Network Working Group
Request for Comments: 4990
Category: Informational

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September 2007

Use of Addresses in Generalized Multiprotocol Label Switching (GMPLS) Networks

Status of This Memo

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Abstract

This document clarifies the use of addresses in Generalized Multiprotocol Label Switching (GMPLS) networks. The aim is to facilitate interworking of GMPLS-capable Label Switching Routers (LSRs). The document is based on experience gained in implementation, interoperability testing, and deployment.

The document describes how to interpret address and identifier fields within GMPLS protocols, and how to choose which addresses to set in those fields for specific control plane usage models. It also discusses how to handle IPv6 sources and destinations in the MPLS and GMPLS Traffic Engineering (TE) Management Information Base (MIB) modules.

This document does not define new procedures or processes. Whenever this document makes requirements statements or recommendations, these are taken from normative text in the referenced RFCs.

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1. Introduction

This informational document clarifies the use of addresses in Generalized Multiprotocol Label Switching (GMPLS) [RFC3945] networks. The aim is to facilitate interworking of GMPLS-capable Label Switching Routers (LSRs). The document is based on experience gained in implementation, interoperability testing, and deployment.

The document describes how to interpret address and identifier fields within GMPLS protocols (RSVP-TE [RFC3473], GMPLS OSPF [RFC4203], and GMPLS ISIS [RFC4205]), and how to choose which addresses to set in those fields for specific control plane usage models.

This document does not define new procedures or processes and the protocol specifications listed above should be treated as definitive. Furthermore, where this document makes requirements statements or recommendations, these are taken from normative text in the referenced RFCs. Nothing in this document should be considered normative.

This document also discusses how to handle IPv6 sources and destinations in the MPLS and GMPLS Traffic Engineering (TE) Management Information Base (MIB) modules [RFC3812], [RFC4802].

2. Terminology

As described in [RFC3945], the components of a GMPLS network may be separated into a data plane and a control plane. The control plane may be further split into signaling components and routing components.

A data plane switch or router is called a data plane entity. It is a node on the data plane topology graph. A data plane resource is a facility available in the data plane, such as a data plane entity (node), data link (edge), or data label (such as a lambda).

In the control plane, there are protocol speakers that are software implementations that communicate using signaling or routing protocols. These are control plane entities, and may be physically located separately from the data plane entities that they control. Further, there may be separate routing entities and signaling entities.

GMPLS supports a control plane entity that is responsible for one or more data plane entities, and supports the separation of signaling and routing control plane entities. For the purposes of this document, it is assumed that there is a one-to-one correspondence between control plane and data plane entities. That is, each data plane switch has a unique control plane entity responsible for participating in the GMPLS signaling and routing protocols, and that each such control plane presence is responsible for a single data plane switch.

The combination of control plane and data plane entities is referred to as a Label Switching Router (LSR).

Note that the term 'Router ID' is used in two contexts within GMPLS. It may refer to an identifier of a participant in a routing protocol, or it may be an identifier for an LSR that participates in TE routing. These could be considered as the control plane and data plane contexts.

In this document, the contexts are distinguished by the following definitions.

o Loopback address: A loopback address is a stable IP address of the advertising router that is always reachable if there is any IP connectivity to it [RFC3477], [RFC3630]. Thus, for example, an IPv4 127/24 address is excluded from this definition.

o TE Router ID: A stable IP address of an LSR that is always reachable in the control plane if there is any IP connectivity to the LSR, e.g., a loopback address. The most important requirement is that the address does not become unusable if an interface on the LSR is down [RFC3477], [RFC3630].

o Router ID: The OSPF protocol version 2 [RFC2328] defines the Router ID to be a 32-bit network-unique number assigned to each router running OSPF. IS-IS [RFC1195] includes a similar concept in the System ID. This document describes both concepts as the "Router ID" of the router running the routing protocol. The Router ID is not required to be a reachable IP address, although an operator may set it to a reachable IP address on the same node.

o TE link: "A TE link is a representation in the IS-IS/OSPF Link State advertisements and in the link state database of certain physical resources, and their properties, between two GMPLS nodes" [RFC3945].

o Data plane node: A vertex on the TE graph. It is a data plane switch or router. Data plane nodes are connected by TE links that are constructed from physical data links. A data plane node is controlled through some combination of management and control plane actions. A data plane node may be under full or partial control of a control plane node.

