

Network Working Group
Request for Comments: 4420
Updates: 3209, 3473
Category: Standards Track

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February 2006

Encoding of Attributes for Multiprotocol Label Switching (MPLS)
Label Switched Path (LSP) Establishment Using
Resource ReserVation Protocol-Traffic Engineering (RSVP-TE)

Status of This Memo

This document specifies an Internet standards track protocol for the Internet community, and requests discussion and suggestions for improvements. Please refer to the current edition of the "Internet Official Protocol Standards" (STD 1) for the standardization state and status of this protocol. Distribution of this memo is unlimited.

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Abstract

Multiprotocol Label Switching (MPLS) Label Switched Paths (LSPs) may be established using the Resource Reservation Protocol Traffic Engineering (RSVP-TE) extensions. This protocol includes an object (the SESSION_ATTRIBUTE object) that carries a Flags field used to indicate options and attributes of the LSP. That Flags field has eight bits allowing for eight options to be set. Recent proposals in many documents that extend RSVP-TE have suggested uses for each of the previously unused bits.

This document defines a new object for RSVP-TE messages that allows the signaling of further attribute bits and also the carriage of arbitrary attribute parameters to make RSVP-TE easily extensible to support new requirements. Additionally, this document defines a way to record the attributes applied to the LSP on a hop-by-hop basis.

The object mechanisms defined in this document are equally applicable to Generalized MPLS (GMPLS) Packet Switch Capable (PSC) LSPs and to GMPLS non-PSC LSPs.

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1. Introduction and Problem Statement

Traffic-Engineered Multiprotocol Label Switching (MPLS) Label Switched Paths (LSPs) [RFC3031] may be set up using the Path message of the RSVP-TE signaling protocol [RFC3209]. The Path message includes the SESSION_ATTRIBUTE object, which carries a Flags field used to indicate desired options and attributes of the LSP.

The Flags field in the SESSION_ATTRIBUTE object has eight bits. Just three of those bits are assigned in [RFC3209]. A further two bits are assigned in [RFC4090] for fast re-reroute functionality leaving only three bits available. Several recent proposals and Internet Drafts have demonstrated that there is a high demand for the use of the other three bits. Some, if not all, of those proposals are likely to go forward as RFCs resulting in depletion or near depletion of the Flags field and a consequent difficulty in signaling new options and attributes that may be developed in the future.

This document defines a new object for RSVP-TE messages that allows the signaling of further attributes bits. The new object is constructed from TLVs, and a new TLV is defined to carry a variable number of attributes bits.

The new RSVP-TE message object is quite flexible, due to the use of the TLV format and allows:

- future specification of bit flags
- additional options and attribute parameters carried in TLV format.

Note that the LSP Attributes defined in this document are specifically scoped to an LSP. They may be set differently on separate LSPs with the same Tunnel ID between the same source and destination (that is, within the same session).

It is noted that some options and attributes do not need to be acted on by all Label Switched Routers (LSRs) along the path of the LSP. In particular, these options and attributes may apply only to key LSRs on the path such as the ingress LSR and egress LSR. Special transit LSRs, such as Area or Autonomous System Border Routers (ABRs or ASBRs), may also fall into this category. This means that the new options and attributes should be signaled transparently, and only examined at those points that need to act on them.

On the other hand, other options and attributes may require action at all transit LSRs along the path of the LSP. Inability to support the required attributes by one of those transit LSRs may require the LSR to refuse the establishment of the LSP.

These considerations are particularly important in the context of backward compatibility. In general, it should be possible to provide new MPLS services across a legacy network without upgrading those LSRs that do not need to participate actively in the new services. Moreover, some features just require action on specific intermediate hops, and not on every visited LSR.

Note that options already specified for the SESSION_ATTRIBUTE object in preexisting RFCs are not migrated to the new mechanisms described in this document.

RSVP includes a way for unrecognized objects to be transparently forwarded by transit nodes without them refusing the incoming protocol messages and without the objects being stripped from the outgoing protocol message (see [RFC2205], Section 3.10). This capability extends to RSVP-TE and provides a good way to ensure that only those LSRs that understand a particular object examine it.

