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BGP Link State Extensions for SRv6
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Abstract

Segment Routing (SR) over IPv6 (SRv6) allows for a flexible definition of end-to-end paths within various topologies by encoding paths as sequences of topological or functional sub-paths, called "segments". These segments are advertised by the various protocols such as BGP, IS-IS and OSPFv3.

BGP Link-state (BGP-LS) address-family solution for SRv6 is similar to BGP-LS for SR for MPLS data-plane. This draft defines extensions to the BGP-LS to advertise SRv6 Segments along with their behaviors and other attributes via BGP.

Status of This Memo

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1. Introduction

SRv6 refers to Segment Routing instantiated on the IPv6 data-plane [RFC8402]. A SRv6 Segment is often referred to by its SRv6 Segment Identifier (SID).

The network programming paradigm [I-D.ietf-spring-srv6-network-programming] is central to SRv6. It describes how different behaviors can be bound to SIDs and how a network program can be expressed as a combination of SIDs.

An SRv6-capable node N maintains all the SRv6 segments explicitly instantiated at node N.

The IS-IS [I-D.ietf-lsr-isis-srv6-extensions] and OSPFv3 [I-D.ietf-lsr-ospfv3-srv6-extensions] link-state routing protocols have been extended to advertise some of these SRv6 SIDs and SRv6-related information. BGP ([I-D.ietf-bess-srv6-services]) has been extended to advertise some of these SRv6 SIDs for VPN services. Certain other SRv6 SIDs may be instantiated on a node via other mechanisms for topological or service functionalities.

The advertisement of SR related information along with the topology for the MPLS data-plane instantiation is specified in [I-D.ietf-idr-bgp-ls-segment-routing-ext] and for the BGP Egress Peer Engineering (EPE) is specified in [I-D.ietf-idr-bgpls-segment-routing-epe]. On the similar lines, introducing the SRv6 related information in BGP-LS allows consumer applications that require topological visibility to also receive the SRv6 SIDs from nodes across a domain or even across Autonomous Systems (AS), as required. This allows applications to leverage the SRv6 capabilities for network programming.

The identifying key of each Link-State object, namely a node, link, or prefix, is encoded in the NLRI and the properties of the object are encoded in the BGP-LS Attribute [RFC7752].

This document describes extensions to BGP-LS to advertise the SRv6 SIDs and other SRv6 information from all the SRv6 capable nodes in the domain when sourced from link-state routing protocols and directly from individual SRv6 capable nodes (e.g. when sourced from BGP for EPE).

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP

14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

2. BGP-LS Extensions for SRv6

BGP-LS [RFC7752] defines the Node, Link and Prefix Link-State Network Layer Reachability Information (NLRI) types and the advertisement of their attributes via BGP.

The SRv6 information pertaining to a node is advertised via the BGP-LS Node NLRI and using the BGP-LS Attribute TLVs as follows:

o SRv6 Capabilities of the node are advertised via SRv6 Capabilities TLV (Section 3.1)

o Maximum SID Depth (MSD) types introduced for SRv6 are advertised (Section 3.2) using the Node MSD TLV specified in [RFC8814]

o Algorithm support for SRv6 is advertised via the SR Algorithm TLV specified in [I-D.ietf-idr-bgp-ls-segment-routing-ext].

The SRv6 information pertaining to a link is advertised via the BGP-LS Link NLRI and using the BGP-LS Attribute TLVs as follows:

o SRv6 SID of the IGP Adjacency SID or the BGP EPE Peer Adjacency SID [RFC8402] is advertised via SRv6 End.X SID TLV introduced in this document (Section 4.1)

o SRv6 SID of the IGP Adjacency SID to a non-Designated Router (DR) or non-Designated Intermediate-System (DIS) [RFC8402] is advertised via SRv6 LAN End.X SID TLV introduced in this document (Section 4.2)

o MSD types introduced for SRv6 are advertised (Section 4.3) using the Link MSD TLV specified in [RFC8814].

