Open Shortest Path First IGP   P. Psenak, Ed.
Internet-Draft   S. Previdi, Ed.
Intended status: Standards Track   C. Filsfils
Expires: January 3, 2015   Cisco Systems, Inc.
                                                           H. Gredler
                                                 Juniper Networks, Inc.
                                                            R. Shakir
                                                       British Telecom
                                                       W. Henderickx
                                                        Alcatel-Lucent
                                                          J. Tantsura
                                                             Ericsson
                                                         July 2, 2014

                   OSPFv3 Extensions for Segment Routing
             draft-psenak-ospf-segment-routing-ospfv3-extension-02

Abstract

   Segment Routing (SR) allows for a flexible definition of end-to-end
   paths within IGP topologies by encoding paths as sequences of
   topological sub-paths, called "segments". These segments are
   advertised by the link-state routing protocols (IS-IS and OSPF).

   This draft describes the necessary OSPFv3 extensions that need to be
   introduced for Segment Routing.

Requirements Language

   The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
   "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this
   document are to be interpreted as described in RFC 2119 [RFC2119].

Status of This Memo

This Internet-Draft will expire on January 3, 2015.

Copyright Notice

Table of Contents

1. Introduction

   Segment Routing (SR) allows for a flexible definition of end-to-end
   paths within IGP topologies by encoding paths as sequences of
   topological sub-paths, called "segments". These segments are
   advertised by the link-state routing protocols (IS-IS and OSPF).
   Prefix segments represent an ecmp-aware shortest-path to a prefix (or
   a node), as per the state of the IGP topology. Adjacency segments
   represent a hop over a specific adjacency between two nodes in the
   IGP. A prefix segment is typically a multi-hop path while an
   adjacency segment, in most of the cases, is a one-hop path. SR's
   control-plane can be applied to both IPv6 and MPLS data-planes, and
   do not require any additional signaling (other than the regular IGP).
   For example, when used in MPLS networks, SR paths do not require any
   LDP or RSVP-TE signaling. Still, SR can interoperate in the presence
   of LSPs established with RSVP or LDP .

   This draft describes the necessary OSPFv3 extensions that need to be
   introduced for Segment Routing.

   Segment Routing architecture is described in
   [I-D.filsfils-rtgwg-segment-routing].

   Segment Routing use cases are described in
   [I-D.filsfils-rtgwg-segment-routing-use-cases].

2. Segment Routing Identifiers

   Segment Routing defines various types of Segment Identifiers (SIDs):
   Prefix-SID, Adjacency-SID, LAN Adjacency SID and Binding SID.

2.1. SID/Label sub-TLV

   SID/Label sub-TLV appears in multiple TLVs or Sub-TLVs defined later
   in this document. It is used to advertise SID or label associated
   with the prefix or adjacency. SID/Label TLV has following format:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             Type              |            Length             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       SID/Label (variable)                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
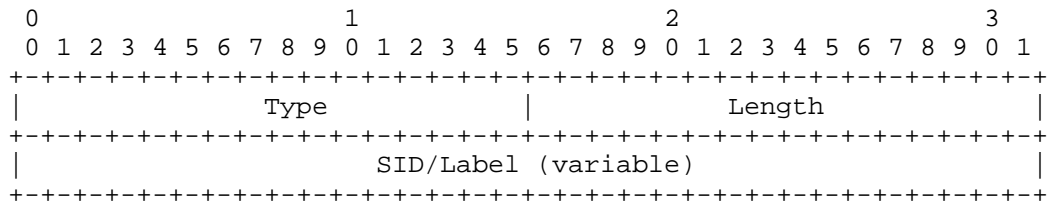
where:

   Type: TBD, suggested value 1

   Length: variable, 3 or 4 bytes

   SID/Label: if length is set to 3, then the 20 rightmost bits
   represent a label. If length is set to 4 then the value
   represents a 32 bit SID.

   The receiving router MUST ignore SID/Label sub-TLV if the length
   is other then 3 or 4.

3. Segment Routing Capabilities

   Segment Routing requires some additional capabilities of the router
   to be advertised to other routers in the area.

   These SR capabilities are advertised in OSPFv3 Router Information
   Opaque LSA (defined in [RFC4970]).

3.1. SR-Algorithm TLV

   SR-Algorithm TLV is a TLV of Router Information Opaque LSA (defined
   in [RFC4970]).

   Router may use various algorithms when calculating reachability to
   other nodes in area or to prefixes attached to these nodes. Examples
   of these algorithms are metric based Shortest Path First (SPF),
   various sorts of Constrained SPF, etc. SR-Algorithm TLV allows a
   router to advertise algorithms that router is currently using to
   other routers in an area. SR-Algorithm TLV has following structure:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Type               |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Algorithm 1   | Algorithm...  | Algorithm n   |               |
+-                                                             -+
|                                                               |
+                                                               +
```
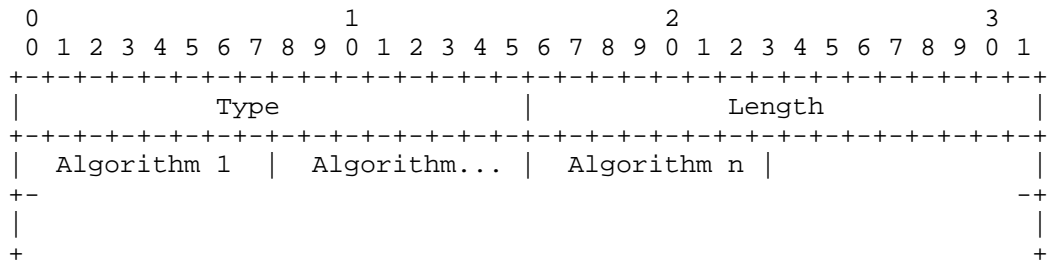
where:

   Type: TBD, suggested value 8

   Length: variable

   Algorithm: one octet identifying the algorithm. The following
   value has been defined:

      0: IGP metric based SPT.

RI LSA can be advertised at any of the defined flooding scopes (link,
area, or autonomous system (AS)). For the purpose of the SR-
Algorithm TLV propagation area scope flooding is required.

3.2. SID/Label Range TLV

   The SID/Label Range TLV is a TLV of Router Information Opaque LSA
   (defined in [RFC4970]).

   SID/Label Sub-TLV MAY appear multiple times and has following format:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Type               |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Range Size                 |    Reserved      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Sub-TLVs (variable)                         |
+-                                                             -+
|                                                               |
+                                                               +
```
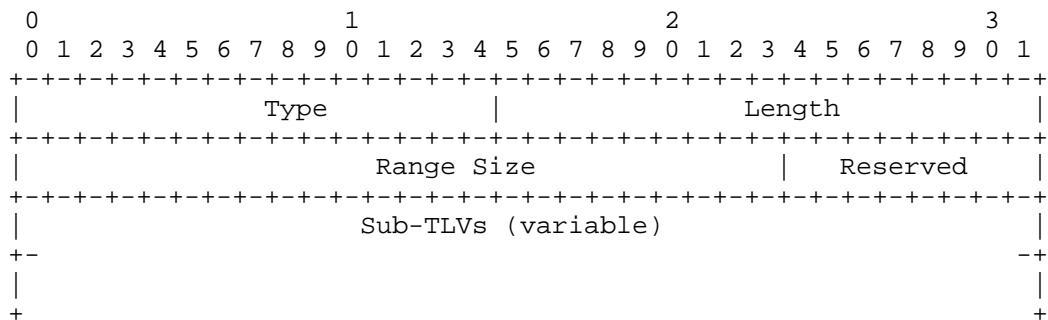
where:

   Type: TBD, suggested value 9

Length: variable

Range Size: 3 octets of SID/label range

Currently the only supported Sub-TLV is the SID/Label TLV as defined in Section 2.1. SID/Label advertised in SID/Label TLV represents the first SID/Label from the advertised range.

