             RSVP Extensions for Reoptimization of Loosely Routed
     Point-to-Multipoint Traffic Engineering Label Switched Paths (LSPs)

Abstract

   The reoptimization of a Point-to-Multipoint (P2MP) Traffic
   Engineering (TE) Label Switched Path (LSP) may be triggered based on
   the need to reoptimize an individual source-to-leaf (S2L) sub-LSP or
   a set of S2L sub-LSPs, both using the Sub-Group-based reoptimization
   method, or the entire P2MP-TE LSP tree using the Make-Before-Break
   (MBB) method. This document discusses the application of the
   existing mechanisms for path reoptimization of loosely routed Point-
   to-Point (P2P) TE LSPs to the P2MP-TE LSPs, identifies issues in
   doing so, and defines procedures to address them. When reoptimizing
   a large number of S2L sub-LSPs in a tree using the Sub-Group-based
   reoptimization method, the S2L sub-LSP descriptor list may need to be
   semantically fragmented. This document defines the notion of a
   fragment identifier to help recipient nodes unambiguously reconstruct
   the fragmented S2L sub-LSP descriptor list.

Status of This Memo

   This is an Internet Standards Track document.

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   received public review and has been approved for publication by the
   Internet Engineering Steering Group (IESG). Further information on
   Internet Standards is available in Section 2 of RFC 7841.

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1. Introduction

   This document defines Resource Reservation Protocol - Traffic
   Engineering (RSVP-TE) [RFC2205] [RFC3209] signaling extensions for
   reoptimizing loosely routed Point-to-Multipoint (P2MP) Traffic
   Engineering (TE) Label Switched Paths (LSPs) [RFC4875] in a
   Multiprotocol Label Switching (MPLS) or Generalized MPLS (GMPLS)
   [RFC3473] network.

   A P2MP-TE LSP is comprised of one or more source-to-leaf (S2L)
   sub-LSPs. A loosely routed P2MP-TE S2L sub-LSP is defined as one
   whose path does not contain the full explicit route identifying each
   node along the path to the egress node at the time of its signaling
   by the ingress node. Such an S2L sub-LSP is signaled with no
   Explicit Route Object (ERO) [RFC3209], with an ERO that contains at
   least one "loose next hop", or with an ERO that contains an abstract
   node that identifies more than one node. This is often the case with
   inter-domain P2MP-TE LSPs where a Path Computation Element (PCE) is
   not used [RFC5440].

   As per [RFC4875], an ingress node may reoptimize the entire P2MP-TE
   LSP tree by re-signaling all its S2L sub-LSPs using the
   Make-Before-Break (MBB) method, or it may reoptimize an individual
   S2L sub-LSP or a set of S2L sub-LSPs, i.e., an individual destination
   or a set of destinations, both using the Sub-Group-based
   reoptimization method.

   [RFC4736] defines an RSVP signaling procedure for reoptimizing the
   path(s) of loosely routed Point-to-Point (P2P) TE LSP(s). The
   mechanisms listed in [RFC4736] include a method for the ingress node
   to trigger a new path re-evaluation request and a method for the
   midpoint node to send a notification regarding the availability of a
   preferred path. This document discusses the application of those
   mechanisms to the reoptimization of loosely routed P2MP-TE LSPs,
   identifies issues in doing so, and defines procedures to address
   them.

   For reoptimizing a group of S2L sub-LSPs in a tree using the
   Sub-Group-based reoptimization method, an S2L sub-LSP descriptor list
   can be used to signal one or more S2L sub-LSPs in an RSVP message.
   This RSVP message may need to be semantically fragmented when a large
   number of S2L sub-LSPs are added to the descriptor list. This
   document defines the notion of a fragment identifier to help
   recipient nodes unambiguously reconstruct the fragmented S2L sub-LSP
   descriptor list.

2. Conventions Used in This Document

2.1. Key Word Definitions

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

2.2. Abbreviations

   ABR: Area Border Router.

   ERO: Explicit Route Object.

   LSP: Label Switched Path.

   LSR: Label Switching Router.

   RRO: Record Route Object.

   S2L sub-LSP: Source-to-leaf sub-LSP.

   TE LSP: Traffic Engineering LSP.

2.3. Terminology

   This document defines the following terms:

   o Ingress node: Head-end / source node of the TE LSP.

   o Egress node: Tail-end / destination node of the TE LSP.

