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                                                                 B. Decraene
                                                                      Orange
                                                                        Z. Hu
                                                          Huawei Technologies
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IS-IS Extensions to Support Segment Routing over IPv6 Dataplane
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Abstract

   The Segment Routing (SR) architecture allows flexible definition of
   the end-to-end path by encoding it as a sequence of topological
   elements called "segments". It can be implemented over the MPLS or
   the IPv6 data plane. This document describes the IS-IS extensions
   required to support Segment Routing over the IPv6 data plane.

   This document updates RFC 7370 by modifying an existing registry.

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.

Status of This Memo

   This Internet-Draft will expire on December 20, 2021.

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1. Introduction

   With Segment Routing (SR) [RFC8402], a node steers a packet through
   an ordered list of instructions, called segments.

   Segments are identified through Segment Identifiers (SIDs).

   Segment Routing can be directly instantiated on the IPv6 data plane
   through the use of the Segment Routing Header defined in [RFC8754].
   SRv6 refers to this SR instantiation on the IPv6 dataplane.

   The network programming paradigm [RFC8986] is central to SRv6. It
   describes how any behavior can be bound to a SID and how any network
   program can be expressed as a combination of SIDs.

   This document specifies IS-IS extensions that allow the IS-IS
   protocol to encode some of these SIDs and their behaviors.

   Familiarity with the network programming paradigm [RFC8986] is
   necessary to understand the extensions specified in this document.

   The new SRv6 Locator top level TLV announces SRv6 locators - a form
   of summary address for the set of topology/algorithm-specific SIDs
   instantiated at the node.

   The SRv6 Capabilities sub-TLV announces the ability to support SRv6.

   Several new sub-TLVs are defined to advertise various SRv6 Maximum
   SID Depths.

   The SRv6 End SID sub-TLV, the SRv6 End.X SID sub-TLV, and the SRv6
   LAN End.X SID sub-TLV are used to advertise which SIDs are
   instantiated at a node and what Endpoint behavior is bound to each
   instantiated SID.

This document updates [RFC7370] by modifying an existing registry
(Section 11.1.2).

2. SRv6 Capabilities sub-TLV

A node indicates that it supports the SR Segment Endpoint Node
functionality as specified in [RFC8754] by advertising a new SRv6
Capabilities sub-TLV of the router capabilities TLV [RFC7981].

The SRv6 Capabilities sub-TLV may contain optional sub-sub-TLVs. No
sub-sub-TLVs are currently defined.