The SRv6 information pertaining to a prefix is advertised via the BGP-LS Prefix NLRI and using the BGP-LS Attribute TLVs as follows:

o SRv6 Locator is advertised via SRv6 Locator TLV introduced in this document (Section 5.1)

o The attributes of the SRv6 Locator are advertised via the Prefix Attribute Flags TLV specified in [I-D.ietf-idr-bgp-ls-segment-routing-ext].

The SRv6 SIDs associated with the node are advertised using the BGP-LS SRv6 SID NLRI introduced in this document. This enables the BGP-

LS encoding to scale to cover a potentially large set of SRv6 SIDs instantiated on a node with the granularity of individual SIDs and without affecting the size and scalability of the BGP-LS updates. BGP-LS Attribute TLVs for the SRv6 SID NLRI are introduced in this document as follows:

- o The endpoint behavior of the SRv6 SID is advertised via SRv6 Endpoint Behavior TLV (Section 7.1)

- o The BGP EPE Peer Node and Peer Set context for a Peer Node and Peer Set SID [RFC8402] respectively is advertised via SRv6 BGP EPE Peer Node SID TLV (Section 7.2)

When the BGP-LS router is advertising topology information that it sources from the underlying link-state routing protocol (as described in [RFC7752]), then it maps the corresponding SRv6 information from the SRv6 extensions for IS-IS [I-D.ietf-lsr-isis-srv6-extensions] and OSPFv3 [I-D.ietf-lsr-ospfv3-srv6-extensions] protocols to their BGP-LS TLVs/sub-TLVs for all SRv6 capable nodes in that routing protocol domain. When the BGP-LS router is advertising topology information from the BGP routing protocol (e.g. for EPE as described in [I-D.ietf-idr-bgpls-segment-routing-epe]), then it advertises the SRv6 information from the local node alone.

Subsequent sections of this document specify the encoding and usage of these extensions.

3. SRv6 Node Attributes

SRv6 attributes of a node are advertised using the BGP-LS Attribute TLVs defined in this section and associated with the BGP-LS Node NLRI.

3.1. SRv6 Capabilities TLV

This BGP-LS Attribute TLV is used to announce the SRv6 capabilities of the node along with the BGP-LS Node NLRI and indicates the SRv6 support by the node. A single instance of this TLV MUST be included in the BGP-LS attribute for each SRv6 capable node. This TLV maps to the SRv6 Capabilities sub-TLV and the SRv6 Capabilities TLV of the IS-IS and OSPFv3 protocol SRv6 extensions respectively.

```
     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              |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 1: SRv6 Capabilities TLV Format

Where:

o Type: 1038

o Length : 4.

o Flags: 2 octet field. The following flags are defined:

```
     0                   1
     0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    | |O|                           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2: SRv6 Capability TLV Flags Format

   * O-flag: If set, then router is capable of supporting SRH O-bit Flags, as specified in [I-D.ietf-6man-spring-srv6-oam].

   * The rest of the bits are reserved for future use and MUST be set to 0 and ignored on receipt.

o Reserved: 2 octet that MUST be set to 0 and ignored on receipt.

3.2. SRv6 Node MSD Types

The Node MSD TLV [RFC8814] of the BGP-LS Attribute of the Node NLRI is also used to advertise the limits and the Segment Routing Header (SRH) [RFC8754] operations supported by the SRv6 capable node. The SRv6 MSD Types specified in section 4 of [I-D.ietf-lsr-isis-srv6-extensions] are also used with the BGP-LS Node MSD TLV as these codepoints are shared between IS-IS, OSPF and BGP-LS protocols. The description and semantics of these new MSD types for BGP-LS are identical as specified in [I-D.ietf-lsr-isis-srv6-extensions].

Each MSD type is encoded as a one octet type followed by a one octet value as specified in [RFC8814].

4. SRv6 Link Attributes

SRv6 attributes and SIDs associated with a link or adjacency are advertised using the BGP-LS Attribute TLVs defined in this section and associated with the BGP-LS Link NLRI.

