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Extensions to RSVP-TE for LSP Egress Local Protection  
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Abstract

This document describes extensions to Resource Reservation Protocol - Traffic Engineering (RSVP-TE) for locally protecting egress nodes of a Traffic Engineered (TE) Label Switched Path (LSP) in a Multi-Protocol Label Switching (MPLS) and Generalized MPLS (GMPLS) network.

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## 1. Introduction

RFC 4090 describes two methods for protecting the transit nodes of a P2P LSP: one-to-one and facility protection. RFC 4875 specifies how to use them to protect the transit nodes of a P2MP LSP. However, they do not mention any local protection for an egress of an LSP.

To protect the egresses of an LSP (P2P or P2MP), an existing approach sets up a backup LSP from a backup ingress (or the ingress of the LSP) to the backup egresses, where each egress is paired with a backup egress and protected by the backup egress.

This approach may use more resources and provide slow fault recovery. This document specifies extensions to RSVP-TE for local protection of an egress of an LSP, which overcomes these disadvantages.

### 1.1. An Example of Egress Local Protection

Figure 1 shows an example of using backup LSPs to locally protect egresses of a primary P2MP LSP from ingress R1 to two egresses: L1 and L2. The primary LSP is represented by star(\*) lines and backup LSPs by hyphen(-) lines.

La and Lb are the designated backup egresses for egresses L1 and L2 respectively. To distinguish an egress (e.g., L1) from a backup egress (e.g., La), an egress is called a primary egress if needed.

The backup LSP for protecting L1 is from its upstream node R3 to backup egress La. The one for protecting L2 is from R5 to Lb.

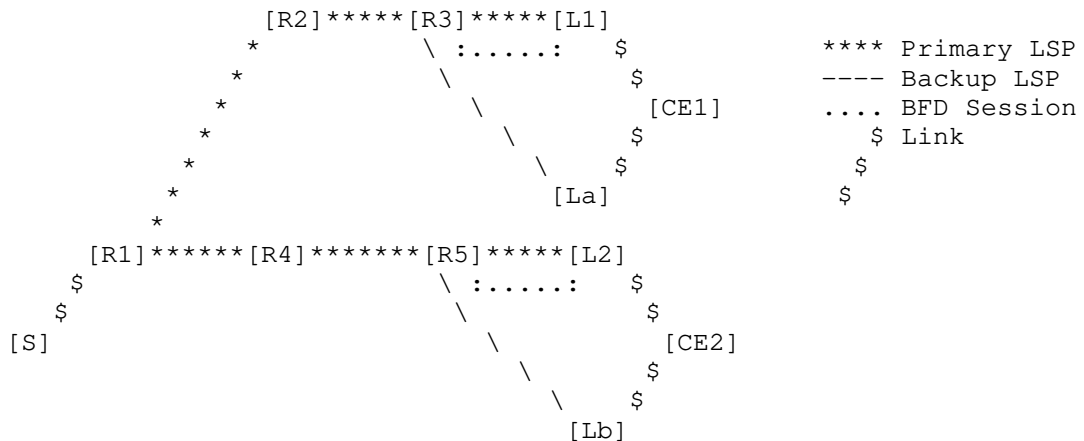


Figure 1: Backup LSP for Locally Protecting Egress

During normal operations, the traffic carried by the P2MP LSP is sent through R3 to L1, which delivers the traffic to its destination CE1. When R3 detects the failure of L1, R3 switches the traffic to the backup LSP to backup egress La, which delivers the traffic to CE1. The time for switching the traffic is within tens of milliseconds.

The failure of a primary egress (e.g., L1 in the figure) MAY be detected by its upstream node (e.g., R3 in the figure) through a BFD between the upstream node and the egress in MPLS networks. Exactly how the failure is detected is out of scope for this document.

#### 1.2. Egress Local Protection with FRR

Using the egress local protection and the FRR, we can locally protect the egresses, the links and the intermediate nodes of an LSP. The traffic switchover time is within tens of milliseconds whenever an egress, any of the links and the intermediate nodes of the LSP fails.

The egress nodes of the LSP can be locally protected via the egress local protection. All the links and the intermediate nodes of the LSP can be locally protected through using the FRR.

### 2. Conventions Used in This Document

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.

### 3. Terminology

This document uses terminologies defined in RFC 2205, RFC 3031, RFC 3209, RFC 3473, RFC 4090, RFC 4461, and RFC 4875.

### 4. Protocol Extensions

A new object EGRESS\_BACKUP is defined for egress local protection. It contains a backup egress for a primary egress.

#### 4.1. EGRESS\_BACKUP Object

The class of the EGRESS\_BACKUP object is TBD-1 to be assigned by IANA. The C-Type of the EGRESS\_BACKUP IPv4/IPv6 object is TBD-2/TBD-3 to be assigned by IANA.

EGRESS\_BACKUP Class Num = TBD-1, IPv4/IPv6 C-Type = TBD-2/TBD-3

```

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
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
~           Egress Backup destination IPv4/IPv6 address           ~
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
~           Egress Primary destination IPv4/IPv6 address           ~
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
~                                     (Subobjects)                                     ~
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

- o Egress Backup destination IPv4/IPv6 address:  
IPv4/IPv6 address of the backup egress node
- o Egress Primary destination IPv4/IPv6 address:  
IPv4/IPv6 address of the primary egress node

The Subobjects are optional. One of them is P2P LSP ID IPv4/IPv6 subobject, whose body has the following format and Type is TBD-4/TBD-5. It may be used to identify a backup LSP.

```

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
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
~           P2P LSP Tunnel Egress IPv4/IPv6 Address (4/16 bytes)           ~
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           Reserved           |           Tunnel ID           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
~           Extended Tunnel ID (4/16 bytes)           ~
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

- o P2P LSP Tunnel Egress IPv4/IPv6 Address:  
IPv4/IPv6 address of the egress of the tunnel
- o Tunnel ID:  
A 16-bit identifier that is constant over the life of the tunnel
- o Extended Tunnel ID:  
A 4/16-byte identifier being constant over the life of the tunnel

Another one is Label subobject, whose body has the format below and Type is TBD-6 to be assigned by IANA.

```

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
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     Label                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

#### 4.2. Flags in FAST\_REROUTE

A bit of the flags in the FAST\_REROUTE object may be used to indicate whether S2L Sub LSP is desired for protecting an egress of a P2MP LSP or One-to-One Backup is preferred for protecting an egress of a P2P LSP when the "Facility Backup Desired" flag is set. This bit is called "S2L Sub LSP Backup Desired" or "One-to-One Backup Preferred".

#### 4.3. Path Message

A Path message is enhanced to carry the information about a backup egress for a primary egress of an LSP through including an egress backup descriptor list. The format of the enhanced Path message is illustrated below.

```
<Path Message> ::= <Common Header> [ <INTEGRITY> ]
    [ [ <MESSAGE_ID_ACK> | <MESSAGE_ID_NACK> ] ... ]
    [ <MESSAGE_ID> ] <SESSION> <RSVP_HOP> <TIME_VALUES>
    [ <EXPLICIT_ROUTE> ]
    <LABEL_REQUEST> [ <PROTECTION> ] [ <LABEL_SET> ... ]
    [ <SESSION_ATTRIBUTE> ] [ <NOTIFY_REQUEST> ]
    [ <ADMIN_STATUS> ] [ <POLICY_DATA> ... ]
    <sender descriptor> [ <S2L sub-LSP descriptor list> ]
    [ <egress backup descriptor list> ]
```

The egress backup descriptor list in the message is defined below. It is a sequence of EGRESS\_BACKUP objects, each of which describes a pair of a primary egress and a backup egress.

```
<egress backup descriptor list> ::=
    <egress backup descriptor>
    [ <egress backup descriptor list> ]