The SRv6 Capabilities sub-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              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   optional sub-sub-TLVs...
```

   Type: 25

   Length: 2 + length of sub-sub-TLVs

   Flags: 2 octets The following flags are defined:

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

   where:

     O-flag: If set, the router supports use of the O-bit
     in the Segment Routing Header (SRH) as defined in
     [I-D.ietf-6man-spring-srv6-oam].

     The remaining bits, including bit 0, are reserved for future use. They
MUST be
     set to zero on transmission and MUST be ignored on receipt.

3. Advertising Supported Algorithms

An SRv6 capable router indicates supported algorithm(s) by
advertising the Segment Routing Algorithm sub-TLV as defined in
[RFC8667].

4. Advertising Maximum SRv6 SID Depths

[RFC8491] defines the means to advertise node/link specific values
for Maximum SID Depths (MSD) of various types. Node MSDs are
advertised in a sub-TLV of the Router Capabilities TLV [RFC7981].
Link MSDs are advertised in a sub-TLV of TLVs 22, 23, 25, 141, 222,
and 223.

This document defines the relevant SRv6 MSDs and requests MSD type
assignments in the MSD Types registry created by [RFC8491].

4.1. Maximum Segments Left MSD Type

The Maximum Segments Left MSD Type signals the maximum value of the
"Segments Left" field [RFC8754] in the SRH of a received packet
before applying the Endpoint behavior associated with a SID.

   SRH Max Segments Left Type: 41

   If no value is advertised, the supported value is 0.

4.2. Maximum End Pop MSD Type

The Maximum End Pop MSD Type signals the maximum number of SIDs in
the SRH to which the router can apply "Penultimate Segment Pop of the
SRH" or "Ultimate Segment Pop of the SRH" behavior, as defined in
[RFC8986] flavors.

   SRH Max End Pop Type: 42

   If the advertised value is zero or no value is advertised,
   then the router cannot apply PSP or USP flavors.

4.3. Maximum H.Encaps MSD Type

The Maximum H.Encaps MSD Type signals the maximum number of SIDs that
can be added to the Segment List of an SRH as part of the "H.Encaps"
behavior as defined in [RFC8986].

SRH Max H.encaps Type: 44

If the advertised value is zero or no value is advertised, then the
headend can apply an SR Policy that only contains one segment, without
inserting any SRH header.

A non-zero SRH Max H.encaps MSD indicates that the headend can insert
an SRH up to the advertised number of SIDs.

4.4. Maximum End D MSD Type

The Maximum End D MSD Type specifies the maximum number of SIDs
present in an SRH when performing decapsulation. As specified in
[RFC8986] the permitted SID types include, but are not limited to
End.DX6, End.DT4, End.DT46, End with USD, End.X with USD.

   SRH Max End D Type: 45

   If the advertised value is zero or no value is advertised
   then the router cannot apply any behavior that results in
   decapsulation and forwarding of the inner packet if the
   outer IPv6 header contains an SRH.

5. SRv6 SIDs and Reachability

As discussed in [RFC8986], an SRv6 Segment Identifier (SID) is 128
bits and consists of Locator, Function and Argument parts.

A node is provisioned with topology/algorithm specific locators for
each of the topology/algorithm pairs supported by that node. Each
locator is a covering prefix for all SIDs provisioned on that node
which have the matching topology/algorithm.

Locators MUST be advertised in the SRv6 Locator TLV (see
Section 7.1). Forwarding entries for the locators advertised in the
SRv6 Locator TLV MUST be installed in the forwarding plane of
receiving SRv6 capable routers when the associated topology/algorithm
is supported by the receiving node. The processing of the prefix
advertised in the SRv6 Locator TLV, the calculation of its
reachability and the installation in the forwarding plane follows the
process defined for the Prefix Reachability TLV 236 [RFC5308], or TLV
237 [RFC5120].

Locators associated with algorithm 0 and 1 (for all supported
topologies) SHOULD be advertised in a Prefix Reachability TLV (236 or
237) so that legacy routers (i.e., routers which do not support SRv6)
will install a forwarding entry for algorithm 0 and 1 SRv6 traffic.

In cases where the same prefix, with the same prefix-length, Multi
Topology ID (MT ID), and algorithm is received in both a Prefix
Reachability TLV and an SRv6 Locator TLV, the Prefix Reachability
advertisement MUST be preferred when installing entries in the
forwarding plane. This is to prevent inconsistent forwarding entries