This document distinguishes between options and attributes that are only required at key LSRs along the path of the LSP, and those that must be acted on by every LSR along the LSP. Two LSP Attributes objects are defined in this document: using the C-Num definition rules inherited from [RFC2205], the first is passed transparently by LSRs that do not recognize it, and the second causes LSP setup failure with the generation of a PathErr message with an appropriate Error Code if an LSR does not recognize it.

1.1. Applicability to Generalized MPLS

The RSVP-TE signaling protocol also forms the basis of a signaling protocol for Generalized MPLS (GMPLS) as described in [RFC3471] and [RFC3473]. The extensions described in this document are equally applicable to MPLS and GMPLS.

1.2. A Rejected Alternate Solution

A rejected alternate solution was to define a new C-Type for the existing SESSION_ATTRIBUTE object. This new C-Type could allow a larger Flags field and address the immediate problem.

This solution was rejected because:

- A new C-Type is not backward compatible with deployed implementations that expect to see a C-Type of 1 or 7. It is important that any solution be capable of carrying new attributes transparently across legacy LSRs if those LSRs are not required to act on the attributes.

- Support for arbitrary attributes parameters through TLVs would have meant a significant change of substance to the existing object.

2. Terminology

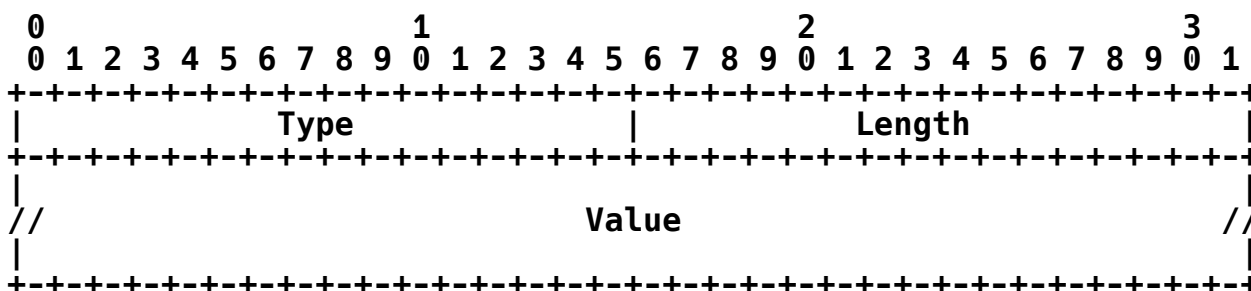
This document uses terminology from the MPLS architecture document [RFC3031] and from the RSVP-TE protocol specification [RFC3209], which inherits from the RSVP specification [RFC2205]. It also makes use of the Generalized MPLS RSVP-TE terminology introduced in [RFC3471] and [RFC3473].

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].

3. Attributes TLVs

Attributes carried by the new objects defined in this document are encoded within TLVs. One or more TLVs may be present in each object. There are no ordering rules for TLVs, and no interpretation should be placed on the order in which TLVs are received.

Each TLV is encoded as follows.



Type

The identifier of the TLV.

Length

The length of the Value field in bytes. Thus, if no Value field is present the Length field contains the value zero. Each Value field must be zero padded at the end to take it up to a four byte boundary -- the padding is not included in the length so that a one byte value would be encoded in an eight byte TLV with Length field set to one.

Value

The data for the TLV padded as described above.

3.1. Attributes Flags TLV

This document defines only one TLV type value. Type 1 indicates the Attributes Flags TLV. Other TLV types may be defined in the future with type values assigned by IANA (see Section 11.2).

The Attributes Flags TLV may be present in an LSP_ATTRIBUTES object and/or an LSP_REQUIRED_ATTRIBUTES object defined in Sections 4 and 5. The bits in the TLV represent the same attributes regardless of which object carries the TLV. Documents that define individual bits MUST specify whether the bit may be set in one object or the other, or both. It is not expected that a bit will be set in both objects on a single Path message at the same time, but this is not ruled out by this document.

