                         RSVP-TE Extensions
           for Associated Bidirectional Label Switched Paths (LSPs)

Abstract

   This document describes Resource Reservation Protocol (RSVP)
   extensions to bind two point-to-point unidirectional Label Switched
   Paths (LSPs) into an associated bidirectional LSP. The association
   is achieved by defining new Association Types for use in ASSOCIATION
   and in Extended ASSOCIATION Objects. One of these types enables
   independent provisioning of the associated bidirectional LSPs on both
   sides, while the other enables single-sided provisioning. The
   REVERSE_LSP Object is also defined to enable a single endpoint to
   trigger creation of the reverse LSP and to specify parameters of the
   reverse LSP in the single-sided provisioning case.

Status of This Memo

   This is an Internet Standards Track document.

   This document is a product of the Internet Engineering Task Force
   (IETF). It represents the consensus of the IETF community. It has
   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 5741.

   Information about the current status of this document, any errata,
   and how to provide feedback on it may be obtained at
   http://www.rfc-editor.org/info/rfc7551.

Copyright Notice

Table of Contents

1. Introduction

   The MPLS Transport Profile (MPLS-TP) requirements document [RFC5654]
   specifies that MPLS-TP MUST support associated bidirectional point-
   to-point Label Switched Paths (LSPs). These requirements are given
   in Section 2.1 ("General Requirements") of that document and are
   partially rephrased below:

   7.   MPLS-TP MUST support associated bidirectional point-to-point
         LSPs.

   11.   The end points of an associated bidirectional LSP MUST be aware
         of the pairing relationship of the forward and reverse LSPs used
         to support the bidirectional service.

   12.   Nodes on the LSP of an associated bidirectional LSP where both
         the forward and backward directions transit the same node in the
         same (sub)layer as the LSP SHOULD be aware of the pairing
         relationship of the forward and the backward directions of the
         LSP.

   50.   The MPLS-TP control plane MUST support establishing associated
         bidirectional P2P LSP including configuration of protection
         functions and any associated maintenance functions.

   The above requirements are also repeated in [RFC6373].

   Furthermore, an associated bidirectional LSP is also useful for
   protection-switching for Operations, Administration, and Maintenance
   (OAM) messages that require a return path.

   A variety of applications, such as Internet services and the return
   paths of OAM messages, exist and may have different upstream and
   downstream bandwidth requirements. [RFC5654] specifies an asymmetric
   bandwidth requirement in Section 2.1 ("General Requirements"), and it
   is repeated below:

   14.   MPLS-TP MUST support bidirectional LSPs with asymmetric
         bandwidth requirements, i.e., the amount of reserved bandwidth
         differs between the forward and backward directions.

   The approach for supporting asymmetric bandwidth co-routed
   bidirectional LSPs is defined in [RFC6387].

   The method of association and the corresponding Resource Reservation
   Protocol (RSVP) ASSOCIATION Object are defined in [RFC4872],
   [RFC4873], and [RFC6689]. In that context, the ASSOCIATION Object is
   used to associate a recovery LSP with the LSP it is protecting. This

object also has broader applicability as a mechanism to associate
RSVP states. [RFC6780] defines the Extended ASSOCIATION Objects that
can be more generally applied for this purpose. This document uses
the term "(Extended) ASSOCIATION Objects" to refer collectively to
the ASSOCIATION Objects defined in [RFC4872] and the Extended
ASSOCIATION Objects defined in [RFC6780].

This document specifies mechanisms for binding two reverse
unidirectional LSPs into an associated bidirectional LSP. The
association is achieved by defining new Association Types for use in
(Extended) ASSOCIATION Objects. One of these types enables
independent provisioning of the associated bidirectional LSPs, while
the other enables single-sided provisioning. The REVERSE_LSP Object
is also defined to enable a single endpoint to trigger creation of
the reverse LSP and to specify parameters of the reverse LSP in the
single-sided provisioning case. For example, the REVERSE_LSP Object
allow asymmetric upstream and downstream bandwidths for the
associated bidirectional LSP.

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. Reverse Unidirectional LSPs

Two reverse unidirectional LSPs are setup in the opposite directions
between a pair of source and destination nodes to form an associated
bidirectional LSP. A reverse unidirectional LSP originates on the
same node where the forward unidirectional LSP terminates, and it
terminates on the same node where the forward unidirectional LSP
originates.