between SRv6 capable and SRv6 incapable routers. Such preference of
Prefix Reachability advertisement does not have any impact on the
rest of the data advertised in the SRv6 Locator TLV.

Locators associated with Flexible Algorithms (see Section 4 of
[I-D.ietf-lsr-flex-algo]) SHOULD NOT be advertised in Prefix
Reachability TLVs (236 or 237). Advertising the Flexible Algorithm
locator in regular Prefix Reachability TLV (236 or 237) would make
the forwarding for it to follow algo 0 path.

SRv6 SIDs are advertised as sub-TLVs in the SRv6 Locator TLV except
for SRv6 SIDs which are associated with a specific Neighbor/Link and
are therefore advertised as sub-TLVs in TLVs 22, 23, 25, 141, 222,
and 223.

SRv6 SIDs received from other nodes are not directly routable and
MUST NOT be installed in the forwarding plane. Reachability to SRv6
SIDs depends upon the existence of a covering locator.

Adherence to the rules defined in this section will assure that SRv6
SIDs associated with a supported topology/algorithm pair will be
forwarded correctly, while SRv6 SIDs associated with an unsupported
topology/algorithm pair will be dropped. NOTE: The drop behavior
depends on the absence of a default/summary route covering a given
locator.

In order for forwarding to work correctly, the locator associated
with SRv6 SID advertisements must be the longest match prefix
installed in the forwarding plane for those SIDs. In order to ensure
correct forwarding, network operators should take steps to make sure
that this requirement is not compromised. For example, the following
situations should be avoided:

o Another locator associated with a different topology/algorithm is
   the longest match

o Another prefix advertisement (i.e., from TLV 236 or 237) is the
   longest match

6. Advertising Anycast Property

Both prefixes and SRv6 Locators may be configured as anycast and as
such the same value can be advertised by multiple routers. It is
useful for other routers to know that the advertisement is for an
anycast identifier.

A new flag in Prefix Attribute Flags Sub-TLV [RFC7794] is defined to
advertise the anycast property:

       Bit #: 4
       Name: Anycast Flag (A-flag)

       When the prefix/SRv6 locator is configured as anycast, the A-flag
       SHOULD be set. Otherwise, this flag MUST be clear.

   The A-flag MUST be preserved when the advertisement is leaked between
   levels.

   The A-flag and the N-flag MUST NOT both be set. If both N-flag and
   A-flag are set in the prefix/SRv6 Locator advertisement, the
   receiving routers MUST ignore the N-flag.

   The same prefix/SRv6 Locator can be advertised by multiple routers.
   If at least one of them sets the A-Flag in its advertisement, the
   prefix/SRv6 Locator SHOULD be considered as anycast.

   A prefix/SRv6 Locator that is advertised by a single node and without
   an A-Flag is considered node specific.

   All the nodes advertising the same anycast locator MUST instantiate
   the exact same set of SIDs under that anycast locator. Failure to do
   so may result in traffic being black-holed or mis-routed.

   The Prefix Attribute Flags Sub-TLV can be carried in the SRv6 Locator
   TLV as well as the Prefix Reachability TLVs. When a router
   originates both the Prefix Reachability TLV and the SRv6 Locator TLV
   for a given prefix, and the router is originating the Prefix
   Attribute Flags Sub-TLV in one of the TLVs, the router SHOULD
   advertise the same flags in the Prefix Attribute Flags Sub-TLV in
   both TLVs. However, unlike TLVs 236 [RFC5308] and 237 [RFC5120] the
   X-flag in the Prefix Attributes Flags sub-TLV is valid when sent in
   the SRv6 Locator TLV. The state of the X-flag in the Prefix
   Attributes Flags sub-TLV when included in the Locator TLV MUST match
   the setting of the embedded "X-bit" in any advertisement for the same
   prefix in TLVs 236 [RFC5308] and 237 [RFC5120]. In case of any
   inconsistency between the Prefix Attribute Flags advertised in the
   Locator TLV and in the Prefix Reachability TLV, the ones advertised
   in Prefix Reachability TLV MUST be preferred.

7. Advertising Locators and End SIDs

   The SRv6 Locator TLV is introduced to advertise SRv6 Locators and End
   SIDs associated with each locator.

   This new TLV shares the sub-TLV space defined for TLVs 135, 235, 236
   and 237.

7.1. **SRv6 Locator TLV Format**

   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    |R|R|R|R|    MT ID             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    Locator Entries . . .                     |
```

