Open Shortest Path First IGP
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OSPF Extensions for Segment Routing
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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 OSPF extensions required 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

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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 cases, is a one-hop path. SR's control-plane can be applied to both IPv6 and MPLS data-planes, and does not require any additional signalling (other than IGP extensions). For example, when used in MPLS networks, SR paths do not require any LDP or RSVP-TE signalling. However, SR can interoperate in the presence of LSPs established with RSVP or LDP.

This draft describes the OSPF extensions required 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].

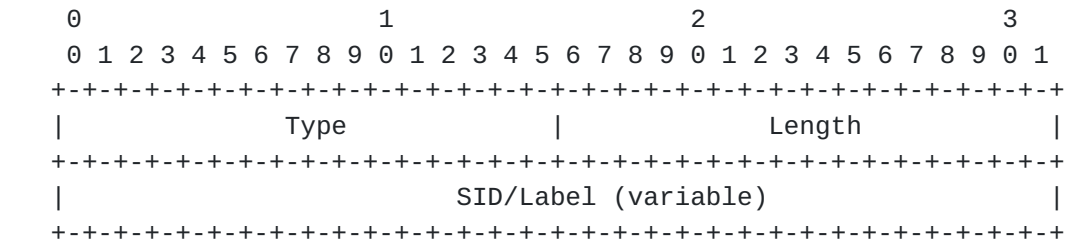
2. Segment Routing Identifiers

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

For the purpose of the advertisements of various SID values, new Opaque LSAs (defined in [RFC5250]) are defined. These new LSAs are defined as generic containers that can be used to advertise any additional attributes associated with the prefix or link. These new Opaque LSAs are complementary to the existing LSAs and are not aimed to replace any of the existing LSAs.

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:



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 router capabilities to be advertised to other routers in the area.

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

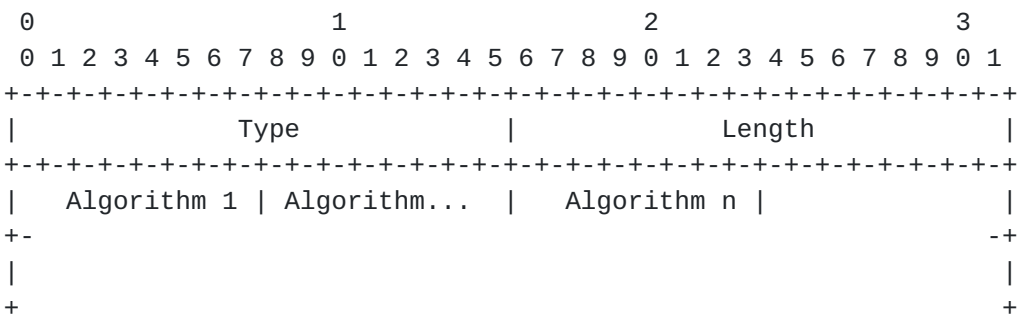
3.1. SR-Algorithm TLV

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

The SR-Algorithm Sub-TLV is optional, it MAY only appear once inside the Router Informational Opaque LSA. If the SID/Label Range TLV, as defined in Section 3.2, is advertised, then SR-Algorithm TLV MUST also be advertised.

As SR Router may use various algorithms when calculating reachability to OSPF routers or prefixes in an OSPF area. Examples of these algorithms are metric based Shortest Path First (SPF), various

flavors of Constrained SPF, etc. The SR-Algorithm TLV allows a router to advertise the algorithms that the router is currently using to other routers in an OSPF area. The SR-Algorithm TLV has following format:



where:

Type: TBD, suggested value 8

Length: variable

Algorithm: Single octet identifying the algorithm. The following value is defined by this document:

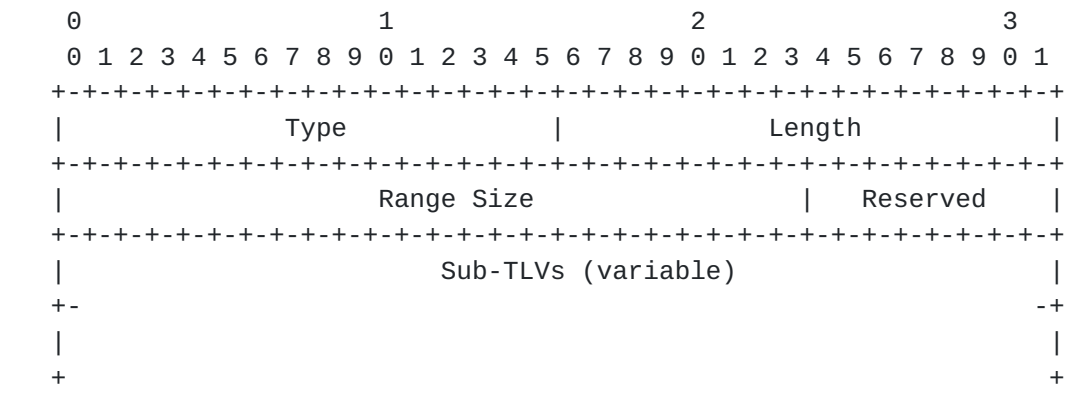
0: IGP metric based Shortest Path Tree (SPT)

The RI LSA can be advertised at any of the defined opaque 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 top-level TLV of Router Information Opaque LSA (defined in [RFC4970]).