4.1. SRv6 End.X SID TLV

The SRv6 End.X SID TLV is used to advertise the SRv6 SIDs associated with an IGP Adjacency SID behavior like the End.X [I-D.ietf-spring-srv6-network-programming] that correspond to a point-to-point or point-to-multipoint link or adjacency of the node running IS-IS and OSPFv3 protocols. This TLV can also be used to advertise the SRv6 SID corresponding to the underlying layer-2 member links for a layer-3 bundle interface as a sub-TLV of the L2 Bundle Member Attribute TLV [I-D.ietf-idr-bgp-ls-segment-routing-ext].

This TLV is also used by BGP to advertise the BGP EPE Peer Adjacency SID for SRv6 on the same lines as specified for SR/MPLS in [I-D.ietf-idr-bgpls-segment-routing-epe]. The SRv6 SID for the BGP Peer Adjacency using and End.X behaviour [I-D.ietf-spring-srv6-network-programming] indicates the cross-connect to a specific layer-3 link to the specific BGP session peer (neighbor).

The TLV has the 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               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |        Endpoint Behavior      |      Flags    |   Algorithm   |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |     Weight    |   Reserved    |  SID (16 octets) ...
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
        SID (cont ...)
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
        SID (cont ...)
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
        SID (cont ...)
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
        SID (cont ...)             | Sub-TLVs (variable) . . .
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3: SRv6 End.X TLV Format

Where:

Type: 1106

Length: variable

Endpoint Behavior: 2 octet field. The Endpoint Behavior code point for this SRv6 SID as defined in section 9.2 of [I-D.ietf-spring-srv6-network-programming].

Flags: 1 octet of flags with the following definition:

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

Figure 4: SRv6 End.X SID TLV Flags Format

* B-Flag: Backup Flag. If set, the SID is eligible for protection (e.g. using IPFRR) as described in [RFC8355].

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

* P-Flag: Persistent Flag: When set, the P-Flag indicates that the SID is persistently allocated, i.e., the value remains consistent across router restart and/or interface flap.

* The other bits are reserved for future use and MUST be set to 0 and ignored on receipt.

Algorithm: 1 octet field. Algorithm associated with the SID. Algorithm values are defined in the IANA IGP Algorithm Type registry.

Weight: 1 octet field. The value represents the weight of the SID for the purpose of load balancing. The use of the weight is defined in [RFC8402].

Reserved: 1 octet field that MUST be set to 0 and ignored on receipt.

SID: 16 octet field. This field encodes the advertised SRv6 SID as 128 bit value.

Sub-TLVs : Used to advertise sub-TLVs that provide additional attributes for the specific SRv6 SID.

4.2. SRv6 LAN End.X SID TLV

For a LAN interface, normally an IGP node only announces its adjacency to the IS-IS pseudo-node (or the equivalent OSPF DR). The SRv6 LAN End.X SID TLV allows a node to announce SRv6 SID corresponding to behaviors like END.X [I-D.ietf-spring-srv6-network-programming] for its adjacencies to all other (i.e. non-DIS or non-DR) nodes attached to the LAN in a single instance of the BGP-LS Link NLRI. Without this TLV, multiple BGP-LS Link NLRI would need to be originated for each additional adjacency in order to advertise the SRv6 End.X SID TLVs for these neighbor adjacencies.

The IS-IS and OSPFv3 SRv6 LAN End.X SID TLVs have the 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               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |        Endpoint Behavior      |      Flags    |   Algorithm   |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |     Weight    |   Reserved    |   Neighbor ID -               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               |
    | ISIS System-ID (6 octets) or OSPFv3 Router-ID (4 octets)      |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |    SID (16 octets) ...
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
         SID (cont ...)
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
         SID (cont ...)
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
         SID (cont ...)                                             |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    | Sub-TLVs (variable) . . .
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5: SRv6 LAN End.X SID TLV Format

Where:

o Type: 1107 in case of IS-IS and 1108 in case of OSPFv3

o Length: variable

o Endpoint Behavior: 2 octet field. The Endpoint Behavior code point for this SRv6 SID as defined in section 9.2 of [I-D.ietf-spring-srv6-network-programming].

o Flags: 1 octet of flags with the following definition:

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

Figure 6: SRv6 LAN End.X SID TLV Flags Format

* B-Flag: Backup Flag. If set, the SID is eligible for protection (e.g. using IPFRR) as described in [RFC8355].