- o Control plane node: A GMPLS protocol speaker. It may be part of a data plane switch or may be a separate computer. Control plane nodes are connected by control channels that are logical connection-less or connection-oriented paths in the control plane. A control plane node is responsible for controlling zero, one, or more data plane nodes.

- o Interface ID: The Interface ID is defined in [RFC3477] and in Section 9.1 of [RFC3471].

- o Data Plane Address: This document refers to a data plane address in the context of GMPLS. It does not refer to addresses such as E.164 SAPI in Synchronous Digital Hierarchy (SDH).

- o Control Plane Address: An address used to identify a control plane resource including, and restricted to, control plane nodes and control channels.

- o IP Time to Live (TTL): The IPv4 TTL field or the IPv6 Hop Limit field, whichever is applicable.

- o TED: Traffic Engineering Database.

- o LSR: Label Switching Router.

- o FA: Forwarding Adjacency.

- o IGP: Interior Gateway Protocol.

3. Support of Numbered and Unnumbered Links

The links in the control and data planes may be numbered or unnumbered [RFC3945]. That is, their end points may be assigned IP addresses, or may be assigned link IDs specific to the control plane or data plane entity at the end of the link. Implementations may decide to support numbered and/or unnumbered addressing.

The argument for numbered addressing is that it simplifies troubleshooting. The argument for unnumbered addressing is to save on IP address resources.

An LSR may choose to only support its own links being configured as numbered, or may only support its own links being configured as unnumbered. But an LSR must not restrict the choice of other LSRs to use numbered or unnumbered links since this might lead to interoperablity issues. Thus, a node should be able to accept and process link advertisements containing both numbered and unnumbered addresses.

Numbered and unnumbered addressing is described in Sections 4 and 5 of this document, respectively.

4. Numbered Addressing

When numbered addressing is used, addresses are assigned to each node and link in both the control and data planes of the GMPLS network.

A numbered link is identified by a network-unique identifier (e.g., an IP address).

4.1. Numbered Addresses in IGPs

In this section, we discuss numbered addressing using two Interior Gateway Protocols (IGPs) that have extensions defined for GMPLS: OSPF-TE and IS-IS-TE. The routing enhancements for GMPLS are defined in [RFC3630], [RFC3784], [RFC4202], [RFC4203], and [RFC4205].

4.1.1. Router Address and TE Router ID

The IGPs define a field called the "Router Address". It is used to advertise the TE Router ID.

The Router Address is advertised in OSPF-TE using the Router Address TLV structure of the TE Link State Advertisement (LSA) [RFC3630].

In IS-IS-TE, this is referred to as the Traffic Engineering router ID, and is carried in the advertised Traffic Engineering router ID TLV [RFC3784].

4.1.2. Link ID and Remote Router ID

In OSPF-TE [RFC3630], the Router ID of the remote end of a TE link is carried in the Link ID sub-TLV. This applies for point-to-point TE links only; multi-access links are for further study.

In IS-IS-TE [RFC3784], the Extended IS Reachability TLV is used to carry the System ID. This corresponds to the Router ID as described in Section 2.

4.1.3. Local Interface IP Address

The Local Interface IP Address is advertised in:

- o the Local Interface IP Address sub-TLV in OSPF-TE [RFC3630]

- o the IPv4 Interface Address sub-TLV in IS-IS-TE [RFC3784].

This is the ID of the local end of the numbered TE link. It must be a network-unique number (since this section is devoted to numbered addressing), but it does not need to be a routable address in the control plane.

4.1.4. Remote Interface IP Address

The Remote Interface IP Address is advertised in:

- o the Remote Interface IP Address sub-TLV in OSPF-TE [RFC3630]

- o the IPv4 Neighbor Address sub-TLV in IS-IS-TE [RFC3784].

This is the ID of the remote end of the numbered TE link. It must be a network-unique number (since this section is devoted to numbered addressing), but it does not need to be a routable address in the control plane

4.2. Numbered Addresses in RSVP-TE

The following subsections describe the use of addresses in the GMPLS signaling protocol [RFC3209], [RFC3473].

4.2.1. IP Tunnel End Point Address in Session Object

The IP tunnel end point address of the Session Object [RFC3209] is either an IPv4 or IPv6 address.

The Session Object is invariant for all messages relating to the same Label Switched Path (LSP). The initiator of a Path message sets the IP tunnel end point address in the Session Object to one of:

- o The TE Router ID of the egress since the TE Router ID is routable and uniquely identifies the egress node.