The SID/Label Range TLV MAY appear multiple times and has the following format:



where:

Type: TBD, suggested value 9

Length: variable

Range Size: 3 octet of the SID/label range

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

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

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

- 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 SID/label range and SID index correspondence is preserved across graceful restarts.

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

The following example illustrates the 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
   ...
```

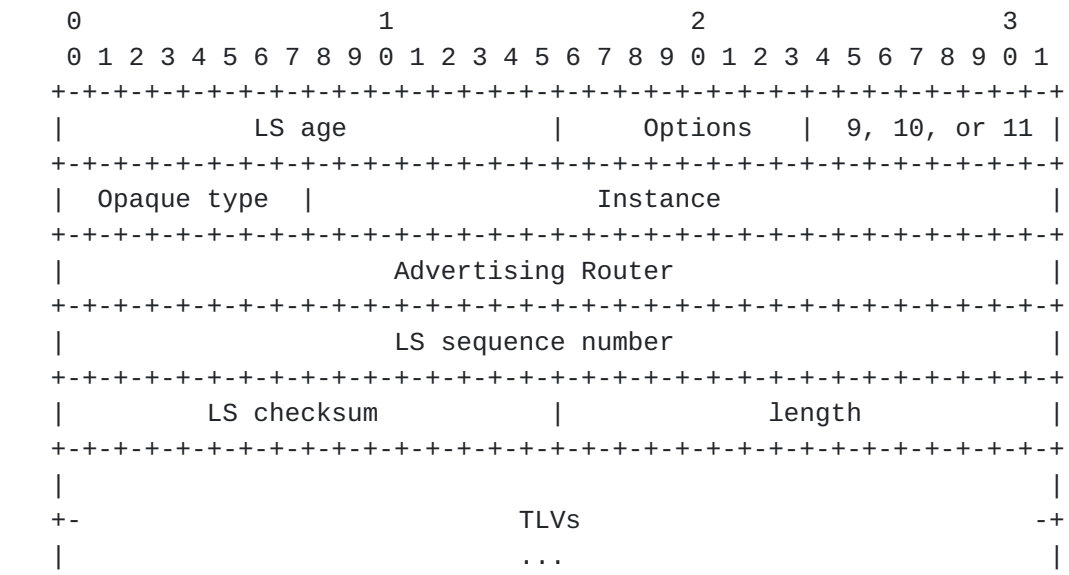
The RI LSA can be advertised at any of the defined flooding scopes (link, area, or autonomous system (AS)). For the purposes of the SR-Capability TLV propagation, area scope flooding is required.

4. OSPFv2 Extended Prefix Opaque LSA

A new Opaque LSA (defined in [RFC5250]) is defined in OSPFv2 in order to advertise additional prefix attributes: OSPFv2 Extended Prefix Opaque LSA.

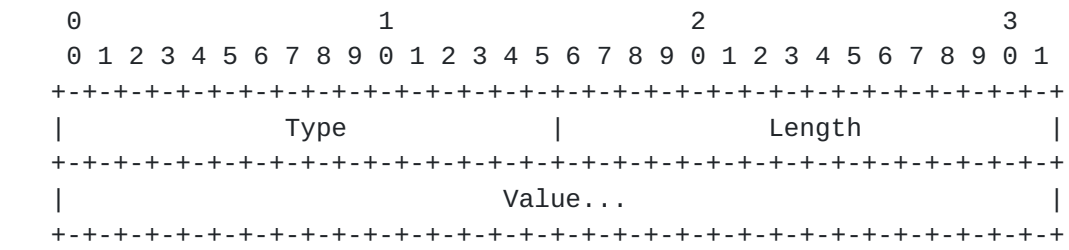
Multiple OSPFv2 Extended Prefix Opaque LSAs can be advertised by an OSPFv2 router. The flooding scope of the OSPFv2 Extended Prefix Opaque LSA depends on the scope of the advertised prefixes and is under the control of the advertising router. In some cases (e.g., mapping server deployment), the LSA flooding scope may be greater than the scope of the corresponding prefixes.

The format of the OSPFv2 Extended Prefix Opaque LSA is as follows:



The opaque type used by OSPFv2 Extended Prefix Opaque LSA is 7.

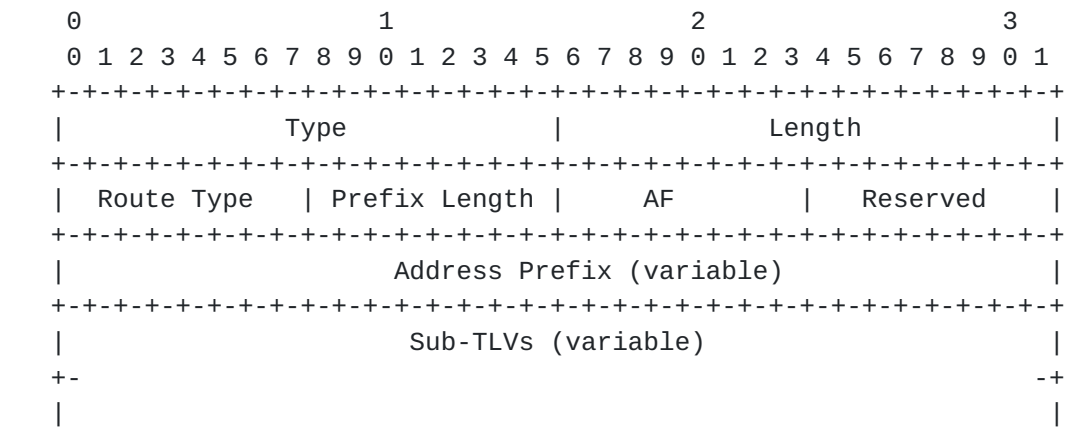
The format of the TLVs within the body of the LSA is the same as the format used by the Traffic Engineering Extensions to OSPF defined in [RFC3630]. The LSA payload consists of one or more nested Type/Length/Value (TLV) triplets. The format of each TLV is:



The Length field defines the length of the value portion in octets. The TLV is padded to 4-octet alignment; padding is not included in the length field. Nested TLVs are also 32-bit aligned. Unrecognized types are ignored.

4.1. OSPF Extended Prefix TLV

The OSPF Extended Prefix TLV is used in order to advertise additional attributes associated with the prefix. Multiple OSPF Extended Prefix TLVs MAY be advertised in each OSPFv2 Extended Prefix Opaque LSA but all prefixes included in a single OSPFv2 Extended Prefix Opaque LSA MUST have the same flooding scope. The OSPF Extended Prefix TLV has the following format:



where:

Type: TBD, suggested value 1.

Length: variable

Route type: type of the OSPF route. Supported types are:

0 - unspecified
1 - intra-area
3 - inter-area
5 - external
7 - NSSA external