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

  * P-Flag: Persistent Flag: When set, the P-Flag indicates that the SID is persistently allocated, i.e., the value remains consistent across router restart and/or interface flap.

  * Other bits are reserved for future use and MUST be set to 0 and ignored on receipt.

- Algorithm: 1 octet field. Algorithm associated with the SID. Algorithm values are defined in the IANA IGP Algorithm Type registry.

- Weight: 1 octet field. The value represents the weight of the SID for the purpose of load balancing. The use of the weight is defined in [RFC8402].

- Reserved: 1 octet field that MUST be set to 0 and ignored on receipt.

- Neighbor ID : 6 octets of ISIS System ID of the neighbor for the ISIS SRv6 LAN End.X SID TLV and 4 octets of OSPFv3 Router-id of the neighbor for the OSPFv3 SRv6 LAN End.X SID TLV.

- SID: 16 octet field. This field encodes the advertised SRv6 SID as 128 bit value.

- Sub-TLVs : Used to advertise sub-TLVs that provide additional attributes for the specific SRv6 SID.

4.3. SRv6 Link MSD Types

The Link MSD TLV [RFC8814] of the BGP-LS Attribute of the Link NLRI is also used to advertise the limits and the SRH operations supported on the specific link by the SRv6 capable node. The SRv6 MSD Types specified in section 4 of[I-D.ietf-lsr-isis-srv6-extensions] are also used with the BGP-LS Link MSD TLV as these codepoints are shared between IS-IS, OSPF and BGP-LS protocols. The description and semantics of these new MSD types for BGP-LS are identical as specified in [I-D.ietf-lsr-isis-srv6-extensions].

Each MSD type is encoded as a one octet type followed by a one octet value as specified in [RFC8814].

5. SRv6 Prefix Attributes

SRv6 attributes with an IPv6 prefix are advertised using the BGP-LS Attribute TLVs defined in this section and associated with the BGP-LS Prefix NLRI.

5.1. SRv6 Locator TLV

As specified in [I-D.ietf-spring-srv6-network-programming], an SRv6 SID comprises of Locator, Function and Argument parts.

A node is provisioned with one or more locators supported by that node. Locators are covering prefixes for the set of SIDs provisioned on that node. These Locators are advertised as BGP-LS Prefix NLRI objects along with the SRv6 Locator TLV in its BGP-LS Attribute.

The IPv6 Prefix matching the Locator MAY be also advertised as a prefix reachability by the underlying routing protocol. In this case, the Prefix NLRI would be also associated with the Prefix Metric TLV that carries the routing metric for this prefix. When the Locator prefix is not being advertised as a prefix reachability, then the Prefix NLRI would have the SRv6 Locator TLV associated with it but no Prefix Metric TLV. In the absence of Prefix Metric TLV, the consumer of the BGP-LS topology information MUST NOT interpret the Locator prefix as a prefix reachability routing advertisement in the IGPs default SPF computation.

The SRv6 Locator TLV has the 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   |           Reserved            |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                            Metric                             |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |   Sub-TLVs (variable) . . .
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 7: SRv6 Locator TLV Format

Where:

Type: 1162

Length: variable

Flags: 1 octet of flags with the following definition:

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

Figure 8: SRv6 Locator TLV Flags Format

* D-Flag: Indicates that the locator has been leaked into the IGP domain when set. IS-IS operations for this are discussed in [I-D.ietf-lsr-isis-srv6-extensions].

* Other bits are reserved for future use and MUST be set to 0 and ignored on receipt.

Algorithm: 1 octet field. Algorithm associated with the SID. Algorithm values are defined in the IANA IGP Algorithm Type registry.

Reserved: 2 octet field. The value MUST be set to 0 and ignored on receipt.

Metric: 4 octet field. The value of the metric for the Locator.