Multiple occurrence of the SID/Label Range TLV MAY be advertised, in order to advertise multiple ranges. In such case:

o The originating router MUST encode each range into a different SID/Label Range TLV.

o The originating router decides in which order the set of SID/Label Range TLVs are advertised inside Router Information Opaque LSA. The originating router MUST ensure the order is same after a graceful restart (using checkpointing, non-volatile storage or any other mechanism) in order to guarantee the same order before and after graceful restart.

o Receiving router must adhere to the order in which the ranges are advertised when calculating a SID/label from the SID index.

o A router not supporting multiple occurrences SID/Label Range TLV MUST take into consideration the first occurrence in the received set.

Here follows an example of advertisement of multiple ranges:

The originating router advertises following ranges:
        Range 1: [100, 199]
        Range 2: [1000, 1099]
        Range 3: [500, 599]

The receiving routers concatenate the ranges and build the SRGB
is as follows:

SRGB = [100, 199]
       [1000, 1099]
       [500, 599]

The indexes span multiple ranges:

    index=0 means label 100
    ...
    index 99 means label 199
    index 100 means label 1000
    index 199 means label 1099
    ...
    index 200 means label 500
    ...

RI LSA can be advertised at any of the defined flooding scopes (link,
area, or autonomous system (AS)). For the purpose of the SR-
Capability TLV propagation area scope flooding is required.

4. Prefix SID Identifier

A new extended OSPFv3 LSAs as defined in
[I-D.ietf-ospf-ospfv3-lsa-extend] are used to advertise SID or label
values associated with the prefix in OSPFv3.
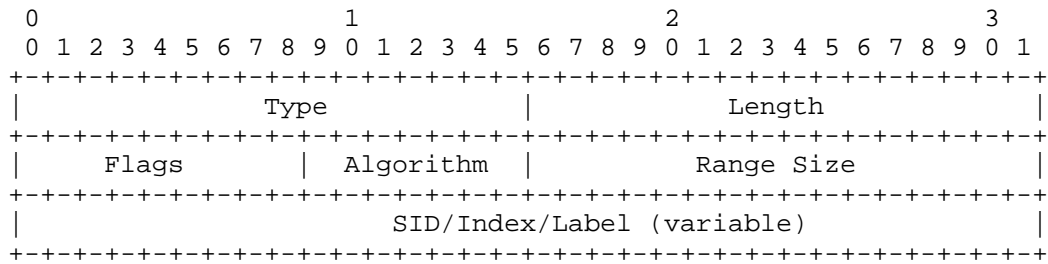
4.1. Prefix SID Sub-TLV

The Prefix SID Sub-TLV is a Sub-TLV of the following OSPFv3 TLVs as
defined in [I-D.ietf-ospf-ospfv3-lsa-extend]:

    Intra-Area Prefix TLV

    Inter-Area Prefix TLV

    External Prefix TLV

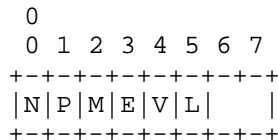It MAY appear more than once and has following format:

```
  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
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |             Type              |            Length             |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |     Flags     |  Algorithm   |           Range Size          |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                     SID/Index/Label (variable)                |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

where:

   Type: TBD, suggested value 2.

   Length: variable

   Flags: 1 octet field. The following flags are defined:

```
 0
 0 1 2 3 4 5 6 7
+-+-+-+-+-+-+-+-+
|N|P|M|E|V|L|   |
+-+-+-+-+-+-+-+-+
```

where:

        N-Flag: Node-SID flag. If set, then the Prefix-SID refers to
        the router identified by the prefix. Typically, the N-Flag is
        set on Prefix-SIDs attached to a router loopback address. The
        N-Flag is set when the Prefix-SID is a Node- SID as described
        in [I-D.filsfils-rtgwg-segment-routing].

        P-Flag: no-PHP flag. If set, then the penultimate hop MUST NOT
        pop the Prefix-SID before delivering the packet to the node
        that advertised the Prefix-SID.

        M-Flag: Mapping Server Flag. If set, the SID is advertised
        from the Segment Routing Mapping Server functionality as
        described in [I-D.filsfils-rtgwg-segment-routing-use-cases].

        E-Flag: Explicit-Null Flag. If set, any upstream neighbor of
        the Prefix-SID originator MUST replace the Prefix-SID with a
        Prefix-SID having an Explicit-NULL value (0 for IPv4) before
        forwarding the packet.

        The V-Flag: Value/Index Flag. If set, then the Prefix-SID
        carries an absolute value. If not set, then the Prefix-SID
        carries an index.

The L-Flag: Local/Global Flag. If set, then the value/index carried by the PrefixSID has local significance. If not set, then the value/index carried by this subTLV has global significance.

Other bits: MUST be zero when sent and ignored when received.

Algorithm: one octet identifying the algorithm the Prefix-SID is associated with as defined in Section 3.1.

Range Size: this field provides the ability to specify a range of addresses and their associated Prefix SIDs. It represents a compression scheme to distribute a continuous Prefix and their continuous, corresponding SID/Label Block. If a single SID is advertised then the Range Size field MUST be set to 1. For range advertisements > 1, Range Size represents the number of addresses that need to be mapped into a Prefix-SID.

SID/Index/Label: label or index value depending on the V-bit setting.

Examples:

A 32 bit global index defining the offset in the SID/Label space advertised by this router - in this case the V and L flags MUST be unset.

A 24 bit local label where the 20 rightmost bits are used for encoding the label value - in this case the V and L flags MUST be set.

If multiple Prefix-SIDs are advertised for the same prefix, the receiving router MUST use the first encoded SID and MAY use the subsequent ones.

When propagating Prefix-SIDs between areas, if multiple prefix-SIDs are advertised for a prefix, an implementation SHOULD preserve the original ordering, when advertising prefix-SIDs to other areas. This allows implementations that only use single Prefix-SID to have a consistent view across areas.

When calculating the outgoing label for the prefix, the router MUST take into account E and P flags advertised by the next-hop router, if next-hop router advertised the SID for the prefix. This MUST be done regardless of next-hop router contributing to the best path to the prefix or not.

P-Flag (no-PHP) MUST be set on the Prefix-SIDs allocated to inter-area prefixes that are originated by the ABR based on intra-area or inter-area reachability between areas. In case the inter-area prefix is generated based on the prefix which is directly attached to the ABR, P-Flag SHOULD NOT be set

P-Flag (no-PHP) MUST NOT be set on the Prefix-SIDs allocated to redistributed prefixes, unless the redistributed prefix is directly attached to ASBR, in which case the P-Flag SHOULD NOT be set.

If the P-flag is not set then any upstream neighbor of the Prefix-SID originator MUST pop the Prefix-SID. This is equivalent to the penultimate hop popping mechanism used in the MPLS dataplane. In such case MPLS EXP bits of the Prefix-SID are not preserved to the ultimate hop (the Prefix-SID being removed). If the P-flag is unset the received E-flag is ignored.

If the P-flag is set then:

   If the E-flag is not set then any upstream neighbor of the Prefix-SID originator MUST keep the Prefix-SID on top of the stack. This is useful when the originator of the Prefix-SID must stitch the incoming packet into a continuing MPLS LSP to the final destination. This could occur at an inter-area border router (prefix propagation from one area to another) or at an inter-domain border router (prefix propagation from one domain to another).

   If the E-flag is set then any upstream neighbor of the Prefix-SID originator MUST replace the PrefixSID with a Prefix-SID having an Explicit-NULL value. This is useful, e.g., when the originator of the Prefix-SID is the final destination for the related prefix and the originator wishes to receive the packet with the original EXP bits.

When M-Flag is set, P-flag MUST be set and E-bit MUST NOT be set.

Example 1: if the following router addresses (loopback addresses) need to be mapped into the corresponding Prefix SID indexes:

        Router-A: 192::1/128, Prefix-SID: Index 1
        Router-B: 192::2/128, Prefix-SID: Index 2
        Router-C: 192::3/128, Prefix-SID: Index 3
        Router-D: 192::4/128, Prefix-SID: Index 4

then the Address Prefix field in Intra-Area Prefix TLV, Inter-Area Prefix TLV or External Prefix TLV is set to 192::1, Prefix Length in

these TLVs would be set to 128, Range Size in Prefix SID sub-TLV
would be set to 4 and Index value would be set to 1.

Example 2: If the following prefixes need to be mapped into the
corresponding Prefix-SID indexes:

