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Fast Reroute Procedures for Co-routed Associated Bidirectional Label Switched Paths (LSPs)

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Abstract

Resource Reservation Protocol (RSVP) association signaling can be used to bind two unidirectional LSPs into an associated bidirectional LSP. When an associated bidirectional LSP is co-routed, the reverse LSP follows the same path as its forward LSP. This document describes Fast Reroute (FRR) procedures for both single-sided and double-sided provisioned associated bidirectional LSPs. The FRR procedures can ensure that for the co-routed LSPs, traffic flows on co-routed paths in the forward and reverse directions after a failure event.

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1. Introduction

The Resource Reservation Protocol (RSVP) (Extended) ASSOCIATION Object is specified in [RFC6780] which can be used generically to associate (G)Multiprotocol Label Switching (MPLS) Traffic Engineering (TE) Label Switched Paths (LSPs). [RFC7551] defines mechanisms for binding two point-to-point unidirectional LSPs [RFC3209] into an associated bidirectional LSP. There are two models described in [RFC7551] for provisioning an associated bidirectional LSP, single-sided and double-sided. In both models, the reverse LSP of the bidirectional LSP may or may not be co-routed and follow the same path as its forward LSP.

The Path Computation Element Communication Protocol (PCEP) provides mechanisms for Path Computation Elements (PCEs) to perform path computations in response to Path Computation Clients (PCCs) requests. The Stateful PCE allows stateful control of the MPLS TE LSPs which may be initiated by the PCE or a PCC. As defined in [PCE-ASSOC-BIDIR], a Stateful PCE can be employed to initiate single-sided and double-sided associated bidirectional LSPs on PCC(s).

In packet transport networks, there are requirements where the reverse LSP of a bidirectional LSP needs to follow the same path as its forward LSP [RFC6373]. The MPLS Transport Profile (TP) [RFC6370] architecture facilitates the co-routed bidirectional LSP by using the GMPLS extensions [RFC3473] to achieve congruent paths. However, the RSVP association signaling allows to enable co-routed bidirectional LSPs without having to deploy GMPLS extensions in the existing networks. The association signaling also allows to take advantage of the existing TE and Fast Reroute (FRR) mechanisms in the network.

[RFC4090] defines FRR extensions for MPLS TE LSPs and those are also applicable to the associated bidirectional LSPs. [RFC8271] defines FRR procedure for GMPLS signaled bidirectional LSPs, such as, coordinate bypass tunnel assignments in the forward and reverse directions of the LSP. The mechanisms defined in [RFC8271] are also useful for the FRR of associated bidirectional LSPs.

This document describes FRR procedures for both single-sided and double-sided provisioned associated bidirectional LSPs. The FRR procedures can ensure that for the co-routed LSPs, traffic flows on co-routed paths in the forward and reverse directions after a failure event.

1.1. Assumptions and Considerations

The following assumptions and considerations apply to this document:

- o The FRR procedure for the unidirectional LSPs is defined in [RFC4090] and is not modified by this document.

- o The FRR procedure when using the unidirectional bypass tunnels is defined in [RFC4090] and is not modified by this document.

- o This document assumes that the FRR bypass tunnels used for protected associated bidirectional LSPs are also associated bidirectional.

- o The FRR bypass tunnels used for protected co-routed associated bidirectional LSPs are assumed to be co-routed associated bidirectional.

- o The FRR procedure to coordinate the bypass tunnel assignment defined in this document may be used for protected non-corouted associated bidirectional LSPs but requires that the downstream Point of Local Repair (PLR) and Merge Point (MP) pair of the forward LSP matches the upstream MP and PLR pair of the reverse LSP.

- o Unless otherwise specified in this document, the fast reroute procedures defined in [RFC4090] are used for associated bidirectional LSPs.

2. Conventions Used in This Document

2.1. Key Word Definitions

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].