<egress backup descriptor> ::= <EGRESS_BACKUP>
```

### 5. Egress Protection Behaviors

#### 5.1. Ingress Behavior

To protect a primary egress of an LSP, the ingress MUST set the "label recording desired" flag and the "node protection desired" flag in the SESSION\_ATTRIBUTE object.

If one-to-one backup or facility backup method is desired to protect a primary egress of an LSP, the ingress SHOULD include a FAST\_REROUTE

object and set the "One-to-One Backup Desired" or "Facility Backup Desired" flag.

If S2L Sub LSP backup method is desired to protect a primary egress of a P2MP LSP, the ingress SHOULD include a FAST\_REROUTE object and set the "S2L Sub LSP Backup Desired" flag.

Note that if "Facility Backup Desired" flag is set for protecting the intermediate nodes of a primary P2P LSP, but we want to use "One-to-One Backup" for protecting the egress of the LSP, then the ingress SHOULD set "One-to-One Backup Preferred" flag.

Optionally, a backup egress may be configured on the ingress of an LSP to protect a primary egress of the LSP.

The ingress sends a Path message for the LSP with the objects above and an optional egress backup descriptor list. For each primary egress of the LSP to be protected, the ingress adds an EGRESS\_BACKUP object into the list if the backup egress is given. The object contains the primary egress and the backup egress for protecting the primary egress.

## 5.2. Intermediate Node and PLR Behavior

If an intermediate node of an LSP receives the Path message with an egress backup descriptor list and it is not an upstream node of any primary egress of the LSP, it forwards the list unchanged.

If the intermediate node is the upstream node of a primary egress to be protected, it determines the backup egress, obtains a path for the backup LSP and sets up the backup LSP along the path.

The PLR (upstream node of the primary egress) tries to get the backup egress from EGRESS\_BACKUP in the egress backup descriptor list if the Path message contains the list. If the PLR can not get it, the PLR tries to find the backup egress, which is not the primary egress but has the same IP address as the destination IP address of the LSP.

Note that the primary egress and the backup egress SHOULD have a same local address configured, and the cost to the local address on the backup egress SHOULD be much bigger than the cost to the local address on the primary egress. Thus another name such as virtual node based egress protection may be used for egress local protection.

After obtaining the backup egress, the PLR tries to compute a path from itself to the backup egress.

The PLR then sets up the backup LSP along the path obtained. It

provides one-to-one backup protection for the primary egress if the "One-to-One Backup Desired" or "One-to-One Backup Preferred" flag is set in the message; otherwise, it provides facility backup protection if the "Facility Backup Desired flag" is set.

The PLR sets the protection flags in the RRO Sub-object for the primary egress in the Resv message according to the status of the primary egress and the backup LSP protecting the primary egress. For example, it will set the "local protection available" and the "node protection" flag indicating that the primary egress is protected when the backup LSP is up and ready for protecting the primary egress.

#### 5.2.1. Signaling for One-to-One Protection

The behavior of the upstream node of a primary egress of an LSP as a PLR is the same as that of a PLR for one-to-one backup method described in RFC 4090 except for that the upstream node creates a backup LSP from itself to a backup egress.

If the LSP is a P2MP LSP and a primary egress of the LSP is a transit node (i.e., bud node), the upstream node of the primary egress as a PLR also creates a backup LSP from itself to each of the next hops of the primary egress.

When the PLR detects the failure of the primary egress, it MUST switch the packets from the primary LSP to the backup LSP to the backup egress. For the failure of the bud node of a P2MP LSP, the PLR MUST also switch the packets to the backup LSPs to the bud node's next hops, where the packets are merged into the primary LSP.

#### 5.2.2. Signaling for Facility Protection

Except for backup LSP and downstream label, the behavior of the upstream node of the primary egress of a primary LSP as a PLR follows the PLR behavior for facility backup method described in RFC 4090.

For a number of primary P2P LSPs going through the same PLR to the same primary egress, the primary egress of these LSPs may be protected by one backup LSP from the PLR to the backup egress designated for protecting the primary egress.

The PLR selects or creates a backup LSP from itself to the backup egress. If there is a backup LSP that satisfies the constraints given in the Path message, then this one is selected; otherwise, a new backup LSP to the backup egress will be created.

After getting the backup LSP, the PLR associates the backup LSP with a primary LSP for protecting its primary egress. The PLR records



that the backup LSP is used to protect the primary LSP against its primary egress failure and includes an EGRESS\_BACKUP object in the Path message to the primary egress. The object contains the backup egress and the backup LSP ID. It indicates that the primary egress SHOULD send the backup egress the primary LSP label as UA label.

After receiving the Path message with the EGRESS\_BACKUP, the primary egress includes the information about the primary LSP label in the Resv message with an EGRESS\_BACKUP object as UA label. When the PLR receives the Resv message with the information about the UA label, it includes the information in the Path message for the backup LSP to the backup egress. Thus the primary LSP label as UA label is sent to the backup egress from the primary egress.

When the PLR detects the failure of the primary egress, it redirects the packets from the primary LSP into the backup LSP to backup egress using the primary LSP label from the primary egress as an inner label. The backup egress delivers the packets to the same destinations as the primary egress using the backup LSP label as context label and the inner label as UA label.

#### 5.2.3. Signaling for S2L Sub LSP Protection

The S2L Sub LSP Protection is used to protect a primary egress of a P2MP LSP. Its major advantage is that the application traffic carried by the LSP is easily protected against the egress failure.

The PLR determines to protect a primary egress of a P2MP LSP via S2L sub LSP protection when it receives a Path message with flag "S2L Sub LSP Backup Desired" set.

The PLR sets up the backup S2L sub LSP to the backup egress, creates and maintains its state in the same way as of setting up a source to leaf (S2L) sub LSP defined in RFC 4875 from the signaling's point of view. It computes a path for the backup LSP from itself to the backup egress, constructs and sends a Path message along the path, receives and processes a Resv message responding to the Path message.

After receiving the Resv message for the backup LSP, the PLR creates a forwarding entry with an inactive state or flag called inactive forwarding entry. This inactive forwarding entry is not used to forward any data traffic during normal operations.

When the PLR detects the failure of the primary egress, it changes the forwarding entry for the backup LSP to active. Thus, the PLR forwards the traffic to the backup egress through the backup LSP, which sends the traffic to its destination.

#### 5.2.4. PLR Procedures during Local Repair

When the upstream node of a primary egress of an LSP as a PLR detects the failure of the primary egress, it follows the procedures defined in section 6.5 of RFC 4090. It SHOULD notify the ingress about the failure of the primary egress in the same way as a PLR notifies the ingress about the failure of an intermediate node.

In the local revertive mode, the PLR re-signals each of the primary LSPs that were routed over the restored resource once it detects that the resource is restored. Every primary LSP successfully re-signaled along the restored resource is switched back.

Moreover, the PLR lets the upstream part of the primary LSP stay after the primary egress fails. The downstream part of the primary LSP from the PLR to the primary egress SHOULD be removed.

### 6. Considering Application Traffic

This section focuses on the application traffic carried by P2P LSPs. When a primary egress of a P2MP LSP fails, the application traffic carried by the P2MP LSP may be delivered to the same destination by the backup egress since the inner label if any for the traffic is a upstream assigned label for every egress of the P2MP LSP.

#### 6.1. A Typical Application

L3VPN is a typical application. An existing solution (refer to Figure 2) for protecting L3VPN traffic against egress failure includes: 1) A multi-hop BFD session between ingress R1 and egress L1 of primary LSP; 2) A backup LSP from ingress R1 to backup egress La; 3) La sends R1 VPN backup label and related information via BGP; 4) R1 has a VRF with two sets of routes: one uses primary LSP and L1 as next hop; the other uses backup LSP and La as next hop.

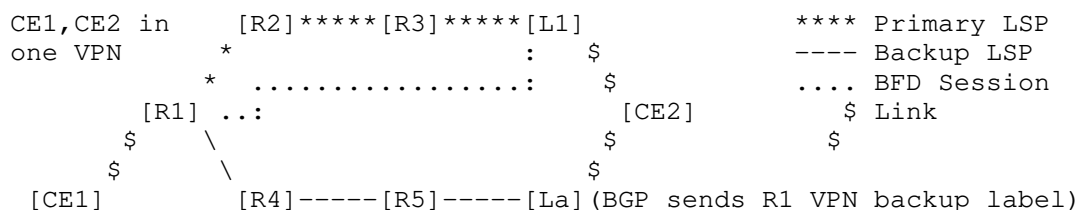


Figure 2: Protect Egress for L3VPN Traffic

In normal operations, R1 sends the traffic from CE1 through primary

LSP with VPN label received from L1 as inner label to L1, which delivers the traffic to CE2 using VPN label.

When R1 detects the failure of L1, R1 sends the traffic from CE1 via backup LSP with VPN backup label received from La as inner label to La, which delivers the traffic to CE2 using VPN backup label.

A new solution (refer to Figure 3) with egress local protection for protecting L3VPN traffic includes: 1) A BFD session between R3 and egress L1 of primary LSP; 2) A backup LSP from R3 to backup egress La; 3) L1 sends La VPN label as UA label and related information; 4) L1 and La is virtualized as one. This can be achieved by configuring a same local address on L1 and La, using the address as a destination of the LSP and BGP next hop for VPN traffic.

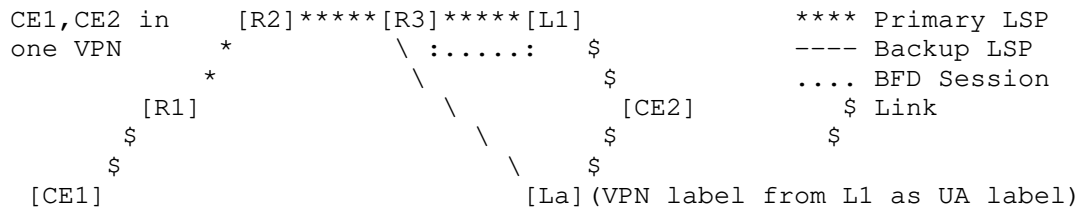


Figure 3: Locally Protect Egress for L3VPN Traffic

When R3 detects L1's failure, R3 sends the traffic from primary LSP via backup LSP to La, which delivers the traffic to CE2 using VPN label as UA label under the backup LSP label as a context label.

