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**Updates to the 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 updates the Fast Reroute (FRR) procedures defined in [RFC 4090](#) to support both single-sided and double-sided provisioned associated bidirectional LSPs. This document also updates the procedure for associating two reverse LSPs defined in [RFC 7551](#) to support co-routed 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. Conventions Used in This Document**

### **1.1. Key Word Definitions**

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [BCP 14](#) [[RFC2119](#)] [[RFC8174](#)] when, and only when, they appear in all capitals, as shown here.

### **1.2. Terminology**

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

#### **1.2.1. 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 Label Switched Path (LSP). In the case of single-sided provisioned LSP, the originating LSP with REVERSE\_LSP Object [[RFC7551](#)] 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.

#### **1.2.2. 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 Label Switched Path (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.

## **2. Introduction**

The Resource Reservation Protocol (RSVP) (Extended) ASSOCIATION Object is specified in [[RFC6780](#)] which can be used generically to associate Multiprotocol Label Switching (MPLS) and Generalized MPLS (GMPLS) 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.

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 updates the FRR procedures defined in [[RFC4090](#)] to support both single-sided and double-sided provisioned associated bidirectional LSPs. This document also updates the procedure for associating two reverse LSPs defined in [[RFC7551](#)] to support co-routed 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 fast reroute.

## **2.1. 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.

### **3. Problem Statement**

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 -->
+-----+          +-----+
```





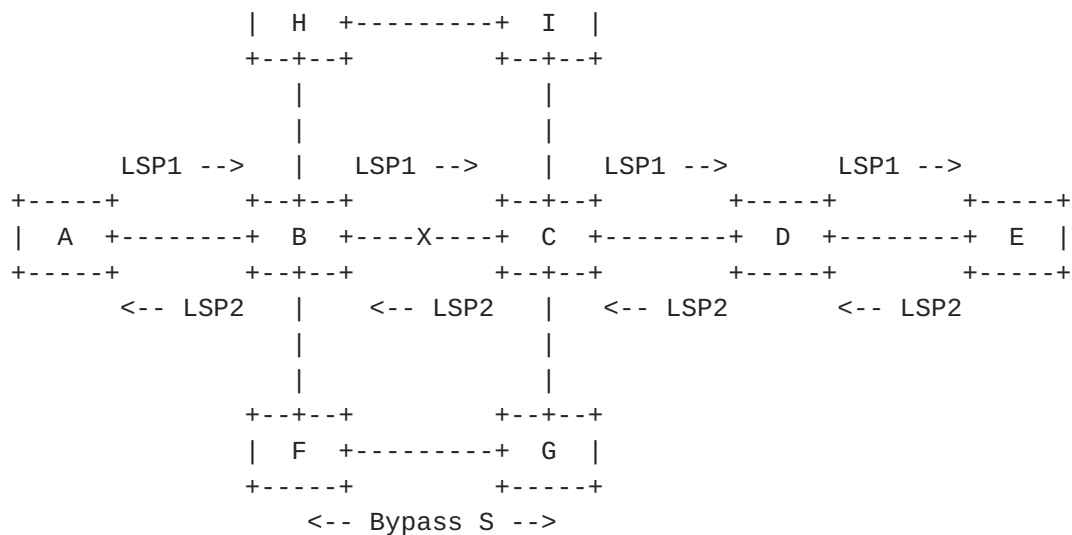
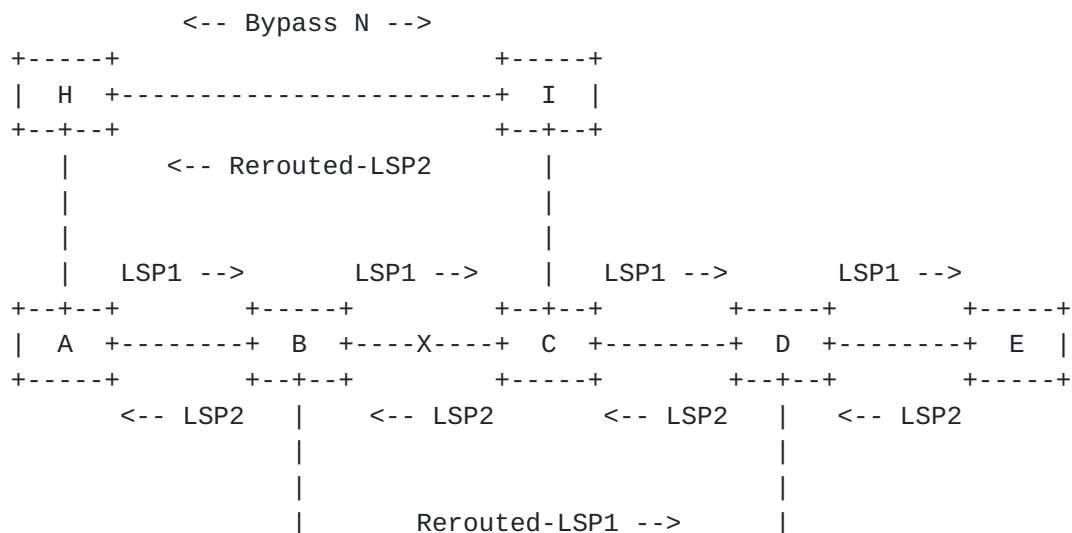


Figure 1: Multiple Bidirectional Bypass Tunnels

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 or the Bypass tunnel S, 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.





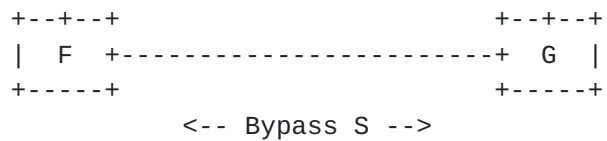


Figure 2: Node Protection Bypass Tunnels

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 reverse 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).

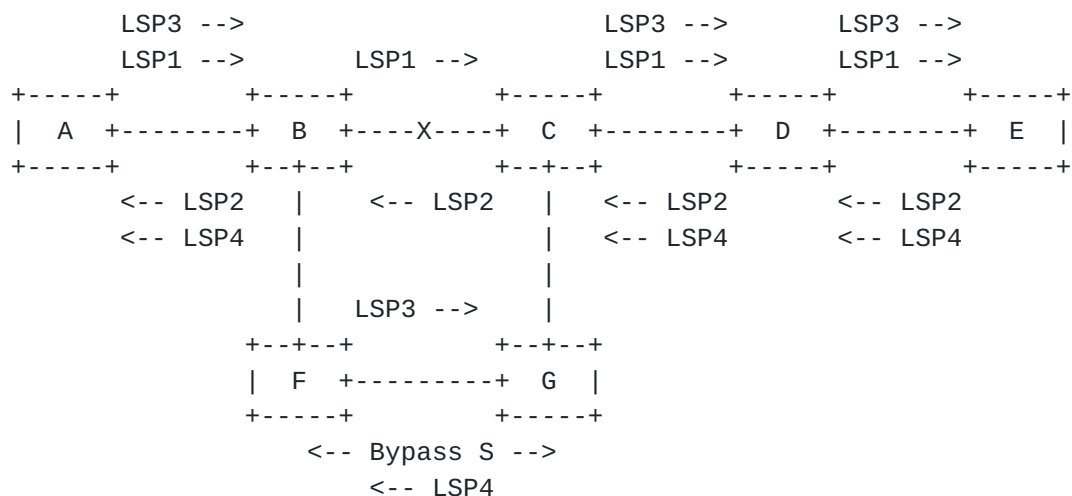


Figure 3: Restoration LSP Set-up after Link Failure



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 initiates the bypass tunnel assignment for the forward LSP. The upstream PLR (forward direction LSP MP) node 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.



- o 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.
- o 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 the 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. An endpoint node MAY set the Extended Association ID to the value shown in [Appendix A](#).

- o 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.
- o 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. Compatibility**

This document updates the procedures for fast reroute for associated bidirectional LSPs defined in [[RFC4090](#)] and for associating bidirectional LSPs defined in [[RFC7551](#)]. The procedures use the signaling messages defined in [[RFC8271](#)] and no new signaling messages are defined in this document. The procedures ensure that