Sub-TLVs : currently none defined. Used to advertise sub-TLVs that provide additional attributes for the given SRv6 Locator.

6. SRv6 SID NLRI

SRv6 SID information is advertised in BGP UPDATE messages using the MP_REACH_NLRI and MP_UNREACH_NLRI attributes [RFC4760]. The "Link-State NLRI" defined in [RFC7752] is extended to carry the SRv6 SID information.

A new "Link-State NLRI Type" is defined for SRv6 SID information as following:

o Link-State NLRI Type: SRv6 SID NLRI (value 6).

The format of this new NLRI type is as shown in the following figure:

```
     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
    +-+-+-+-+-+-+-+-+
    |  Protocol-ID  |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                         Identifier                            |
    |                         (64 bits)                             |
    ++-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+|
    |                Local Node Descriptors (variable)             //
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                SRv6 SID Descriptors (variable)               //
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 9: SRv6 SID NLRI Format

Where:

- o Protocol-ID: 1 octet field that specifies the protocol component through which BGP-LS learns the SRv6 SIDs of the node. The Protocol-ID registry was created by [RFC7752] and then extended by other BGP-LS extensions.

- o Identifier: 8 octet value as defined in [RFC7752].

- o Local Node Descriptors TLV: as defined in [RFC7752] for IGPs, local and static configuration and as defined in [I-D.ietf-idr-bgpls-segment-routing-epe] for BGP protocol.

- o SRv6 SID Descriptors: MUST include a single SRv6 SID Information TLV defined in Section 6.1 and optionally MAY include the Multi-Topology Identifier TLV as defined in [RFC7752].

New TLVs for advertisement within the BGP Link State Attribute [RFC7752] are defined in Section 7 to carry the attributes of an SRv6 SID.

6.1. SRv6 SID Information TLV

An SRv6 SID is encoded using the SRv6 SID Information TLV.

The TLV has the 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 (16 octets) ...
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
         SID (cont ...)
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
         SID (cont ...)
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
         SID (cont ...)                                             |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 10: SRv6 SID Information TLV Format

Where:

Type: 518

Length: 16.

SID: 16 octet field. This field encodes the advertised SRv6 SID as 128 bit value.

7. SRv6 SID Attributes

This section specifies the TLVs to be carried in the BGP Link State Attribute associated with the BGP-LS SRv6 SID NLRI.

7.1. SRv6 Endpoint Behavior TLV

Each SRv6 SID instantiated on an SRv6 capable node has specific instructions (called behavior) bound to it. [I-D.ietf-spring-srv6-network-programming] describes how behaviors are bound with a SID and also defines the initial set of well-known behaviors.

The SRv6 Endpoint Behavior TLV is a mandatory TLV that MUST be included in the BGP-LS Attribute associated with the BGP-LS SRv6 SID NLRI. The TLV has the 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               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |        Endpoint Behavior      |      Flags    |   Algorithm   |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 11: SRv6 Endpoint Behavior TLV

Where:

Type: 1250

Length: 4.

Endpoint Behavior: 2 octet field. The Endpoint Behavior code point for this SRv6 SID as defined in section 9.2 of [I-D.ietf-spring-srv6-network-programming].

Flags: 1 octet of flags with the none defined currently. Reserved for future use and MUST be set to 0 and ignored on receipt.

Algorithm: 1 octet field. Algorithm associated with the SID. Algorithm values are defined in the IGP Algorithm Type registry.

7.2. SRv6 BGP Peer Node SID TLV

The BGP Peer Node SID and Peer Set SID for SR with MPLS data-plane are specified in [I-D.ietf-idr-bgpls-segment-routing-epe]. The similar Peer Node and Peer Set functionality can be realized with SRv6 using SIDs with END.X behavior. The SRv6 BGP Peer Node SID TLV is an optional TLV for use in the BGP-LS Attribute for an SRv6 SID NLRI advertised by BGP for the EPE functionality. This TLV MUST be included along with SRv6 SIDs that are associated with the BGP Peer Node or Peer Set functionality.