```
          10:1:1::0/120,   Prefix-SID: Index 51
          10:1:1::100/120, Prefix-SID: Index 52
          10:1:1::200/120, Prefix-SID: Index 53
          10:1:1::300/120, Prefix-SID: Index 54
          10:1:1::400/120, Prefix-SID: Index 55
          10:1:1::500/120, Prefix-SID: Index 56
          10:1:1::600/120, Prefix-SID: Index 57
```

then the Address Prefix field in Intra-Area Prefix TLV, Inter-Area
Prefix TLV or External Prefix TLV is set to 10:1:1::0, Prefix Length
in these TLVs would be set to 120, Range Size in Prefix SID sub-TLV
would be set to 7 and Index value would be set to 51.

4.2. SID/Label Binding sub-TLV

   SID/Label Binding sub-TLV is used to advertise SID/Label mapping for
   a path to the prefix.

   The SID/Label Binding TLV MAY be originated by any router in an
   OSPFv3 domain. The router may advertise a SID/Label binding to a FEC
   along with at least a single 'nexthop style' anchor. The protocol
   supports more than one 'nexthop style' anchor to be attached to a
   SID/Label binding, which results into a simple path description
   language. In analogy to RSVP the terminology for this is called an
   'Explicit Route Object' (ERO). Since ERO style path notation allows
   to anchor SID/label bindings to both link and node IP addresses any
   label switched path, can be described. Furthermore also SID/Label
   Bindings from external protocols can get easily re-advertised.

   The SID/Label Binding TLV may be used for advertising SID/Label
   Bindings and their associated Primary and Backup paths. In one
   single TLV either a primary ERO Path, a backup ERO Path or both are
   advertised. If a router wants to advertise multiple parallel paths
   then it can generate several TLVs for the same Prefix/FEC. Each
   occurrence of a Binding TLV with respect with a given FEC Prefix has
   accumulating and not canceling semantics.

   SID/Label Binding sub-TLV is a sub-TLV of the following OSPFv3 TLVs,
   as defined in [I-D.ietf-ospf-ospfv3-lsa-extend]:

      Intra-Area Prefix TLV

Inter-Area Prefix TLV

External Prefix TLV

Multiple SID/Label Binding sub-TLVs can be present in above mentioned
TLVs. SID/Label Binding sub-TLV has following format:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              Type             |            Length             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Flags     |    Weight     |          Range Size           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Sub-TLVs (variable)                      |
+-                                                            -+
|                                                               |
```
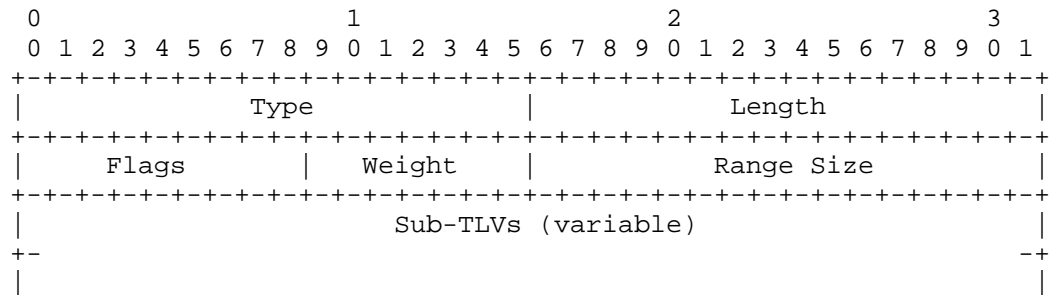
where:

   Type: TBD, suggested value 5

   Length: variable

   Flags: 1 octet field of following flags:

```
 0 1 2 3 4 5 6 7
+-+-+-+-+-+-+-+-+
|M|             |
+-+-+-+-+-+-+-+-+
```
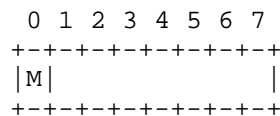
   where:

      M-bit - When the bit is set the binding represents the
      mirroring context as defined in
      [I-D.minto-rsvp-lsp-egress-fast-protection].

   Weight: weight used for load-balancing purposes. The use of the
   weight is defined in [I-D.filsfils-rtgwg-segment-routing].

   Range Size: usage is the same as described in Section 4.1

SID/Label Binding sub-TLV currently supports following Sub-TLVs:

   SID/Label sub-TLV as described in Section 2.1. This sub-TLV MUST
   appear in the SID/Label Binding Sub-TLV and it MUST only appear
   once.

ERO Metric sub-TLV as defined in Section 4.2.1.