2.2. Terminology

The reader is assumed to be familiar with the terminology defined in [RFC2205], [RFC3209], [RFC4090], [RFC7551], and [RFC8271].

2.2.1. Forward Unidirectional LSPs

Two reverse unidirectional point-to-point (P2P) LSPs are setup in the opposite directions between a pair of source and destination nodes to form an associated bidirectional LSP. In the case of single-sided provisioned LSP, the originating LSP with REVERSE_LSP Object is identified as a forward unidirectional LSP. In the case of double-sided provisioned LSP, the LSP originating from the higher node address (as source) and terminating on the lower node address (as

destination) is identified as a forward unidirectional LSP.

2.2.2. Reverse Co-routed Unidirectional LSPs

Two reverse unidirectional point-to-point (P2P) LSPs are setup in the opposite directions between a pair of source and destination nodes to form an associated bidirectional LSP. A reverse unidirectional LSP originates on the same node where the forward unidirectional LSP terminates, and it terminates on the same node where the forward unidirectional LSP originates. A reverse co-routed unidirectional LSP traverses along the same path as the forward direction unidirectional LSP in the opposite direction.

3. Overview

As specified in [RFC7551], in the single-sided provisioning case, the RSVP TE tunnel is configured only on one endpoint node of the bidirectional LSP. An LSP for this tunnel is initiated by the originating endpoint with (Extended) ASSOCIATION Object containing Association Type set to "single-sided associated bidirectional LSP" and REVERSE_LSP Object inserted in the RSVP Path message. The remote endpoint then creates the corresponding reverse TE tunnel and signals the reverse LSP in response using the information from the REVERSE_LSP Object and other objects present in the received RSVP Path message. As specified in [RFC7551], in the double-sided provisioning case, the RSVP TE tunnel is configured on both endpoint nodes of the bidirectional LSP. Both forward and reverse LSPs are initiated independently by the two endpoints with (Extended) ASSOCIATION Object containing Association Type set to "double-sided associated bidirectional LSP". With both single-sided and double-sided provisioned bidirectional LSPs, the reverse LSP may or may not be congruent (i.e. co-routed) and follow the same path as its forward LSP.

Both single-sided and double-sided associated bidirectional LSPs require solutions to the following issues for fast reroute to ensure co-routing after a failure event.

3.1. Fast Reroute Bypass Tunnel Assignment

In order to ensure that the traffic flows on a co-routed path after a link or node failure on the protected co-routed LSP path, the mid-point Point of Local Repair (PLR) nodes need to assign matching bidirectional bypass tunnels for fast reroute. Such bypass assignment requires coordination between the forward and reverse direction PLR nodes when more than one bypass tunnels are present on a PLR node.

```
                      <-- Bypass N -->
                  +-----+         +-----+
                  |  H  +---------+  I  |
                  +--+--+         +--+--+
                     |               |
                     |               |
          LSP1 -->   |   LSP1 -->    |   LSP1 -->       LSP1 -->
   +-----+        +--+--+         +--+--+        +-----+        +-----+
   |  A  +--------+  B  +----X----+  C  +--------+  D  +--------+  E  |
   +-----+        +--+--+         +--+--+        +-----+        +-----+
          <-- LSP2   |    <-- LSP2   |   <-- LSP2       <-- LSP2
                     |               |
                     |               |
                  +--+--+         +--+--+
                  |  F  +---------+  G  |
                  +-----+         +-----+
                      <-- Bypass S -->
```

Figure 1: Multiple Bidirectional Bypass Tunnels

As shown in Figure 1, there are two bypass tunnels available, Bypass tunnel N (on path B-H-I-C) and Bypass tunnel S (on path B-F-G-C). The mid-point PLR nodes B and C need to coordinate bypass tunnel assignment to ensure that traffic in both directions flow through either on the Bypass tunnel N (on path B-H-I-C) or the Bypass tunnel S (on path B-F-G-C), after the link B-C failure.