The TLV has the 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    |          Reserved             |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                      Peer AS Number                           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Peer BGP Identifier                       |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 12: SRv6 BGP Peer Node SID TLV Format

Where:

o Type: 1251

o Length: 12

o Flags: 1 octet of flags with the following definition:

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

Figure 13: SRv6 BGP Peer End.X SID TLV Flags Format

* B-Flag: Backup Flag. If set, the SID is eligible for protection (e.g. using IPFRR) as described in [RFC8355].

* S-Flag: Set Flag. When set, the S-Flag indicates that the SID refers to a set of BGP peering sessions (i.e. BGP Peer Set SID functionality) and therefore MAY be assigned to one or more End.X SIDs associated with BGP peer sessions.

* P-Flag: Persistent Flag: When set, the P-Flag indicates that the SID is persistently allocated, i.e., the value remains consistent across router restart and/or session flap.

* Other bits are reserved for future use and MUST be set to 0 and ignored on receipt.

- Weight: 1 octet field. The value represents the weight of the SID for the purpose of load balancing. The use of the weight is defined in [RFC8402].

- Reserved: 2 octet field. The value MUST be set to 0 and ignored on receipt.

- Peer AS Number : 4 octets of BGP AS number of the peer router.

- Peer BGP Identifier : 4 octets of the BGP Identifier (BGP Router-ID) of the peer router.

For a SRv6 BGP EPE Peer Node SID, one instance of this TLV is associated with the SRv6 SID. For SRv6 BGP EPE Peer Set SID, multiple instances of this TLV (one for each peer in the "peer set") are associated with the SRv6 SID and the S (set/group) flag is SET.

8. SRv6 SID Structure TLV

SRv6 SID Structure TLV is used to advertise the length of each individual part of the SRv6 SID as defined in [I-D.ietf-spring-srv6-network-programming]. It is an optional TLV for use in the BGP-LS Attribute for an SRv6 SID NLRI and as a sub-TLV of the SRv6 End.X, IS-IS SRv6 LAN End.X and OSPFv3 SRv6 LAN End.X TLVs. The TLV has the 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               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |    LB Length  |  LN Length    | Fun. Length   |  Arg. Length  |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 14: SRv6 SID Structure TLV

Where:

Type: 2 octet field with value 1252

Length: 2 octet field with the value 4.

Locator Block Length: 1 octet field. SRv6 SID Locator Block length in bits.

Locator Node Length: 1 octet field. SRv6 SID Locator Node length in bits.

Function Length: 1 octet field. SRv6 SID Function length in bits.

Argument Length: 1 octet field. SRv6 SID Argument length in bits.

The total of the locator block, locator node, function and argument lengths MUST be less than or equal to 128.

9. IANA Considerations

This document requests assigning code-points from the IANA "Border Gateway Protocol - Link State (BGP-LS) Parameters" registry as described in the sub-sections below.

9.1. BGP-LS NLRI-Types

The following codepoints are assigned by IANA via the early allocation process from within the sub-registry called "BGP-LS NLRI-Types":

Type	NLRI Type	Reference
6	SRv6 SID	this document

Figure 15: SRv6 SID NLRI Type Codepoint

9.2. BGP-LS TLVs

The following TLV codepoints are assigned by IANA via the early allocation process from within the sub-registry called "BGP-LS Node Descriptor, Link Descriptor, Prefix Descriptor, and Attribute TLVs":

TLV Code Point	Description	Value defined in
1038	SRv6 Capabilities TLV	this document
1106	SRv6 End.X SID TLV	this document
1107	IS-IS SRv6 LAN End.X SID TLV	this document
1108	OSPFv3 SRv6 LAN End.X SID TLV	this document
1162	SRv6 Locator TLV	this document
518	SRv6 SID Information TLV	this document
1250	SRv6 Endpoint Behavior TLV	this document
1251	SRv6 BGP Peer Node SID TLV	this document
1252	SRv6 SID Structure TLV	this document

Figure 16: SRv6 BGP-LS Attribute TLV Codepoints

10. Manageability Considerations

This section is structured as recommended in [RFC5706].