## 6.2. PLR Procedure for Applications

When the PLR gets a backup LSP from itself to a backup egress for protecting a primary egress of a primary LSP, it includes an EGRESS\_BACKUP object in the Path message for the primary LSP. The object contains the ID information of the backup LSP and indicates that the primary egress SHOULD send the backup egress the application traffic label (e.g., VPN label) as UA label when needed.

### 6.3. Egress Procedures for Applications

When a primary egress of an LSP sends the ingress of the LSP a label for an application such as a VPN, it SHOULD send the backup egress for protecting the primary egress the label as a UA label via BGP or another protocol. Exactly how the label is sent is out of scope for this document.

When the backup egress receives a UA label from the primary egress,

it adds a forwarding entry with the label into the LFIB for the primary egress. When the backup egress receives a packet from the backup LSP, it uses the top label as a context label to find the LFIB for the primary egress and the inner label to deliver the packet to the same destination as the primary egress according to the LFIB.

## 7. Security Considerations

In principle this document does not introduce new security issues. The security considerations pertaining to RFC 4090, RFC 4875 and other RSVP protocols remain relevant.

## 8. IANA Considerations

IANA considerations for new objects will be specified after the objects used are decided upon.

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Abstract

This document describes extensions to Resource Reservation Protocol - Traffic Engineering (RSVP-TE) for locally protecting the ingress node of a Traffic Engineered (TE) Label Switched Path (LSP) in a Multi-Protocol Label Switching (MPLS) and Generalized MPLS (GMPLS) network.

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## 2. Introduction

For MPLS LSPs it is important to have a fast-reroute method for protecting its ingress node as well as transit nodes. This is not covered either in the fast-reroute method defined in [RFC4090] or in the P2MP fast-reroute extensions to fast-reroute in [RFC4875].

An alternate approach to local protection (fast-reroute) is to use global protection and set up a second backup LSP (whether P2MP or P2P) from a backup ingress to the egresses. The main disadvantage of this is that the backup LSP may reserve additional network bandwidth.

This specification defines a simple extension to RSVP-TE for local protection of the ingress node of a P2MP or P2P LSP.

## 2.1. An Example of Ingress Local Protection

Figure 1 shows an example of using a backup P2MP LSP to locally protect the ingress of a primary P2MP LSP, which is from ingress R1 to three egresses: L1, L2 and L3. The backup LSP is from backup ingress Ra to the next hops R2 and R4 of ingress R1.

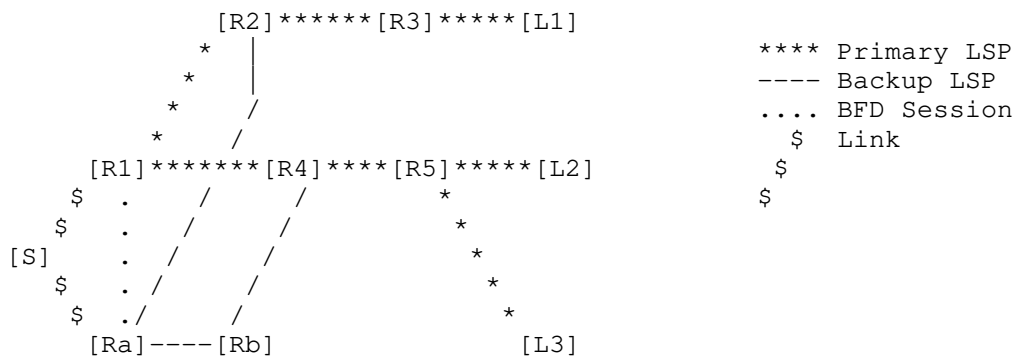


Figure 1: Backup P2MP LSP for Locally Protecting Ingress

Source S may send the traffic simultaneously to both primary ingress R1 and backup ingress Ra. R1 imports the traffic into the primary LSP. Ra normally does not put the traffic into the backup LSP.

Ra should be able to detect the failure of R1 and switch the traffic within 10s of ms. The exact method by which Ra does so is out of scope. Different options are discussed in this draft.

When Ra detects the failure of R1, it imports the traffic from S into the backup LSP to R1's next hops R2 and R4, where the traffic is merged into the primary LSP, and then sent to egresses L1, L2 and L3.

Note that the backup egress must be one logical hop away from the ingress. A logical hop is a direct link or a tunnel such as a GRE tunnel, over which RSVP-TE messages may be exchanged.

## 2.2. Ingress Local Protection with FRR

Through using the ingress local protection and the FRR, we can locally protect the ingress node, all the links and the intermediate nodes of an LSP. The traffic switchover time is within tens of milliseconds whenever the ingress, any of the links and the intermediate nodes of the LSP fails.

The ingress node of the LSP can be locally protected through using the ingress local protection. All the links and all the intermediate nodes of the LSP can be locally protected through using the FRR.

## 3. Ingress Failure Detection

Exactly how the failure of the ingress (e.g. R1 in Figure 1) is detected is out of scope for this document. However, it is necessary to discuss different modes for detecting the failure because they determine what must be signaled and what is the required behavior for the traffic source, backup ingress, and merge-points.

### 3.1. Backup and Source Detect Failure

Backup and Source Detect Failure or Backup-Source-Detect for short means that both the backup ingress and the source are concurrently responsible for detecting the failures of the primary ingress.

In normal operations, the source sends the traffic to the primary ingress. It switches the traffic to the backup ingress when it detects the failure of the primary ingress.

The backup ingress does not import any traffic from the source into the backup LSP in normal operations. When it detects the failure of the primary ingress, it imports the traffic from the source into the backup LSP to the next hops of the primary ingress, where the traffic is merged into the primary LSP.

Note that the source may locally distinguish between the failure of the primary ingress and that of the link between the source and the primary ingress. When the source detects the failure of the link, it may continue to send the traffic to the primary ingress via another link between the source and the primary ingress if there is one.

### 3.2. Backup Detects Failure

Backup Detects Failure or Backup-Detect means that the backup ingress is responsible for detecting the failure of the primary ingress of an LSP. The source SHOULD send the traffic simultaneously to both the primary ingress and backup ingress.

The backup ingress does not import any traffic from the source into the backup LSP in normal operations. When it detects the failure of the primary ingress, it imports the traffic from the source into the backup LSP to the next hops of the primary ingress, where the traffic is merged into the primary LSP.

Note that the backup ingress may locally distinguish between the failure of the primary ingress and that of the link between the backup ingress and the primary ingress through two BFDs between the backup ingress and the primary ingress. One is through the link, and the other is not. If the first BFD is down and the second is up, the link fails and the primary ingress does not.

### 3.3. Source Detects Failure

Source Detects Failure or Source-Detect means that the source is responsible for detecting the failure of the primary ingress of an LSP. The backup ingress is ready to import the traffic from the source into the backup LSP after the backup LSP is up.

In normal operations, the source sends the traffic to the primary ingress. When the source detects the failure of the primary ingress, it switches the traffic to the backup ingress, which delivers the traffic to the next hops of the primary ingress through the backup LSP, where the traffic is merged into the primary LSP.

### 3.4. Next Hops Detect Failure

Next Hops Detect Failure or Next-Hop-Detect means that each of the next hops of the primary ingress of an LSP is responsible for detecting the failure of the primary ingress.

In normal operations, the source sends the traffic to both the primary ingress and the backup ingress. Both ingresses deliver the traffic to the next hops of the primary ingress. Each of the next

hops selects the traffic from the primary ingress and sends the traffic to the destinations of the LSP.

When each of the next hops detects the failure of the primary ingress, it switches to receive the traffic from the backup ingress and then sends the traffic to the destinations.

### 3.5. Comparing Different Detection Modes

\_Behavior \_Detection\ Mode	Traffic Always Sent to Backup Ingress	Backup Ingress Activation of Forwarding Entry	Next-Hop Select Stream	Incorrect Failure Detection Cause Traffic Duplication (Ingress does FRR)
Backup- Source- Detect	No	Yes	No	No
Backup- Detect	Yes	Yes	No	Yes
Source- Detect	No	No (Always Active)	No	No
Next-Hop- Detect	Yes	No (Always Active)	Yes	(If Ingress-Next- Hop link fails, stream selection at Next-Next-Hops can mitigate)

A primary goal of failure detection and FRR protection is to avoid traffic duplication, particularly along the P2MP. A reasonable assumption when this ingress protection is in use is that the ingress is also trying to provide link and node protection. When the failure cannot be accurately identified as that of the ingress, this can lead to the ingress sending traffic on bypass to the next-next-hop(s) for node-protection while the backup ingress is sending traffic to its next-hop(s) if Next-Hop-Detect mode is used. RSVP Path messages from the bypass may help to eventually resolve this by removing the forwarding entry for receiving the traffic from the next-hop.

## 4. Backup Forwarding State

Before the primary ingress fails, the backup ingress is responsible

for creating the necessary backup LSPs to the next hops of the ingress. These LSPs might be multiple bypass P2P LSPs that avoid the ingress. Alternately, the backup ingress could choose to use a single backup P2MP LSP as a bypass or detour to protect the primary ingress of a primary P2MP LSP.

The backup ingress may be off-path or on-path of an LSP. When a backup ingress is not any node of the LSP, we call the backup ingress is off-path. When a backup ingress is a next-hop of the primary ingress of the LSP, we call it is on-path. If the backup ingress is on-path, the primary forwarding state associated with the primary LSP SHOULD be clearly separated from the backup LSP(s) state. Specifically in Backup-Detect mode, the backup ingress will receive traffic from the primary ingress and from the traffic source; only the former should be forwarded until failure is detected even if the backup ingress is the only next-hop.

#### 4.1. Forwarding State for Backup LSP

A forwarding entry for a backup LSP is created on the backup ingress after the LSP is set up. Depending on the failure-detection mode (e.g., source-detect), it may be used to forward received traffic or simply be inactive (e.g., backup-detect) until required. In either case, when the primary ingress fails, this forwarding entry is used to import the traffic into the backup LSP to the next hops of the primary ingress, where the traffic is merged into the primary LSP.