The Attribute Flags TLV Value field is an array of units of 32 flags numbered from the most significant bit as bit zero. The Length field for this TLV is therefore always a multiple of 4 bytes, regardless of the number of bits carried and no padding is required.

Unassigned bits are considered as reserved and MUST be set to zero on transmission by the originator of the object. Bits not contained in the TLV MUST be assumed to be set to zero. If the TLV is absent either because it is not contained in the LSP_ATTRIBUTES or LSP_REQUIRED_ATTRIBUTES object, or because those objects are themselves absent, all processing MUST be performed as though the bits were present and set to zero. That is to say, assigned bits that are not present either because the TLV is deliberately foreshortened or because the TLV is not included MUST be treated as though they are present and are set to zero.

No bits are defined in this document. The assignment of bits is managed by IANA (see Section 11.3).

4. LSP_ATTRIBUTES Object

The LSP_ATTRIBUTES object is used to signal attributes required in support of an LSP, or to indicate the nature or use of an LSP where that information is not required to be acted on by all transit LSRs. Specifically, if an LSR does not support the object, it forwards it unexamined and unchanged. This facilitates the exchange of attributes across legacy networks that do not support this new object.

An LSR that does support this object, but does not recognize a TLV type code carried in this object, **MUST** pass the TLV on unaltered in the LSP_ATTRIBUTES object that it places in the Path message that it sends downstream.

An LSR that does support this object and recognizes a TLV, but does not support the attribute defined by the TLV, **MUST** act as specified in the document that defines the TLV.

An LSR that supports the Attributes Flags TLV, but does not recognize a bit set in the Attributes Flags TLV, **MUST** forward the TLV unchanged.

An LSR that supports the Attributes Flags TLV and recognizes a bit that is set, but does not support the indicated attribute, **MUST** act as specified in the document that defines the bit.

4.3. Generic Processing Rules for Resv Messages

An LSR that wishes to report operational status of an LSP may include this object in a Resv message, or update the object that is already carried in a Resv message.

Note that this usage reports the state of the entire LSP and not the state of the LSP at an individual LSR. This latter function is achieved using the LSP Attributes subobject of the Record Route object (RR0) as described in Section 7.

The bits in the Attributes TLV may be used to report operational status for the whole LSP. For example, an egress LSR may report a particular status by setting a bit. LSRs within the network that determine that this status has not been achieved may clear the bit as they forward the Resv message.

Observe that LSRs that do not support the object or do not support the function characterized by a particular bit in the Attributes TLV will not clear the bit when forwarding the Resv. Thus, care must be taken in defining the usage of this object on a Resv. The usage of an individual bit in the Attributes TLV of the LSP_ATTRIBUTES object on a Resv must be fully defined in the document that defines the bit.

Additional TLVs may also be defined to be carried in this object on a Resv.

An LSR that does not support this object will pass it on unaltered because of the C-Num.

An LSR that does not recognize a TLV type code carried in this object **MUST** reject the Path message using a PathErr with Error Code "Unknown Attributes TLV" and Error Value set to the value of the unknown TLV type code.

An LSR that does not recognize a bit set in the Attributes Flags TLV **MUST** reject the Path message using a PathErr with Error Code "Unknown Attributes Bit" and Error Value set to the bit number of the unknown bit in the Attributes Flags.

An LSR that recognizes an attribute (however encoded), but that does not support that attribute, **MUST** act according to the behavior specified in the document that defines that specific attribute.

Note that this object is not used on a Resv. In order to report the status of an LSP, either the LSP_ATTRIBUTES object on a Resv or the Attributes subobject in the Record Route object (see Section 7) must be used.

6. Inheritance Rules

In certain circumstances, when reaching an LSP region boundary, a forwarding adjacency LSP (FA-LSP; see [RFC4206]) is initially set up to allow the establishment of the LSP carrying the LSP_ATTRIBUTES and/or LSP_REQUIRED_ATTRIBUTES objects. In this case, when the boundary LSR supports LSP_ATTRIBUTES and LSP_REQUIRED_ATTRIBUTES processing, the FA-LSP **MAY** upon local policy inherit a subset of the Attributes TLVs, in particular when the FA-LSP belongs to the same switching capability class as the triggering LSP.