ERO sub-TLVs as defined in Section 4.2.2.

4.2.1. ERO Metric sub-TLV

ERO Metric sub-TLV is a Sub-TLV of the SID/Label Binding TLV.

The ERO Metric sub-TLV carries the cost of an ERO path. It is used
to compare the cost of a given source/destination path. A router
SHOULD advertise the ERO Metric sub-TLV. The cost of the ERO Metric
sub-TLV SHOULD be set to the cumulative IGP or TE path cost of the
advertised ERO. Since manipulation of the Metric field may attract
or distract traffic from and to the advertised segment it MAY be
manually overridden.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             Type              |            Length             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Metric (4 octets)                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
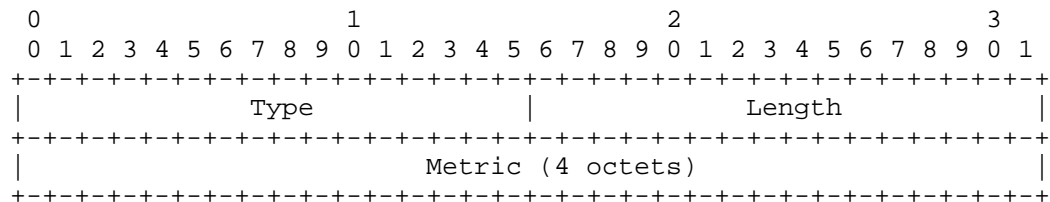
                        ERO Metric sub-TLV format

where:

   Type: TBD, suggested value 6

   Length: 4 bytes

   Metric: 4 bytes

4.2.2. ERO sub-TLVs

All 'ERO' information represents an ordered set which describes the
segments of a path. The last ERO sub-TLV describes the segment
closest to the egress point, contrary the first ERO sub-TLV describes
the first segment of a path. If a router extends or stitches a path
it MUST prepend the new segments path information to the ERO list.
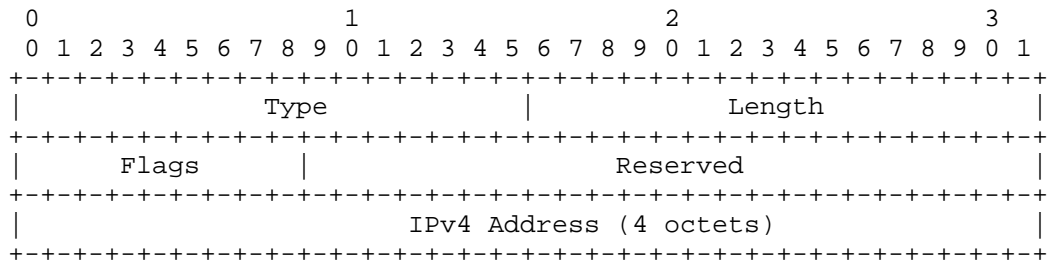
The above similarly applies to backup EROs.

All ERO Sub-TLVs must immediately follow the (SID)/Label Sub-TLV.

All Backup ERO sub-TLVs must immediately follow last ERO Sub-TLV.

4.2.2.1. IPv4 ERO sub-TLV

   IPv4 ERO sub-TLV is a sub-TLV of the SID/Label Binding sub-TLV.

   The IPv4 ERO sub-TLV describes a path segment using IPv4 Address
   style of encoding. Its semantics have been borrowed from [RFC3209].

```
    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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |             Type              |             Length            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     Flags     |                 Reserved                      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    IPv4 Address (4 octets)                    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

                        IPv4 ERO sub-TLV format

   where:

      Type: TBD, suggested value 7

      Length: 8 bytes

      Flags: 1 octet field of following flags:

```
    0 1 2 3 4 5 6 7
   +-+-+-+-+-+-+-+-+
   |L|             |
   +-+-+-+-+-+-+-+-+
```

      where:

         L-bit - If the L bit is set, then the value of the attribute is
         'loose.' Otherwise, the value of the attribute is 'strict.'

      IPv4 Address - the address of the explicit route hop.

4.2.2.2. IPv6 ERO sub-TLV

   IPv6 ERO sub-TLV is a sub-TLV of the SID/Label Binding sub-TLV.

   The IPv6 ERO sub-TLV (Type TBA) describes a path segment using IPv6
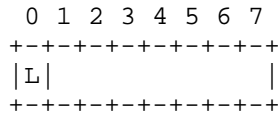   Address style of encoding. Its semantics have been borrowed from
   [RFC3209].

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Type               |            Length             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Flags     |                Reserved                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+-                                                             -+
|                                                               |
+-                     IPv6 Address                            -+
|                                                               |
+-                                                             -+
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

                    IPv6 ERO sub-TLV format

   where:

      Type: TBD, suggested value 8

      Length: 8 bytes

      Flags: 1 octet field of following flags:

```
 0 1 2 3 4 5 6 7
+-+-+-+-+-+-+-+-+
|L|             |
+-+-+-+-+-+-+-+-+
```

         where:
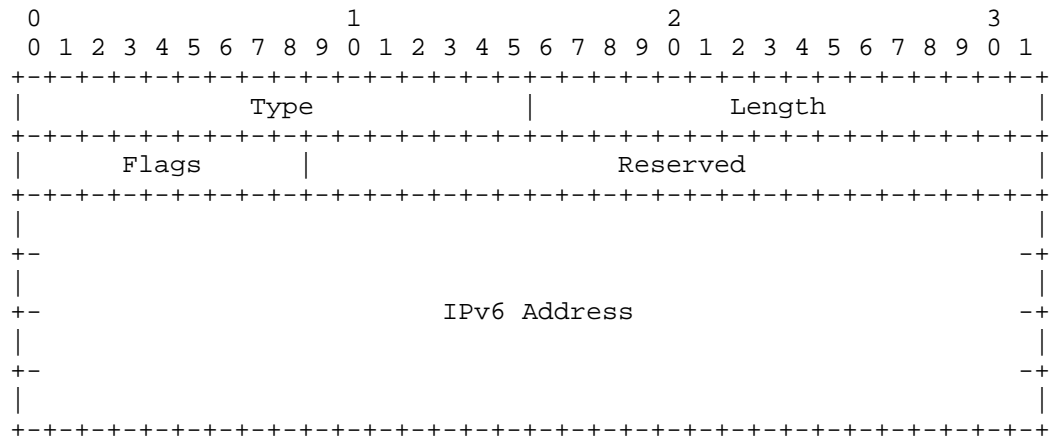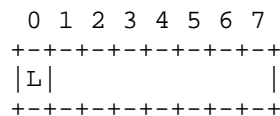
            L-bit - If the L bit is set, then the value of the attribute is
            'loose.' Otherwise, the value of the attribute is 'strict.'

      IPv6 Address - the address of the explicit route hop.
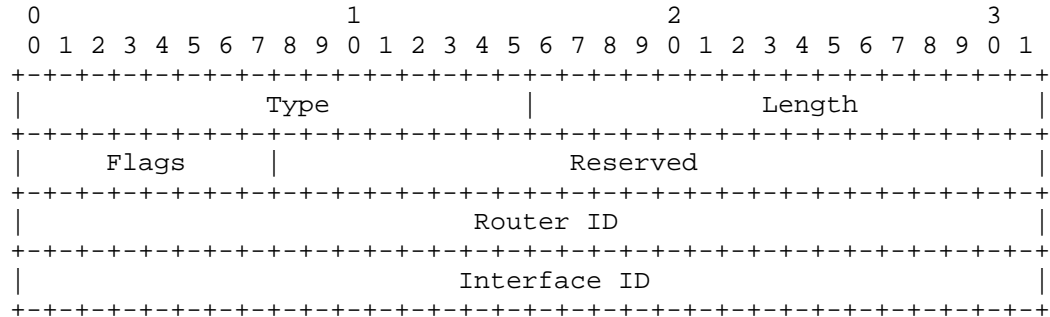
4.2.2.3. Unnumbered Interface ID ERO sub-TLV

   Unnumbered Interface ID ERO sub-TLV is a sub-TLV of the SID/Label
   Binding sub-TLV.

   The appearance and semantics of the 'Unnumbered Interface ID' have
   been borrowed from [RFC3477].

   The Unnumbered Interface-ID ERO sub-TLV describes a path segment that
   spans over an unnumbered interface. Unnumbered interfaces are

referenced using the interface index. Interface indices are assigned
local to the router and therefore not unique within a domain. All
elements in an ERO path need to be unique within a domain and hence
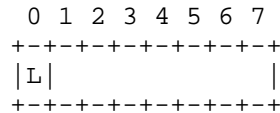need to be disambiguated using a domain unique Router-ID.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              Type             |              Length           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Flags     |                  Reserved                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Router ID                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Interface ID                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

where:

              Unnumbered Interface ID ERO sub-TLV format

   Type: TBD, suggested value 9

   Length: 12 bytes

   Flags: 1 octet field of following flags:

```
 0 1 2 3 4 5 6 7
+-+-+-+-+-+-+-+-+
|L|             |
+-+-+-+-+-+-+-+-+
```

where:

       L-bit - If the L bit is set, then the value of the attribute is
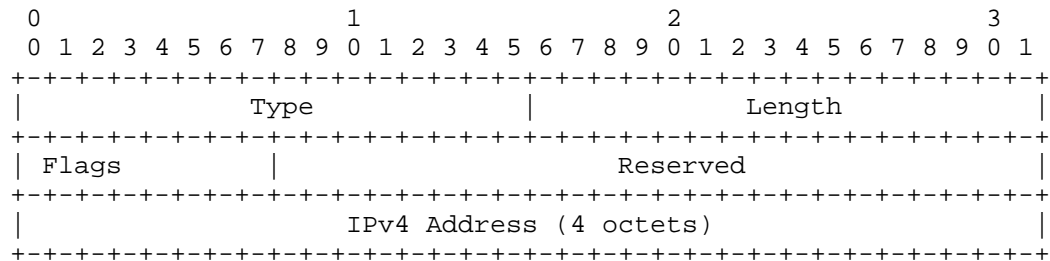   'loose.' Otherwise, the value of the attribute is 'strict.'

   Router-ID: Router-ID of the next-hop.

   Interface ID: is the identifier assigned to the link by the router
   specified by the Router-ID.

4.2.2.4. IPv4 Backup ERO sub-TLV

   IPv4 Prefix Backup ERO sub-TLV is a sub-TLV of the SID/Label Binding
   sub-TLV.

The IPv4 Backup ERO sub-TLV describes a path segment using IPv4
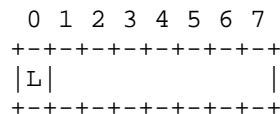Address style of encoding. Its semantics have been borrowed from
[RFC3209].

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              Type             |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Flags         |                  Reserved                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    IPv4 Address (4 octets)                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

                    IPv4 Backup ERO sub-TLV format

where:

   Type: TBD, suggested value 10

   Length: 8 bytes

   Flags: 1 octet field of following flags:

```
 0 1 2 3 4 5 6 7
+-+-+-+-+-+-+-+-+
|L|             |
+-+-+-+-+-+-+-+-+
```

   where:

      L-bit - If the L bit is set, then the value of the attribute is
      'loose.' Otherwise, the value of the attribute is 'strict.'
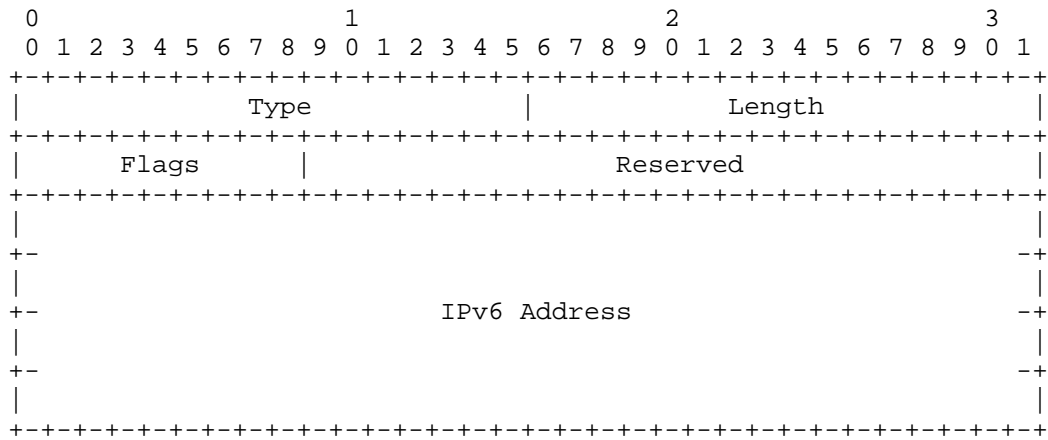
   IPv4 Address - the address of the explicit route hop.

4.2.2.5. IPv6 Backup ERO sub-TLV

   IPv6 ERO sub-TLV is a sub-TLV of the SID/Label Binding sub-TLV.

   The IPv6 Backup ERO sub-TLV describes a Backup path segment using
   IPv6 Address style of encoding. Its appearance and semantics have
   been borrowed from [RFC3209].

   The 'L' bit in the Flags is a one-bit attribute. If the L bit is
   set, then the value of the attribute is 'loose.' Otherwise, the
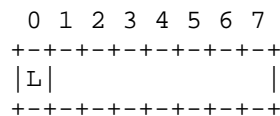   value of the attribute is 'strict.'

```
     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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |             Type              |            Length             |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |     Flags     |                  Reserved                     |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                                                               |
    +-                                                             -+
    |                                                               |
    +-                        IPv6 Address                         -+
    |                                                               |
    +-                                                             -+
    |                                                               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

                    IPv6 Backup ERO sub-TLV format

   where:

      Type: TBD, suggested value 11

      Length: 8 bytes

      Flags: 1 octet field of following flags:

```
    0 1 2 3 4 5 6 7
   +-+-+-+-+-+-+-+-+
   |L|             |
   +-+-+-+-+-+-+-+-+
```

         where:

            L-bit - If the L bit is set, then the value of the attribute is
            'loose.' Otherwise, the value of the attribute is 'strict.'