   It is assumed that the reader is also familiar with the terminology
   in [RFC4736] and [RFC4875].

3. Overview

   [RFC4736] defines RSVP signaling extensions for reoptimizing loosely
   routed P2P TE LSPs as follows:

   o A midpoint LSR that expands loose next hop(s) sends a solicited or
      unsolicited PathErr with Notify error code 25 (as defined in
      [RFC3209]), with sub-code 6 to indicate "Preferable Path Exists"
      to the ingress node.

   o An ingress node triggers a path re-evaluation request at all
      midpoint LSRs that expand loose next hop(s) by setting the "Path
      Re-evaluation Request" flag (0x20) in the SESSION_ATTRIBUTES
      object in the Path message.

   o The ingress node, upon receiving this PathErr with the Notify
      error code (either solicited or unsolicited), initiates the
      reoptimization of the LSP, using the MBB method with a different
      LSP-ID.

   The following sections discuss the issues that may arise when
   applying the mechanisms defined in [RFC4736] for reoptimizing loosely
   routed P2MP-TE LSPs.

3.1. Loosely Routed Inter-domain P2MP-TE LSP Tree

   An example of a loosely routed inter-domain P2MP-TE LSP tree is shown
   in Figure 1. In this example, the P2MP-TE LSP tree consists of three
   S2L sub-LSPs, to destinations (i.e., leafs) R10, R11, and R12 from
   the ingress node (i.e., source) R1. Nodes R2 and R5 are branch
   nodes, and nodes ABR3, ABR4, ABR7, ABR8, and ABR9 are ABRs. For the
   S2L sub-LSP to destination R10, nodes ABR3, ABR7, and R10 are defined
   as loose next hops. For the S2L sub-LSP to destination R11, nodes
   ABR3, ABR8, and R11 are defined as loose next hops. For the S2L
   sub-LSP to destination R12, nodes ABR4, ABR9, and R12 are defined as
   loose next hops.

```
          <--area1--><--area0--><-area2->

                                ABR7---R10
                               /
                              /
                    ABR3---R5
                   /         \
                  /           \
             R1---R2           ABR8---R11
                  \
                   \
                    ABR4---R6
                              \
                               \
                                ABR9---R12
```
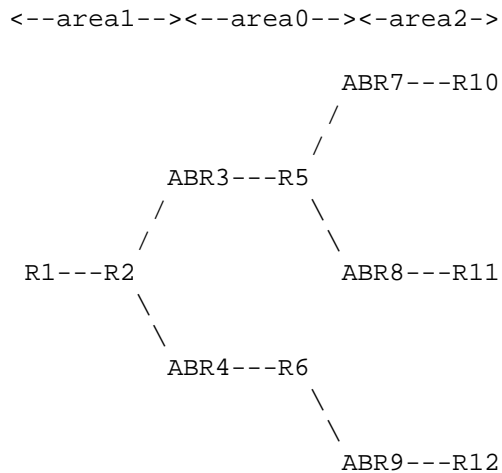
        Figure 1: Example of Loosely Routed Inter-domain P2MP-TE LSP Tree

3.2. Existing Mechanism for Tree-Based P2MP-TE LSP Reoptimization

   The mechanisms defined in [RFC4736] can be easily applied to trigger
   the reoptimization of an individual S2L sub-LSP or a group of S2L
   sub-LSPs. However, to apply those mechanisms for triggering the
   reoptimization of a P2MP-TE LSP tree, an ingress node needs to send
   path re-evaluation requests on all (typically hundreds) of the
   S2L sub-LSPs, and the midpoint LSR needs to send PathErrs with the
   Notify error code for all S2L sub-LSPs. Such mechanisms may lead to
   the following issues:

   o A midpoint LSR that expands loose next hop(s) may have to
      accumulate the received path re-evaluation request(s) for all S2L
      sub-LSPs (e.g., by using a wait timer) and interpret them as a
      reoptimization request for the whole P2MP-TE LSP tree. Otherwise,
      a midpoint LSR may prematurely send a "Preferable Path Exists"
      notification for one S2L sub-LSP or a subset of S2L sub-LSPs.

   o Similarly, the ingress node may have to heuristically determine
      when to perform P2MP-TE LSP tree reoptimization and when to
      perform S2L sub-LSP reoptimization. For example, an
      implementation may choose to delay reoptimization long enough to
      allow all PathErrs to be received. Such timer-based procedures
      may produce undesired results.