When these conditions are met, the LSP_ATTRIBUTES and/or LSP_REQUIRED_ATTRIBUTES objects are simply copied with the inherited Attributes TLVs in the Path message used to establish the FA-LSP. By default (and in order to simplify deployment), none of the incoming LSP Attributes TLVs are considered as inheritable. Note that when the FA-LSP establishment itself requires one or more Attributes TLVs, an 'OR' operation is performed with the inherited set of values.

Documents that define individual bits for the LSP Attributes Flags TLV **MUST** specify whether or not these bits **MAY** be inherited (including the condition to be met in order for this inheritance to occur). The same applies for any other TLV that will be defined following the rules specified in Section 3.

7. Recording Attributes Per LSP

7.1. Requirements

In some circumstances, it is useful to determine which of the requested LSP attributes have been applied at which LSRs along the path of the LSP. For example, an attribute may be requested in the LSP_ATTRIBUTES object such that LSRs that do not support the object are not required to support the attribute or provide the requested function. In this case, it may be useful to the ingress LSR to know which LSRs acted on the request and which ignored it.

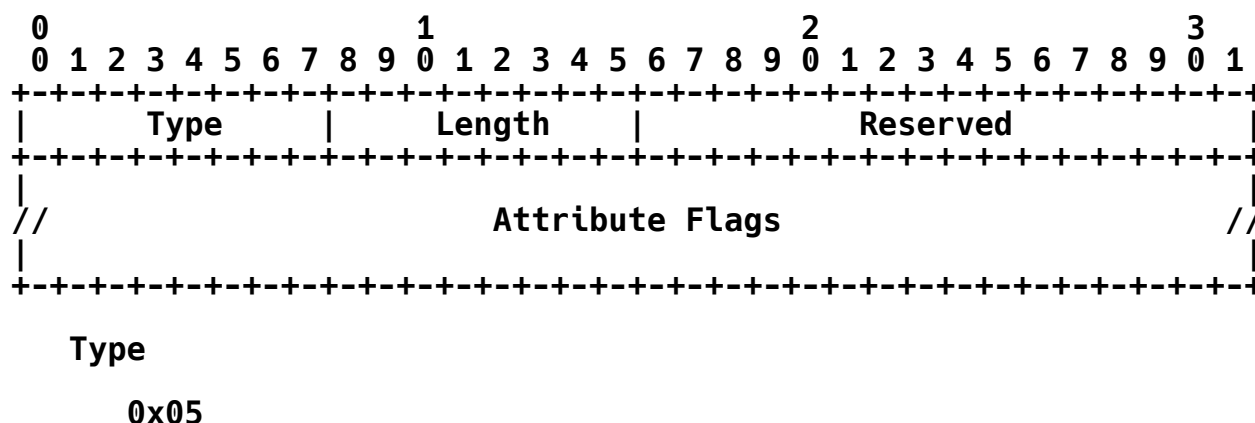
Additionally, there may be other qualities that need to be reported on a hop-by-hop basis. These are currently indicated in the Flags field of RR0 subobjects. Since there are only eight bits available in this field, and since some are already assigned and there is also likely to be an increase in allocations in new documents, there is a need for some other method to report per-hop attributes.

7.2. RR0 Attributes Subobject

The RR0 Attributes Subobject may be carried in the RECORD_ROUTE object if it is present. The subobject uses the standard format of an RR0 subobject.

The length is variable as for the Attributes Flags TLV. The content is the same as the Attribute Flags TLV -- that is, it is a series of bit flags.

There is a one-to-one correspondence between bits in the Attributes Flags TLV and the RR0 Attributes Subobject. If a bit is only required in one of the two places, it is reserved in the other place. See the procedures sections, below, for more information.



Length

The Length contains the total length of the subobject in bytes, including the Type and Length fields. This length must be a multiple of 4 and must be at least 8.

Attribute Flags

The attribute flags recorded for the specific hop.