for the co-routed LSPs, traffic flows on co-routed paths in the forward and reverse directions after fast reroute. Operators wishing to use this function SHOULD ensure that it is supported on all the nodes on the LSP path. The nodes not supporting this function can cause the traffic to flow on asymmetric paths in the forward and reverse directions of the associated bidirectional LSPs after fast reroute.

#### **6. Security Considerations**

This document updates the signaling mechanisms defined in [[RFC4090](#)] and [[RFC7551](#)]; and does not introduce any additional security considerations other than those already covered in [[RFC4090](#)], [[RFC7551](#)], [[RFC8271](#)], and the MPLS/GMPLS security framework [[RFC5920](#)].

#### **7. IANA Considerations**



This document does not require any IANA actions.

**Appendix A. Extended ASSOCIATION ID**

Extended Association ID in the Extended ASSOCIATION Object [[RFC6780](#)] can be set to the value shown in the following example to uniquely identify associated forward and reverse LSP pair of an associated bidirectional LSP.

An example of IPv4 Extended Association ID format is shown below:

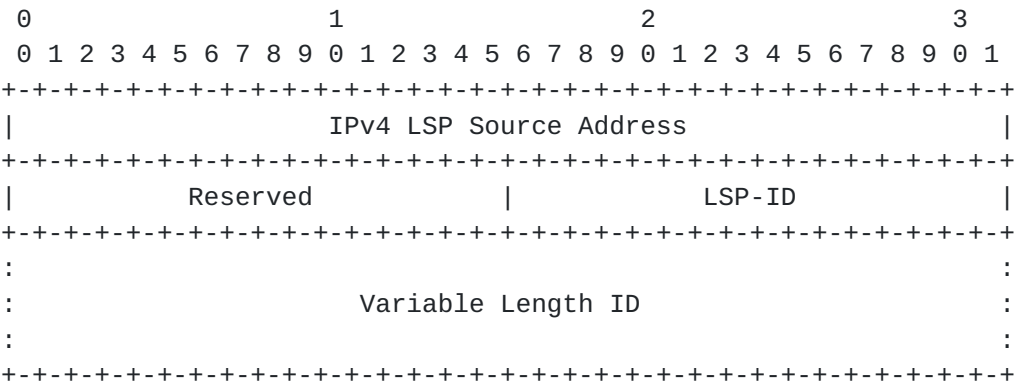


Figure 4: IPv4 Extended Association ID Format Example

LSP Source Address

IPv4 source address of the forward LSP [[RFC3209](#)].

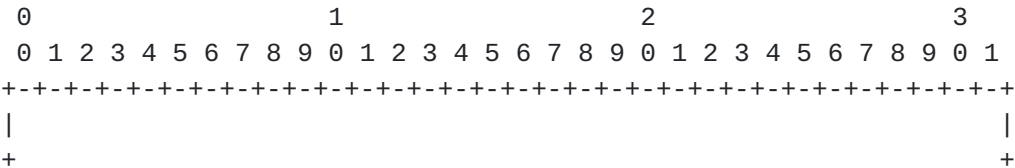
LSP-ID

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](#)].

An example of IPv6 Extended Association ID format is shown below:





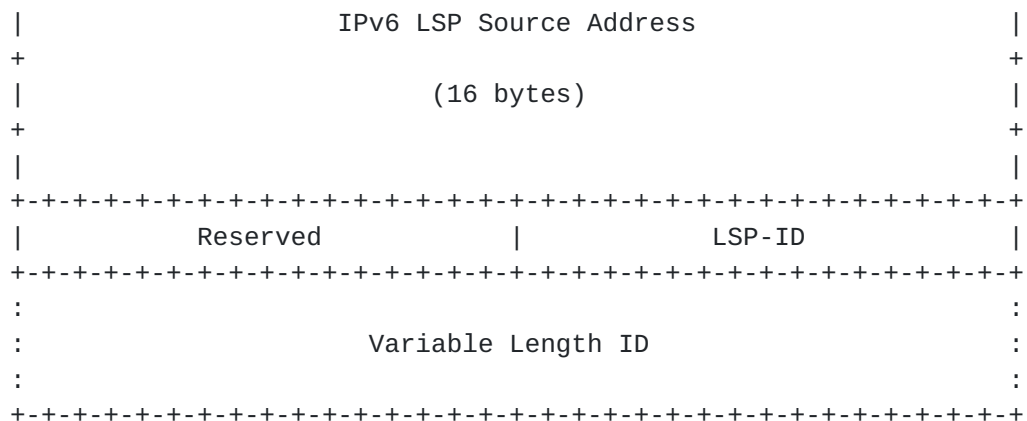


Figure 5: IPv6 Extended Association ID Format Example

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](#)].





## **8. References**

### **8.1. Normative References**

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