If the route type is 0 (unspecified), the information inside the OSPF External Prefix TLV applies to the prefix regardless of prefix's route-type. This is useful when some prefix specific attributes are advertised by some external entity, which is not aware of the route-type associated with the prefix.

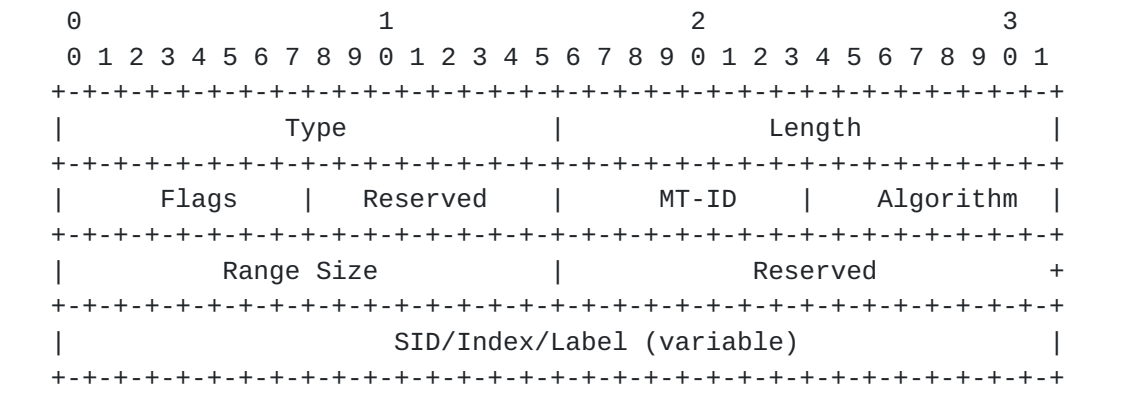
Prefix length: length of the prefix

AF: 0 - IPv4 unicast

Address Prefix: the prefix itself encoded as an even multiple of 32-bit words, padded with zeroed bits as necessary. This encoding consumes ((PrefixLength + 31) / 32) 32-bit words. The default route is represented by a prefix of length 0.

4.2. Prefix SID Sub-TLV

The Prefix SID Sub-TLV is a Sub-TLV of the OSPF Extended Prefix TLV. It MAY appear more than once and has following format:

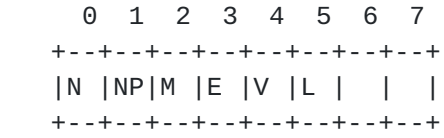


where:

Type: TBD, suggested value 2.

Length: variable

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



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].

NP-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].

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.

MT-ID: Multi-Topology ID (as defined in [RFC4915]).

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 one. For range advertisements > 1, Range Size represents the number of addresses that need to be mapped into a Prefix-SID.

SID/Index/Label: according to the V and L flags, it contains either:

A 32 bit index defining the offset in the SID/Label space advertised by this router.

A 24 bit label where the 20 rightmost bits are used for encoding the label value.

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.

NP-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, NP-Flag SHOULD NOT be set

NP-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 NP-flag SHOULD NOT be set.

If the NP-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 NP-flag is clear the received E-flag is ignored.

If the NP-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, NP-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: 192.0.2.1/32, Prefix-SID: Index 1
Router-B: 192.0.2.2/32, Prefix-SID: Index 2
Router-C: 192.0.2.3/32, Prefix-SID: Index 3
Router-D: 192.0.2.4/32, Prefix-SID: Index 4

then the Prefix field in Extended Prefix TLV would be set to 192.0.2.1, Prefix Length would be set to 32, Range Size in Prefix SID sub-TLV would be 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:

10.1.1/24, Prefix-SID: Index 51
10.1.2/24, Prefix-SID: Index 52
10.1.3/24, Prefix-SID: Index 53
10.1.4/24, Prefix-SID: Index 54
10.1.5/24, Prefix-SID: Index 55
10.1.6/24, Prefix-SID: Index 56
10.1.7/24, Prefix-SID: Index 57

then the Prefix field in Extended Prefix TLV would be set to 10.1.1.0, Prefix Length would be set to 24, Range Size in Prefix SID sub-TLV would be 7 and Index value would be set to 51.

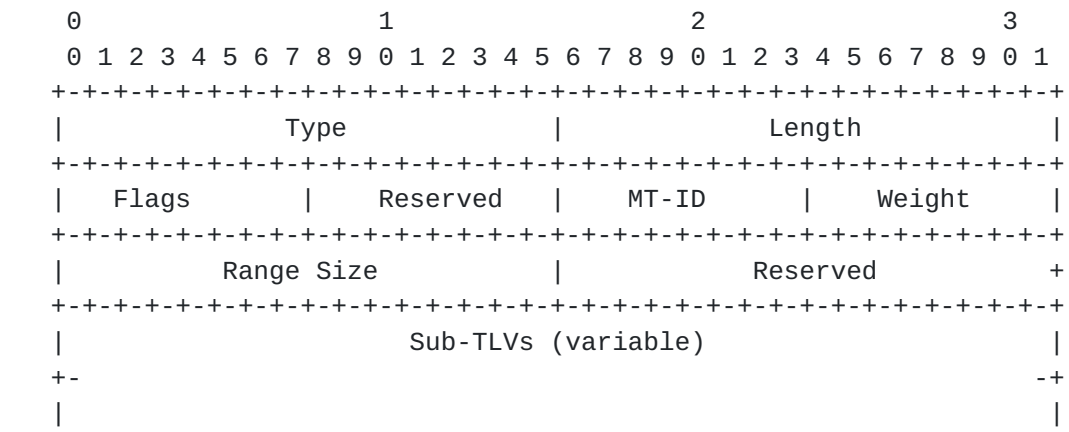