2.3. Message Formats

This document uses the Routing Backus-Naur Form (RBNF) to define
message formats as defined in [RFC5511].

3. Overview

3.1. Provisioning Model Overview

   This section provides an overview and definition of the models for
   provisioning associated bidirectional LSPs.

   The associated bidirectional LSP's forward and reverse unidirectional
   LSPs are established, monitored, and protected independently as
   specified by [RFC5654]. Configuration information regarding the LSPs
   can be provided at one or both endpoints of the associated
   bidirectional LSP. Depending on the method chosen, there are two
   models of creating an associated bidirectional LSP -- single-sided
   provisioning and double-sided provisioning.

3.1.1. Single-Sided Provisioning

   For the single-sided provisioning, the Traffic Engineering (TE)
   tunnel is configured only on one endpoint. An LSP for this tunnel is
   initiated by the initiating endpoint with the (Extended) ASSOCIATION
   and REVERSE_LSP Objects inserted in the Path message. The other
   endpoint then creates the corresponding reverse TE tunnel and signals
   the reverse LSP in response using information from the REVERSE_LSP
   Object and other objects present in the received Path message.

3.1.2. Double-Sided Provisioning

   For the double-sided provisioning, two unidirectional TE tunnels are
   configured independently, one on each endpoint. The LSPs for the
   tunnels are signaled with (Extended) ASSOCIATION Objects inserted in
   the Path message by both endpoints to indicate that the two LSPs are
   to be associated to form a bidirectional LSP.

3.2. Association Signaling Overview

   This section provides an overview of the association signaling
   methods for the associated bidirectional LSPs.

   Three scenarios exist for binding two unidirectional LSPs together to
   form an associated bidirectional LSP. These are:

   1) Neither unidirectional LSP exists, and both must be established.

   2) Both unidirectional LSPs exist, but the association must be
      established.

   3) One LSP exists, but the reverse associated LSP must be
      established.

The following sections describe the applicable provisioning models
for each of these scenarios.

Path Computation Element (PCE)-based approaches [RFC4655] may be used
for path computation of an associated bidirectional LSP. However,
these approaches are outside the scope of this document.

Consider the topology described in Figure 1. LSP1 from node A to B,
takes the path A,D,B, and LSP2 from node B to A takes the path
B,D,C,A. These two LSPs, once established and associated, form an
associated bidirectional LSP between nodes A and B.

```
                        LSP1 -->
                        A-------D-------B
                         \       / <-- LSP2
                          \     /
                           \   /
                            \ /
                             C
```
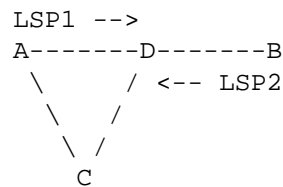
Figure 1: An Example of Associated Bidirectional LSP

3.2.1. Single-Sided Provisioning

For the single-sided provisioning model, creation of reverse LSP1
shown in Figure 1 is triggered by LSP2, or creation of reverse LSP2
is triggered by LSP1. When creation of reverse LSP2 is triggered by
LSP1, LSP1 is provisioned first (or refreshed, if LSP1 already
exists) at node A. LSP1 is then signaled with an (Extended)
ASSOCIATION, and REVERSE_LSP Objects are inserted in the Path
message. The Association Type indicates single-sided provisioning.
Upon receiving this Path message for LSP1, node B establishes reverse
LSP2. The (Extended) ASSOCIATION Object inserted in LSP2's Path
message is the same as that received in LSP1's Path message.

A similar procedure is used if LSP2 is provisioned first at node B,
and the creation of reverse LSP1 at node A is triggered by LSP2. In
both scenarios, the two unidirectional LSPs are bound together to
form an associated bidirectional LSP based on identical (Extended)
ASSOCIATION Objects in the two LSPs' Path messages.

3.2.2. Double-Sided Provisioning

For the double-sided provisioning model, both LSP1 and LSP2 shown in
Figure 1 are signaled independently with (Extended) ASSOCIATION
Objects inserted in the Path messages, in which the Association Type
indicating double-sided provisioning is included. In this case, the
two unidirectional LSPs are bound together to form an associated
bidirectional LSP based on identical (Extended) ASSOCIATION Objects

in the two LSPs' Path messages. In all three scenarios described in
Section 3.2, the LSPs to be selected for the association are
provisioned by the management action applied at both endpoints.