   o The ingress node that receives (un)solicited PathErr(s) with the
      Notify error code for one or more individual S2L sub-LSPs may
      prematurely start reoptimizing the subset of S2L sub-LSPs.
      However, as mentioned in [RFC4875], Section 14.2, such a
      Sub-Group-based reoptimization procedure may result in data

duplication that can be avoided if the entire P2MP-TE LSP tree is
reoptimized using the MBB method with a different LSP-ID,
especially if the ingress node eventually receives PathErrs with
the Notify error code for all S2L sub-LSPs of the P2MP-TE
LSP tree.

In order to address the above-mentioned issues and to align the
reoptimization of P2MP-TE LSPs with P2P LSPs [RFC4736], a mechanism
is needed to trigger the reoptimization of the LSP tree by
re-signaling all S2L sub-LSPs with a different LSP-ID. To meet this
requirement, this document defines RSVP-TE signaling extensions for
the ingress node to trigger the re-evaluation of the P2MP LSP tree on
every hop that has a next hop defined as a loose or abstract hop for
one or more S2L sub-LSP paths, and a midpoint LSR to signal to the
ingress node that a preferable LSP tree exists (compared to the
current path) or that the whole P2MP-TE LSP must be reoptimized
(because of maintenance required on the TE LSP path) (see
Section 4.1).

3.3. Existing Mechanism for Sub-Group-Based P2MP-TE LSP Reoptimization

Applying the procedures discussed in [RFC4736] in conjunction with
the Sub-Group-based reoptimization procedures ([RFC4875],
Section 14.2), an ingress node MAY trigger path re-evaluation
requests for a set of S2L sub-LSPs in a single Path message using an
S2L sub-LSP descriptor list. Similarly, a midpoint LSR may send a
PathErr with Notify error code 25 and sub-code 6 ("Preferable Path
Exists") containing a list of S2L sub-LSPs transiting through the LSR
using an S2L sub-LSP descriptor list to notify the ingress node.
This method can be used for reoptimizing a sub-group of S2L sub-LSPs
within an LSP tree using the same LSP-ID. This method can alleviate
the scaling issue associated with sending RSVP messages for
individual S2L sub-LSPs. However, this procedure can lead to the
following issues when used to reoptimize the LSP tree:

o A Path message that is intended to carry the path re-evaluation
   request as defined in [RFC4736] with a full list of S2L sub-LSPs
   in an S2L sub-LSP descriptor list will be decomposed at branching
   LSRs, and only a subset of the S2L sub-LSPs that are routed over
   the same next hop will be added in the descriptor list of the Path
   message propagated to downstream midpoint LSRs. Consequently,
   when a preferable path exists at such midpoint LSRs, the PathErr
   with the Notify error code can only include the subset of S2L
   sub-LSPs traversing the LSR. In this case, at the ingress node
   there is no way to distinguish which mode of reoptimization to
   invoke, i.e., Sub-Group-based reoptimization using the same LSP-ID
   or tree-based reoptimization using a different LSP-ID.

   o An LSR may semantically fragment a large RSVP message (when a
      combined message may not be large enough to fit all S2L sub-LSPs).
      In this case, the ingress node may receive multiple PathErrs with
      subsets of S2L sub-LSPs in each (due to either the combined Path
      message getting fragmented or the combined PathErr message getting
      fragmented) and would require additional logic to determine how to
      reoptimize the LSP tree (for example, waiting for some time to
      aggregate all possible PathErr messages before taking an action).
      When fragmented, RSVP messages may arrive out of order, and the
      receiver has no way of knowing the beginning and end of the S2L
      sub-LSP list.

   In order to address the above-mentioned issues caused by semantic
   fragmentation of an RSVP message, this document defines a new
   fragment identifier object for the S2L sub-LSP descriptor list when
   combining a large number of S2L sub-LSPs in an RSVP message (see
   Section 4.2).

4. Signaling Extensions for Loosely Routed P2MP-TE LSP Reoptimization

4.1. Tree-Based Reoptimization

   To evaluate a P2MP-TE LSP tree on midpoint LSRs that expand loose
   next hop(s), an ingress node MAY send a Path message with the
   "P2MP-TE Tree Re-evaluation Request" flag set (bit number 14 in the
   Attribute Flags TLV) as defined in this document. The ingress node
   selects one of the S2L sub-LSPs of the P2MP-TE LSP tree transiting a
   midpoint LSR to trigger the re-evaluation request. The ingress node
   MAY send a re-evaluation request to each border LSR on the path of
   the LSP tree.