The forwarding entry for a backup LSP is a local implementation issue. In one device, it may have an inactive flag. This inactive forwarding entry is not used to forward any traffic normally. When the primary ingress fails, it is changed to active, and thus the traffic from the source is imported into the backup LSP.

#### 4.2. Forwarding State on Next Hops

When Next-Hop-Detect is used, a forwarding entry for a backup LSP is created on each of the next hops of the primary ingress of the LSP. This forwarding entry does not forward any traffic normally. When the primary ingress fails, it is used to import/select the traffic from the backup LSP into the primary LSP.

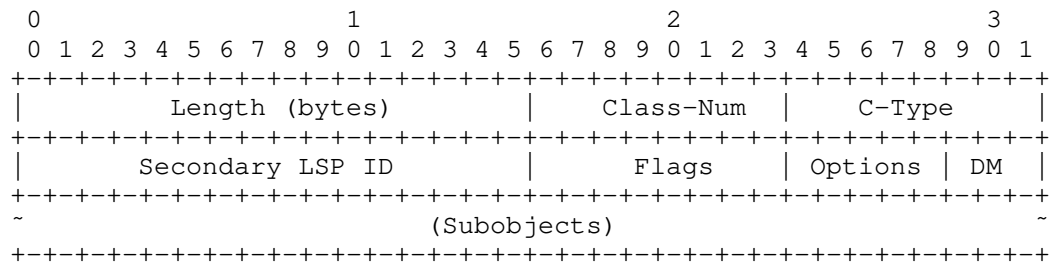
### 5. Protocol Extensions

A new object INGRESS\_PROTECTION is defined for signaling ingress local protection. It is backward compatible.

### 5.1. INGRESS\_PROTECTION Object

The INGRESS\_PROTECTION object with the FAST\_REROUTE object in a PATH message is used to control the backup for protecting the primary ingress of a primary LSP. The primary ingress MUST insert this object into the PATH message to be sent to the backup ingress for protecting the primary ingress. It has the following format:

Class-Num = TBD            C-Type = TBD



#### Flags

- 0x01      Ingress local protection available
- 0x02      Ingress local protection in use
- 0x04      Bandwidth protection

#### Options

- 0x01      Revert to Ingress
- 0x02      Ingress-Proxy/Relay-Message
- 0x04      P2MP Backup

#### DM (Detection Mode)

- 0x00      Backup-Source-Detect
- 0x01      Backup-Detect
- 0x02      Source-Detect
- 0x03      Next-Hop-Detect

For backward compatible, the two high-order bits of the Class-Num in the object are set as follows:

- o Class-Num = 0bbbbbbb for the object in a message not on LSP path. The entire message should be rejected and an "Unknown Object Class" error returned.
- o Class-Num = 10bbbbbb for the object in a message on LSP path. The node should ignore the object, neither forwarding it nor sending an error message.



The Secondary LSP ID in the object is an LSP ID that the primary ingress has allocated for a protected LSP tunnel. The backup ingress will use this LSP ID to set up a new LSP from the backup ingress to the destinations of the protected LSP tunnel. This allows the new LSP to share resources with the old one.

The flags are used to communicate status information from the backup ingress to the primary ingress.

- o Ingress local protection available: The backup ingress sets this flag after backup LSPs are up and ready for locally protecting the primary ingress. The backup ingress sends this to the primary ingress to indicate that the primary ingress is locally protected.
- o Ingress local protection in use: The backup ingress sets this flag when it detects a failure in the primary ingress. The backup ingress keeps it and does not send it to the primary ingress since the primary ingress is down.
- o Bandwidth protection: The backup ingress sets this flag if the backup LSPs guarantee to provide desired bandwidth for the protected LSP against the primary ingress failure.

The options are used by the primary ingress to specify the desired behavior to the backup ingress and next-hops.

- o Revert to Ingress: The primary ingress sets this option indicating that the traffic for the primary LSP successfully re-signaled will be switched back to the primary ingress from the backup ingress when the primary ingress is restored.
- o Ingress-Proxy/Relay-Message: This option is set to one indicating that Ingress-Proxy method is used. It is set to zero indicating that Relay-Message method is used.
- o P2MP Backup: This option is set to ask for the backup ingress to use P2MP backup LSP to protect the primary ingress. Note that one spare bit of the flags in the FAST-REROUTE object can be used to indicate whether P2MP or P2P backup LSP is desired for protecting an ingress and intermediate node.

The DM (Detection Mode) is used by the primary ingress to specify a desired failure detection mode.

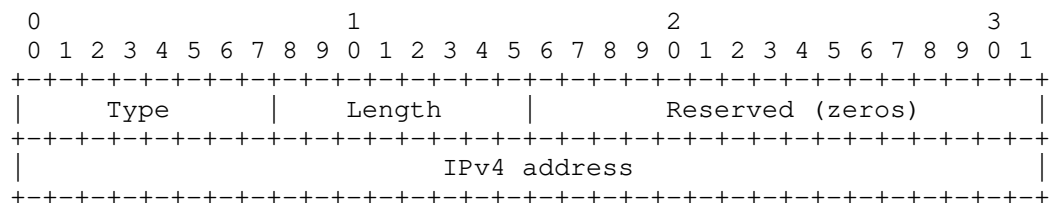
- o Backup-Source-Detect (0x00): The backup ingress and the source are concurrently responsible for detecting the failure involving the primary ingress and redirecting the traffic.

- o Backup-Detect (0x01): The backup ingress is responsible for detecting the failure and redirecting the traffic.
- o Source-Detect (0x02): The source is responsible for detecting the failure and redirecting the traffic.
- o Next-Hop-Detect (0x03): The next hops of the primary ingress are responsible for detecting the failure and selecting the traffic.

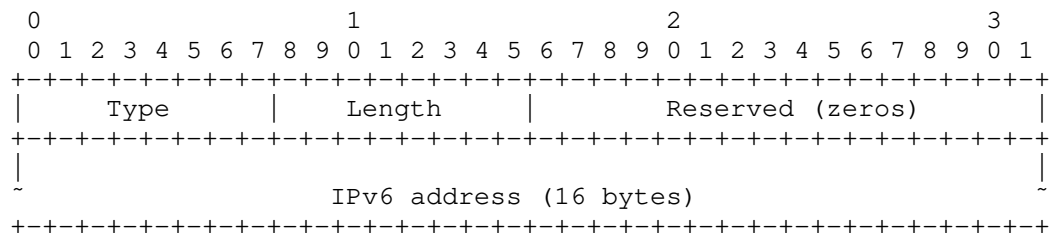
The INGRESS\_PROTECTION object may contain some of the sub objects described below.

#### 5.1.1. Subobject: Backup Ingress IPv4/IPv6 Address

When the primary ingress of a protected LSP sends a PATH message with an INGRESS\_PROTECTION object to the backup ingress, the object may have a Backup Ingress IPv4/IPv6 Address sub object containing an IPv4/IPv6 address belonging to the backup ingress. The formats of the sub object for Backup Ingress IPv4/IPv6 Address is given below:



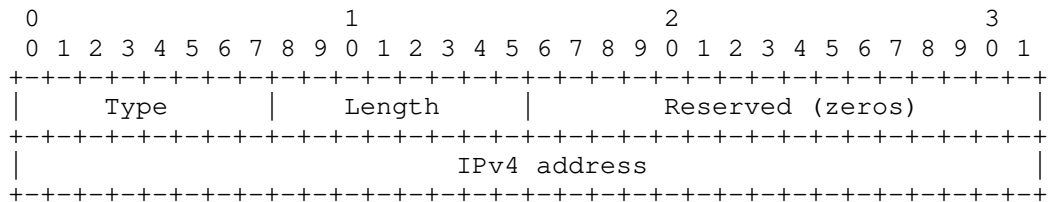
Type: TBD-1 Backup Ingress IPv4 Address  
 Length: Total length of the subobject in bytes, including the Type and Length fields. The Length is always 8.  
 Reserved: Reserved two bytes are set to zeros.  
 IPv4 address: A 32-bit unicast, host address.



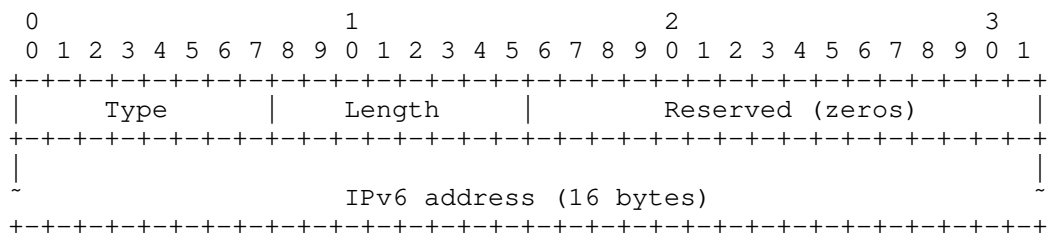
Type: TBD-2 Backup Ingress IPv6 Address  
 Length: Total length of the subobject in bytes, including the Type and Length fields. The Length is always 20.  
 Reserved: Reserved two bytes are set to zeros.  
 IPv6 address: A 128-bit unicast, host address.

## 5.1.2. Subobject: Ingress IPv4/IPv6 Address

The INGRESS\_PROTECTION object in a PATH message from the primary ingress to the backup ingress may have an Ingress IPv4/IPv6 Address sub object containing an IPv4/IPv6 address belonging to the primary ingress. The sub object has the following format:



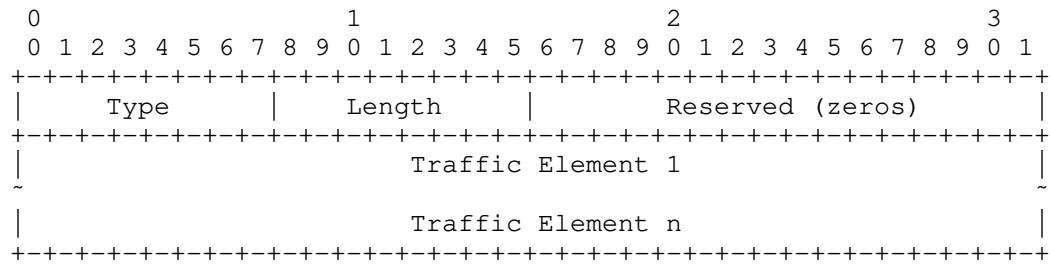
Type: TBD-3 Ingress IPv4 Address  
 Length: Total length of the subobject in bytes, including the Type and Length fields. The Length is always 8.  
 Reserved: Reserved two bytes are set to zeros.  
 IPv4 address: A 32-bit unicast, host address.



Type: TBD-4 Backup Ingress IPv6 Address  
 Length: Total length of the subobject in bytes, including the Type and Length fields. The Length is always 20.  
 Reserved: Reserved two bytes are set to zeros.  
 IPv6 address: A 128-bit unicast, host address.

## 5.1.3. Subobject: Traffic Descriptor

The INGRESS\_PROTECTION object in a PATH message from the primary ingress to the backup ingress may have a Traffic Descriptor sub object describing the traffic to be mapped to the backup LSP on the backup ingress for locally protecting the primary ingress. The sub object has the following format:



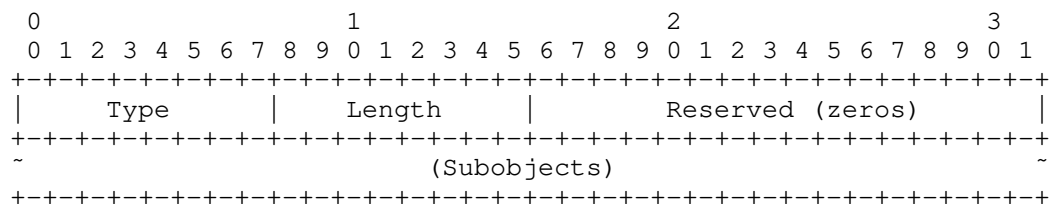
Type: TBD-5/TBD-6/TBD-7 Interface/IPv4/6 Prefix  
Length: Total length of the subobject in bytes, including the Type and Length fields.  
Reserved: Reserved two bytes are set to zeros.

The Traffic Descriptor sub object may contain multiple Traffic Elements of same type as follows.

- o Interface Traffic (Type TBD-5): Each of the Traffic Elements is a 32 bit index of an interface, from which the traffic is imported into the backup LSP.
- o IPv4/6 Prefix Traffic (Type TBD-6/TBD-7): Each of the Traffic Elements is an IPv4/6 prefix, containing an 8-bit prefix length followed by an IPv4/6 address prefix, whose length, in bits, was specified by the prefix length, padded to a byte boundary.

#### 5.1.4. Subobject: Label-Routes

The INGRESS\_PROTECTION object in a PATH message from the primary ingress to the backup ingress will have a Label-Routes sub object containing the labels and routes that the next hops of the ingress use. The sub object has the following format:



Type: TBD-8 Label-Routes  
Length: Total length of the subobject in bytes, including the Type and Length fields.  
Reserved: Reserved two bytes are set to zeros.

The Subobjects in the Label-Routes are copied from the Subobjects in the RECORD\_ROUTE objects contained in the RESV messages that the primary ingress receives from its next hops for the protected LSP. They MUST contain the first hops of the LSP, each of which is paired with its label.

## 6. Behavior of Ingress Protection

### 6.1. Overview

There are four parts of ingress protection: 1) setting up the necessary backup LSP forwarding state; 2) identifying the failure and providing the fast repair (as discussed in Sections 2 and 3); 3) maintaining the RSVP-TE control plane state until a global repair can be done; and 4) performing the global repair (see Section 5.5).

There are two different proposed signaling approaches to obtain ingress protection. They both use the same new INGRESS-PROTECTION object. The object is sent in both PATH and RESV messages.

#### 6.1.1. Relay-Message Method

The primary ingress relays the information for ingress protection of an LSP to the backup ingress via PATH messages. Once the LSP is created, the ingress of the LSP sends the backup ingress a PATH message with an INGRESS-PROTECTION object with Label-Routes subobject, which is populated with the next-hops and labels. This provides sufficient information for the backup ingress to create the appropriate forwarding state and backup LSP(s).

The ingress also sends the backup ingress all the other PATH messages for the LSP with an empty INGRESS-PROTECTION object. Thus, the backup ingress has access to all the PATH messages needed for modification to be sent to refresh control-plane state after a failure.

The advantages of this method include: 1) the primary LSP is independent of the backup ingress; 2) simple; 3) less configuration; and 4) less control traffic.

#### 6.1.2. Proxy-Ingress Method

Conceptually, a proxy ingress is created that starts the RSVP signaling. The explicit path of the LSP goes from the proxy ingress to the backup ingress and then to the real ingress. The behavior and signaling for the proxy ingress is done by the real ingress; the use of a proxy ingress address avoids problems with loop detection.