3.3. Asymmetric Bandwidth Signaling Overview

   This section provides an overview of the methods for signaling
   asymmetric upstream and downstream bandwidths for the associated
   bidirectional LSPs.

3.3.1. Single-Sided Provisioning

   A new REVERSE_LSP Object for use in the single-sided provisioning
   model is defined in this document, in Section 4.4. The REVERSE_LSP
   Object allows the initiating node of the single-sided provisioned LSP
   to trigger creation of the reverse LSP on the remote node. When the
   single-sided provisioning model is used, a SENDER_TSPEC Object can be
   added in the REVERSE_LSP Object as a subobject in the initiating
   LSP's Path message to specify a different bandwidth for the reverse
   LSP. As described in Section 4.4, addition of the REVERSE_LSP Object
   also allows the initiating node to control other aspects of the
   reverse LSP (such as its path) by including other objects in a
   REVERSE_LSP Object.

   Consider again the topology described in Figure 1, where the creation
   of reverse LSP2 is triggered by LSP1. Node A signals LSP1 with the
   (Extended) ASSOCIATION Object with Association Type indicating
   single-sided provisioning and inserts a SENDER_TSPEC subobject for
   use by LSP2 in the REVERSE_LSP Object in the Path message. Node B
   then establishes the LSP2 in the reverse direction using the
   asymmetric bandwidth thus specified by LSP1 and allows node A to
   control the reverse LSP2.

3.3.2. Double-Sided Provisioning

   When the double-sided provisioning model is used, the two
   unidirectional LSPs are established with separate bandwidths, which
   may or may not be identical. However, these LSPs are associated
   purely based on the identical contents of their (Extended)
   ASSOCIATION Objects.

3.4. Recovery LSP Overview

   Recovery of each unidirectional LSP forming the bidirectional LSP is
   independent [RFC5654] and is based on the parameters signaled in
   their respective RSVP Path messages.

   Recovery LSP association is based on the identical content of the
   (Extended) ASSOCIATION Objects signaled in their Path messages during
   the initial LSP setup for both single-sided and double-sided
   provisioning. As defined in [RFC6780], multiple ASSOCIATION Objects
   may be present in the signaling of a single LSP.

4. Message and Object Definitions

4.1. RSVP Message Formats

   This section presents the RSVP message-related formats as modified by
   this document. Unmodified RSVP message formats are not listed.

   The format of a Path message is as follows:

       <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>]
                          [<ASSOCIATION> ...]
                          [<REVERSE_LSP> ...]
                          [<POLICY_DATA> ...]
                          <sender descriptor>

   The format of the <sender descriptor> is not modified by this
   document.

4.2. ASSOCIATION Object

   The ASSOCIATION Object is populated using the rules defined below for
   associating two reverse unidirectional LSPs to form an associated
   bidirectional LSP.

   Association Types:

      In order to bind two reverse unidirectional LSPs to be an
      associated bidirectional LSP, the Association Type MUST be set to
      indicate either single-sided or double-sided LSPs.

The new Association Types are defined as follows:

```
Value       Type
-----       -----
  3         Double-Sided Associated Bidirectional LSP (D)
  4         Single-Sided Associated Bidirectional LSP (A)
```

Association ID:

   For both single-sided and double-sided provisioning, Association
   ID MUST be set to a value assigned by the node that originates the
   association for the bidirectional LSP.

Association Source:

   Association Source MUST be set to an address selected by the node
   that originates the association for the bidirectional LSP. For
   example, this may be a management entity or, in the case of
   single-sided provisioning, an address assigned to the node that
   originates the LSP.

4.3. Extended ASSOCIATION Object

The Extended ASSOCIATION Object is populated using the rules defined
below for associating two reverse unidirectional LSPs to form a
bidirectional LSP.

The Association Type, Association ID, and Association Source MUST be
set as defined for the ASSOCIATION Object in Section 4.1.

Global Association Source:

   For both single-sided and double-sided provisioning, Global
   Association Source, when used, MUST be set to the Global_ID
   [RFC6370] of the node that originates the association for the
   bidirectional LSP.

Extended Association ID:

   For both single-sided and double-sided provisioning, Extended
   Association ID, when used, MUST be set to a value selected by the
   node that originates the association for the bidirectional LSP.