   A midpoint LSR that expands loose next hop(s) for one or more S2L
   sub-LSP paths does the following upon receiving a Path message with
   the "P2MP-TE Tree Re-evaluation Request" flag set:

   o The midpoint LSR MUST check for a preferable P2MP-TE LSP tree by
      re-evaluating all S2L sub-LSPs that are expanded paths of the
      loose next hops of the P2MP-TE LSP.

   o If a preferable P2MP-TE LSP tree is found, the midpoint LSR MUST
      send to the ingress node an RSVP PathErr with Notify error code 25
      [RFC3209] and sub-code 13 ("Preferable P2MP-TE Tree Exists)" as
      defined in this document. The midpoint LSR, in turn, SHOULD NOT
      propagate the "P2MP-TE Tree Re-evaluation Request" flag in the
      subsequent RSVP Path messages sent downstream for the re-evaluated
      P2MP-TE LSP.

   o If no preferable tree for P2MP-TE LSPs can be found, the midpoint
      LSR that expands loose next hop(s) for one or more S2L sub-LSP
      paths MUST propagate the request downstream by setting the
      "P2MP-TE Tree Re-evaluation Request" flag in the LSP_ATTRIBUTES
      object of the RSVP Path message.

   A midpoint LSR MAY send an unsolicited PathErr with the Notify error
   code and the "Preferable P2MP-TE Tree Exists" sub-code to the ingress
   node to notify the ingress node of a preferred P2MP-TE LSP tree when
   it determines that it exists. In this case, the midpoint LSR that
   expands loose next hop(s) for one or more S2L sub-LSP paths selects
   one of the S2L sub-LSPs of the P2MP-TE LSP tree to send this PathErr
   message to the ingress node. The midpoint LSR SHOULD consider how
   frequently it chooses to send such a PathErr, considering that both
   (1) a PathErr may be lost during its transit to the ingress node and
   (2) the ingress node may choose not to reoptimize the LSP when such a
   PathErr is received.

   The sending of an RSVP PathErr with the Notify error code and the
   "Preferable P2MP-TE Tree Exists" sub-code to the ingress node
   notifies the ingress node of the existence of a preferable P2MP-TE
   LSP tree, and upon receiving this PathErr, the ingress node SHOULD
   trigger the reoptimization of the LSP, using the MBB method with a
   different LSP-ID.

4.2. Sub-Group-Based Reoptimization Using Fragment Identifier

   It might be preferable, as per [RFC4875], to reoptimize the entire
   P2MP-TE LSP by re-signaling all of its S2L sub-LSPs (Section 14.1
   ("Make-before-Break") in [RFC4875]) or to reoptimize an individual
   S2L sub-LSP or a group of S2L sub-LSPs, i.e., an individual
   destination or a group of destinations (Section 14.2
   ("Sub-Group-Based Re-Optimization") in [RFC4875]), both using the
   same LSP-ID. For loosely routed S2L sub-LSPs, this can be achieved
   by using the procedures defined in [RFC4736] to reoptimize one or
   more S2L sub-LSPs of the P2MP-TE LSP.

   An ingress node may trigger path re-evaluation requests using the
   procedures defined in [RFC4736] for a set of S2L sub-LSPs by
   combining multiple Path messages using an S2L sub-LSP descriptor list
   [RFC4875]. An S2L sub-LSP descriptor list is created using a series
   of S2L_SUB_LSP objects as defined in [RFC4875]. Similarly, a
   midpoint LSR may send a PathErr with Notify error code 25 and
   sub-code 6 ("Preferable Path Exists") containing a list of S2L
   sub-LSPs transiting through the LSR using an S2L sub-LSP descriptor
   list to notify the ingress node of preferable paths available.

The S2L_SUB_LSP_FRAG object defined in this document is optional,
with the following exceptions:

o As per [RFC4875], Section 5.2.3 ("Transit Fragmentation of Path
   State Information"), when a Path message is not large enough to
   fit all S2L sub-LSPs in the descriptor list, an LSR may
   semantically fragment the message. In this case, the LSR MUST add
   the S2L_SUB_LSP_FRAG object defined in this document for each
   fragment in the S2L sub-LSP descriptor to be able to rebuild the
   list from the received fragments that may arrive out of order.

o In any other situation where an RSVP message needs to be
   fragmented, an LSR MUST add the S2L_SUB_LSP_FRAG object for each
   fragment in the S2L sub-LSP descriptor.