4.3. SID/Label Binding sub-TLV

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

The SID/Label Binding TLV MAY be originated by any router in an OSPF 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 in 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. Additionally, SID/Label Bindings from external protocols can be easily re-advertised.

The SID/Label Binding TLV may be used for advertising SID/Label Bindings and their associated Primary and Backup paths. In a single TLV, a primary ERO Path, backup ERO Path, or both can be 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 for a given FEC Prefix will add a new path.

The SID/Label Binding sub-TLV is a sub-TLV of the OSPF Extended Prefix TLV. Multiple SID/Label Binding TLVs can be present in OSPF Extended Prefix TLV. The SID/Label Binding sub-TLV has following format:

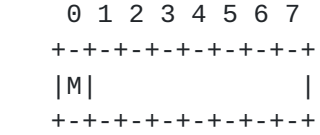


where:

Type: TBD, suggested value 3

Length: variable

Flags: 1 octet field of following flags:



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].

MT-ID: Multi-Topology ID (as defined in [RFC4915]).

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 4.2.

The SID/Label Binding TLV supports the 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.

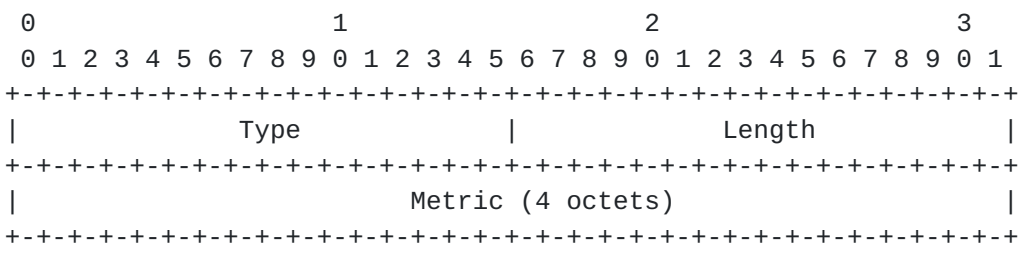
ERO Metric sub-TLV as defined in Section 4.3.1.

ERO sub-TLVs as defined in Section 4.3.2.

4.3.1. ERO Metric sub-TLV

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

The ERO Metric sub-TLV advertises 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 repel traffic to and from the advertised segment, it MAY be manually overridden.



ERO Metric sub-TLV format

where:

Type: TBD, suggested value 8

Length: 4 bytes

Metric: 4 bytes

4.3.2. 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 sub-ERO TLVs must immediately follow last ERO Sub-TLV.

4.3.2.1. 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].

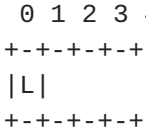
IPv4 ERO sub-TLV format

where:

Type: TBD, suggested value 4

Length: 8 bytes

Flags: 1 octet field of following flags:



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.'

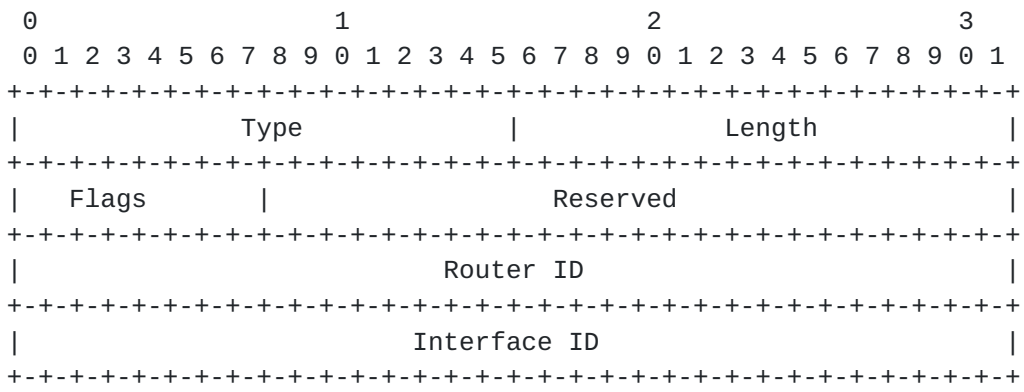
IPv4 Address - the address of the explicit route hop.

4.3.2.2. 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 includes 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.



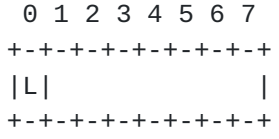
where:

Unnumbered Interface ID ERO sub-TLV format

Type: TBD, suggested value 5

Length: 12 bytes

Flags: 1 octet field of following flags:



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.

4.3.2.3. 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].

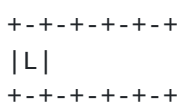
IPv4 Backup ERO sub-TLV format

where:

Type: TBD, suggested value 6