3.2. Node Protection Bypass Tunnels

When using a node protection bypass tunnel with a protected associated bidirectional LSP, after a link failure, the forward and reverse LSP traffic can flow on different node protection bypass tunnels in the upstream and downstream directions.

```
              <-- Bypass N -->
   +-----+                        +-----+
   |  H  +------------------------+  I  |
   +--+--+                        +--+--+
      |      <-- Rerouted-LSP2       |
      |                              |
      |                              |
      |   LSP1 -->       LSP1 -->    |   LSP1 -->       LSP1 -->
   +--+--+        +-----+         +--+--+        +-----+        +-----+
   |  A  +--------+  B  +----X----+  C  +--------+  D  +--------+  E  |
   +-----+        +--+--+         +-----+        +--+--+        +-----+
          <-- LSP2   |    <-- LSP2       <-- LSP2   |   <-- LSP2
                     |                              |
```

```
                    |                              |
                    |       Rerouted-LSP1 -->      |
                 +--+--+                        +--+--+
                 |  F  +------------------------+  G  |
                 +-----+                        +-----+
                            <-- Bypass S -->
```

Figure 2: Node Protection Bypass Tunnels

As shown in Figure 2, after the link B-C failure, the downstream PLR node B reroutes the protected forward LSP1 traffic over the bypass tunnel S (on path B-F-G-D) to reach downstream MP node D whereas the upstream PLR node C reroute the protected reverse LSP2 traffic over the bypass tunnel N (on path C-I-H-A) to reach the upstream MP node A. As a result, the traffic in the forward and revere directions flows on different bypass tunnels and this can cause the co-routed associated bidirectional LSP to become non-corouted. However, unlike GMPLS LSPs, the asymmetry of paths in the forward and reverse directions does not result in RSVP soft-state timeout with the associated bidirectional LSPs.

3.3. Bidirectional LSP Association At Mid-Points

In packet transport networks, a restoration LSP is signaled after a link failure on the protected LSP path and the protected LSP may or may not be torn down [RFC8131]. In this case, multiple forward and reverse LSPs of a co-routed associated bidirectional LSP may be present at mid-point nodes with identical (Extended) ASSOCIATION Objects. This creates an ambiguity at mid-point nodes to identify the correct associated LSP pair for fast reroute bypass assignment (e.g. during the recovery phase of RSVP graceful restart procedure).

```
          LSP3 -->                       LSP3 -->       LSP3 -->
          LSP1 -->       LSP1 -->        LSP1 -->       LSP1 -->
       +-----+        +-----+         +-----+        +-----+        +-----+
       |  A  +--------+  B  +-----X----+  C  +--------+  D  +--------+  E  |
       +-----+        +--+--+         +--+--+        +-----+        +-----+
          <-- LSP2     |     <-- LSP2   |    <-- LSP2       <-- LSP2
          <-- LSP4     |                |    <-- LSP4       <-- LSP4
                       |                |
                       |   LSP3 -->     |
                    +--+--+          +--+--+
                    |  F  +----------+  G  |
                    +-----+          +-----+
                        <-- Bypass S -->
                            <-- LSP4
```

Figure 3: Restoration LSP Set-up after Link Failure

As shown in Figure 3, the protected LSPs LSP1 and LSP2 are an associated LSP pair, similarly the restoration LSPs LSP3 and LSP4 are an associated LSP pair, both pairs belong to the same associated bidirectional LSP and carry identical (Extended) ASSOCIATION Objects. In this example, the mid-point node D may mistakenly associate LSP1 with the reverse LSP4 instead of the reverse LSP3 due to the matching (Extended) ASSOCIATION Objects. This may cause the co-routed associated bidirectional LSP to become non-corouted after fast reroute. Since the bypass assignment needs to be coordinated between the forward and reverse LSPs, this can also lead to undesired bypass tunnel assignments.