4.4. REVERSE_LSP Object Definition

4.4.1. REVERSE_LSP Object Format

   The REVERSE_LSP Object is carried in the Path message of a forward
   LSP to provide information to be used by the reverse LSP. The object
   also indicates that the LSP is the forward LSP of a single-sided
   associated bidirectional LSP.

   The Object has the following format:

   Class_Num = 203, C_Type = 1.

```
    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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                                                               |
   //                          (Subobjects)                       //
   |                                                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

4.4.2. REVERSE_LSP Subobjects

   Subobjects are used to override the default contents of a Path
   message of a reverse LSP; see Section 5.2. The contents of a
   REVERSE_LSP Object is zero or more variable-length subobjects that
   have the same format as RSVP Objects; see Section 3.1.2 of [RFC2205].
   Any object that may be carried in a Path message MAY be carried in
   the REVERSE_LSP Object. Subobject ordering MUST follow any Path
   message Object ordering requirements.

   Examples of the Path message Objects that can be carried in the
   REVERSE_LSP Object are (but not limited to):

      - SENDER_TSPEC [RFC2205]
      - EXPLICIT_ROUTE Object (ERO) [RFC3209]
      - SESSION_ATTRIBUTE Object [RFC3209]
      - ADMIN_STATUS Object [RFC3473]
      - LSP_REQUIRED_ATTRIBUTES Object [RFC5420]
      - PROTECTION Object [RFC3473] [RFC4872]

5. Processing Rules

   In general, the processing rules for the ASSOCIATION Object are as
   specified in [RFC4872], and those for the Extended ASSOCIATION Object
   are as specified in [RFC6780]. The following sections describe the
   rules for processing (Extended) ASSOCIATION Objects for both double-
   sided and single-sided associated bidirectional LSPs and REVERSE_LSP
   Objects for single-sided associated bidirectional LSPs.

5.1. Rules for ASSOCIATION Object

   This section defines the processing for the association of two
   unidirectional LSPs to form an associated bidirectional LSP. Such
   association is based on the use of an (Extended) ASSOCIATION Object.

   The procedures related to the actual identification of associations
   between LSPs based on (Extended) ASSOCIATION Objects are defined in
   [RFC6780]. [RFC6780] specifies that in the absence of rules for
   identifying the association that are specific to the Association
   Type, the included (Extended) ASSOCIATION Objects in the LSPs MUST be
   identical in order for an association to exist. This document adds
   no specific rules for the new Association Types defined, and the
   identification of an LSP association therefore proceeds as specified
   in [RFC6780].

   As described in [RFC6780], association of LSPs can be upstream or
   downstream initiated, as indicated by (Extended) ASSOCIATION Objects
   in Path or Resv Messages. The association of bidirectional LSPs is
   always upstream initiated; therefore, the Association Types defined
   in this document are only to be interpreted in Path Messages. These
   types SHOULD NOT be used in ASSOCIATION Objects carried in Resv
   messages and SHOULD be ignored if present.

   To indicate an associated bidirectional LSP, an ingress node MUST
   insert an (Extended) ASSOCIATION Object into the Path message of the
   unidirectional LSP that is part of the associated bidirectional LSP
   it initiates. If either Global Association Source or Extended
   Association Address is required, then an Extended ASSOCIATION Object
   [RFC6780] MUST be inserted in the Path message. Otherwise, an
   ASSOCIATION Object MAY be used. (Extended) ASSOCIATION Objects with
   both single-sided and double-sided Association Types MUST NOT be
   added or sent in the same Path message.

   The ingress node MUST set the Association Type field in the
   (Extended) ASSOCIATION Object to "Single-Sided Associated
   Bidirectional LSP" when single-sided provisioning is used, and to
   "Double-Sided Associated Bidirectional LSP" when double-sided
   provisioning is used.

A transit node MAY identify the unidirectional LSPs of an associated
bidirectional LSP based on (Extended) ASSOCIATION Objects, with the
Association Type values defined in this document, carried in Path
messages. Clearly, such associations are only possible when the LSPs
transit the node. As mentioned above, such associations are made per
the rules defined in [RFC6780].