   Type: 27

   Length: variable.

   R bits: reserved for future use. They MUST be set to zero on
   transmission and MUST be ignored on receipt.

   MT ID: Multitopology Identifier as defined in [RFC5120]. Note
   that the value 0 is legal.

   Followed by one or more locator entries of the form:

```
    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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                            Metric                            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |    Flags      |   Algorithm   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |  Loc Size     | Locator (variable)...
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |  Sub-TLV-len  |       Sub-TLVs (variable) . . .              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   Metric: 4 octets. As described in Section 4 of [RFC5305].

   Flags: 1 octet. The following flags are defined:

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

   D-flag: Same as described in section 4.1. of [RFC5305].

The remaining bits are reserved for future use. They MUST be
set to zero on transmission and MUST be ignored on receipt.

Algorithm: 1 octet. As defined in IGP Algorithm Types registry
[RFC8665].

Loc-Size: 1 octet. Number of bits in the SRv6 Locator field.
MUST be from the range (1 - 128). The TLV MUST be ignored if the
Loc-Size is outside this range.

Locator: 1-16 octets. This field encodes the advertised SRv6
Locator. The Locator is encoded in the minimal number of octets
for the given number of bits. Trailing bits MUST be set to zero
and ignored when received.

Sub-TLV-length: 1 octet. Number of octets used by sub-TLVs.

Optional sub-TLVs: Supported sub-TLVs are specified in
Section 11.1.2. Any Sub-TLV that is not allowed in the SRv6
Locator TLV MUST be ignored.

Prefix Attribute Flags Sub-TLV [RFC7794] SHOULD be included in the
Locator TLV.

Prefix Attribute Flags Sub-TLV MUST be included in the the Locator
TLV when it is leaked upwards in the hierarchy or originated as a
result of the redistribution from another protocol or another ISIS
instance. If the Prefix Attribute Flags Sub-TLV is not included in
these cases, receivers will be unable to determine the correct source
of the advertisement. The receivers will be unable to detect the
violation.

7.2. SRv6 End SID sub-TLV

The SRv6 End SID sub-TLV is introduced to advertise SRv6 Segment
Identifiers (SID) with Endpoint behaviors which do not require a
particular neighbor in order to be correctly applied. SRv6 SIDs
associated with a neighbor are advertised using the sub-TLVs defined
in Section 8.

Supported behavior values, together with parent TLVs in which they
are advertised, are specified in Section 10 of this document. Please
note that not all behaviors defined in [RFC8986] are defined in this
document, e.g. END.T is not.

This new sub-TLV is advertised in the SRv6 Locator TLV defined in the
previous section. SRv6 End SIDs inherit the topology/algorithm from
the parent locator.

The SRv6 End SID sub-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     |       Endpoint Behavior       |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 | SID (128 bits) . . .                                         |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 | SID (cont . . .)                                             |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 | SID (cont . . .)                                             |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 | SID (cont . . .)                                             |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |Sub-sub-TLV-len|        Sub-sub-TLVs (variable) . . .         |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
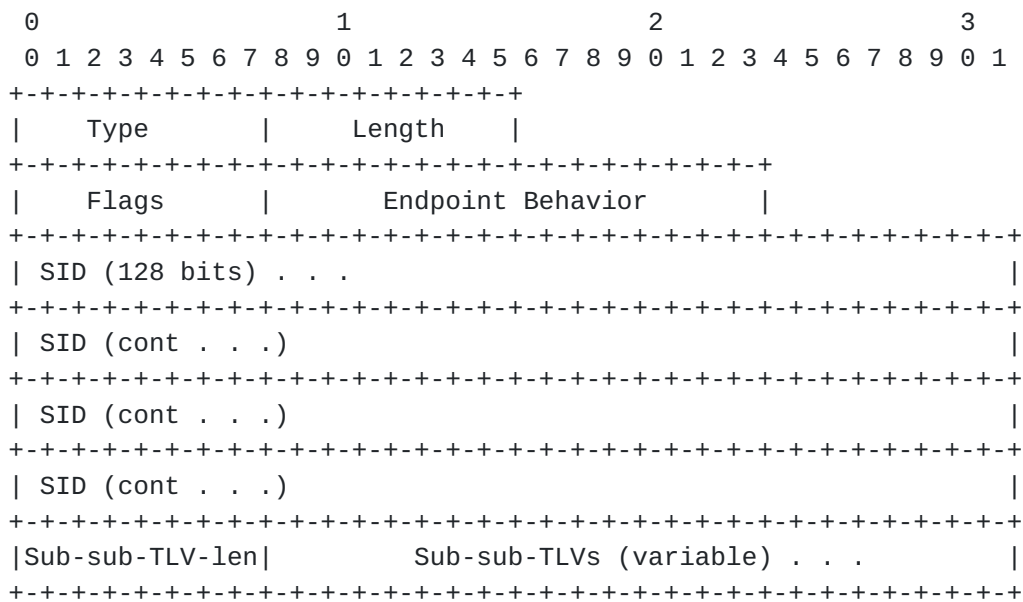
Type: 5.

Length: variable.

Flags: 1 octet. No flags are currently defined. All bits are
reserved for future use. They MUST be set to zero on transmission
and MUST be ignored on receipt.

Endpoint Behavior: 2 octets, as defined in [RFC8986]. Supported
behavior values for this sub-TLV are defined in Section 10 of this
document. Unsupported or unrecognized behavior values are ignored
by the receiver.

SID: 16 octets. This field encodes the advertised SRv6 SID.

Sub-sub-TLV-length: 1 octet. Number of octets used by sub-sub-
TLVs.

Optional Sub-sub-TLVs: Supported Sub-sub-TLVs are specified in
Section 11.6. Any Sub-sub-TLV that is not allowed in SRv6 End SID
sub-TLV MUST be ignored.

The SRv6 End SID MUST be allocated from its associated locator. SRv6
End SIDs that are not allocated from the associated locator MUST be
ignored.