4. Signaling Procedure

4.1. Associated Bidirectional LSP Fast Reroute

For both single-sided and double-sided associated bidirectional LSPs, the fast reroute procedure specified in [RFC4090] is used. In addition, the mechanisms defined in [RFC8271] are used as following.

o The BYPASS_ASSIGNMENT IPv4 subobject (value: 38) and IPv6 subobject (value: 39) defined in [RFC8271] are used to coordinate bypass tunnel assignment between the forward and reverse direction PLR nodes (see Figure 1). The BYPASS_ASSIGNMENT and Node-ID address [RFC4561] subobjects MUST be added by the downstream PLR node in the RECORD_ROUTE Object (RRO) of the RSVP Path message of the forward LSP to indicate the local bypass tunnel assignment using the procedure defined in [RFC8271]. The upstream node uses the bypass assignment information (namely, bypass tunnel source address, destination address and Tunnel ID) in the received RSVP Path message of the protected forward LSP to find the associated bypass tunnel in the reverse direction. The upstream PLR node MUST NOT add the BYPASS_ASSIGNMENT subobject in the RRO of the RSVP Path message of the reverse LSP.

o The downstream PLR node always initiates the bypass tunnel assignment for the forward LSP. The upstream PLR (forward direction LSP MP) node simply reflects the associated bypass tunnel assignment for the reverse direction LSP. The upstream PLR node MUST NOT initiate the bypass tunnel assignment.

o If the indicated forward bypass tunnel or the associated reverse bypass tunnel is not found, the upstream PLR SHOULD send a Notify message [RFC3473] with Error-code "FRR Bypass Assignment Error" (value: 44) and Sub-code "Bypass Tunnel Not Found" (value: 1)

[RFC8271] to the downstream PLR.

- If the bypass tunnel can not be used as described in Section 4.5.3 in [RFC8271], the upstream PLR SHOULD send a Notify message [RFC3473] with Error-code "FRR Bypass Assignment Error" (value: 44) and Sub-code "Bypass Assignment Cannot Be Used" (value: 0) [RFC8271] to the downstream PLR.

- After a link or node failure, the PLR nodes in both forward and reverse directions trigger fast reroute independently using the procedures defined in [RFC4090] and send the forward and protected reverse LSP modified RSVP Path messages and traffic over the bypass tunnel. The RSVP Resv signaling of the protected forward and reverse LSPs follows the same procedure as defined in [RFC4090] and is not modified by this document.

4.1.1. Restoring Co-routing with Node Protection Bypass Tunnels

After fast reroute, the downstream MP node assumes the role of upstream PLR and reroutes the reverse LSP RSVP Path messages and traffic over the bypass tunnel on which the forward LSP RSVP Path messages and traffic are received. This procedure is defined as restoring co-routing in [RFC8271]. This procedure is used to ensure that both forward and reverse LSP signaling and traffic flow on the same bidirectional bypass tunnel after fast reroute.

As shown in Figure 2, when using a node protection bypass tunnel with protected co-routed LSPs, asymmetry of paths can occur in the forward and reverse directions after a link failure [RFC8271]. In order to restore co-routing, the downstream MP node D (acting as an upstream PLR) SHOULD trigger procedure to restore co-routing and reroute the protected reverse LSP2 RSVP Path messages and traffic over the bypass tunnel S (on path D-G-F-B) to the upstream MP node B upon receiving the protected forward LSP modified RSVP Path messages and traffic over the bypass tunnel S (on path D-G-F-B) from node B. The upstream PLR node C stops receiving the RSVP Path messages and traffic for the reverse LSP2 from node D (resulting in RSVP soft-state timeout) and it stops sending the RSVP Path messages for the reverse LSP2 over the bypass tunnel N (on path C-I-H-A) to node A.