Length: 8 bytes

Flags: 1 octet field of following flags:



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.'

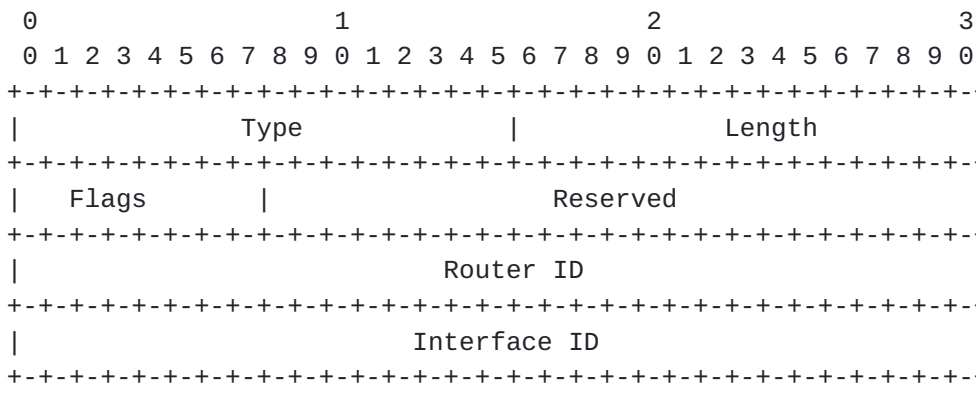
IPv4 Address - the address of the explicit route hop.

4.3.2.4. 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 includes 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.



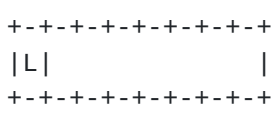
Unnumbered Interface ID Backup ERO sub-TLV format

where:

Type: TBD, suggested value 7

Length: 12 bytes

Flags: 1 octet field of following flags:



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)

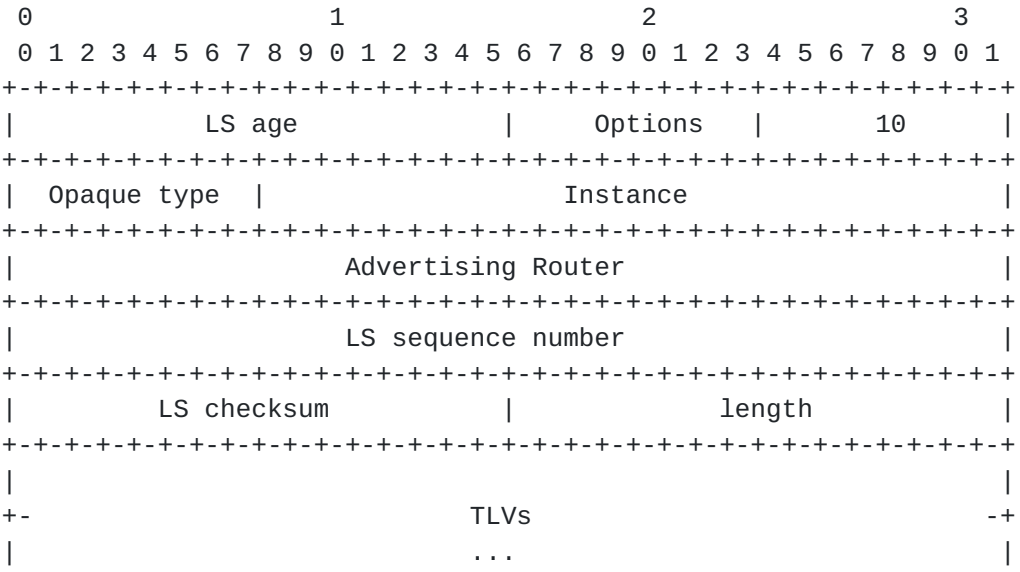
An Adjacency Segment Identifier (Adj-SID) represents a router adjacency in Segment Routing.

5.1. OSPFv2 Extended Link Opaque LSA

A new Opaque LSA (defined in [RFC5250]) is defined in OSPFv2 in order to advertise additional link attributes: the OSPFv2 Extended Link Opaque LSA.

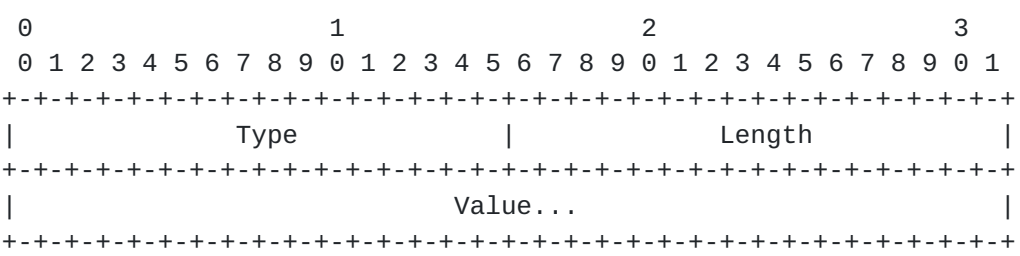
The OSPFv2 Extended Link Opaque LSA has an area flooding scope. Multiple OSPFv2 Extended Link Opaque LSAs can be advertised by a single router in an area.

The format of the OSPFv2 Extended Link Opaque LSA is as follows:



Opaque type used by OSPFv2 Extended Link Opaque LSA is 8.

The format of the TLVs within the body of LSA is the same as the format used by the Traffic Engineering Extensions to OSPF defined in [RFC3630]. The LSA payload consists of one or more nested Type/Length/Value (TLV) triplets. The format of each TLV is:

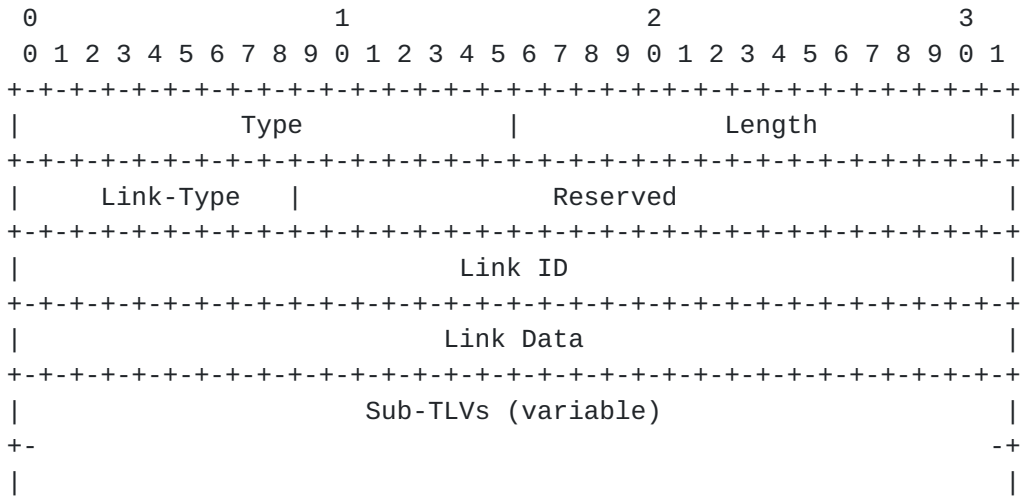


The Length field defines the length of the value portion in octets. The TLV is padded to 4-octet alignment; padding is not included in the length field. Nested TLVs are also 32-bit aligned. Unrecognized types are ignored.

5.2. OSPFv2 Extended Link TLV

OSPFv2 Extended Link TLV is used in order to advertise various attributes of the link. It describes a single link and is constructed of a set of Sub-TLVs. There are no ordering requirements for the Sub-TLVs. Only one Extended Link TLV SHALL be advertised in each Extended Link Opaque LSA, allowing for fine granularity changes in the topology.

The Extended Link TLV has following format:



where:

Type is 1.

Length is variable.

Link-Type: as defined in section A.4.2 of [RFC2328].

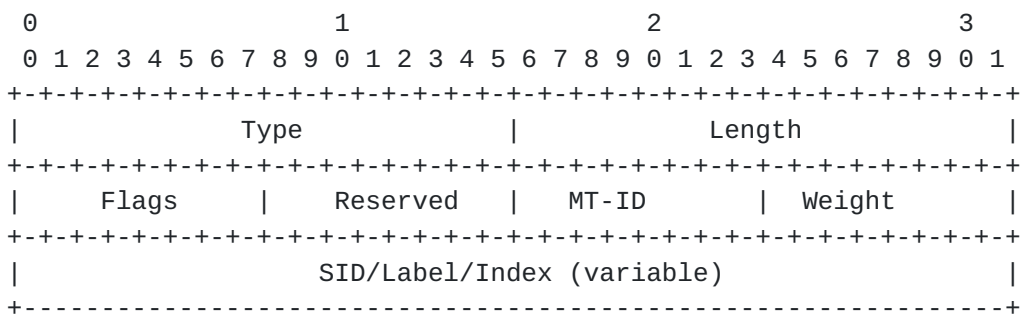
Link-ID: as defined in section A.4.2 of [RFC2328].

Link Data: as defined in section A.4.2 of [RFC2328].

5.3. Adj-SID sub-TLV

Adj-SID is an optional sub-TLV of the Extended Link TLV. It MAY appear multiple times in the Extended 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 Adj-SID sub-TLV has the following format:

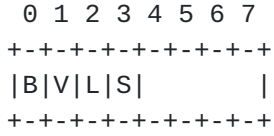


where:

Type: TBD, suggested value 2.

Length: variable.

Flags. 1 octet field of following flags:



where:

B-Flag: Backup-flag: set if the Adj-SID refers 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.

MT-ID: Multi-Topology ID (as defined in [RFC4915].

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

SID/Index/Label: according to the V and L flags, it contains either:

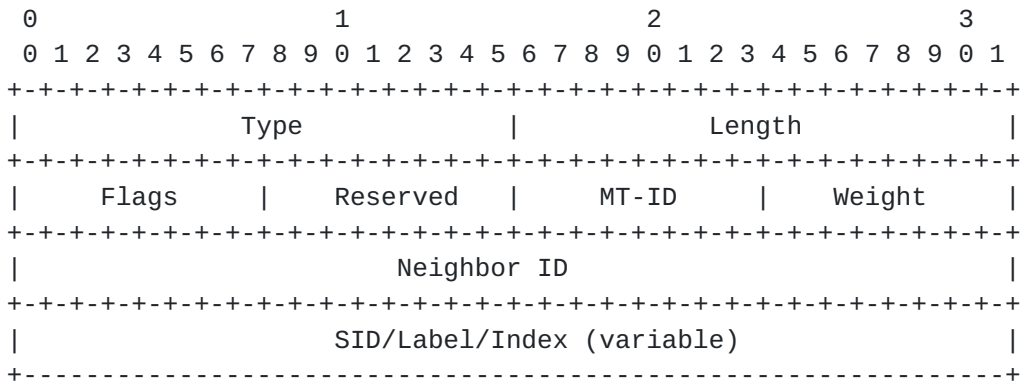
A 32 bit index defining the offset in the SID/Label space advertised by this router.

A 24 bit label where the 20 rightmost bits are used for encoding the label value.

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

5.4. LAN Adj-SID Sub-TLV

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

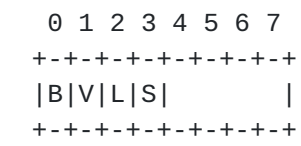


where:

Type: TBD, suggested value 3.

Length: variable.

Flags. 1 octet field of following flags:



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.

MT-ID: Multi-Topology ID (as defined in [RFC4915].

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

SID/Index/Label: according to the V and L flags, it contains either:

A 32 bit index defining the offset in the SID/Label space advertised by this router.

A 24 bit label where the 20 rightmost bits are used for encoding the label value.

6. Elements of Procedure

6.1. Intra-area Segment routing in OSPFv2

The OSPFv2 node that supports segment routing MAY advertise Prefix-SIDs for any prefix to which it is advertising reachability (e.g., a loopback IP address as described in Section 4.2).

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-SIDs for remote prefixes that exist in the OSPFv2 routing domain. Multiple Mapping Servers can advertise Prefix-SIDs for the same prefix, in which case the same Prefix-SID MUST be advertised by all of them. The flooding scope of the OSPF Extended Prefix Opaque LSA that is generated by the SR Mapping Server could be either area scoped or AS scoped and is determined based on the configuration of the SR Mapping Server.

6.2. Inter-area Segment routing in OSPFv2

In order to support SR in a multi-area environment, OSPFv2 must propagate Prefix-SID information between areas. The following procedure is used in order to propagate Prefix SIDs between areas.

When an OSPF ABR advertises a Type-3 Summary LSA from an intra-area prefix to all its connected areas, it will also originate an Extended Prefix Opaque LSA, as described in Section 4. The flooding scope of the Extended Prefix Opaque LSA type will be set to area-scope. The route-type in OSPF Extended Prefix TLV is set to inter-area. The Prefix-SID Sub-TLV will be included in this LSA and 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 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 the Prefix-SID for the prefix to other areas.