Multiple SRv6 End SIDs MAY be associated with the same locator. In
cases where the number of SRv6 End SID sub-TLVs exceeds the capacity

of a single TLV, multiple Locator TLVs for the same locator MAY be
advertised. For a given MTID/Locator the algorithm MUST be the same
in all TLVs. If this restriction is not met all TLVs for that MTID/
Locator MUST be ignored.

8. Advertising SRv6 Adjacency SIDs

Certain SRv6 Endpoint behaviors [RFC8986] are associated with a
particular adjacency.

This document defines two new sub-TLVs of TLV 22, 23, 25, 141, 222,
and 223 - namely "SRv6 End.X SID sub-TLVs" and "SRv6 LAN End.X SID
sub-TLVs".

IS-IS Neighbor advertisements are topology specific - but not
algorithm specific. SIDs advertised in SRv6 End.X SID and SRv6 LAN
End.X SID sub-TLVs therefore inherit the topology from the associated
neighbor advertisement, but the algorithm is specified in the
individual SID.

All SIDs advertised in SRv6 End.X SID and SRv6 LAN End.X SID sub-TLVs
MUST be a subnet of a Locator with matching topology and algorithm
which is advertised by the same node in an SRv6 Locator TLV. SIDs
that do not meet this requirement MUST be ignored. This ensures that
the node advertising these SIDs is also advertising its corresponding
Locator with the algorithm that will be used for computing paths
destined to the SID.

8.1. SRv6 End.X SID sub-TLV

This sub-TLV is used to advertise an SRv6 SID associated with a point
to point adjacency. Multiple SRv6 End.X SID sub-TLVs MAY be
associated with the same adjacency.

The SRv6 End.X SID sub-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   |   Weight      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |        Endpoint Behavior      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | SID (128 bits) . . .                                         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | SID (cont . . .)                                             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | SID (cont . . .)                                             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | SID (cont . . .)                                             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Sub-sub-tlv-len|        Sub-sub-TLVs (variable) . . .         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   Type: 43

   Length: variable.

   Flags: 1 octet.

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

   where:

   B-Flag: Backup flag. If set, the SID is eligible for
   protection, e.g., using IP Fast Re-route (IPFRR) [RFC5286], 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 SID value remains
   consistent across router restart and/or interface flap.

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

Algorithm: 1 octet. As defined in IGP Algorithm Types registry
[RFC8665].

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

Endpoint Behavior: 2 octets. As defined in [RFC8986]. Supported
behavior values for this sub-TLV are defined in Section 10 of this
document. Unsupported or unrecognized behavior values are ignored
by the receiver.

SID: 16 octets. This field encodes the advertised SRv6 SID.

Sub-sub-TLV-length: 1 octet. Number of octets used by sub-sub-
TLVs.

Optional Sub-sub-TLVs: Supported Sub-sub-TLVs are specified in
Section 11.6. Any Sub-sub-TLV that is not allowed in SRv6 End.X
SID sub-TLV MUST be ignored.

Note that multiple TLVs for the same neighbor may be required in
order to advertise all the SRv6 SIDs associated with that neighbor.

8.2. SRv6 LAN End.X SID sub-TLV

This sub-TLV is used to advertise an SRv6 SID associated with a LAN
adjacency. Since the parent TLV is advertising an adjacency to the
Designated Intermediate System (DIS) for the LAN, it is necessary to
include the System ID of the physical neighbor on the LAN with which
the SRv6 SID is associated. Given that many neighbors may exist on a
given LAN, multiple SRv6 LAN END.X SID sub-TLVs may be associated
with the same LAN. Note that multiple TLVs for the same DIS neighbor
may be required in order to advertise all the SRv6 SIDs associated
with that neighbor.

The SRv6 LAN End.X SID sub-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     |                             |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                             |