      IPv6 Address - the address of the explicit route hop.
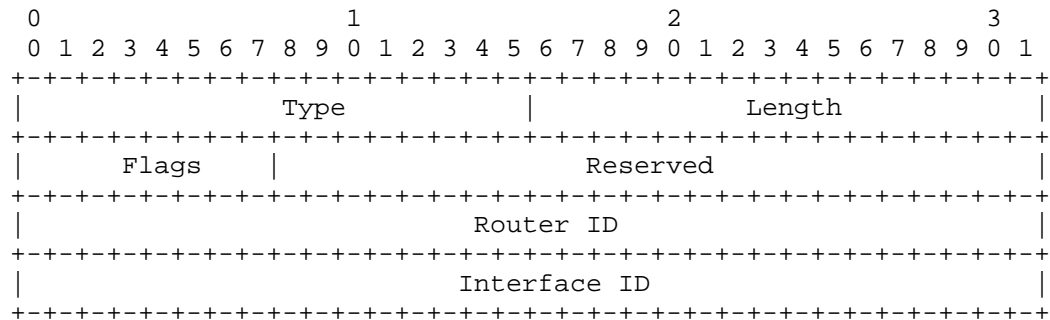
4.2.2.6. Unnumbered Interface ID Backup ERO sub-TLV

   Unnumbered Interface ID Backup sub-TLV is a sub-TLV of the SID/Label
   Binding sub-TLV.

   The appearance and semantics of the 'Unnumbered Interface ID' have
   been borrowed from [RFC3477].

   The Unnumbered Interface-ID ERO sub-TLV describes a path segment that
   spans over an unnumbered interface. Unnumbered interfaces are

referenced using the interface index. Interface indices are assigned
local to the router and therefore not unique within a domain. All
elements in an ERO path need to be unique within a domain and hence
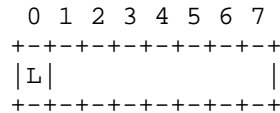need to be disambiguated using a domain unique Router-ID.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              Type             |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Flags     |                 Reserved                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Router ID                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Interface ID                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

            Unnumbered Interface ID Backup ERO sub-TLV format

   where:

      Type: TBD, suggested value 12

      Length: 12 bytes

      Flags: 1 octet field of following flags:

```
 0 1 2 3 4 5 6 7
+-+-+-+-+-+-+-+-+
|L|             |
+-+-+-+-+-+-+-+-+
```

      where:

         L-bit - If the L bit is set, then the value of the attribute is
         'loose.' Otherwise, the value of the attribute is 'strict.'

      Router-ID: Router-ID of the next-hop.

      Interface ID: is the identifier assigned to the link by the router
      specified by the Router-ID.

5. Adjacency Segment Identifier (Adj-SID)

   An Adjacency Segment Identifier (Adj-SID) represents a router
   adjacency in Segment Routing. At the current stage of Segment
   Routing architecture it is assumed that the Adj-SID value has local
   significance (to the router).

5.1. Adj-SID sub-TLV

   A new extended OSPFv3 LSAs, as defined in
   [I-D.ietf-ospf-ospfv3-lsa-extend], are used to advertise prefix SID
   in OSPFv3

   Adj-SID sub-TLV is an optional sub-TLV of the Router-Link TLV as
   defined in [I-D.ietf-ospf-ospfv3-lsa-extend]. It MAY appear multiple
   times in Router-Link TLV. Examples where more than one Adj-SID may
   be used per neighbor are described in
   [I-D.filsfils-rtgwg-segment-routing-use-cases]. The structure of the
   Adj-SID Sub-TLV is as follows:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              Type             |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Flags         |    Weight     |            Reserved           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    SID/Label/Index (variable)                 |
+---------------------------------------------------------------+
```

   where:

      Type: TBD, suggested value 10.

      Length: variable.

      Flags. 1 octet field of following flags:

```
 0 1 2 3 4 5 6 7
+-+-+-+-+-+-+-+-+
|B|V|L|S|       |
+-+-+-+-+-+-+-+-+
```

   where:

         B-Flag: Backup-flag: set if the Adj-SID refer to an adjacency
         being protected (e.g.: using IPFRR or MPLS-FRR) as described in
         [I-D.filsfils-rtgwg-segment-routing-use-cases].

         The V-Flag: Value/Index Flag. If set, then the Prefix-SID
         carries an absolute value. If not set, then the Prefix-SID
         carries an index.

         The L-Flag: Local/Global Flag. If set, then the value/index
         carried by the PrefixSID has local significance. If not set,

then the value/index carried by this subTLV has global
significance.

The S-Flag. Set Flag. When set, the S-Flag indicates that the
Adj-SID refers to a set of adjacencies (and therefore MAY be
assigned to other adjacencies as well).

Other bits: MUST be zero when originated and ignored when
received.

Weight: weight used for load-balancing purposes. The use of the
weight is defined in [I-D.filsfils-rtgwg-segment-routing].

SID/Index/Label: label or index value depending on the V-bit
setting.

Examples:

A 32 bit global index defining the offset in the SID/Label
space advertised by this router - in this case the V and L
flags MUST be unset.

A 24 bit local label where the 20 rightmost bits are used
for encoding the label value - in this case the V and L
flags MUST be set.

16 octet IPv6 address - in this case the V-flag MUST be set.
The L-flag MUST be set for link-local IPv6 address and MUST
be unset for IPv6 global unicast address.

A SR capable router MAY allocate an Adj-SID for each of its
adjacencies and set the B-Flag when the adjacency is protected by a
FRR mechanism (IP or MPLS) as described in
[I-D.filsfils-rtgwg-segment-routing-use-cases].

5.2. LAN Adj-SID Sub-TLV

LAN Adj-SID is an optional sub-TLV of the Router-Link TLV. It MAY
appear multiple times in Router-Link TLV. It is used to advertise
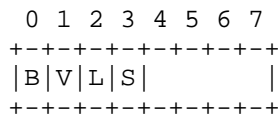SID/Label for adjacency to non-DR node on broadcast or NBMA network.