```

          [ traffic source ]          *** Primary LSP
          $                      $    --- Backup LSP
          $                      $    $$  Link
          $                      $
[ proxy ingress ] [ backup ]
[ & ingress      ]
  *
  *****[ MP ]----|

```

Figure 2: Example Protected LSP with Proxy Ingress Node

The backup ingress must know the merge points or next-hops and their associated labels. This is accomplished by having the RSVP PATH and RESV messages go through the backup ingress, although the forwarding path need not go through the backup ingress. If the backup ingress fails, the ingress simply removes the INGRESS-PROTECTION object and forwards the PATH messages to the LSP's next-hop(s). If the ingress has its LSP configured for ingress protection, then the ingress can add the backup ingress and itself to the ERO and start forwarding the PATH messages to the backup ingress.

Slightly different behavior can apply for the on-path and off-path cases. In the on-path case, the backup ingress is a next hop node after the ingress for the LSP. In the off-path, the backup ingress is not any next-hop node after the ingress for all associated sub-LSPs.

The key advantage of this approach is that it minimizes the special handling code requires. Because the backup ingress is on the signaling path, it can receive various notifications. It easily has access to all the PATH messages needed for modification to be sent to refresh control-plane state after a failure.

#### 6.1.3. Comparing Two Methods

Method	Primary LSP Depends on Backup Ingress	Simple	Config Proxy-Ingress-ID	PATH Msg from Backup to primary RESV Msg from Primary to backup	Reuse Some of Existing Functions
Relay-Message	No	Yes	No	No	Yes-
Proxy-Ingress	Yes	Yes-	Yes	Yes	Yes

## 6.2. Ingress Behavior

The primary ingress must be configured with four pieces of information for ingress protection.

- o Backup Ingress Address: The primary ingress must know an IP address for it to be included in the INGRESS-PROTECTION object.
- o Failure Detection Mode: The primary ingress must know what failure detection mode is to be used: Backup-Source-Detect, Backup-Detect, Source-Detect, or Next-Hop-Detect.
- o Proxy-Ingress-Id (only needed for Proxy-Ingress Method): The Proxy-Ingress-Id is only used in the Record Route Object for recording the proxy-ingress. If no proxy-ingress-id is specified, then a local interface address that will not otherwise be included in the Record Route Object can be used. A similar technique is used in [RFC4090 Sec 6.1.1].
- o Application Traffic Identifier: The primary ingress and backup ingress must both know what application traffic should be directed into the LSP. If a list of prefixes in the Traffic Descriptor sub-object will not suffice, then a commonly understood Application Traffic Identifier can be sent between the primary ingress and backup ingress. The exact meaning of the identifier should be configured similarly at both the primary ingress and backup ingress. The Application Traffic Identifier is understood within the unique context of the primary ingress and backup ingress.

With this additional information, the primary ingress can create and signal the necessary RSVP extensions to support ingress protection.

### 6.2.1. Relay-Message Method

To protect the ingress of an LSP, the ingress does the following after the LSP is up.

1. Select a PATH message.
2. If the backup ingress is off-path, then send the backup ingress a PATH message with the content from the selected PATH message and an INGRESS-PROTECTION object; else (the backup ingress is a next hop, i.e., on-path case) add an INGRESS-PROTECTION object into the existing PATH message to the backup ingress (i.e., the next hop). The INGRESS-PROTECTION object contains the Traffic-Descriptor sub-object, the Backup Ingress Address sub-object and the Label-Routes sub-object. The DM (Detection Mode) in the

object is set to indicate the failure detection mode desired. The flags is set to indicate whether a Backup P2MP LSP is desired. If not yet allocated, allocate a second LSP-ID to be used in the INGRESS-PROTECTION object. The Label-Routes sub-object contains the next-hops of the ingress and their labels.

3. For each of the other PATH messages, if the node to which the message is sent is not the backup ingress, then send the backup ingress a PATH message with the content copied from the message to the node and an empty INGRESS-PROTECTION object; else send the node the message with an empty INGRESS-PROTECTION object.

#### 6.2.2. Proxy-Ingress Method

The primary ingress is responsible for starting the RSVP signaling for the proxy-ingress node. To do this, the following is done for the RSVP PATH message.

1. Compute the EROs for the LSP as normal for the ingress.
2. If the selected backup ingress node is not the first node on the path (for all sub-LSPs), then insert at the beginning of the ERO first the backup ingress node and then the ingress node.
3. In the PATH RRO, instead of recording the ingress node's address, replace it with the Proxy-Ingress-Id.
4. Leave the HOP object populated as usual with information for the ingress-node.
5. Add the INGRESS-PROTECTION object to the PATH message. Allocate a second LSP-ID to be used in the INGRESS-PROTECTION object. Include the Backup Ingress Address (IPv4 or IPv6) sub-object and the Traffic-Descriptor sub-object. Set the control-options to indicate the failure detection mode desired. Set or clear the flag indicating that a Backup P2MP LSP is desired.
6. Optionally, add the FAST-REROUTE object [RFC4090] to the Path message. Indicate whether one-to-one backup is desired. Indicate whether facility backup is desired.
7. The RSVP PATH message is sent to the backup node as normal.

If the ingress detects that it can't communicate with the backup ingress, then the ingress should instead send the PATH message to the next-hop indicated in the ERO computed in step 1. Once the ingress detects that it can communicate with the backup ingress, the ingress SHOULD follow the steps 1-7 to obtain ingress failure protection.



When the ingress node receives an RSVP PATH message with an INGRESS-PROTECTION object and the object specifies that node as the ingress node and the PHOP as the backup ingress node, the ingress node SHOULD check the Failure Scenario specified in the INGRESS-PROTECTION object and, if it is not the Next-Hop-Detect, then the ingress node SHOULD remove the INGRESS-PROTECTION object from the PATH message before sending it out. Additionally, the ingress node must store that it will install ingress forwarding state for the LSP rather than midpoint forwarding.

When an RSVP RESV message is received by the ingress, it uses the NHOP to determine whether the message is received from the backup ingress or from a different node. The stored associated PATH message contains an INGRESS-PROTECTION object that identifies the backup ingress node. If the RESV message is not from the backup node, then ingress forwarding state should be set up, and the INGRESS-PROTECTION object MUST be added to the RESV before it is sent to the NHOP, which should be the backup node. If the RESV message is from the backup node, then the LSP should be considered available for use.

If the backup ingress node is on the forwarding path, then a RESV is received with an INGRESS-PROTECTION object and an NHOP that matches the backup ingress. In this case, the ingress node's address will not appear after the backup ingress in the RRO. The ingress node should set up ingress forwarding state, just as is done if the LSP weren't ingress-node protected.

### 6.3. Backup Ingress Behavior

An LER determines that the ingress local protection is requested for an LSP if the INGRESS\_PROTECTION object is included in the PATH message it receives for the LSP. The LER can further determine that it is the backup ingress if one of its addresses is in the Backup Ingress Address sub-object of the INGRESS-PROTECTION object. The LER as the backup ingress will assume full responsibility of the ingress after the primary ingress fails. In addition, the LER determines that it is off-path if it is not a next hop of the primary ingress.

#### 6.3.1. Backup Ingress Behavior in Off-path Case

The backup ingress considers itself as a PLR and the primary ingress as its next hop and provides a local protection for the primary ingress. It behaves very similarly to a PLR providing fast-reroute where the primary ingress is considered as the failure-point to protect. Where not otherwise specified, the behavior given in [RFC4090] for a PLR should apply.

The backup ingress SHOULD follow the control-options specified in the

INGRESS-PROTECTION object and the flags and specifications in the FAST-REROUTE object. This applies to providing a P2MP backup if the "P2MP backup" is set, a one-to-one backup if "one-to-one desired" is set, facility backup if the "facility backup desired" is set, and backup paths that support the desired bandwidth, and administrative-colors that are requested.

If multiple INGRESS-PROTECTION objects have been received via multiple PATH messages for the same LSP, then the most recent one that specified a Traffic-Descriptor sub-object MUST be the one used.

The backup ingress creates the appropriate forwarding state based on failure detection mode specified. For the Source-Detect and Next-Hop-Detect, this means that the backup ingress forwards any received identified traffic into the backup LSP tunnel(s) to the merge point(s). For the Backup-Detect and Backup-Source-Detect, this means that the backup ingress creates state to quickly determine the primary ingress has failed and switch to sending any received identified traffic into the backup LSP tunnel(s) to the merge point(s).

When the backup ingress sends a RESV message to the primary ingress, it should add an INGRESS-PROTECTION object into the message. It SHOULD set or clear the flags in the object to report "Ingress local protection available", "Ingress local protection in use", and "bandwidth protection".

If the backup ingress doesn't have a backup LSP tunnel to all the merge points, it SHOULD clear "Ingress local protection available". [Editor Note: It is possible to indicate the number or which are unprotected via a sub-object if desired.]

When the primary ingress fails, the backup ingress redirects the traffic from a source into the backup P2P LSPs or the backup P2MP LSP transmitting the traffic to the next hops of the primary ingress, where the traffic is merged into the protected LSP.

In this case, the backup ingress keeps the PATH message with the INGRESS\_PROTECTION object received from the primary ingress and the RESV message with the INGRESS\_PROTECTION object to be sent to the primary ingress. The backup ingress sets the "local protection in use" flag in the RESV message, indicating that the backup ingress is actively redirecting the traffic into the backup P2P LSPs or the backup P2MP LSP for locally protecting the primary ingress failure.

Note that the RESV message with this piece of information will not be sent to the primary ingress because the primary ingress has failed.

If the backup ingress has not received any PATH message from the primary ingress for an extended period of time (e.g., a cleanup timeout interval) and a confirmed primary ingress failure did not occur, then the standard RSVP soft-state removal SHOULD occur. The backup ingress SHALL remove the state for the PATH message from the primary ingress, and tear down the one-to-one backup LSPs for protecting the primary ingress if one-to-one backup is used or unbind the facility backup LSPs if facility backup is used.

When the backup ingress receives a PATH message from the primary ingress for locally protecting the primary ingress of a protected LSP, it checks to see if any critical information has been changed. If the next hops of the primary ingress are changed, the backup ingress SHALL update its backup LSP(s).

#### 6.3.1.1. Relay-Message Method

When the backup ingress receives a PATH message with the INGRESS-PROTECTION object, it examines the object to learn what traffic associated with the LSP and what ingress failure detection mode is being used. It determines the next-hops to be merged to by examining the Label-Routes sub-object in the object. If the Traffic-Descriptor sub-object isn't included, this object is considered "empty".

The backup ingress stores the PATH message received from the primary ingress, but does NOT forward it.

The backup ingress MUST respond with a RESV to the PATH message received from the primary ingress. If the INGRESS-PROTECTION object is not "empty", the backup ingress SHALL send the RESV message with the state indicating protection is available after the backup LSP(s) are successfully established.

#### 6.3.1.2. Proxy-Ingress Method

The backup ingress determines the next-hops to be merged to by collecting the set of the pair of (IPv4/IPv6 sub-object, Label sub-object) from the Record Route Object of each RESV that are closest to the top and not the Ingress router; this should be the second to the top pair. If a Label-Routes sub-object is included in the INGRESS-PROTECTION object, the included IPv4/IPv6 sub-objects are used to filter the set down to the specific next-hops where protection is desired. A RESV message must have been received before the Backup Ingress can create or select the appropriate backup LSP.

When the backup ingress receives a PATH message with the INGRESS-PROTECTION object, the backup ingress examines the object to learn what traffic associated with the LSP and what ingress failure

detection mode is being used. The backup ingress forwards the PATH message to the ingress node with the normal RSVP changes.

When the backup ingress receives a RESV message with the INGRESS-PROTECTION object, the backup ingress records an IMPLICIT-NULL label in the RRO. Then the backup ingress forwards the RESV message to the ingress node, which is acting for the proxy ingress.

#### 6.3.2. Backup Ingress Behavior in On-path Case

An LER as the backup ingress determines that it is on-path if one of its addresses is a next hop of the primary ingress and the primary ingress is not its next hop via checking the PATH message with the INGRESS\_PROTECTION object received from the primary ingress. The LER on-path sends the corresponding PATH messages without any INGRESS\_PROTECTION object to its next hops. It creates a number of backup P2P LSPs or a backup P2MP LSP from itself to the other next hops (i.e., the next hops other than the backup ingress) of the primary ingress. The other next hops are from the Label-Routes sub object.