A midpoint LSR SHOULD wait to accumulate all S2L sub-LSPs before
attempting to re-evaluate a preferable path when a Path message for
"Path Re-evaluation Request" is received with the S2L_SUB_LSP_FRAG
object. If a midpoint LSR does not receive all fragments of the Path
message (for example, when fragments are lost) within a configurable
time interval, it SHOULD trigger the re-evaluation of all S2L
sub-LSPs of the P2MP-TE LSP transiting on the node. A midpoint LSR
MUST receive at least one fragment of the Path message to trigger
this behavior.

An ingress node SHOULD wait to accumulate all S2L sub-LSPs before
attempting to trigger reoptimization when a PathErr with the Notify
error code and the "Preferable Path Exists" sub-code is received with
an S2L_SUB_LSP_FRAG object. If an ingress node does not receive all
fragments of the PathErr message (for example, when fragments are
lost) within a configurable time interval, it SHOULD trigger the
reoptimization of all S2L sub-LSPs of the P2MP-TE LSP transiting on
the midpoint node that had sent the PathErr message. An ingress node
MUST receive at least one fragment of the PathErr message to trigger
this behavior.

The S2L_SUB_LSP_FRAG object defined in this document has a wider
applicability in addition to the P2MP-TE LSP reoptimization. It can
also be used (in Path and Resv messages) to set up a new P2MP-TE LSP
and to send other PathErr messages as well as Path Tear and Resv Tear
messages for a set of S2L sub-LSPs. This is outside the scope of
this document.

5. Message and Object Definitions

5.1. "P2MP-TE Tree Re-evaluation Request" Flag

   In order to trigger a tree re-evaluation request, a new flag in the
   Attribute Flags TLV of the LSP_ATTRIBUTES object [RFC5420] is defined
   by this document:

      Bit Number 14: "P2MP-TE Tree Re-evaluation Request" flag

   The "P2MP-TE Tree Re-evaluation Request" flag is meaningful in a Path
   message of a P2MP-TE S2L sub-LSP and is inserted by the ingress node
   using the message format defined in [RFC6510].

5.2. "Preferable P2MP-TE Tree Exists" Path Error Sub-code

   In order to indicate to an ingress node that a preferable P2MP-TE LSP
   tree exists, the following new sub-code for PathErr messages with
   Notify error code 25 [RFC3209] is defined by this document:

      Sub-code 13: "Preferable P2MP-TE Tree Exists" sub-code

   When a preferable path for a P2MP-TE LSP tree exists, the midpoint
   LSR sends a solicited or unsolicited "Preferable P2MP-TE Tree Exists"
   sub-code with a PathErr message with Notify error code 25 to the
   ingress node of the P2MP-TE LSP.

5.3. Fragment Identifier for S2L Sub-LSP Descriptor

   The S2L_SUB_LSP object [RFC4875] identifies a particular S2L sub-LSP
   belonging to the P2MP-TE LSP. An S2L sub-LSP descriptor list is
   created using a series of S2L_SUB_LSP objects as defined in
   [RFC4875]. The RSVP message may need to be semantically fragmented
   [RFC4875] due to a large number of S2L sub-LSPs added in the
   descriptor list, and such fragments may be received out of order. To
   be able to rebuild the fragmented S2L sub-LSP descriptor list
   correctly, the following object is defined to identify the fragments:

   S2L_SUB_LSP_FRAG: Class Number 204

```
    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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |          Length (8 bytes)     | Class Num 204 |   C-Type 1    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |           Fragment ID         | Fragments Tot.| Fragment Num. |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Fragment ID: 16-bit integer in the range of 1 to 65535.

   This value is incremented for each new RSVP message that needs to
   be semantically fragmented. The fragment ID is reset to 1 when it
   reaches the maximum value of 65535. The scope of the fragment ID
   is limited to the RSVP message type (e.g., Path) carrying the
   fragment. In other words, fragment IDs do not have any
   correlation between different RSVP message types (e.g., Path and
   PathErr). The receiver does not check to ensure that the
   consecutive new RSVP messages (e.g., Path messages) are received
   with fragment IDs incremented by 1.

Fragments Total: 8-bit integer in the range of 1 to 255.

   This value indicates the number of fragments sent for the given
   RSVP message. This value MUST be the same in all fragmented RSVP
   messages with a common fragment ID.

Fragment Number: 8-bit integer in the range of 1 to 255.

   This value indicates the position of this fragment in the given
   RSVP message.

The format of an S2L sub-LSP descriptor message is as follows:

   <S2L sub-LSP descriptor> ::=
                   [<S2L_SUB_LSP_FRAG>]
                     <S2L_SUB_LSP>
                   [<P2MP SECONDARY_EXPLICIT_ROUTE>]

The S2L_SUB_LSP_FRAG object is added before adding the S2L_SUB_LSP
object in the semantically fragmented RSVP message.

6. Compatibility

The LSP_ATTRIBUTES object has been defined in [RFC5420] and its
message formats in [RFC6510] with class numbers in the form 11bbbbbb,
which ensures compatibility with non-supporting nodes. Per
[RFC2205], nodes not supporting this extension will ignore the new
flag defined for this object in this document and will forward it
without modification.

The S2L_SUB_LSP_FRAG object has been defined with class numbers in
the form 11bbbbbb, which ensures compatibility with non-supporting
nodes. Per [RFC2205], nodes not supporting this object will ignore
the object and will forward it without modification.

7. IANA Considerations

   IANA has performed the actions described below.

7.1. "P2MP-TE Tree Re-evaluation Request" Flag

   IANA maintains the "Resource Reservation Protocol-Traffic Engineering
   (RSVP-TE) Parameters" registry (see
   <http://www.iana.org/assignments/rsvp-te-parameters>). Per
   Section 5.1 of this document, IANA has registered a new flag in the
   "Attribute Flags" registry. This new flag is defined for the
   Attribute Flags TLV in the LSP_ATTRIBUTES object [RFC5420].

   +-----+--------------+---------+---------+-----+-----+-----------+
Bit	Name	Attribute	Attribute	RRO	ERO	Reference
No		Flags	Flags			
		Path	Resv			
   +-----+--------------+---------+---------+-----+-----+-----------+
	P2MP-TE Tree	Yes	No	No	No	This
14	Re-evaluation					document
	Request					
   +-----+--------------+---------+---------+-----+-----+-----------+

7.2. "Preferable P2MP-TE Tree Exists" Path Error Sub-code

   IANA maintains the "Resource Reservation Protocol (RSVP) Parameters"
   registry (see <http://www.iana.org/assignments/rsvp-parameters>).
   Per Section 5.2 of this document, IANA has registered a new error
   code in the "Sub-Codes - 25 Notify Error" sub-registry of the "Error
   Codes and Globally-Defined Error Value Sub-Codes" registry.

As defined in [RFC3209], error code 25 in the ERROR_SPEC object
corresponds to a PathErr with the Notify error. This document adds a
new "Preferable P2MP-TE Tree Exists" sub-code for this PathErr as
follows:

```
+----------+-------------------+---------+---------+-----------+
| Value    | Description       | PathErr | PathErr | Reference |
|          |                   | Code    | Name    |           |
+----------+-------------------+---------+---------+-----------+
|   13     | Preferable P2MP-TE | 25     | Notify  | This      |
|          | Tree Exists       |         | Error   | document  |
+----------+-------------------+---------+---------+-----------+
```

7.3. Fragment Identifier for S2L Sub-LSP Descriptor

IANA maintains the "Resource Reservation Protocol (RSVP) Parameters"
registry (see <http://www.iana.org/assignments/rsvp-parameters>).
Per Section 5.3 of this document, IANA has registered a new class
number in the "Class Names, Class Numbers, and Class Types" registry.