- o The destination data plane address to precisely identify the interface that should be used for the final hop of the LSP. That is, the Remote Interface IP Address of the final TE link, if the ingress knows that address.

The IP tunnel end point address in the Session Object is not required to be routable in the control plane, but should be present in the TED.

4.2.2. IP Tunnel Sender Address in Sender Template Object

The IP tunnel sender address of the Sender Template Object [RFC3209] is either an IPv4 or IPv6 address.

When an LSP is being set up to support an IPv4-numbered FA, [RFC4206] recommends that the IP tunnel sender address be set to the head-end address of the TE link that is to be created so that the tail-end address can be inferred as the /31 partner address.

When an LSP is being set up that will not be used to form an FA, the IP tunnel sender address in the Sender Template Object may be set to one of:

- o The TE Router ID of the ingress LSR since the TE Router ID is a unique, routable ID per node.
- o The sender data plane address (i.e., the Local Interface IP Address).

4.2.3. IF_ID RSVP_HOP Object for Numbered Interfaces

There are two addresses used in the IF_ID RSVP_HOP object.

1. The IPv4/IPv6 Next/Previous Hop Address [RFC3473]

   When used in a Path or Resv messages, this address specifies the IP reachable address of the control plane interface used to send the messages, or the TE Router ID of the node that sends the message. That is, it is a routable control plane address of the sender of the message and can be used to send return messages. Note that because of data plane / control plane separation (see Section 7.1) and data plane robustness in the face of control plane faults, it may be advisable to use the TE Router ID since it is a more stable address.

2. The IPv4/IPv6 address in the Value Field of the Interface_ID TLV [RFC3471]

   This address identifies the data channel associated with the signaling message. In all cases, the data channel is indicated by the use of the data plane local interface address at the upstream LSR, that is, at the sender of the Path message.

See Section 6.2 for a description of these fields when bundled links are used.

4.2.4. Explicit Route Object (ERO)

The IPv4/IPv6 address in the ERO provides a data-plane identifier of an abstract node, TE node, or TE link to be part of the signaled LSP.

See Section 6 for a description of the use of addresses in the ERO.

4.2.5. Record Route Object (RRO)

The IPv4/IPv6 address in the RRO provides a data-plane identifier of either a TE node or a TE link that is part of an LSP that has been established or is being established.

See Section 6 for a description of the use of addresses in the RRO.

4.2.6. IP Packet Source Address

GMPLS signaling messages are encapsulated in IP. The IP packet source address is either an IPv4 or IPv6 address and must be a reachable control plane address of the node sending the TE message. In order to provide control plane robustness, a stable IPv4 or IPv6 control plane address (for example, the TE Router ID) can be used.

Some implementations may use the IP source address of a received IP packet containing a Path message as the destination IP address of a packet containing the corresponding Resv message (see Section 4.2.7). Using a stable IPv4 or IPv6 address in the IP packet containing the Path message supports this situation robustly when one of the control plane interfaces is down.

4.2.7. IP Packet Destination Address

The IP packet destination address for an IP packet carrying a GMPLS signaling message is either an IPv4 or IPv6 address, and must be reachable in the control plane if the message is to be delivered. It must be an address of the intended next-hop recipient of the message. That is, unlike RSVP, the IP packet is not addressed to the ultimate destination (the egress).

For a Path message, a stable IPv4 or IPv6 address of the next-hop node may be used. This may be the TE Router ID of the next-hop node. A suitable address may be determined by examining the TE advertisements for the TE link that will form the next-hop data link.

A Resv message is sent to the previous-hop node. The IPv4 or IPv6 destination of an IP packet carrying a Resv message may be any of the following:

o The IPv4 or IPv6 source address of the received IP packet containing the Path message.

o A stable IPv4 or IPv6 address of the previous node found by examining the TE advertisements for the upstream data plane interface.

o The value in the received in the Next/Previous Hop Address field of the RSVP_HOP (PHOP) Object [RFC2205].

5. Unnumbered Addressing

An unnumbered address is the combination of a network-unique node identifier and a node-unique interface identifier.

An unnumbered link is identified by the combination of the TE Router ID that is a reachable address in the control plane and a node-unique Interface ID [RFC3477].

5.1. Unnumbered Addresses in IGPs

In this section, we consider unnumbered address advertisement using OSPF-TE and IS-IS-TE.