7.3. Procedures

7.3.1. Subobject Presence Rules

As will be clear from [RFC3209], the RECORD_ROUTE object is managed as a "stack" with each LSR adding subobjects to the start of the object. The Attributes subobject is pushed onto the RECORD_ROUTE object immediately prior to pushing the node's IP address or link identifier. Thus, if label recording is being used, the Attributes subobject SHOULD be pushed onto the RECORD_ROUTE object after the Record Label subobject(s).

A node MUST NOT push an Attributes subobject onto the RECORD_ROUTE object without also pushing an IPv4, IPv6, or Unnumbered Interface ID subobject.

This means that an Attributes subobject is bound to the LSR identified by the subobject found in the RRO immediately before the Attributes subobject.

If the new subobject causes the RRO to be too big to fit in a Path (or Resv) message, the processing MUST be as described in Section 4.4.3 of [RFC3209].

If more than one Attributes subobject is found between a pair of subobjects that identify LSRs, only the first one found (that is, the nearest to the top of the stack) SHALL have any meaning within the context of this document. All such subobjects MUST be forwarded unmodified by transit LSRs

7.3.2. Reporting Compliance with LSP Attributes

To report compliance with an attribute requested in the Attributes Flags TLV, an LSR MAY set the corresponding bit (see Section 8) in the Attributes subobject. To report non-compliance, an LSR MAY clear the corresponding bit in the Attributes subobject.

The requirement to report compliance **MUST** be specified in the document that defines the usage of any bit. This will reduce to a statement of whether hop-by-hop acknowledgement is required.

7.3.3. Reporting Per-Hop Attributes

To report a per-hop attribute, an LSR sets the appropriate bit in the Attributes subobject.

The requirement to report a per-hop attribute **MUST** be specified in the document that defines the usage of the bit.

7.3.4. Default Behavior

By default, all bits in an Attributes subobject **SHOULD** be set to zero.

If a received Attribute subobject is not long enough to include a specific numbered bit, that bit **MUST** be treated as though present and as if set to zero.

If the RRO subobject is not present for a hop in the LSP, all bits **MUST** be assumed to be set to zero.

8. Summary of Attribute Bit Allocation

This document defines two uses of per-LSP attribute flag bit fields. The bit numbering in the Attributes Flags TLV and the RRO Attributes subobject is identical. That is, the same attribute is indicated by the same bit in both places. This means that only a single registry of bits is maintained.

The consequence is a degree of clarity in implementation and registration.

Note, however, that it is not always the case that a bit will be used in both the Attributes Flags TLV and the RRO Attributes subobject. For example, an attribute may be requested using the Attributes Flags TLV, but there is no requirement to report the handling of the attribute on a hop-by-hop basis. Conversely, there may be a requirement to report the attributes of an LSP on a hop-by-hop basis, but there is no corresponding request attribute.

In these cases, a single bit number is still assigned for both the Attributes Flags TLV and the RRO Attributes subobject even though the bit may be irrelevant in either the Attributes Flags or the RRO

Attributes subobject. The document that defines the usage of the new bit MUST state in which places it is used and MUST handle a default setting of zero.

9. Message Formats

The LSP_ATTRIBUTES object and the LSP_REQUIRED_ATTRIBUTES object MAY be carried in a Path message. The LSP_ATTRIBUTES object MAY be carried in a Resv message.

The order of objects in RSVP-TE messages is recommended, but implementations must be capable of receiving the objects in any meaningful order.

On a Path message, the LSP_ATTRIBUTES object and LSP_REQUIRED_ATTRIBUTES objects are RECOMMENDED to be placed immediately after the SESSION_ATTRIBUTE object if it is present, or otherwise immediately after the LABEL_REQUEST object.

If both the LSP_ATTRIBUTES object and the LSP_REQUIRED_ATTRIBUTES object are present, the LSP_REQUIRED_ATTRIBUTES object is RECOMMENDED to be placed first.

LSRs MUST be prepared to receive these objects in any order in any position within a Path message. Subsequent instances of these objects within a Path message SHOULD be ignored and those objects MUST be forwarded unchanged.