It also creates a forwarding entry, which sends/multicasts the traffic from the source to the next hops of the backup ingress along the protected LSP when the primary ingress fails. The traffic is described by the Traffic-Descriptor.

After the forwarding entry is created, all the backup P2P LSPs or the backup P2MP LSP is up and associated with the protected LSP, the backup ingress sends the primary ingress the RESV message with the INGRESS\_PROTECTION object containing the state of the local protection such as "local protection available" flag set to one, which indicates that the primary ingress is locally protected.

When the primary ingress fails, the backup ingress sends/multicasts the traffic from the source to its next hops along the protected LSP and imports the traffic into each of the backup P2P LSPs or the backup P2MP LSP transmitting the traffic to the other next hops of the primary ingress, where the traffic is merged into protected LSP.

During the local repair, the backup ingress continues to send the PATH messages to its next hops as before, keeps the PATH message with the INGRESS\_PROTECTION object received from the primary ingress and the RESV message with the INGRESS\_PROTECTION object to be sent to the primary ingress. It sets the "local protection in use" flag in the RESV message.

### 6.3.3. Failure Detection

Failure detection happens much faster than RSVP, whether via a link-level notification or BFD. As discussed, there are different modes for detecting it. The backup ingress MUST have properly set up its forwarding state to either always forward the specified traffic into the backup LSP(s) for the Source-Detect and Next-Hop-Detect modes or to swap from discarding to forwarding when a failure is detected for the Backup-Source-Detect and Backup-Detect modes.

For facility backup LSPs, the correct inner MPLS label to use must be determined. For the ingress-proxy method, that MPLS label comes directly from the RRO of the RESV. For the relay-message method, that MPLS label comes from the Label-Routes sub-object in the non-empty INGRESS-PROTECTION object.

As described in [RFC4090], it is necessary to refresh the PATH messages via the backup LSP(s). The Backup Ingress MUST wait to refresh the backup PATH messages until it can accurately detect that the ingress node has failed. An example of such an accurate detection would be that the IGP has no bi-directional links to the ingress node and the last change was long enough in the past that changes should have been received (i.e., an IGP network convergence time or approximately 2-3 seconds) or a BFD session to the primary ingress' loopback address has failed and stayed failed after the network has reconverged.

As described in [RFC4090 Section 6.4.3], the backup ingress, acting as PLR, SHOULD modify - including removing any INGRESS-PROTECTION and FAST-REROUTE objects - and send any saved PATH messages associated with the primary LSP.

### 6.4. Merge Point Behavior

An LSR that is serving as a Merge Point may need to support the INGRESS-PROTECTION object and functionality defined in this specification if the LSP is ingress-protected where the failure scenario is Next-Hop-Detect. An LSR can determine that it must be a merge point if it is not the ingress, it is not the backup ingress (determined by examining the Backup Ingress Address (IPv4 or IPv6) sub-object in the INGRESS-PROTECTION object), and the PHOP is the ingress node.

In that case, when the LSR receives a PATH message with an INGRESS-PROTECTION object, the LSR MUST remove the INGRESS-PROTECTION object before forwarding on the PATH message. If the failure scenario specified is Next-Hop-Detect, the MP must connect up the fast-failure detection (as configured) to accepting backup traffic received from

the backup node. There are a number of different ways that the MP can enforce not forwarding traffic normally received from the backup node. For instance, first, any LSPs set up from the backup node should not be signaled with an IMPLICIT NULL label and second, the associated label for the ingress-protected LSP could be set to normally discard inside that context.

When the MP receives a RESV message whose matching PATH state had an INGRESS-PROTECTION object, the MP SHOULD add the INGRESS-PROTECTION object to the RESV message before forwarding it. The Backup PATH handling is as described in [RFC4090] and [RFC4875].

#### 6.5. Revertive Behavior

Upon a failure event in the (primary) ingress of a protected LSP, the protected LSP is locally repaired by the backup ingress. There are a couple of basic strategies for restoring the LSP to a full working path.

- Revert to Primary Ingress: When the primary ingress is restored, it re-signals each of the LSPs that start from the primary ingress. The traffic for every LSP successfully re-signaled is switched back to the primary ingress from the backup ingress.
- Global Repair by Backup Ingress: After determining that the primary ingress of an LSP has failed, the backup ingress computes a new optimal path, signals a new LSP along the new path, and switches the traffic to the new LSP.

##### 6.5.1. Revert to Primary Ingress

If "Revert to Primary Ingress" is desired for a protected LSP, the (primary) ingress of the LSP re-signals the LSP that starts from the primary ingress after the primary ingress restores. When the LSP is re-signaled successfully, the traffic is switched back to the primary ingress from the backup ingress and redirected into the LSP starting from the primary ingress.

It is possible that the Ingress failure was inaccurately detected, that the Ingress recovers before the Backup Ingress does Global Repair, or that the Ingress has the ability to take over an LSP based on receiving the associated RESVs.

If the ingress can resignal the PATH messages for the LSP, then the ingress can specify the "Revert to Ingress" control-option in the INGRESS-PROTECTION object. Doing so may cause a duplication of traffic while the Ingress starts sending traffic again before the Backup Ingress stops; the alternative is to drop traffic for a short

period of time.

Additionally, the Backup Ingress can set the "Revert To Ingress" control-option as a request for the Ingress to take over.

#### 6.5.2. Global Repair by Backup Ingress

When the backup ingress has determined that the primary ingress of the protected LSP has failed (e.g., via the IGP), it can compute a new path and signal a new LSP along the new path so that it no longer relies upon local repair. To do this, the backup ingress uses the same tunnel sender address in the Sender Template Object and uses the previously allocated second LSP-ID in the INGRESS-PROTECTION object of the PATH message as the LSP-ID of the new LSP. This allows the new LSP to share resources with the old LSP.

When the backup ingress has determined that the primary ingress of the protected LSP has failed (e.g., via the IGP), it can compute a new path and signal a new LSP along the new path so that it no longer relies upon local repair. To do this, the backup ingress uses the same tunnel sender address in the Sender Template Object and uses the previously allocated second LSP-ID in the INGRESS-PROTECTION object of the PATH message as the LSP-ID of the new LSP. This allows the new LSP to share resources with the old LSP. In addition, if the Ingress recovers, the Backup Ingress SHOULD send it RESVs with the INGRESS-PROTECTION object where either the "Force to Backup" or "Revert to Ingress" is specified. The Secondary LSP ID should be the unused LSP ID - while the LSP ID signaled in the RESV will be that currently active. The Ingress can learn from the RESVs what to signal. Even if the Ingress does not take over, the RESVs notify it that the particular LSP IDs are in use. The Backup Ingress can reoptimize the new LSP as necessary until the Ingress recovers. Alternately, the Backup Ingress can create a new LSP with no bandwidth reservation that duplicates the path(s) of the protected LSP, move traffic to the new LSP, delete the protected LSP, and then resignal the new LSP with bandwidth.

### 7. Security Considerations

In principle this document does not introduce new security issues. The security considerations pertaining to RFC 4090, RFC 4875 and other RSVP protocols remain relevant.

### 8. IANA Considerations

TBD

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Support for RSVP-TE in L3VPNs  
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Abstract

IP Virtual Private Networks (VPNs) provide connectivity between sites across an IP/MPLS backbone. These VPNs can be operated using BGP/MPLS and a single provider edge (PE) node may provide access to multiple customer sites belonging to different VPNs.

The VPNs may support a number of customer services including RSVP and RSVP-TE traffic. This document describes how to support RSVP-TE between customer sites when a single PE supports multiple VPNs and labels are not used to identify VPNs between PEs.

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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 [RFC2119].

## 1. Introduction

Service Providers would like to use BGP/MPLS IP-VPNs [RFC4364] to support connections between Customer Edge (CE) sites. As described in [RFC5824], these connections can be MPLS Traffic Engineered (TE) Label Switched Paths (LSPs) established using extensions to RSVP [RFC3209] for a number of different deployment scenarios. The requirements for supporting MPLS-TE LSP connections across BGP/MPLS IP-VPNs are documented in [RFC5824].

In order to establish a customer MPLS-TE LSP over a BGP/MPLS IP-VPN, it is necessary for the RSVP-TE control messages, including Path messages and Resv messages described in [RFC3209], to be appropriately handled by the Provider Edge (PE) routers. [RFC4364] allows RSVP messages sent within a VPN's context to be handled just like any other VPN data. In such a solution, the RSVP-TE component at a PE that sends messages toward a remote PE must process the messages in the context of the VPN and must ensure that the messages are correctly labelled. Similarly, when a message is received by a PE having been sent across the core, both labels to indicate the correct VPN context.

Implementation of the standards-based solution described in the previous paragraph is possible, but requires proper support on the PE. In particular, a PE must be able to process RSVP messages within the context of the appropriate VPN VRF. This may be achieved easily in some implementations, in others it is not so easy to achieved.

This document defines experimental formats and mechanisms that follows a different approach. The documented approach enables the VPN identifier to be carried in the RSVP-TE protocol message so that there is no requirement for label based VRF identification on the PE.

The experiment proposed by this document does not negate the label based approach supported by [RFC4364]. The experiment is intended to enable research into alternate methods of supporting RSVP-TE within VPNs.

## 2. Motivation



If multiple BGP/MPLS IP-VPNs are supported at the same PE, new RSVP-TE extensions are required so that RSVP-TE control messages from the CEs can be appropriately handled by the PE.

## 2.1 Network Example

Figure 1 (Customer MPLS TE LSPs in the context of BGP/MPLS IP-VPNs) shows two VPNs supported by a core IP/MPLS network. Both VPNs have customer sites supported by the two PEs shown in the figure. The customer sites operate MPLS-TE LSPs.

Here, we make the following set of assumptions.

1. VPN1 and VPN2 are for different customers.
2. CE1 and CE3 are head-end routers.
3. CE2 and CE4 are tail-end routers.
4. The same address (e.g., 192.0.2.1) is assigned at CE2 and CE4.

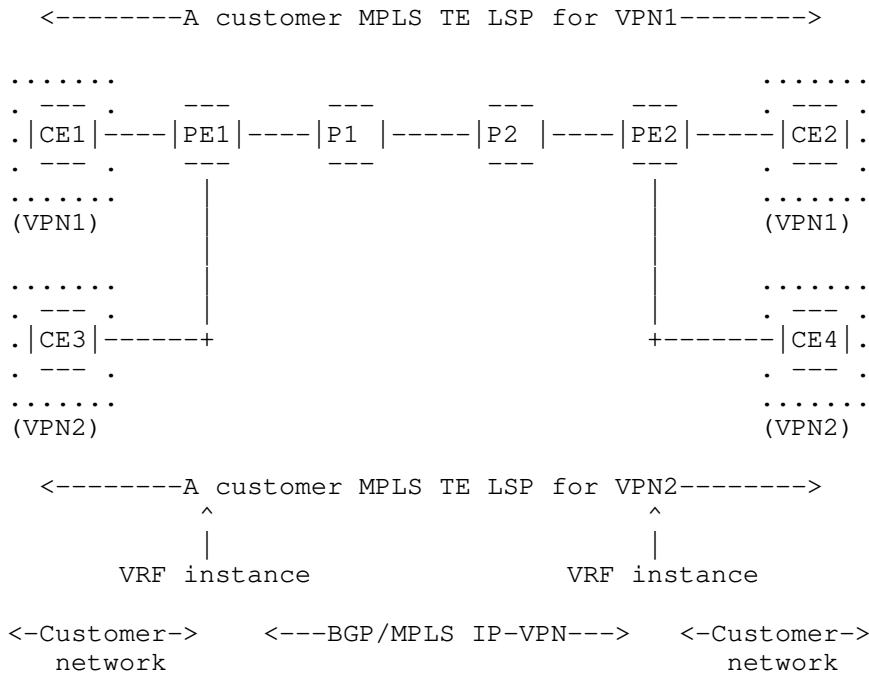


Figure 1: Customer MPLS TE LSPs in the context of BGP/MPLS IP-VPNs

Consider that customers in VPN1 and VPN2 would like to establish a customer MPLS TE LSPs between their sites (i.e., between CE1 and CE2, and between CE3 and CE4). In this situation the following RSVP-TE Path messages would be sent:

1. CE1 would send a Path message to PE1 to establish the MPLS TE LSP (VPN1) between CE1 and CE2.
2. CE3 would also send a Path message to PE1 to establish the MPLS TE LSP (VPN2) between CE1 and CE2.

After receiving each Path messages, PE1 can identify the customer context for each Path message from the incoming interface over which the message was received. PE1 forwards the messages to PE2 using the routing mechanisms described in [RFC4364] and [RFC4659].

When the Path messages are received at PE2, that node needs to distinguish the messages and determine which applies to VPN1 and which to VPN2 so that the right forwarding state can be established and so that the messages can be passed on to the correct CE. Although the messages will arrive at PE2 with an MPLS label that identifies the VPN, the messages will be delivered to the RSVP-TE component on PE2 and the context of the core VPN LSP (i.e., the label) will be lost. Some RSVP-TE protocol mechanism is therefore needed to embed the VPN identifier within the RSVP-TE message.

Similarly, Resv messages sent from PE2 to PE1 need an RSVP-TE mechanisms to assign them to the correct VPN.

### 3. Protocol Extensions and Procedures

This section provides the additional RSVP-TE objects to meet the requirements described in Section 2. These are new variants of the SESSION, SENDER\_TEMPLATE and FILTERSPEC objects. These new objects will act as identifiers and allow PEs to The new object types are defined in Section 3.1, and the specific procedure is described in Section 3.2.

#### 3.1 Object Definitions

##### 3.1.1 LSP\_TUNNEL\_VPN-IPv4 and LSP\_TUNNEL\_VPN-IPv6 SESSION Object

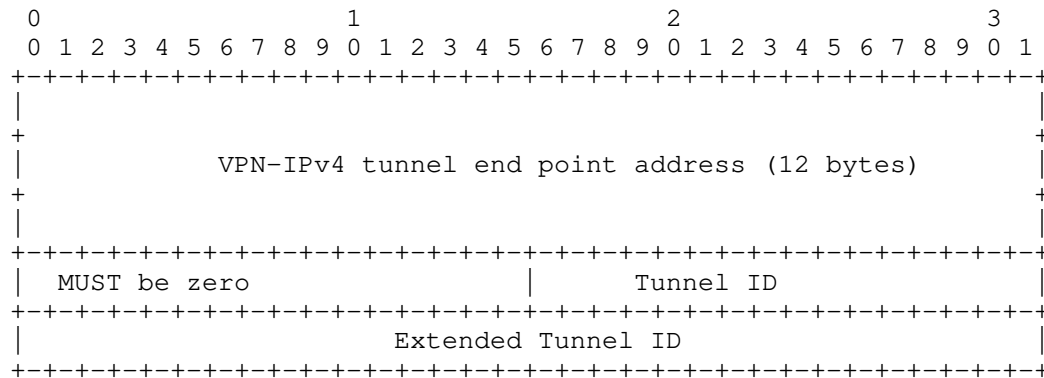
The LSP\_TUNNEL\_VPN-IPv4 (or VPN-IPv6) SESSION object appears in RSVP-TE messages that ordinarily contain a SESSION object and are sent between ingress PE and egress PE in either direction. The object MUST NOT be included in any RSVP-TE message that is sent outside of the provider's backbone.

The LSP\_TUNNEL\_VPN-IPv6 SESSION object is analogous to the LSP\_TUNNEL\_VPN-IPv4 SESSION object, using a VPN-IPv6 address ([RFC4659]) instead of a VPN-IPv4 address ([RFC4364]).

This experimentation will be carried out using private Class Types. These can be identified in this document as C-Type=EXPn:

Experimenters MUST ensure that there is no conflict between the private Class Types used for this experiment and other Class Types used by the PEs.