```
+-----------------+-------------------------+-----------------+
| Class Number    | Class Name              | Reference       |
+-----------------+-------------------------+-----------------+
| 204             | S2L_SUB_LSP_FRAG        | This document   |
+-----------------+-------------------------+-----------------+
```

IANA has also created the "Class Types or C-Types - 204
S2L_SUB_LSP_FRAG" registry and populated it as follows:

```
+-----------------+-------------------------+-----------------+
| Value           | Description             | Reference       |
+-----------------+-------------------------+-----------------+
| 1               | S2L_SUB_LSP_FRAG        | This document   |
+-----------------+-------------------------+-----------------+
```

8. Security Considerations

This document defines RSVP-TE signaling extensions to allow an
ingress node of a P2MP-TE LSP to request the re-evaluation of the LSP
tree downstream of a node and to allow a midpoint LSR to notify the
ingress node of the existence of a preferable tree by sending a
PathErr message. As per [RFC4736], in the case of a P2MP-TE LSP S2L
sub-LSP spanning multiple domains, it may be desirable for a midpoint
LSR to modify the RSVP PathErr message to preserve confidentiality
across domains.

   This document also defines a fragment identifier for the S2L sub-LSP
   descriptor when combining a large number of S2L sub-LSPs in an RSVP
   message and the message needs to be semantically fragmented. The
   introduction of the fragment identifier, by itself, introduces no
   additional information to signaling. For a general discussion on
   security issues related to MPLS and GMPLS, see the MPLS/GMPLS
   security framework [RFC5920].

9. References

9.1. Normative References

   [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate
              Requirement Levels", BCP 14, RFC 2119,
              DOI 10.17487/RFC2119, March 1997,
              <http://www.rfc-editor.org/info/rfc2119>.

   [RFC2205] Braden, R., Ed., Zhang, L., Berson, S., Herzog, S., and S.
              Jamin, "Resource ReSerVation Protocol (RSVP) -- Version 1
              Functional Specification", RFC 2205, DOI 10.17487/RFC2205,
              September 1997, <http://www.rfc-editor.org/info/rfc2205>.

   [RFC3209] Awduche, D., Berger, L., Gan, D., Li, T., Srinivasan, V.,
              and G. Swallow, "RSVP-TE: Extensions to RSVP for LSP
              Tunnels", RFC 3209, DOI 10.17487/RFC3209, December 2001,
              <http://www.rfc-editor.org/info/rfc3209>.

   [RFC4736] Vasseur, JP., Ed., Ikejiri, Y., and R. Zhang,
              "Reoptimization of Multiprotocol Label Switching (MPLS)
              Traffic Engineering (TE) Loosely Routed Label Switched
              Path (LSP)", RFC 4736, DOI 10.17487/RFC4736,
              November 2006, <http://www.rfc-editor.org/info/rfc4736>.

   [RFC4875] Aggarwal, R., Ed., Papadimitriou, D., Ed., and S.
              Yasukawa, Ed., "Extensions to Resource Reservation
              Protocol - Traffic Engineering (RSVP-TE) for
              Point-to-Multipoint TE Label Switched Paths (LSPs)",
              RFC 4875, DOI 10.17487/RFC4875, May 2007,
              <http://www.rfc-editor.org/info/rfc4875>.

   [RFC5420] Farrel, A., Ed., Papadimitriou, D., Vasseur, JP., and A.
              Ayyangarps, "Encoding of Attributes for MPLS LSP
              Establishment Using Resource Reservation Protocol Traffic
              Engineering (RSVP-TE)", RFC 5420, DOI 10.17487/RFC5420,
              February 2009, <http://www.rfc-editor.org/info/rfc5420>.

9.2. Informative References

   [RFC3473] Berger, L., Ed., "Generalized Multi-Protocol Label
              Switching (GMPLS) Signaling Resource ReserVation
              Protocol-Traffic Engineering (RSVP-TE) Extensions",
              RFC 3473, DOI 10.17487/RFC3473, January 2003,
              <http://www.rfc-editor.org/info/rfc3473>.

   [RFC5440] Vasseur, JP., Ed., and JL. Le Roux, Ed., "Path Computation
              Element (PCE) Communication Protocol (PCEP)", RFC 5440,
              DOI 10.17487/RFC5440, March 2009,
              <http://www.rfc-editor.org/info/rfc5440>.

   [RFC5920] Fang, L., Ed., "Security Framework for MPLS and GMPLS
              Networks", RFC 5920, DOI 10.17487/RFC5920, July 2010,
              <http://www.rfc-editor.org/info/rfc5920>.

   [RFC6510] Berger, L. and G. Swallow, "Resource Reservation Protocol
              (RSVP) Message Formats for Label Switched Path (LSP)
              Attributes Objects", RFC 6510, DOI 10.17487/RFC6510,
              February 2012, <http://www.rfc-editor.org/info/rfc6510>.

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