On a Resv message, the LSP_ATTRIBUTES object is placed in the flow descriptor and is associated with the FILTER_SPEC object that precedes it. It is RECOMMENDED that the LSP_ATTRIBUTES object be placed immediately after the LABEL object.

LSRs MUST be prepared to receive this object in any order in any position within a Resv message subject to the previous note. Only one instance of the LSP_ATTRIBUTES object is meaningful within the context of a FILTER_SPEC object. Subsequent instances of the object SHOULD be ignored and MUST be forwarded unchanged.

10. Guidance for Key Application Scenarios

As described in the Introduction section of this document, it may be that requested LSP attributes need to be acted on by only the egress LSR of the LSP, by certain key transit points (such as ABRs and ASBRs), or by all LSRs along the LSP. This section briefly describes how each of these scenarios is met. This section is informational and does not define any new procedures.

10.1. Communicating to Egress LSRs

When communicating LSP attributes that must be acted on only by the LSP egress LSR, the attributes should be communicated in the LSP_ATTRIBUTES object. Because of its C-Num, this object may be ignored (passed onwards, untouched) by transit LSRs that do not understand it. This means that the Path message will not be rejected by LSRs that do not understand the object. In this way, the requested LSP attributes are guaranteed to reach the egress LSR.

Attributes are set within the LSP_ATTRIBUTES object according to which LSP attributes are required. Each attribute is defined in some RFC and is accompanied by a statement of what the expected behavior is. This behavior will include whether the attribute must be acted on by any LSR that recognizes it, or specifically by the egress LSR. Thus, any attribute that must be acted on only by an egress LSR will be defined in this way -- any transit LSR seeing this attribute either will understand the semantics of the attribute and ignore it (forwarding it, unchanged) or will not understand the attribute and ignore it (forwarding it, unchanged) according to the rules of the LSP_ATTRIBUTES object.

The remaining issue is how the ingress LSR can know whether the egress LSR has acted correctly on the required LSP attribute. Another part of the definition of the attribute (in the defining RFC) is whether reporting is required. If reporting is required, the egress LSR is required to use the RRO Attributes subobject to report whether it has acted on the received attribute.

If an egress LSR understands a received attribute as mandatory for an egress LSR, but does not wish to satisfy the request, it will reject the Path message. If an egress LSR understands the attribute, but believes it to be optional and does not wish to satisfy the request, it will report its non-compliance in the RRO Attributes subobject. If the egress LSR does not understand the received attribute, it may report non-compliance in the RRO Attributes subobject explicitly, or may omit the RRO Attributes subobject implying that it has not satisfied the request.

10.2. Communicating to Key Transit LSRs

Processing for key transit LSRs (such as ABRs and ASBRs) follows exactly as for egress LSR. The only difference is that the definition of the LSP attribute in the defining RFC will state that the attribute must be acted on by these transit LSRs.

10.3. Communicating to All LSRs

In order to force all LSRs to examine the LSP attributes, the LSP_REQUIRED_ATTRIBUTES object is used. The C-Num of this object is such that any LSR that does not recognize the object must reject a received Path message containing the object.

An LSR that recognizes the LSP_REQUIRED_ATTRIBUTES object, but does not recognize an attribute, will reject the Path message.

An LSR that recognizes an attribute, but does not wish to support the attribute, reacts according to the definition of the attribute in the defining RFC. This may allow the LSR to ignore the attribute and forward it unchanged, or may require it to fail the LSP setup. The LSR may additionally be required to report whether it supports the attribute using the RRO Attributes subobject.

11. IANA Considerations

11.1. New RSVP C-Nums and C-Types

Two new RSVP C-Nums are defined in this document and have been assigned by IANA.

o LSP_ATTRIBUTES object

The C-Num (value 197) is of the form 11bbbbbb so that LSRs that do not recognize the object will ignore the object but forward it, unexamined and unmodified, in all messages resulting from this message.

One C-Type is defined for this object and has been assigned by IANA.

o LSP Attributes TLVs

Recommended C-Type value 1.

o LSP_REQUIRED_ATTRIBUTES object

The C-Num (value 67) is of the form 0bbbbbbb so that LSRs that do not recognize the object will reject the message that carries it with an "Unknown Object Class" error.