  |             Neighbor System-ID (ID length octets)            |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |   Flags         |   Algorithm   |   Weight      |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |       Endpoint Behavior         |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  | SID (128 bits) . . .                                         |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  | SID (cont . . .)                                             |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  | SID (cont . . .)                                             |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  | SID (cont . . .)                                             |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |Sub-sub-TLV-len|     sub-sub-TLVs (variable) . . .            |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type: 44

Length: variable.

Neighbor System-ID: IS-IS System-ID of length "ID Length" as
defined in [ISO10589].

Flags: 1 octet.

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

   where B,S, and P flags are as described in Section 8.1.
   Reserved bits MUST be zero when originated and MUST be ignored
   when received.

Algorithm: 1 octet. As defined in IGP Algorithm Types registry
[RFC8665].

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

      Endpoint Behavior: 2 octets. As defined in [RFC8986]. Supported
      behavior values for this sub-TLV are defined in Section 10 of this
      document. Unsupported or unrecognized behavior values are ignored
      by the receiver.

      SID: 16 octets. This field encodes the advertised SRv6 SID.

      Sub-sub-TLV-length: 1 octet. Number of octets used by sub-sub-
      TLVs.

      Optional Sub-sub-TLVs: Supported Sub-sub-TLVs are specified in
      Section 11.6. Any Sub-sub-TLV that is not allowed in SRv6 LAN
      End.X SID sub-TLV MUST be ignored.

   Note that multiple TLVs for the same neighbor, on the same LAN, may
   be required in order to advertise all the SRv6 SIDs associated with
   that neighbor.

9. SRv6 SID Structure Sub-Sub-TLV

   SRv6 SID Structure Sub-Sub-TLV is an optional Sub-Sub-TLV of:

      SRv6 End SID Sub-TLV (Section 7.2)

      SRv6 End.X SID Sub-TLV (Section 8.1)

      SRv6 LAN End.X SID Sub-TLV (Section 8.2)

   SRv6 SID Structure Sub-Sub-TLV is used to advertise the structure of
   the SRv6 SID as defined in [RFC8986]. It 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  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   where:

      Type: 1

      Length: 4 octets.

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

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

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

Arg. Length: 1 octet. SRv6 SID Arguments length in bits.

ISIS SRv6 SID Structure Sub-Sub-TLV MUST NOT appear more than once in its parent Sub-TLV. If it appears more than once in its parent Sub-TLV, the parent Sub-TLV MUST be ignored by the receiver.

The sum of all four sizes advertised in ISIS SRv6 SID Structure Sub-Sub-TLV MUST be less than or equal to 128 bits. If the sum of all four sizes advertised in the ISIS SRv6 SID Structure Sub-Sub-TLV is larger than 128 bits, the parent Sub-TLV MUST be ignored by the receiver.

The SRv6 SID Sub-Sub-TLV is intended for informational use by the control and management planes. It MUST NOT be used at a transit node (as defined in [RFC8754]) for forwarding packets. As an example, this information could be used for:

o validation of SRv6 SIDs being instantiated in the network and advertised via ISIS. These can be learnt by controllers via BGP-LS and then be monitored for conformance to the SRv6 SID allocation scheme chosen by the operator as described in Section 3.2 of [RFC8986].

o verification and the automation for securing the SRv6 domain by provisioning filtering rules at SR domain boundaries as described in Section 5 of [RFC8754].

The details of these potential applications are outside the scope of this document.

10. Advertising Endpoint Behaviors

Endpoint behaviors are defined in [RFC8986]. The codepoints for the Endpoint behaviors are defined in the "SRv6 Endpoint Behaviors" registry defined in [RFC8986]. If a behavior is advertised it MUST only be advertised in the TLV[s] as indicated by "Y" in the table below, and MUST NOT be advertised in the TLV[s] as indicated by "N" in the table below.

Endpoint Behavior	Endpoint Behavior Codepoint	End SID	End.X SID	Lan End.X SID
End (PSP, USP, USD)	1-4, 28-31	Y	N	N
End.X (PSP, USP, USD)	5-8, 32-35	N	Y	Y
End.DX6	16	N	Y	Y
End.DX4	17	N	Y	Y
End.DT6	18	Y	N	N
End.DT4	19	Y	N	N
End.DT46	20	Y	N	N

11. IANA Considerations

   This document requests allocation for the following TLVs, sub-TLVs,
   and sub-sub-TLVs as well as updating the ISIS TLV registry and
   defining new registries.

11.1. SRv6 Locator TLV

   This document makes the following registrations in the IS-IS TLV
   Codepoints registry.