4.1.2. Unidirectional Link Failures

The unidirectional link failures can cause co-routed associated bidirectional LSPs to become non-corouted after fast reroute with both link protection and node protection bypass tunnels. However, the unidirectional link failures in the upstream and/or downstream directions do not result in RSVP soft-state timeout with the associated bidirectional LSPs as upstream and downstream PLRs trigger

fast reroute independently. The asymmetry of forward and reverse LSP paths due to the unidirectional link failure in the downstream direction can be corrected by using the procedure to restore co-routing specified in Section 4.1.1.

4.1.3. Revertive Behavior after Fast Reroute

When the revertive behavior is desired for a protected LSP after the link is restored, the procedure defined in [RFC4090], Section 6.5.2, is followed.

- o The downstream PLR node starts sending the RSVP Path messages and traffic flow of the protected forward LSP over the restored link and stops sending them over the bypass tunnel [RFC4090].

- o The upstream PLR node (when the protected LSP is present) also starts sending the RSVP Path messages and traffic flow of the protected reverse LSPs over the restored link and stops sending them over the bypass tunnel [RFC4090].

- o In case of node protection bypass tunnels (see Figure 2), after restoring co-routing, the upstream PLR node D SHOULD start sending RSVP Path messages and traffic for the reverse LSP over the original link (C-D) when it receives the un-modified RSVP Path messages and traffic for the protected forward LSP over it and stops sending them over the bypass tunnel S (on path D-G-F-B).

4.1.4. Bypass Tunnel Provisioning

Fast reroute bidirectional bypass tunnels can be single-sided or double-sided associated tunnels. For both single-sided and double-sided associated bypass tunnels, the fast reroute assignment policies need to be configured on the downstream PLR nodes of the protected LSPs that initiate the bypass tunnel assignments. For single-sided associated bypass tunnels, these nodes are the originating endpoints of their signaling.

4.1.5. One-to-One Bypass Tunnel

The fast reroute signaling procedure defined in this document can be used for both facility backup described in Section 3.2 of [RFC4090] and one-to-one backup described in Section 3.1 of [RFC4090]. As described in Section 5.4.2 of [RFC8271], in one-to-one backup method, if the associated bidirectional bypass tunnel is already in-use at the upstream PLR, it SHOULD send a Notify message [RFC3473] with Error-code "FRR Bypass Assignment Error" (value: 44) and Sub-code "One-to-One Bypass Already in Use" (value: 2) to the downstream PLR.

4.2. Bidirectional LSP Association At Mid-points

In order to associate the LSPs unambiguously at a mid-point node (see Figure 3), the endpoint node MUST signal Extended ASSOCIATION Object and add unique Extended Association ID for each associated forward and reverse LSP pair forming the bidirectional LSP. As an example, an endpoint node MAY set the Extended Association ID to the value specified in Section 5.1.

- For single-sided provisioned bidirectional LSPs [RFC7551], the originating endpoint signals the Extended ASSOCIATION Object with a unique Extended Association ID. The remote endpoint copies the contents of the received Extended ASSOCIATION Object including the Extended Association ID in the RSVP Path message of the reverse LSP's Extended ASSOCIATION Object.

- For double-sided provisioned bidirectional LSPs [RFC7551], both endpoints need to ensure that the bidirectional LSP has a unique Extended ASSOCIATION Object for each forward and reverse LSP pair by selecting appropriate unique Extended Association IDs signaled by them.

5. Message and Object Definitions

5.1. Extended ASSOCIATION ID

The Extended Association ID in the Extended ASSOCIATION Object [RFC6780] can be set to the value specified as following to uniquely identify associated forward and reverse LSP pair of an associated bidirectional LSP.

IPv4 Extended Association ID format is shown below:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    IPv4 LSP Source Address                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Reserved            |            LSP-ID             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:                                                               :
:                      Variable Length ID                       :
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4: IPv4 Extended Association ID Format

LSP Source Address

IPv4 source address of the forward LSP [RFC3209].

LSP-ID

16-bits LSP-ID of the forward LSP [RFC3209].

Variable Length ID

Variable length ID inserted by the endpoint node of the associated bidirectional LSP [RFC6780].