5.1.1. Link Local/Remote Identifiers in OSPF-TE

Link Local and Link Remote Identifiers are carried in OSPF using a single sub-TLV of the Link TLV [RFC4203]. They advertise the IDs of an unnumbered TE link's local and remote ends, respectively. Link Local/Remote Identifiers are numbers unique within the scopes of the advertising LSR and the LSR managing the remote end of the link respectively [RFC3477].

Note that these numbers are not network-unique and therefore cannot be used as TE link end identifiers on their own. An unnumbered TE link end network-wide identifier is comprised of two elements as defined in [RFC3477]:

- A TE Router ID that is associated with the link local end

- The link local identifier.

5.1.2. Link Local/Remote Identifiers in IS-IS-TE

The Link Local and Link Remote Identifiers are carried in IS-IS using a single sub-TLV of the Extended IS Reachability TLV. Link identifiers are exchanged in the Extended Local Circuit ID field of the "Point-to-Point Three-Way Adjacency" IS-IS Option type [RFC4205].

The same discussion of unique identification applies here as in Section 5.1.1.

5.2. Unnumbered Addresses in RSVP-TE

We consider in this section the interface ID fields of objects used in RSVP-TE in the case of unnumbered addressing.

5.2.1. Sender and End Point Addresses

The IP Tunnel End Point Address in the RSVP Session Object and the IP Tunnel Sender Address in the RSVP Sender Template Object cannot use unnumbered addresses [RFC3209], [RFC3473].

5.2.2. IF_ID RSVP_HOP Object for Unnumbered Interfaces

The interface ID field in the IF_INDEX TLV specifies the interface of the data channel for an unnumbered interface.

In both Path and Resv messages, the value of the interface ID in the IF_INDEX TLV specifies the local interface ID of the associated data channel at the upstream node (the node sending the Path message and receiving the Resv message).

See Section 6.2 for a description of the use bundled links.

5.2.3. Explicit Route Object (ERO)

The ERO may use an unnumbered identifier of a TE link to be part of the signaled LSP.

See Section 6 for a description of the use of addresses in the ERO.

5.2.4. Record Route Object (RRO)

The RRO records the data-plane identifiers of TE nodes and TE links that are part of an LSP that has been established or is being established. TE links may be identified using unnumbered addressing.

See Section 6 for a description of the use of addresses in the RRO.

5.2.5. LSP_Tunnel Interface ID Object

The LSP_TUNNEL_INTERFACE_ID Object includes the LSR's Router ID and Interface ID, as described in [RFC3477], to specify an unnumbered Forward Adjacency Interface ID. The Router ID of the GMPLS-capable LSR must be set to the TE Router ID.

5.2.6. IP Packet Addresses

IP packets can only be addressed to numbered addresses.

6. RSVP-TE Message Content

This section examines the use of addresses in RSVP EROs and RROs, the identification of component links, and forwarding addresses for RSVP messages.

6.1. ERO and RRO Addresses

EROs may contain strict or loose hop subobjects. These are discussed separately below. A separate section describes the use of addresses in the RRO.

Implementations making limited assumptions about the content of an ERO or RRO when processing a received RSVP message may cause or experience interoperability issues. Therefore, implementations that want to ensure full interoperability need to support the receipt for processing of all ERO and RRO options applicable to their hardware capabilities.

Note that the phrase "receipt for processing" is intended to indicate that an LSR is not expected to look ahead in an ERO or process any subobjects that do not refer to the LSR itself or to the next hop in the ERO. An LSR is not generally expected to process an RRO except by adding its own information.

Note also that implementations do not need to support the ERO options containing Component Link IDs if they do not support link bundling [RFC4201].

ERO processing at region boundaries is described in [RFC4206].

6.1.1. Strict Subobject in ERO

Depending on the level of control required, a subobject in the ERO includes an address that may specify an abstract node (i.e., a group of nodes), a simple abstract node (i.e., a specific node), or a specific interface of a TE link in the data plane [RFC3209].

A hop may be flagged as strict (meaning that the LSP must go directly to the identified next hop without any intervening nodes), or loose.

If a hop is strict, the ERO may contain any of the following.

1. Address prefix or AS number specifying a group of nodes.

2. TE Router ID identifying a specific node.

3. Link ID identifying an incoming TE link.

4. Link ID identifying an outgoing TE link, optionally followed by a Component Interface ID and/or one or two Labels.

5. Link ID identifying an incoming TE link, followed by a Link ID identifying an outgoing TE link, optionally followed by a Component Interface ID and/or one or two Labels.