```
Class = SESSION, LSP_TUNNEL_VPN-IPv4 C-Type = EXP1
```

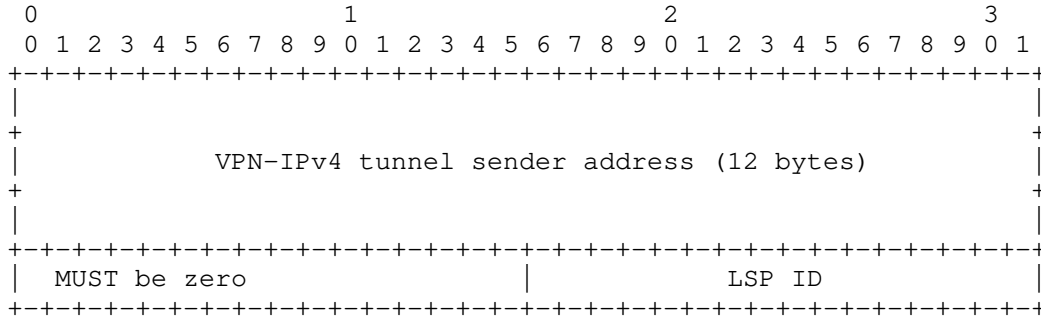


[illegible]

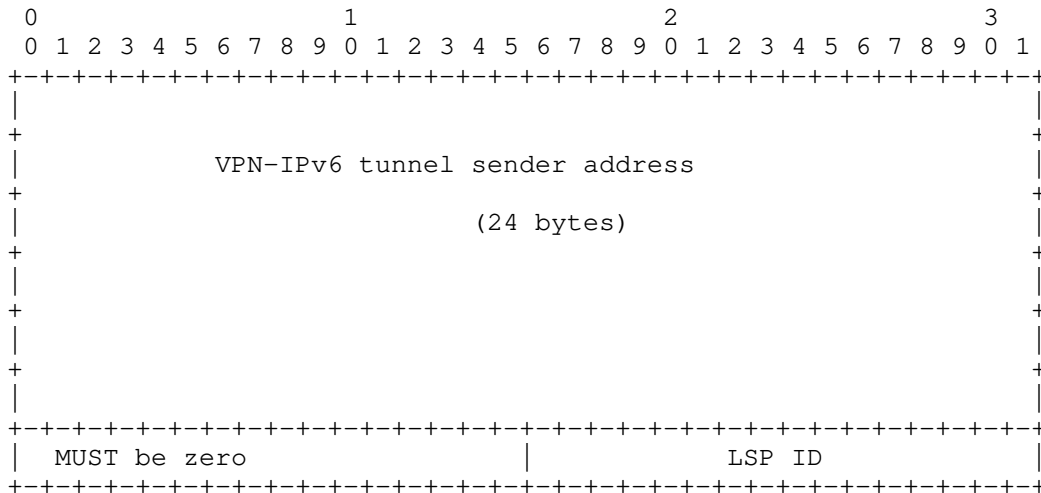
The Tunnel ID and Extended Tunnel ID are identical to the same fields in the LSP\_TUNNEL\_IPv4 and LSP\_TUNNEL\_IPv6 SESSION objects as per [RFC3209].

The LSP\_TUNNEL\_VPN-IPv4 (or VPN-IPv6) SENDER\_TEMPLATE object appears in RSVP-TE messages that ordinarily contain a SENDER\_TEMPLATE object and are sent between ingress PE and egress PE in either direction (such as Path, PathError, and PathTear). The object MUST NOT be included in any RSVP-TE messages that are sent outside of the provider's backbone. The format of the object is as follows:

Class = SENDER\_TEMPLATE, LSP\_TUNNEL\_VPN-IPv4 C-Type = EXP3