When an OSPF ABR advertises Type-3 Summary LSAs from an inter-area route to all its connected areas it will also originate an Extended Prefix Opaque LSA, as described in Section 4. The flooding scope of the Extended Prefix Opaque LSA type will be set to area-scope. The route-type in OSPF Extended Prefix TLV is set to inter-area. The Prefix-SID Sub-TLV will be included in this LSA and the Prefix-SID will be set as follows:

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

The ABR will then determine 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 the Prefix-SID for the prefix to other areas.

6.3. SID for External Prefixes

Type-5 LSAs are flooded domain wide. When an ASBR, which supports SR, generates Type-5 LSAs, it should also originate an Extended Prefix Opaque LSAs, as described in Section 4. The flooding scope of the Extended Prefix Opaque LSA type is set to AS-scope. The route-type in OSPF Extended Prefix TLV is set to external. The Prefix-SID sub-TLV is included in this LSA and the Prefix-SID value will be set to the SID that has been reserved for that prefix.

When a NSSA ASBR translates Type-7 LSAs into Type-5 LSAs, it should also advertise the Prefix-SID for the prefix. The NSSA ABR determines its best path to the prefix advertised in the translated Type-7 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 for the Type-5 prefix. 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 a p2p link that is in neighbor 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 OSPF 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 5.3.

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 5.4.

7. IANA Considerations

This specification updates two existing OSPF registries.

Opaque Link-State Advertisements (LSA) Option Types:

o suggested value 7 - OSPFv2 Extended Prefix Opaque LSA

o suggested value 8 - OSPFv2 Extended Link Opaque LSA

OSPF Router Information (RI) TLVs:

o suggested value 8 - SR-Algorithm TLV

o suggested value 9 - SID/Label Range TLV

This specification also creates four new registries:

- OSPF Extended Prefix LSA TLVs and sub-TLVs

- OSPF Extended Link LSA TLVs and sub-TLVs

7.1. OSPF Extend Prefix LSA TLV Registry

The OSPF Extend Prefix LSA TLV registry will define top-level TLVs for Extended Prefix LSAs and should be placed in the existing OSPF

IANA registry. New values can be allocated via IETF Consensus or IESG Approval.

Following initial values are allocated:

o 0 - Reserved

o 1 - OSPF Extended Prefix TLV

Types in the range 32768-32023 are for experimental use; these will not be registered with IANA, and MUST NOT be mentioned by RFCs.

Types in the range 32023-65535 are not to be assigned at this time. Before any assignments can be made in this range, there MUST be a Standards Track RFC that specifies IANA Considerations that covers the range being assigned.

7.2. OSPF Extend Prefix LSA sub-TLV Registry