Egress nodes that support the Association Types defined in this
document identify the unidirectional LSPs of an associated
bidirectional LSP based on (Extended) ASSOCIATION Objects carried in
Path messages. Note that an ingress node will normally be the
ingress for one of the unidirectional LSPs that make up an associated
bidirectional LSP. When an egress node receives a Path message
containing an (Extended) ASSOCIATION Object with one of the
Association Types defined in this document, it MUST attempt to
identify other LSPs (including ones for which it is an ingress node)
with which the LSP being processed is associated. As defined above,
such associations are made per the rules defined in [RFC6780]. An
LSP not being associated at the time of signaling (for example,
during rerouting or re-optimization) on an egress node is not
necessarily considered an error condition.

Associated bidirectional LSP teardown follows the standard procedures
defined in [RFC3209] and [RFC3473] either without or with the
administrative status. Generally, the teardown procedures of the
unidirectional LSPs forming an associated bidirectional LSP are
independent of each other, so it is possible that while one LSP
follows graceful teardown with administrative status, the reverse LSP
is torn down without administrative status (using
PathTear/ResvTear/PathErr with state removal). See Section 5.2 for
additional rules related to LSPs established using single-sided
provisioning.

When an LSP signaled with a Path message containing an (Extended)
ASSOCIATION Object with an Association Type defined in this document
is torn down, the processing node SHALL remove the binding of the LSP
to any previously identified associated bidirectional LSP.

No additional processing is needed for Path messages with an
(Extended) ASSOCIATION Object containing an Association Type field
set to "Double-Sided Associated Bidirectional LSP".

5.1.1. Compatibility for ASSOCIATION Object

   The ASSOCIATION Object has been defined in [RFC4872] and the Extended
   ASSOCIATION Object has been defined in [RFC6780], both with class
   numbers in the form 11bbbbbb, which ensures compatibility with non-
   supporting nodes. Per [RFC2205], such nodes will ignore the object
   but forward it without modification.

   Operators wishing to use a function supported by a particular
   Association Type SHOULD ensure that the type is supported on any node
   that is expected to act on the association [RFC6780].

   An egress node that does not support the Association Types defined in
   this document is expected to return a PathErr with Error Code
   "Admission Control Failure" (1) [RFC2205] and Sub-code "Bad
   Association Type" (5) [RFC4872].

   LSP recovery as defined in [RFC4872] and [RFC4873] is not impacted by
   this document. The recovery mechanisms defined in [RFC4872] and
   [RFC4873] rely on the use of the (Extended) ASSOCIATION Objects, but
   they use a different value for Association Type; multiple ASSOCIATION
   Objects can be present in the LSP Path message and can coexist with
   the procedures defined in this document.

5.2. Rules for REVERSE_LSP Object

   When a node initiates setup of an LSP using a Path message containing
   an ASSOCIATION or Extended ASSOCIATION Object, and the Association
   Type set to "Single-Sided Associated Bidirectional LSP", the Path
   message MUST carry the REVERSE_LSP Object to trigger creation of a
   reverse LSP on the egress node.

   The REVERSE_LSP subobject MAY contain any of the objects that the
   initiating node desires to have included in the Path message for the
   associated reverse LSP. The REVERSE_LSP Object SHOULD NOT be
   included in a REVERSE_LSP Object.

   A transit node receiving a valid Path message containing a
   REVERSE_LSP Object MUST forward the REVERSE_LSP Object unchanged in
   the outgoing Path message.

   An egress node, upon receiving a Path message containing an
   REVERSE_LSP Object MUST verify that the Path message contains an
   ASSOCIATION or Extended ASSOCIATION Object with the Association Type
   set to "Single-Sided Associated Bidirectional LSP". If it does not,
   the Path message MUST NOT trigger a reverse LSP. This verification
   failure SHOULD NOT trigger any RSVP message but can be logged
   locally, and perhaps reported through network management mechanisms.

Once validated, the egress node MUST create an LSP in the reverse
direction or reject the Path message. If the creation of a reverse
LSP fails, the egress node MUST return a PathErr with Error Code