```
Class = SENDER_TEMPLATE, LSP_TUNNEL_VPN-IPv6 C-Type = EXP4
```



The VPN-IPv4 tunnel sender address (respectively, VPN-IPv6 tunnel sender address) field contains an address of the VPN-IPv4 (respectively, VPN-IPv6) address family encoded as specified in [RFC4364] (respectively, [RFC4659]).

The LSP ID is identical to the LSP ID field in the LSP\_TUNNEL\_IPv4 and LSP\_TUNNEL\_IPv6 SENDER\_TEMPLATE objects as per [RFC3209].

### 3.1.3 LSP\_TUNNEL\_VPN-IPv4 and LSP\_TUNNEL\_VPN-IPv6 FILTER\_SPEC Objects

The LSP\_TUNNEL\_VPN-IPv4 (or VPN-IPv6) FILTER\_SPEC object appears in RSVP-TE messages that ordinarily contain a FILTER\_SPEC object and are sent between ingress PE and egress PE in either direction (such as Resv, ResvError, and ResvTear). The object MUST NOT be included in any RSVP-TE messages that are sent outside of the provider's backbone.

Class = FILTER SPECIFICATION, LSP\_TUNNEL\_VPN-IPv4 C-Type = EXP5

The format of the LSP\_TUNNEL\_VPN-IPv4 FILTER\_SPEC object is identical to the LSP\_TUNNEL\_VPN-IPv4 SENDER\_TEMPLATE object.

Class = FILTER SPECIFICATION, LSP\_TUNNEL\_VPN-IPv6 C-Type = EXP6

The format of the LSP\_TUNNEL\_VPN-IPv6 FILTER\_SPEC object is identical to the LSP\_TUNNEL\_VPN-IPv6 SENDER\_TEMPLATE object.

#### 3.1.4 VPN-IPv4 and VPN-IPv6 RSVP\_HOP Objects

The format of the VPN-IPv4 and VPN-IPv6 RSVP\_HOP objects are identical to objects described in [RFC6016].

### 3.2 Handling

It assumes that ingress PEs and egress PEs in the context of BGP/MPLS IP-VPNs have RSVP-TE capabilities.

#### 3.2.1 Path Message Processing at Ingress PE

When a Path message arrives at the ingress PE (PE1 in Figure 1), the PE needs to establish suitable Path state and forward the Path message on to the egress PE (PE2 in Figure 1). In this section we described the message handling process at the ingress PE.

1. CE1 would send a Path message to PE1 to establish the MPLS TE LSP (VPN1) between CE1 and CE2. The Path message is addressed to the eventual destination (the receiver at the remote customer site) and carries the IP Router Alert option, in accordance with [RFC2205]. The ingress PE must recognize the router alert, intercept these messages and process them as RSVP-TE signalling messages.
2. When the ingress PE receives a Path message from a CE that is addressed to the receiver, the VRF that is associated with the incoming interface can be identified (this step does not deviate from current behavior).
3. The tunnel end point address of the receiver is looked up in the appropriate VRF, and the BGP Next-Hop for that tunnel end point address is identified. The next-hop is the egress PE.
4. A new LSP\_TUNNEL\_VPN-IPv4/VPN-IPv6 SESSION object is constructed, containing the Route Distinguisher (RD) that is part of the VPN-IPv4/VPN-IPv6 route prefix for this tunnel end point address, and the IPv4/IPv6 tunnel end point address from the original SESSION object.

5. A new LSP\_TUNNEL\_VPN-IPv4/IPv6 SENDER\_TEMPLATE object is constructed, with the original IPv4/IPv6 tunnel sender address from the incoming SENDER\_TEMPLATE plus the RD that is used by the PE to advertise the prefix for the customers VPN.
6. A new Path message is sent containing all the objects from the original Path message, replacing the original SESSION and SENDER\_TEMPLATE objects with the new LSP\_TUNNEL\_VPN-IPv4/VPN-IPv6 type objects. This Path message is sent directly to the egress PE (the next hop as being looked up in step 3 above) without IP Router Alert.

### 3.2.2 Path Message Processing at Egress PE

In this section we described the message handling process at the egress PE.

1. When a Path message arrives at the egress PE (PE2 in Figure 1) , it is addressed to the PE itself, and is handed to RSVP for processing.
2. The router extracts the RD and IPv4/IPv6 address from the LSP\_TUNNEL\_VPN-IPv4/VPN-IPv6 SESSION object, and determines the local VRF context by finding a matching VPN-IPv4 prefix with the specified RD that has been advertised by this router into BGP.
3. The entire incoming RSVP message, including the VRF information, is stored as part of the Path state.
4. The egress PE can now construct a Path message which differs from the Path message it received in the following ways:
  - a. Its tunnel end point address is the IP address extracted from the SESSION object;
  - b. The SESSION and SENDER\_TEMPLATE objects are converted back to IPv4-type/IPv6-type by discarding the attached RD;
  - c. The RSVP\_HOP object contains the IP address of the outgoing interface of the egress PE and an Logical Interface Handle (LIH), as per normal RSVP processing.
5. The egress PE then sends the Path message on towards its tunnel end point address over the interface identified above. This Path message carries the IP Router-Alert option as required by [RFC2205].

### 3.2.3 Resv Processing at Egress PE

When a receiver at the customer site originates a Resv message for the session, normal RSVP procedures apply until the Resv, making its way back towards the sender, arrives at the "egress" PE (it is "egress" with respect to the direction of data flow, i.e. PE2 in figure 1). On arriving at PE2, the SESSION and FILTER\_SPEC objects in the Resv, and the VRF in which the Resv was received, are used to find the matching Path state stored previously.

The PE constructs a Resv message to send to the RSVP HOP stored in the Path state, i.e., the ingress PE (PE1 in Figure 1). The LSP TUNNEL IPv4/IPv6 SESSION object is replaced with the same LSP\_TUNNEL\_VPN-IPv4/VPN-IPv6 SESSION object received in the Path. The LSP TUNNEL IPv4/IPv6 FILTER\_SPEC object is replaced with a LSP\_TUNNEL\_VPN-IPv4/VPN-IPv6 FILTER\_SPEC object, which copies the VPN-IPv4/VPN-IPv6 address from the LSP TUNNEL SENDER\_TEMPLATE received in the matching Path message.

The Resv message MUST be addressed to the IP address contained within the RSVP\_HOP object in the Path message.

#### 3.2.4 Resv Processing at Ingress PE

Upon receiving a Resv message at the ingress PE (with respect to data flow, i.e. PE1 in Figure 1), the PE determines the local VRF context and associated Path state for this Resv by decoding the received SESSION and FILTER\_SPEC objects. It is now possible to generate a Resv message to send to the appropriate CE. The Resv message sent to the ingress CE will contain LSP TUNNEL IPv4/IPv6 SESSION and LSP TUNNEL FILTER\_SPEC objects, derived from the appropriate Path state.

#### 3.2.5 Other RSVP Messages

Processing of other RSVP messages, i.e., PathError, PathTear, ResvError, ResvTear, and ResvConf message in general follows the rules defined in [RFC2205], with additional rules that MUST be observed for messages transmitted within the VPN, i.e., between the PEs as follows:

- o The SESSION, SENDER\_TEMPLATE, and FILTER\_SPEC objects MUST be converted from LSP\_TUNNEL\_IPv4/LSP\_TUNNEL\_IPv6 [RFC3209] to LSP\_TUNNEL\_VPN\_IPv4/LSP\_TUNNEL\_VPN\_IPv6 form, respectively, and back in the same manner as described above for Path and Resv messages.
- o The appropriate type of RSVP\_HOP object (VPN-IPv4 or VPN-IPv6) MUST be used as described in Section 8.4 of [RFC6016].
- o Depending on the type of RSVP\_HOP object received from the neighbor, the message MUST be MPLS encapsulated or IP encapsulated.



- o The matching state and VRF MUST be determined by decoding the corresponding RD and IPv4 (respectively, IPv6) address in the SESSION and FILTER\_SPEC objects.
- o The message MUST be directly addressed to the appropriate PE, without using the Router Alert Option.

#### 4. Management Considerations

MPLS-TE based BGP/MPLS IP-VPNs are based on a peer model. If an operator would like to configure a new site to an existing VPN configuration of both the CE router and the attached PE router is required. The operator is not required to modify the configuration of PE routers connected to other sites or modify the configuration of other VPNs.

##### 4.1 Impact on Network Operation

It is expected that the use of the extensions specified in this document will not significantly increase the level of operational traffic.

Furthermore, the additional extensions described in this document will have no impact on the operation of existing resiliency mechanisms available within MPLS-TE.

#### 5. Security Considerations

This document defines RSVP-TE extensions for BGP/MPLS IP-VPNs. The general security issues for RSVP-TE are described in [RFC3209], [RFC4364] addresses the specific security considerations of BGP/MPLS VPNs. General security considerations for MPLS are described in [RFC5920].

In order to secure the control plane, techniques such as TCP Authentication Option (TCP-AO) [RFC5925] MAY be used to authenticate BGP messages.

To ensure the integrity of an RSVP request, the RSVP Authentication mechanisms defined in [RFC2747], updated by [RFC3097], SHOULD be used.

#### 6. IANA Considerations

This document makes no request for IANA actions.

#### 7. References

## 7.1 Normative References

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