The OSPF Extended Prefix sub-TLV registry will define will define sub-TLVs at any level of nesting for Extended Prefix LSAs and should be placed in the existing OSPF IANA registry. New values can be allocated via IETF Consensus or IESG Approval.

Following initial values are allocated:

o 0 - Reserved

o 1 - SID/Label sub-TLV

o 2 - Prefix SID sub-TLV

o 3 - SID/Label Binding sub-TLV

o 4 - IPv4 ERO sub-TLV

o 5 - Unnumbered Interface ID ERO sub-TLV

o 6 - IPv4 Backup ERO sub-TLV

o 7 - Unnumbered Interface ID Backup ERO sub-TLV

o 8 - ERO Metric sub-TLV

Types in the range 32768-32023 are for experimental use; these will not be registered with IANA, and MUST NOT be mentioned by RFCs.

Types in the range 32023-65535 are not to be assigned at this time. Before any assignments can be made in this range, there MUST be a Standards Track RFC that specifies IANA Considerations that covers the range being assigned.

7.3. OSPF Extend Link LSA TLV Registry

The OSPF Extend Link LSA TLV registry will define top-level TLVs for Extended Link LSAs and should be placed in the existing OSPF IANA registry. New values can be allocated via IETF Consensus or IESG Approval.

Following initial values are allocated:

o 0 - Reserved

o 1 - OSPFv2 Extended Link TLV

Types in the range 32768-32023 are for experimental use; these will not be registered with IANA, and MUST NOT be mentioned by RFCs.

Types in the range 32023-65535 are not to be assigned at this time. Before any assignments can be made in this range, there MUST be a Standards Track RFC that specifies IANA Considerations that covers the range being assigned.

7.4. OSPF Extend Link LSA sub-TLV Registry

The OSPF Extended Link LSA sub-TLV registry will define will define sub-TLVs at any level of nesting for Extended Link LSAs and should be placed in the existing OSPF IANA registry. New values can be allocated via IETF Consensus or IESG Approval.

Following initial values are allocated:

o 1 - SID/Label sub-TLV

o 2 - Adj-SID sub-TLV

o 3 - LAN Adj-SID/Label Sub-TLV

Types in the range 32768-32023 are for experimental use; these will not be registered with IANA, and MUST NOT be mentioned by RFCs.

Types in the range 32023-65535 are not to be assigned at this time. Before any assignments can be made in this range, there MUST be a Standards Track RFC that specifies IANA Considerations that covers the range being assigned.

8. Security Considerations

In general, new LSAs defined in this document are subject to the same security concerns as those described in [RFC2328]. Additionally, implementations must assure that malformed TLV and Sub-TLV permutations do not result in errors which cause hard OSPF failures.

9. Contributors

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

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