```
    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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |             Type              |             Length            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     Flags     |    Weight     |            Reserved           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                          Neighbor ID                          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    SID/Label/Index (variable)                 |
   +---------------------------------------------------------------+
```
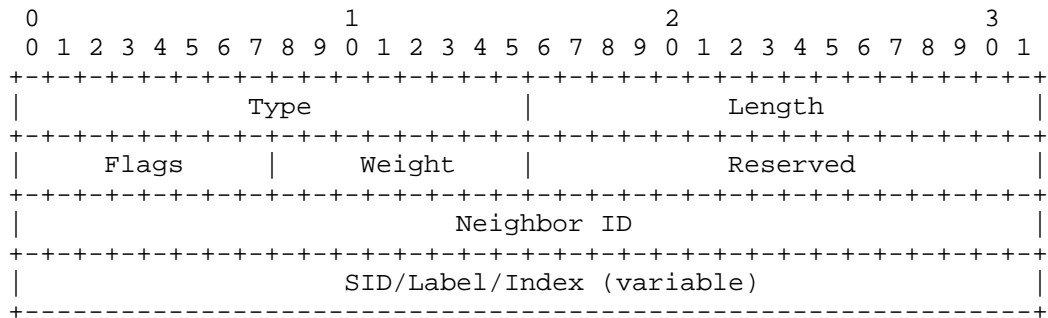
   where:

      Type: TBD, suggested value 11.

      Length: variable.

      Flags. 1 octet field of following flags:

```
 0 1 2 3 4 5 6 7
+-+-+-+-+-+-+-+-+
|B|V|L|S|       |
+-+-+-+-+-+-+-+-+
```

   where:

         B-Flag: Backup-flag: set if the LAN-Adj-SID refer to an
         adjacency being protected (e.g.: using IPFRR or MPLS-FRR) as
         described in [I-D.filsfils-rtgwg-segment-routing-use-cases].

         The V-Flag: Value/Index Flag. If set, then the Prefix-SID
         carries an absolute value. If not set, then the Prefix-SID
         carries an index.

         The L-Flag: Local/Global Flag. If set, then the value/index
         carried by the PrefixSID has local significance. If not set,
         then the value/index carried by this subTLV has global
         significance.

         The S-Flag. Set Flag. When set, the S-Flag indicates that the
         Adj-SID refers to a set of adjacencies (and therefore MAY be
         assigned to other adjacencies as well).

         Other bits: MUST be zero when originated and ignored when
         received.

Weight: weight used for load-balancing purposes. The use of the
weight is defined in [I-D.filsfils-rtgwg-segment-routing].

SID/Index/Label: label or index value depending on the V-bit
setting.

Examples:

A 32 bit global index defining the offset in the SID/Label
space advertised by this router - in this case the V and L
flags MUST be unset.

A 24 bit local label where the 20 rightmost bits are used
for encoding the label value - in this case the V and L
flags MUST be set.

16 octet IPv6 address - in this case the V-flag MUST be set.
The L-flag MUST be set for link-local IPv6 address and MUST
be unset for IPv6 global unicast address.

6. Elements of Procedure

6.1. Intra-area Segment routing in OSPFv3

The OSPFv3 node that supports segment routing MAY advertise Prefix-
SIDs for any prefix that it is advertising reachability for (e.g.
loopback IP address) as described in Section 4.1.

If multiple routers advertise Prefix-SID for the same prefix, then
the Prefix-SID MUST be the same. This is required in order to allow
traffic load-balancing if multiple equal cost paths to the
destination exist in the network.

Prefix-SID can also be advertised by the SR Mapping Servers (as
described in [I-D.filsfils-rtgwg-segment-routing-use-cases]). The
Mapping Server advertises Prefix-SID for remote prefixes that exist
in the network. Multiple Mapping Servers can advertise Prefix-SID
for the same prefix, in which case the same Prefix-SID MUST be
advertised by all of them. SR Mapping Server could use either area
scope or autonomous system flooding scope when advertising Prefix SID
for prefixes, based on the configuration of the SR Mapping Server.
Depending on the flooding scope used, SR Mapping Server chooses the
LSA that will be used. If the area flooding scope is needed, E-
Intra-Area-Prefix-LSA ([I-D.ietf-ospf-ospfv3-lsa-extend]) is used.
If autonomous system flooding scope is needed, E-AS-External-LSA
([I-D.ietf-ospf-ospfv3-lsa-extend]) is used.

When Prefix-SID is advertised by the Mapping Server, which is indicated by the M-flag in the Prefix-SID sub-TLV (Section 4.1), route-type as indicated by the LSA type which is being used for flooding is ignored. Prefix SID is bound to a prefix, in which case route-type becomes unimportant.

Advertisement of the Prefix-SID by the Mapping Server using Inter-Area Prefix TLV, External Prefix TLV or Intra-Area-Prefix TLV ([I-D.ietf-ospf-ospfv3-lsa-extend]) does not itself contribute to the prefix reachability. NU-bit MUST be set in the PrefixOptions field of the LSA which is used by the Mapping Server to advertise SID or SID range, which prevents such advertisement to contribute to the prefix reachability.

6.2. Inter-area Segment routing in OSPFv3

   In order to support SR in a multi-area environment, OSPFv3 must propagate Prefix-SID information between areas. The following procedure is used in order to propagate Prefix SIDs between areas.

   When an OSPFv3 ABR advertises a Inter-Area-Prefix-LSA from an intra-area prefix to all its connected areas, it will also include Prefix-SID sub-TLV, as described in Section 4.1. The Prefix-SID value will be set as follows:

      The ABR will look at its best path to the prefix in the source area and find out the advertising router associated with its best path to that prefix.

      If no Prefix-SID was advertised for the prefix in the source area by the router that contributes to the best path to the prefix, then the ABR will use the Prefix-SID advertised by any other router (e.g.: a Prefix-SID coming from an SR Mapping Server as defined in [I-D.filsfils-rtgwg-segment-routing-use-cases]) when propagating Prefix-SID for the prefix to other areas.

   When an OSPFv3 ABR advertises Inter-Area-Prefix-LSA LSAs from an inter-area route to all its connected areas it will also include Prefix-SID sub-TLV, as described in Section 4.1. The Prefix-SID value will be set as follows:

      The ABR will look at its best path to the prefix in the source area and find out the advertising router associated with its best path to that prefix.

      The ABR will then look if such router advertised a Prefix-SID for the prefix and use it when advertising the Prefix-SID to other connected areas.

If no Prefix-SID was advertised for the prefix in the source area
by the ABR that contributes to the best path to the prefix, the
originating ABR will use the Prefix-SID advertised by any other
router (e.g.: a Prefix-SID coming from an SR Mapping Server as
defined in [I-D.filsfils-rtgwg-segment-routing-use-cases]) when
propagating Prefix-SID for the prefix to other areas.

6.3. SID for External Prefixes

AS-External-LSAs are flooded domain wide. When an ASBR, which
supports SR, generates AS-External-LSA, it should also include
Prefix-SID sub-TLV, as described in Section 4.1 Prefix-SID value will
be set to the SID that has been reserved for that prefix.

When a NSSA ASBR translates NSSA-LSA into AS-External-LSA, it should
also advertise the Prefix-SID for the prefix. The NSSA ABR
determines its best path to the prefix advertised in the translated
NSSA-LSA and finds the advertising router associated with such path.
If such advertising router has advertised a Prefix-SID for the
prefix, then the NSSA ASBR uses it when advertising the Prefix-SID in
AS-External-LSA. Otherwise the Prefix-SID advertised by any other
router will be used (e.g.: a Prefix-SID coming from an SR Mapping
Server as defined in [I-D.filsfils-rtgwg-segment-routing-use-cases]).

6.4. Advertisement of Adj-SID

The Adjacency Segment Routing Identifier (Adj-SID) is advertised
using the Adj-SID Sub-TLV as described in Section 5.

6.4.1. Advertisement of Adj-SID on Point-to-Point Links

Adj-SID MAY be advertised for any adjacency on p2p link that is in a
state 2-Way or higher. If the adjacency on a p2p link transitions
from the FULL state, then the Adj-SID for that adjacency MAY be
removed from the area. If the adjacency transitions to a state lower
then 2-Way, then the Adj-SID MUST be removed from the area.

6.4.2. Adjacency SID on Broadcast or NBMA Interfaces

Broadcast or NBMA networks in OSPFv3 are represented by a star
topology where the Designated Router (DR) is the central point all
other routers on the broadcast or NBMA network connect to. As a
result, routers on the broadcast or NBMA network advertise only their
adjacency to DR and BDR. Routers that are neither DR nor BDR do not
form and do not advertise adjacencies between them. They, however,
maintain a 2-Way adjacency state between them.

When Segment Routing is used, each router on the broadcast or NBMA network MAY advertise the Adj-SID for its adjacency to DR using Adj-SID Sub-TLV as described in Section 5.1.

SR capable router MAY also advertise Adj-SID for other neighbors (e.g. BDR, DR-OTHER) on broadcast or NBMA network using the LAN ADJ-SID Sub-TLV as described in section 5.1.1.2. Section 5.2.

7. IANA Considerations

   This specification updates two existing OSPF registries.

7.1. OSPF Router Information (RI) TLVs Registry

   o suggested value 8 - SR-Algorithm TLV

   o suggested value 9 - SID/Label Range TLV

7.2. OSPFv3 Extend-LSA sub-TLV registry

   o suggested value 1 - SID/Label sub-TLV

   o suggested value 2 - Prefix SID sub-TLV

   o suggested value 3 - Adj-SID sub-TLV

   o suggested value 4 - LAN Adj-SID sub-TLV

   o suggested value 5 - SID/Label Binding sub-TLV

   o suggested value 6 - ERO Metric sub-TLV

   o suggested value 7 - IPv4 ERO sub-TLV

   o suggested value 8 - IPv6 ERO sub-TLV

   o suggested value 9 - Unnumbered Interface ID ERO sub-TLV

   o suggested value 10 - IPv4 Backup ERO sub-TLV

   o suggested value 11 - IPv6 Backup ERO sub-TLV

   o suggested value 12 - Unnumbered Interface ID Backup ERO sub-TLV

8. Security Considerations

   Implementations must assure that malformed permutations of the newly
   defined sub-TLvs do not result in errors which cause hard OSPFv3
   failures.

9. Contributors

   The following people gave a substantial contribution to the content
   of this document: Ahmed Bashandy, Martin Horneffer, Bruno Decraene,
   Stephane Litkowski, Igor Milojevic, Rob Shakir and Saku Ytti.

10. Acknowledgements

   We would like to thank Anton Smirnov for his contribution.

   Many thanks to Yakov Rekhter, John Drake and Shraddha Hedge for their
   contribution on earlier incarnations of the "Binding / MPLS Label
   TLV" in [I-D.gredler-ospf-label-advertisement].

11. References

11.1. Normative References

   [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate
              Requirement Levels", BCP 14, RFC 2119, March 1997.

   [RFC3209] Awduche, D., Berger, L., Gan, D., Li, T., Srinivasan, V.,
              and G. Swallow, "RSVP-TE: Extensions to RSVP for LSP
              Tunnels", RFC 3209, December 2001.

   [RFC3477] Kompella, K. and Y. Rekhter, "Signalling Unnumbered Links
              in Resource ReSerVation Protocol - Traffic Engineering
              (RSVP-TE)", RFC 3477, January 2003.

   [RFC4970] Lindem, A., Shen, N., Vasseur, JP., Aggarwal, R., and S.
              Shaffer, "Extensions to OSPF for Advertising Optional
              Router Capabilities", RFC 4970, July 2007.

11.2. Informative References

   [I-D.filsfils-rtgwg-segment-routing]
              Filsfils, C., Previdi, S., Bashandy, A., Decraene, B.,
              Litkowski, S., Horneffer, M., Milojevic, I., Shakir, R.,
              Ytti, S., Henderickx, W., Tantsura, J., and E. Crabbe,
              "Segment Routing Architecture", draft-filsfils-rtgwg-
              segment-routing-01 (work in progress), October 2013.

[I-D.filsfils-rtgwg-segment-routing-use-cases]
          Filsfils, C., Francois, P., Previdi, S., Decraene, B.,
          Litkowski, S., Horneffer, M., Milojevic, I., Shakir, R.,
          Ytti, S., Henderickx, W., Tantsura, J., Kini, S., and E.
          Crabbe, "Segment Routing Use Cases", draft-filsfils-rtgwg-
          segment-routing-use-cases-02 (work in progress), October
          2013.

[I-D.gredler-ospf-label-advertisement]
          Gredler, H., Amante, S., Scholl, T., and L. Jalil,
          "Advertising MPLS labels in OSPF", draft-gredler-ospf-
          label-advertisement-03 (work in progress), May 2013.

[I-D.ietf-ospf-ospfv3-lsa-extend]
          Lindem, A., Mirtorabi, S., Roy, A., and F. Baker, "OSPFv3
          LSA Extendibility", draft-ietf-ospf-ospfv3-lsa-extend-03
          (work in progress), May 2014.

[I-D.minto-rsvp-lsp-egress-fast-protection]
          Jeganathan, J., Gredler, H., and Y. Shen, "RSVP-TE LSP
          egress fast-protection", draft-minto-rsvp-lsp-egress-fast-
          protection-03 (work in progress), November 2013.

Authors' Addresses

   Peter Psenak (editor)
   Cisco Systems, Inc.
   Apollo Business Center
   Mlynske nivy 43
   Bratislava 821 09
   Slovakia

   Email: ppsenak@cisco.com

   Stefano Previdi (editor)
   Cisco Systems, Inc.
   Via Del Serafico, 200
   Rome 00142
   Italy

   Email: sprevidi@cisco.com

Clarence Filsfils
Cisco Systems, Inc.
Brussels
Belgium

Email: cfilsfil@cisco.com

Hannes Gredler
Juniper Networks, Inc.
1194 N. Mathilda Ave.
Sunnyvale, CA 94089
US

Email: hannes@juniper.net

Rob Shakir
British Telecom
London
UK

Email: rob.shakir@bt.com

Wim Henderickx
Alcatel-Lucent
Copernicuslaan 50
Antwerp 2018
BE

Email: wim.henderickx@alcatel-lucent.com

Jeff Tantsura
Ericsson
300 Holger Way
San Jose, CA 95134
US

Email: Jeff.Tantsura@ericsson.com