6. TE Router ID identifying a specific node, followed by a Link ID identifying an outgoing TE link, optionally followed by a Component Interface ID and/or one or two Labels.

7. Link ID identifying an incoming TE link, followed by a TE Router ID identifying a specific node, followed by a Link ID identifying an outgoing TE link, optionally followed by Component Interface ID and/or one or two Labels.

The label value that identifies a single unidirectional resource between two nodes may be different from the perspective of upstream and downstream nodes. This is typically the case in fiber switching because the label value is a number indicating the port/fiber. It may also be the case for lambda switching, because the label value is an index for the lambda in the hardware and may not be a globally defined value such as the wavelength in nanometers.

The value of a label in any RSVP-TE object indicates the value from the perspective of the sender of the object/TLV [RFC3471]. Therefore, any label in an ERO is given using the upstream node's identification of the resource.

6.1.2. Loose Subobject in ERO

There are two differences between Loose and Strict subobjects.

- o A subobject marked as a loose hop in an ERO must not be followed by a subobject indicating a label value [RFC3473].

- o A subobject marked as a loose hop in an ERO should never include an identifier (i.e., address or ID) of the outgoing interface.

There is no way to specify in an ERO whether a subobject identifies an incoming or outgoing TE link. Path computation must be performed by an LSR when it encounters a loose hop in order to resolve the LSP route to the identified next hop. If an interface is specified as a loose hop and is treated as an incoming interface, the path computation will select a path that enters an LSR through that interface. If the interface was intended to be used as an outgoing interface, the computed path may be unsatisfactory and the explicit route in the ERO may be impossible to resolve. Thus a loose hop that identifies an interface should always identify the incoming TE link in the data plane.

6.1.3. RRO

The RRO is used on Path and Resv messages to record the path of an LSP. Each LSR adds subobjects to the RRO to record information. The information added to an RRO by a node should be the same in the Path and the Resv message although there may be some information that is not available during LSP setup.

One use of the RRO is to allow the operator to view the path of the LSP. At any transit node, it should be possible to construct the path of the LSP by joining together the RRO from the Path and the Resv messages.

It is also important that a whole RRO on a Resv message received at an ingress LSR can be used as an ERO on a subsequent Path message to completely recreate the LSP.

Therefore, when a node adds one or more subobjects to an RRO, any of the following options is valid.

1. TE Router ID identifying the LSR.

2. Link ID identifying the incoming (upstream) TE link.

3. Link ID identifying the outgoing (downstream) TE link, optionally followed by a Component Interface ID and/or one or two Labels.

4. Link ID identifying the incoming (upstream) TE link, followed by a Link ID identifying the outgoing (downstream) TE link, optionally followed by a Component Interface ID and/or one or two Labels.

5. TE Router ID identifying the LSR, followed by a Link ID identifying the outgoing (downstream) TE link, optionally followed by a Component Interface ID and/or one or two Labels.

6. Link ID identifying the incoming (upstream) TE link, followed by the TE Router ID identifying the LSR, followed by a Link ID identifying the outgoing (downstream) TE link, optionally followed by a Component Interface ID and/or one or two Labels.

An implementation may choose any of these options and must be prepared to receive an RRO that contains any of these options.

6.1.4. Label Record Subobject in RRO

RRO Label recording is requested by an ingress node setting the Label Recording flag in the SESSION_ATTRIBUTE object and including an RRO is included in the Path message as described in [RFC3209]. Under these circumstances, each LSR along the LSP should include label information in the RRO in the Path message if it is available.

As described in [RFC3209], the processing for a Resv message "mirrors that of the Path" and "The only difference is that the RRO in a Resv message records the path information in the reverse direction." This means that hops are added to the RRO in the reverse order, but the information added at each LSR is in the same order (see Sections 6.1.1, 6.1.2, and 6.1.3). Thus, when label recording is requested, labels are included in the RROs in both the Path and Resv messages.

6.2. Component Link Identification

When a bundled link [RFC4201] is used to provide a data channel, a component link identifier is specified in the Interface Identification TLV in the IF_ID RSVP_HOP Object in order to indicate which data channel from within the bundle is to be used. The Interface Identification TLV is IF_INDEX TLV (Type 3) in the case of an unnumbered component link and IPv4 TLV (Type 1) or IPv6 TLV (Type 2) in the case of a numbered component link.