"Admission Control Failure" (1) [RFC2205] and Sub-code "Reverse LSP
Failure" (6) defined in this document. Note that normal Resv
processing SHOULD NOT be impacted by the presence of an ASSOCIATION
Object with an Association Type set to "Single-Sided Associated
Bidirectional LSP".

The egress node MUST use the subobjects contained in the REVERSE_LSP
Object for initiating the reverse LSP. When a subobject is not
present in the received REVERSE_LSP Object, the egress node SHOULD
initiate the reverse LSP based on the information contained in the
received Path message of the forward LSP as follows:

o The egress node SHOULD copy the information from the received
   SESSION_ATTRIBUTE, CLASS_TYPE, LABEL_REQUEST, ASSOCIATION,
   ADMIN_STATUS, and PROTECTION Objects in the forward LSP Path
   message to form the Path message of the reverse LSP when the
   object is not present in the received REVERSE_LSP Object.

o The IP address in the reverse LSP's SESSION Object SHOULD be set
   to the IP address carried in the received SENDER_TEMPLATE Object;
   and conversely, the IP address in the SENDER_TEMPLATE Object
   SHOULD be set to the IP address carried in the received SESSION
   Object. There are no additional requirements related to the IDs
   carried in the SESSION and SENDER_TEMPLATE Objects.

o When the forward LSP Path message contains a RECORD_ROUTE Object,
   the egress node SHOULD include the received RECORD_ROUTE Object in
   the reverse LSP Path message. Local node information SHOULD also
   be recorded per standard Path message processing.

o There are no specific requirements related to other objects.

The resulting Path message is used to create the reverse LSP. From
this point on, standard Path message processing is used in processing
the resulting Path message.

Note that the contents of a forward LSP, including a carried
REVERSE_LSP Object, may change over the life of an LSP, and such
changes MUST result in corresponding changes in the reverse LSP. In
particular, any object or subobject that was copied during the
creation of the initial reverse LSP's Path message MUST be copied
when modified in the forward LSP, and a trigger Path message MUST be
processed.

   The removal of the REVERSE_LSP Object in the received Path message
   SHOULD cause the egress node to tear down any previously established
   reverse LSP.

   When the egress node receives a PathTear message for the forward LSP
   or whenever the forward LSP is torn down, the node MUST remove the
   associated reverse LSP using standard PathTear message processing.
   Teardown of the reverse LSP for other reasons SHOULD NOT trigger
   removal of the initiating LSP, but it SHOULD result in the egress
   node sending a PathErr with Error Code "Admission Control Failure"
   (1) [RFC2205] and Sub-code "Reverse LSP Failure" (6) defined in this
   document.

5.2.1. Compatibility for REVERSE_LSP Object

   The REVERSE_LSP Object is defined with class numbers in the form
   11bbbbbb, which ensures compatibility with non-supporting nodes. Per
   [RFC2205], such nodes will ignore the object but forward it without
   modification.

6. IANA Considerations

   IANA has registered values for the namespace defined in this document
   and summarized in this section.

6.1. Association Types

   IANA maintains the "Generalized Multi-Protocol Label Switching
   (GMPLS) Signaling Parameters" registry (see
   <http://www.iana.org/assignments/gmpls-sig-parameters>). The
   "Association Type" subregistry is included in this registry.

   This registry has been updated by new Association Types for
   ASSOCIATION and Extended ASSOCIATION Objects defined in this document
   as follows:

   Value   Name   Reference
    3   Double-Sided Associated Bidirectional LSP (D)   Section 4.2
    4   Single-Sided Associated Bidirectional LSP (A)   Section 4.2

6.2. REVERSE_LSP Object

   IANA maintains the "Resource Reservation Protocol (RSVP) Parameters"
   registry (see <http://www.iana.org/assignments/rsvp-parameters>).
   The "Class Names, Class Numbers, and Class Types" subregistry is
   included in this registry.

This registry has been extended for new Class Number (Class-Num) and
Class Type (C-type) for RSVP REVERSE_LSP Object requested in the
11bbbbbb range defined in this document as follows:

    Class Number   Class Name   Reference
       203   REVERSE_LSP   Section 4.4

    o REVERSE_LSP : Class Type or C-type = 1

6.3. Reverse LSP Failure PathErr Sub-code

   IANA maintains the "Resource Reservation Protocol (RSVP) Parameters"