One C-Type is defined for this object and has been assigned by IANA.

- o LSP Required Attributes TLVs

Recommended C-Type value 1.

11.2. New TLV Space

The two new objects referenced above are constructed from TLVs. Each TLV includes a 16-bit type identifier (the T-field). The same T-field values are applicable to both objects.

The IANA has created a new registry and will manage TLV type identifiers as follows:

- TLV Type (T-field value)
- TLV Name
- Whether allowed on LSP_ATTRIBUTES object
- Whether allowed on LSP_REQUIRED_ATTRIBUTES object.

This document defines one TLV type as follows:

- TLV Type = 1
- TLV Name = Attributes Flags TLV
- allowed on LSP_ATTRIBUTES object
- allowed on LSP_REQUIRED_ATTRIBUTES object.

New TLV type values may be allocated only by an IETF Consensus action.

11.3. Attributes Flags

This document provides new attributes bit flags for use in other documents that specify new RSVP-TE attributes. These flags are present in the Attributes Flags TLV referenced in the previous section.

The IANA has created a new registry and will manage the space of attributes bit flags numbering them in the usual IETF notation starting at zero and continuing at least through 31.

New bit numbers may be allocated only by an IETF Consensus action.

Each bit should be tracked with the following qualities:

- Bit number
- Defining RFC
- Name of bit
- Whether there is meaning in the Attribute Flags TLV on a Path
- Whether there is meaning in the Attribute Flags TLV on a Resv

- Whether there is meaning in the RRO Attributes Subobject.

Note that this means that all bits in the Attribute Flags TLV and the RRO Attributes Subobject use the same bit number regardless of whether they are used in one or both places. Thus, only one list of bits is required to be maintained. (It would be meaningless in the context of this document for a bit to have no meaning in either the Attribute Flags TLV or the RRO Attributes Subobject.)

11.4. New Error Codes

This document defines the following new Error Codes and Error Values. Numeric values have been assigned by IANA.

Error Code	Error Value
29 "Unknown Attributes TLV"	Identifies the unknown TLV type code.
30 "Unknown Attributes Bit"	Identifies the unknown Attribute Bit.

11.5. New Record Route Subobject Identifier

A new subobject is defined for inclusion in the RECORD_ROUTE object.

The RRO Attributes subobject is identified by a Type value of 5.

12. Security Considerations

This document adds two new objects to the RSVP Path message as used in MPLS and GMPLS signaling, and a new subobject to the RECORD_ROUTE object carried on many RSVP messages. It does not introduce any new direct security issues, and the reader is referred to the security considerations expressed in [RFC2205], [RFC3209], and [RFC3473].

It is of passing note that any signaling request that indicates the functional preferences or attributes of an MPLS LSP may provide anyone with unauthorized access to the contents of the message with information about the LSP that an administrator may wish to keep secret. Although this document adds new objects for signaling desired LSP attributes, it does not contribute to this issue, which can only be satisfactorily handled by encrypting the content of the signaling message.

Similarly, the addition of attribute recording information to the RRO may reveal information about the status of the LSP and the capabilities of individual LSRs that operators wish to keep secret. The same strategy that applies to other RRO subobjects also applies here. Note, however, that there is a tension between notifying the head end of the LSP status at transit LSRs, and hiding the existence or identity of the transit LSRs.

13. Acknowledgements

Credit to the OSPF Working Group for inspiration from their solution to a similar problem. Thanks to Rahul Aggarwal for his careful review and support of this work. Thanks also to Raymond Zhang, Kireeti Kompella, Philip Matthews, Jim Gibson, and Alan Kullberg for their input. As so often, thanks to John Drake for useful offline discussions. Thanks to Mike Shand for providing the Routing Directorate review and to Joel Halpern for the General Area review -- both picked up on some unclarities.

14. Normative References

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Acknowledgement

Funding for the RFC Editor function is provided by the IETF Administrative Support Activity (IASA).