IPv6 Extended Association ID format is shown below:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                                                               +
|                    IPv6 LSP Source Address                    |
+                                                               +
|                          (16 bytes)                           |
+                                                               +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Reserved            |             LSP-ID            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:                                                               :
:                      Variable Length ID                       :
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5: IPv6 Extended Association ID Format

LSP Source Address

IPv6 source address of the forward LSP [RFC3209].

LSP-ID

16-bits LSP-ID of the forward LSP [RFC3209].

Variable Length ID

Variable length ID inserted by the endpoint node of the associated

bidirectional LSP [RFC6780].

6. Compatibility

This document describes the procedures for fast reroute for associated bidirectional LSPs. Operators wishing to use this function SHOULD ensure that it is supported on the nodes on the LSP path. No new signaling messages are defines in this document.

7. Security Considerations

This document uses the signaling mechanisms defined in [RFC7551] and [RFC8271] and does not introduce any additional security considerations other than those already covered in [RFC7551], [RFC8271], and the MPLS/GMPLS security framework [RFC5920].

8. IANA Considerations

This document does not require any IANA actions.

9. References

9.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC2205] Braden, B., Zhang, L., Berson, S., Herzog, S., and S. Jamin, "Resource ReSerVation Protocol (RSVP) -- Version 1 Functional Specification", RFC 2205, September 1997.

[RFC4090] Pan, P., Ed., Swallow, G., Ed., and A. Atlas, Ed., "Fast Reroute Extensions to RSVP-TE for LSP Tunnels", RFC 4090, May 2005.

[RFC4561] Vasseur, J.P., Ed., Ali, Z., and S. Sivabalan, "Definition of a Record Route Object (RRO) Node-Id Sub-Object", RFC 4561, June 2006.

[RFC6780] Berger, L., Le Faucheur, F., and A. Narayanan, "RSVP Association Object Extensions", RFC 6780, October 2012.

[RFC7551] Zhang, F., Ed., Jing, R., and R. Gandhi, Ed., "RSVP-TE Extensions for Associated Bidirectional Label Switched Paths (LSPs)", RFC 7551, DOI 10.17487/RFC7551, May 2015, <https://www.rfc-editor.org/info/rfc7551>.

[RFC8271] Taillon, M., Saad, T., Ed., Gandhi, R., Ed., Ali, Z., and M. Bhatia, "Updates to Resource Reservation Protocol for Fast Reroute of Traffic Engineering GMPLS Label Switched Paths (LSPs)", RFC 8271, October 2017.

9.2. Informative References

[RFC3209] Awduche, D., Berger, L., Gan, D., Li, T., Srinivasan, V., and G. Swallow, "RSVP-TE: Extensions to RSVP for LSP Tunnels", RFC 3209, December 2001.

[RFC3473] Berger, L., "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) Extensions", RFC 3473, January 2003.

[RFC5920] Fang, L., "Security Framework for MPLS and GMPLS Networks", RFC 5920, July 2010.

[RFC6370] Bocci, M., Swallow, G., and E. Gray, "MPLS Transport Profile (MPLS-TP) Identifiers", RFC 6370, September 2011.

[RFC6373] Andersson, L., Berger, L., Fang, L., Bitar, N., and E. Gray, "MPLS Transport Profile (MPLS-TP) Control Plane Framework", RFC 6373, September 2011.

[RFC8131] Zhang, X., Zheng, H., Ed., Gandhi, R., Ed., Ali, Z., and P. Brzozowski, "RSVP-TE Signaling Procedure for End-to-End GMPLS Restoration and Resource Sharing", RFC 8131, March 2017.

[PCE-ASSOC-BIDIR] Barth, C., Gandhi, R., Ed., and B. Wen, "PCEP Extensions for Associated Bidirectional Label Switched Paths (LSPs)", draft-ietf-pce-association-bidir (work in progress).

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