of the Proxy Forwarding Table, the behavior found is to swap to Segment list {30034, 40045}.
- d. RT2 swaps Binding-SID:100 to Segment list {30034, 40045}, and uses the 3034 to lookup the Next Label record of the Proxy Forwarding table again. The behavior found is to forward the packet to RT4.
- e. RT2 queries the Routing Table to RT4, using primary or backup path to RT4. The next hop is RT7.
- f. RT2 forwards packets to RT7. RT7 queries the local routing table to forward the packet to RT4.

5. Security Considerations

The extensions to OSPF and IS-IS described in this document result in two types of behaviors in data plane when a node in a network fails. One is that for a node, which is a upstream (except for the direct upstream) node of the failed node along a SR-TE path, it continues to send the traffic to the failed node along the SR-TE path for an extended period of time. The other is that for a node, which is the direct upstream node of the failed node, it fast re-routes the traffic around the failed node to the direct downstream node of the failed node along the SR-TE path. These behaviors are internal to a network and should not cause extra security issues.

6. IANA Considerations

6.1. OSPFv2

Under Subregistry Name "OSPF Router Functional Capability Bits" within the "Open Shortest Path First v2 (OSPFv2) Parameters" [RFC7770], IANA is requested to assign one bit for Proxy Forwarding Capability as follows:

Bit number	Capability Name	Reference
31	Proxy Forwarding	This document

Under Registry Name "OSPFv2 Extended Prefix Opaque LSA TLVs" [RFC7684], IANA is requested to assign one new TLV value for OSPF Proxy Node SIDs as follows:

TLV Value	TLV Name	Reference
2	Proxy Node SIDs TLV	This document

Under Registry Name "Opaque Link-State Advertisements (LSA) Option Types" [RFC5250], IANA is requested to assign new Opaque Type registry values for Binding Segment LSA as follows:

Registry Value	Opaque Type	Reference
10	Binding Segment	This document

IANA is requested to create and maintain new registries:

- o OSPFv2 Binding Segment Opaque LSA TLVs

Initial values for the registry are given below. The future assignments are to be made through IETF Review [[RFC5226](#)].

Value	TLV Name	Definition
0	Reserved	
1	Binding Segment TLV	This Document
2-32767	Unassigned	
32768-65535	Reserved	

6.2. OSPFv3

Under Registry Name "OSPFv3 LSA Function Codes", IANA is requested to assign new registry values for Binding Segment LSA as follows:

```

+=====+=====+=====+
| Value | LSA Function Code Name | Reference |
+-----+-----+-----+
| 16    | Binding Segment LSA   | This document |
+-----+-----+-----+

```

IANA is requested to create and maintain new registries:

- o OSPFv3 Binding Segment LSA TLVs

Initial values for the registry are given below. The future assignments are to be made through IETF Review [[RFC5226](#)].

Value	TLV Name	Definition
0	Reserved	
1	Binding Segment TLV	This Document
2-32767	Unassigned	
32768-65535	Reserved	

6.3. IS-IS

Under Registration "Segment Routing Capability" in the "sub-TLVs for TLV 242" registry [[I-D.ietf-isis-segment-routing-extensions](#)], IANA is requested to assign one bit flag for Proxy Forwarding Capability as follows:

Bit number	Capability Name	Reference
2	Proxy Forwarding (PF)	This document

Under Registration "Segment Identifier/Label Binding TLV 149" [[I-D.ietf-isis-segment-routing-extensions](#)], IANA is requested to assign one bit P-Flag as follows:

Bit number	Flag Name	Reference
5	P-Flag	This document

Under Registry Name: IS-IS TLV Codepoints, IANA is requested to assign one new TLV value for IS-IS Binding Segment as follows:

Value	TLV Name	Reference
152	Binding Segment TLV	This Document

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