The new protocol extensions introduced in this document augment the existing IGP topology information that is distributed via [RFC7752]. Procedures and protocol extensions defined in this document do not affect the BGP protocol operations and management other than as discussed in the Manageability Considerations section of [RFC7752]. Specifically, the malformed attribute tests for syntactic checks in the Fault Management section of [RFC7752] now encompass the new BGP-LS extensions defined in this document. The semantic or content checking for the TLVs specified in this document and their association with the BGP-LS NLRI types or their BGP-LS Attribute is left to the consumer of the BGP-LS information (e.g. an application or a controller) and not the BGP protocol.

A consumer of the BGP-LS information retrieves this information over a BGP-LS session (refer Section 1 and 2 of [RFC7752]). The handling of semantic or content errors by the consumer would be dictated by the nature of its application usage and hence is beyond the scope of this document.

The SR information introduced in BGP-LS by this specification, may be used by BGP-LS consumer applications like a SR path computation engine (PCE) to learn the SRv6 capabilities of the nodes in the topology and the mapping of SRv6 segments to those nodes. This can enable the SR PCE to perform path computations based on SR for traffic engineering use-cases and to steer traffic on paths different from the underlying IGP based distributed best path computation. Errors in the encoding or decoding of the SRv6 information may result

in the unavailability of such information to the SR PCE or incorrect information being made available to it. This may result in the SR PCE not being able to perform the desired SR based optimization functionality or to perform it in an unexpected or inconsistent manner. The handling of such errors by applications like SR PCE may be implementation specific and out of scope of this document.

The manageability considerations related to BGP EPE functionality are discussed in [I-D.ietf-idr-bgpls-segment-routing-epe] in the context of SR-MPLS and they also apply to this document in the context of SRv6.

The extensions, specified in this document, do not introduce any new configuration or monitoring aspects in BGP or BGP-LS other than as discussed in [RFC7752]. The manageability aspects of the underlying SRv6 features are covered by [I-D.ietf-spring-srv6-yang].

11. Security Considerations

The new protocol extensions introduced in this document augment the existing IGP topology information that is distributed via [RFC7752]. The advertisement of the SRv6 link-state information defined in this document presents similar risk as associated with the existing set of link-state information as described in [RFC7752]. The Security Considerations section of [RFC7752] also applies to these extensions. The procedures and new TLVs defined in this document, by themselves, do not affect the BGP-LS security model discussed in [RFC7752].

The extensions introduced in this document are used to propagate IGP defined information ([I-D.ietf-lsr-isis-srv6-extensions] and [I-D.ietf-lsr-ospfv3-srv6-extensions]). These extensions represent the advertisement of SRv6 information associated with the IGP node, link and prefix. The IGP instances originating these TLVs are assumed to support all the required security and authentication mechanisms (as described in [I-D.ietf-lsr-isis-srv6-extensions] and [I-D.ietf-lsr-ospfv3-srv6-extensions]) in order to prevent any security issue when propagating the information into BGP-LS.

The security considerations related to BGP EPE functionality are discussed in [I-D.ietf-idr-bgpls-segment-routing-epe] in the context of SR-MPLS and they also apply to this document in the context of SRv6.

BGP-LS SRv6 extensions enable traffic engineering use-cases within the Segment Routing domain. SR operates within a trusted domain [RFC8402] and its security considerations also apply to BGP-LS sessions when carrying SR information. The SR traffic engineering policies using the SIDs advertised via BGP-LS are expected to be used

entirely within this trusted SR domain (e.g. between multiple AS/ domains within a single provider network). Therefore, precaution is necessary to ensure that the link-state information (including SRv6 information) advertised via BGP-LS sessions is limited to consumers in a secure manner within this trusted SR domain. BGP peering sessions for address-families other than Link-State may be setup to routers outside the SR domain. The isolation of BGP-LS peering sessions is recommended to ensure that BGP-LS topology information (including the newly added SR information) is not advertised to an external BGP peering session outside the SR domain.

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