The component link for the upstream data channel may differ from that for the downstream data channel in the case of a bidirectional LSP. In this case, the Interface Identification TLV specifying a downstream interface is followed by another Interface Identification TLV specifying an upstream interface.

Note that identifiers in TLVs for upstream and downstream data channels in both Path and Resv messages are specified from the viewpoint of the upstream node (the node sending the Path message and receiving the Resv message), using identifiers belonging to the node.

An LSR constructing an ERO may include a Link ID that identifies a bundled link. If the LSR knows the identities of the component links and wishes to exert control, it may also include component link identifiers in the ERO. Otherwise, the component link identifiers are not included in the ERO.

When a bundled link is in use, the RRO may include the Link ID that identifies the link bundle. Additionally, the RRO may include a component link identifier.

6.3. Forwarding Destination of Path Messages with ERO

The final destination of the Path message is the Egress node that is specified by the tunnel end point address in the Session object.

The Egress node must not forward the corresponding Path message downstream, even if the ERO includes the outgoing interface ID of the Egress node for Egress control [RFC4003].

7. Topics Related to the GMPLS Control Plane

7.1. Control Channel Separation

In GMPLS, a control channel can be separated from the data channel and there is not necessarily a one-to-one association of a control channel to a data channel. Two nodes that are adjacent in the data plane may have multiple IP hops between them in the control plane.

There are two broad types of separated control planes: native and tunneled. These differ primarily in the nature of encapsulation used for signaling messages, which also results in slightly different address handling with respect to the control plane address.

7.1.1. Native and Tunneled Control Plane

A native control plane uses IP forwarding to deliver RSVP-TE messages between protocol speakers. The message is not further encapsulated.

IP forwarding applies normal rules to the IP header. Note that an IP hop must not decrement the TTL of the received RSVP-TE message.

For the case where two adjacent nodes have multiple IP hops between them in the control plane, then as stated in Section 9 of [RFC3945], implementations should use the mechanisms of Section 6.1.1 of [RFC4206] whether or not they use LSP Hierarchy. Note that Section 6.1.1 of [RFC4206] applies to an "FA-LSP" as stated in that section, but also to a "TE link" for the case where a normal TE link is used.

With a tunneled control plane, the RSVP-TE message is packaged in an IP packet that is inserted into a tunnel such that the IP packet will traverse exactly one IP hop. Various tunneling techniques can be used including (but not limited to) IP-in-IP, Generic Routing Encapsulation (GRE), and IP in MPLS.

Where the tunneling mechanism includes a TTL, it should be treated as for any network message sent on that network. Implementations receiving RSVP-TE messages on the tunnel interface must not compare the RSVP-TE TTL to any other TTL (whether the IP TTL or the tunnel TTL).

It has been observed that some implementations do not support the tunneled control plane features, and it is suggested that to enable interoperability, all implementations should support at least a native control plane.

7.2. Separation of Control and Data Plane Traffic

Data traffic must not be transmitted through the control plane. This is crucial when attempting PSC (Packet-Switching Capable) GMPLS with separated control and data channels.

8. Addresses in the MPLS and GMPLS TE MIB Modules

This section describes a method of defining or monitoring an LSP tunnel using the MPLS-TE-STD-MIB module [RFC3812] and GMPLS-TE-STD-MIB module [RFC4802] where the ingress and/or egress routers are identified using 128-bit IPv6 addresses. This is the case when the mplsTunnelIngressLSRId and mplsTunnelEgressLSRId objects in the mplsTunnelTable [RFC3812] cannot be used to carry the tunnel end point address and Extended Tunnel Id fields from the signaled Session Object because the IPv6 variant (LSP_TUNNEL_IPv6_SESSION object) is in use.

The normative text for MIB objects for control and monitoring MPLS and GMPLS nodes is found in the RFCs referenced above. This section makes no changes to those objects, but describes how they may be used to provide the necessary function.

8.1. Handling IPv6 Source and Destination Addresses

8.1.1. Identifying LSRs

For this feature to be used, all LSRs in the network must advertise a 32-bit value that can be used to identify the LSR. In this document, this is referred to as the 32-bit LSR ID. The 32-bit LSR ID is the OSPFv3 router ID [RFC2740] or the ISIS IPv4 TE Router ID [RFC3784]. Note that these are different from TE router ID (see Section 2).