   registry (see <http://www.iana.org/assignments/rsvp-parameters>).
   The "Error Codes and Globally-Defined Error Value Sub-Codes"
   subregistry is included in this registry.

   This registry has been extended for the new PathErr Sub-code defined
   in this document as follows:

     Error Code = 01: "Admission Control Failure" (see [RFC2205])

     o "Reverse LSP Failure" (6)

7. Security Considerations

   This document introduces two new Association Types for the (Extended)
   ASSOCIATION Object, Double-Sided Associated Bidirectional LSP and
   Single-Sided Associated Bidirectional LSP. These types, by
   themselves, introduce no additional information to signaling.
   Related security considerations are already covered for this in RFC
   6780.

   The REVERSE_LSP Object is carried in the Path message of a forward
   LSP of the single-sided associated bidirectional LSP. It can carry
   parameters for the reverse LSP. This does allow for additional
   information to be conveyed, but this information is not fundamentally
   different from the information that is already carried in a
   bidirectional LSP message. The processing of such messages is
   already subject to local policy as well as security considerations
   discussions. For a general discussion on MPLS- and GMPLS-related
   security issues, see the MPLS/GMPLS security framework [RFC5920].

8. References

8.1. 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>.

   [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>.

   [RFC4872]   Lang, J., Ed., Rekhter, Y., Ed., and D. Papadimitriou,
               Ed., "RSVP-TE Extensions in Support of End-to-End
               Generalized Multi-Protocol Label Switching (GMPLS)
               Recovery", RFC 4872, DOI 10.17487/RFC4872, May 2007,
               <http://www.rfc-editor.org/info/rfc4872>.

   [RFC4873]   Berger, L., Bryskin, I., Papadimitriou, D., and A. Farrel,
               "GMPLS Segment Recovery", RFC 4873, DOI 10.17487/RFC4873,
               May 2007, <http://www.rfc-editor.org/info/rfc4873>.

   [RFC5511]   Farrel, A., "Routing Backus-Naur Form (RBNF): A Syntax
               Used to Form Encoding Rules in Various Routing Protocol
               Specifications", RFC 5511, DOI 10.17487/RFC5511, April
               2009, <http://www.rfc-editor.org/info/rfc5511>.

   [RFC6780]   Berger, L., Le Faucheur, F., and A. Narayanan, "RSVP
               ASSOCIATION Object Extensions", RFC 6780,
               DOI 10.17487/RFC6780, October 2012,
               <http://www.rfc-editor.org/info/rfc6780>.

8.2. Informative References

   [RFC4655] Farrel, A., Vasseur, J.-P., and J. Ash, "A Path
              Computation Element (PCE)-Based Architecture", RFC 4655,
              DOI 10.17487/RFC4655, August 2006,
              <http://www.rfc-editor.org/info/rfc4655>.

   [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>.

   [RFC5654] Niven-Jenkins, B., Ed., Brungard, D., Ed., Betts, M., Ed.,
              Sprecher, N., and S. Ueno, "Requirements of an MPLS
              Transport Profile", RFC 5654, DOI 10.17487/RFC5654,
              September 2009, <http://www.rfc-editor.org/info/rfc5654>.

   [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>.

   [RFC6370] Bocci, M., Swallow, G., and E. Gray, "MPLS Transport
              Profile (MPLS-TP) Identifiers", RFC 6370,
              DOI 10.17487/RFC6370, September 2011,
              <http://www.rfc-editor.org/info/rfc6370>.

   [RFC6373] Andersson, L., Ed., Berger, L., Ed., Fang, L., Ed., Bitar,
              N., Ed., and E. Gray, Ed., "MPLS Transport Profile
              (MPLS-TP) Control Plane Framework", RFC 6373,
              DOI 10.17487/RFC6373, September 2011,
              <http://www.rfc-editor.org/info/rfc6373>.

   [RFC6387] Takacs, A., Berger, L., Caviglia, D., Fedyk, D., and J.
              Meuric, "GMPLS Asymmetric Bandwidth Bidirectional Label
              Switched Paths (LSPs)", RFC 6387, DOI 10.17487/RFC6387,
              September 2011, <http://www.rfc-editor.org/info/rfc6387>.

   [RFC6689] Berger, L., "Usage of the RSVP ASSOCIATION Object",
              RFC 6689, DOI 10.17487/RFC6689, July 2012,
              <http://www.rfc-editor.org/info/rfc6689>.

Acknowledgements

Contributors

   Fan Yang
   ZTE

   EMail: yang.fan240347@gmail.com

   Weilian Jiang
   ZTE

   EMail: jiang.weilian@gmail.com

Authors' Addresses

   Fei Zhang (editor)
   Huawei

   EMail: zhangfei7@huawei.com

   Ruiquan Jing
   China Telecom

   EMail: jingrq@ctbri.com.cn

   Rakesh Gandhi (editor)
   Cisco Systems

   EMail: rgandhi@cisco.com