8.1.2. Configuring GMPLS Tunnels

When setting up RSVP TE tunnels, it is common practice to copy the values of the mplsTunnelIngressLSRId and mplsTunnelEgressLSRId fields in the MPLS TE MIB mplsTunnelTable [RFC3812] into the Extended Tunnel ID and IPv4 tunnel end point address fields, respectively, in the RSVP-TE LSP_TUNNEL_IPv4 SESSION object [RFC3209].

This approach cannot be used when the ingress and egress routers are identified by 128-bit IPv6 addresses as the mplsTunnelIngressLSRId, and mplsTunnelEgressLSRId fields are defined to be 32-bit values [RFC3811], [RFC3812].

Instead, the IPv6 addresses should be configured in the mplsHopTable as the first and last hops of the mplsTunnelHopTable entries defining the explicit route for the tunnel. Note that this implies that a tunnel with IPv6 source and destination addresses must have an explicit route configured, although it should be noted that the configuration of an explicit route in this way does not imply that an explicit route will be signaled.

In more detail, the tunnel is configured at the ingress router as follows. See [RFC3812] for definitions of MIB table objects and for default (that is, "normal") behavior.

The mplsTunnelIndex and mplsTunnelInstance fields are set as normal.

The mplsTunnelIngressLSRId and mplsTunnelEgressLSRId fields should be set to 32-bit LSR IDs for ingress and egress LSRs, respectively.

The mplsTunnelHopTableIndex must be set to a non-zero value. That is, an explicit route must be specified.

The first hop of the explicit route must have mplsTunnelHopAddrType field set to ipv6(2) and should have the mplsTunnelHopIpAddr field set to a global scope IPv6 address of the ingress router that is reachable in the control plane.

The last hop of the explicit route must have mplsTunnelHopAddrType field set to ipv6(2) and should have the mplsTunnelHopIpAddr field set to a global scope IPv6 address of the egress router that is reachable in the control plane.

The ingress router should set the signaled values of the Extended

Tunnel ID and IPv6 tunnel end point address fields, respectively, of the RSVP-TE LSP_TUNNEL_IPv6 SESSION object [RFC3209] from the mplsTunnelHopIpAddr object of the first and last hops in the configured explicit route.

8.2. Managing and Monitoring Tunnel Table Entries

In addition to their use for configuring LSPs as described in Section 8.1, the TE MIB modules (MPLS-TE-STD-MIB and GMPLS-TE-STD-MIB) may be used for managing and monitoring MPLS and GMPLS TE LSPs, respectively. This function is particularly important at egress and transit LSRs.

For a tunnel with IPv6 source and destination addresses, an LSR implementation should return values in the mplsTunnelTable as follows (where "normal" behavior is the default taken from [RFC3812]).

The mplsTunnelIndex and mplsTunnelInstance fields are set as normal.

The mplsTunnelIngressLSRId field and mplsTunnelEgressLSRId are set to 32-bit LSR IDs. That is, each transit and egress router maps from the IPv6 address in the Extended Tunnel ID field to the 32-bit LSR ID of the ingress LSR. Each transit router also maps from the IPv6 address in the IPv6 tunnel end point address field to the 32-bit LSR ID of the egress LSR.

9. Security Considerations

In the interoperability testing we conducted, the major issue we found was the use of control channels for forwarding data. This was due to the setting of both control and data plane addresses to the same value in PSC (Packet-Switching Capable) equipment. This occurred when attempting to test PSC GMPLS with separated control and data channels. What resulted instead were parallel interfaces with the same addresses. This could be avoided simply by keeping the addresses for the control and data plane separate.

10. Acknowledgments

The following people made textual contributions to this document:

Alan Davey, Yumiko Kawashima, Kaori Shimizu, Thomas D. Nadeau, Ashok Narayanan, Eiji Oki, Lyndon Ong, Vijay Pandian, Hari Rakotoranto, and Adrian Farrel.

The authors would like to thank Adrian Farrel for the helpful discussions and the feedback he gave on the document. In addition, Jari Arkko, Arthi Ayyangar, Deborah Brungard, Diego Caviglia, Lisa Dusseault, Dimitri Papadimitriou, Jonathan Sadler, Hidetsugu Sugiyama, and Julien Meuric provided helpful comments and suggestions.

Adrian Farrel edited the final revisions of this document before and after working group last call.

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