```
 Type  Description              IIH LSP SNP Purge
 ----  --------------------     --- --- --- -----
  27   SRv6 Locator TLV          n   y   n    n
```

11.1.1. SRv6 End SID sub-TLV

   The SRv6 Locator TLV shares sub-TLV space with TLVs 135, 235, 236 and
   237. This document updates the "Sub-TLVs for TLVs 135, 235, 236, and
   237 (Extended IP reachability, MT IP. Reach, IPv6 IP. Reach, and MT
   IPv6 IP. Reach TLVs)" registry defined in [RFC7370]. IANA is
   requested to update the name of the "Sub-TLVs for TLVs 135, 235, 236,
   and 237 (Extended IP reachability, MT IP. Reach, IPv6 IP. Reach,
   and MT IPv6 IP. Reach TLVs)" registry to "Sub-TLVs for TLVs 27, 135,
   235, 236, and 237 (SRv6 Locator, Extended IP reachability, MT IP.
   Reach, IPv6 IP. Reach, and MT IPv6 IP. Reach TLVs)".

   IANA is asked to add this document as a reference to (renamed) "Sub-
   TLVs for TLVs 27, 135, 235, 236, and 237 (SRv6 Locator, Extended IP

reachability, MT IP. Reach, IPv6 IP. Reach, and MT IPv6 IP. Reach
TLVs)" registry.

This document makes the following registrations in the (renamed)
"Sub-TLVs for TLVs 27, 135, 235, 236, and 237 (SRv6 Locator, Extended
IP reachability, MT IP. Reach, IPv6 IP. Reach, and MT IPv6 IP.
Reach TLVs)" registry:

   Type: 5

   Description: SRv6 End SID sub-TLV.

   Reference: This document (Section 7.2).

11.1.2. Revised sub-TLV table

The revised table of sub-TLVs for the (renamed) "Sub-TLVs for TLVs
27, 135, 235, 236, and 237 (SRv6 Locator, Extended IP reachability,
MT IP. Reach, IPv6 IP. Reach, and MT IPv6 IP. Reach TLVs)"
registry is shown below:

Type	27	135	235	236	237
1	y	y	y	y	y
2	y	y	y	y	y
3	n	y	y	y	y
4	y	y	y	y	y
5	y	n	n	n	n
6	n	y	y	y	y
11	y	y	y	y	y
12	y	y	y	y	y
32	n	y	y	y	y

11.2. SRv6 Capabilities sub-TLV

This document makes the following registrations in the "Sub-TLVs for
TLV 242 (IS-IS Router CAPABILITY TLV)":

   Type: 25

   Description: SRv6 Capabilities sub-TLV.

   Reference: This document (Section 2).

11.3. Sub-Sub-TLVs of the SRv6 Capability sub-TLV

This document requests a new IANA registry be created under the IS-IS
TLV Codepoints Registry to control the assignment of sub-TLV types
for the SRv6 Capability sub-TLV specified in this document -
Section 2. The suggested name of the new registry is "sub-sub-TLVs
of the SRv6 Capability sub-TLV". The registration procedure is
"Expert Review" as defined in [RFC8126]. Guidance for the Designated
Experts is provided in the [RFC7370]. No sub-sub-TLVs are defined by
this document except for the reserved value.

0: Reserved

1-255: Unassigned

11.4. SRv6 End.X SID and SRv6 LAN End.X SID sub-TLVs

This document makes the following registrations in the "Sub-TLVs for
TLVs 22, 23, 25, 141, 222, and 223 (Extended IS reachability, IS
Neighbor Attribute, L2 Bundle Member Attributes, inter-AS
reachability information, MT-ISN, and MT IS Neighbor Attribute TLVs)"
registry:

Type: 43

Description: SRv6 End.X SID sub-TLV.

Reference: This document (Section 8.1).

Type: 44

Description: SRv6 LAN End.X SID sub-TLV.

Reference: This document (Section 8.2).

Type	22	23	25	141	222	223
43	y	y	y	y	y	y
44	y	y	y	y	y	y

11.5. MSD Types

This document makes the following registrations in the IGP MSD-Types
registry:

```
Value    Name                  Reference
-----------------
 41      SRH Max SL            [This Document]
 42      SRH Max End Pop       [This Document]
 44      SRH Max H.encaps      [This Document]
 45      SRH Max End D         [This Document]
```

11.6. Sub-Sub-TLVs for SID Sub-TLVs

This document requests a new IANA registry be created under the IS-IS
TLV Codepoints Registry to control the assignment of sub-TLV types
for the SID Sub-TLVs specified in this document - Section 7.2,
Section 8.1, Section 8.2. The suggested name of the new registry is
"sub-sub-TLVs for SRv6 End SID (5) (sub-TLV of TLVs 27, 135, 235, 236
and 237) and SRv6 End.X SID (43)/SRv6 LAN End.X SID (44) (Sub-TLVs
for TLVs 22, 23, 25, 141, 222, and 223)". The registration procedure
is "Expert Review" as defined in [RFC8126]. Guidance for the
Designated Experts is provided in [RFC7370]. The following
assignments are made by this document:

```
 Type    Description                           Encoding
                                               Reference
 ----------------------------------------------------------
  0      Reserved
  1      SRv6 SID Structure Sub-Sub-TLV        [This Document]
 2-255  Unassigned
```

```
 Type    5   43  44

  1      y   y   y
```

11.7. Prefix Attribute Flags Sub-TLV

This document adds a new bit in the "Bit Values for Prefix Attribute
Flags Sub-TLV" registry:

   Bit #: 4

   Description: Anycast Flag (A-flag)

   Reference: This document (Section 6).

11.8. ISIS SRv6 Capabilities sub-TLV Flags Registry

This document requests a new IANA registry be created under the IS-IS
TLV Codepoints Registry to control the assignment of bits 0 to 15 in
the Flags field of the ISIS SRv6 Capabilities sub-TLV specified in
this document (Section 2). The suggested name of the new registry is
"ISIS SRv6 Capabilities sub-TLV Flags". The registration procedure
is "Expert Review" as defined in [RFC8126]. Guidance for the
Designated Experts is provided in [RFC7370]. The following
assignments are made by this document:

   Bit #: 1

   Description: O-flag

   Reference: This document (Section 2).

11.9. ISIS SRv6 Locator TLV Flags Registry

This document requests a new IANA registry be created under the IS-IS
TLV Codepoints Registry to control the assignment of bits 0 to 7 in
the Flags field of the ISIS SRv6 Locator TLV specified in this
document (Section 7.1). The suggested name of the new registry is
"ISIS SRv6 Locator TLV Flags". The registration procedure is "Expert
Review" as defined in [RFC8126]. Guidance for the Designated Experts
is provided in [RFC7370]. The following assignments are made by this
document:

   Bit #: 0

   Description: D-flag

   Reference: This document (Section 7.1).

11.10. ISIS SRv6 End SID sub-TLV Flags Registry

This document requests a new IANA registry be created under the IS-IS
TLV Codepoints Registry to control the assignment of bits 0 to 7 in
the Flags field of the ISIS SRv6 End SID sub-TLV specified in this
document (Section 7.2). The suggested name of the new registry is
"ISIS SRv6 End SID sub-TLV Flags". The registration procedure is
"Expert Review" as defined in [RFC8126]. Guidance for the Designated
Experts is provided in [RFC7370]. No assignments are made by this
document.

11.11. ISIS SRv6 End.X SID and LAN End.X SID sub-TLVs Flags Registry

This document requests a new IANA registry be created under the IS-IS
TLV Codepoints Registry to control the assignment of bits 0 to 7 in
the Flags field of the ISIS SRv6 End.X SID and LAN End.X SID sub-TLVs
(Section 8.1 and Section 8.2). The suggested name of the new
registry is "ISIS SRv6 End.X SID and LAN End.X SID sub-TLVs Flags".
The registration procedure is "Expert Review" as defined in
[RFC8126]. Guidance for the Designated Experts is provided in
[RFC7370]. The following assignments are made by this document:

   Bit #: 0

   Description: B-flag

   Reference: This document (Section 8.1).

   Bit #: 1

   Description: S-flag

   Reference: This document (Section 8.1).

   Bit #: 2

   Description: P-flag

   Reference: This document (Section 8.1).

12. Security Considerations

Security concerns for IS-IS are addressed in [ISO10589], [RFC5304],
and [RFC5310]. While IS-IS is deployed under a single administrative
domain, there can be deployments where potential attackers have
access to one or more networks in the IS-IS routing domain. In these
deployments, the stronger authentication mechanisms defined in the
aforementioned documents SHOULD be used.

This document describes the IS-IS extensions required to support
Segment Routing over an IPv6 data plane. The security considerations
for Segment Routing are discussed in [RFC8402]. [RFC8986] defines
the SRv6 Network Programming concept and specifies the main Segment
Routing behaviors to enable the creation of interoperable overlays;
the security considerations from that document apply too.

The advertisement for an incorrect MSD value may have negative
consequences, see [RFC8491] for additional considerations.

Security concerns associated with the setting of the O-flag are
described in [I-D.ietf-6man-spring-srv6-oam].

Security concerns associated with the usage of Flex-Algorithms are
described in [I-D.ietf-lsr-flex-algo]).

13. Contributors

The following people gave a substantial contribution to the content
of this document and should be considered as co-authors:

      Stefano Previdi
      Huawei Technologies
      Email: stefano@previdi.net

      Paul Wells
      Cisco Systems
      Saint Paul,
      Minnesota
      United States
      Email: pauwells@cisco.com

      Daniel Voyer
      Email: daniel.voyer@bell.ca

      Satoru Matsushima
      Email: satoru.matsushima@g.softbank.co.jp

      Bart Peirens
      Email: bart.peirens@proximus.com

      Hani Elmalky
      Email: hani.elmalky@ericsson.com

      Prem Jonnalagadda
      Email: prem@barefootnetworks.com

      Milad Sharif
      Email: msharif@barefootnetworks.com>

      Robert Hanzl
      Cisco Systems
      Millenium Plaza Building, V Celnici 10, Prague 1,
      Prague, Czech Republic
      Email rhanzl@cisco.com

      Ketan Talaulikar
      Cisco Systems, Inc.
      Email: ketant@cisco.com

14. Acknowledgments

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Authors' Addresses

   Peter Psenak (editor)
   Cisco Systems
   Pribinova Street 10
   Bratislava 81109
   Slovakia

   Email: ppsenak@cisco.com

   Clarence Filsfils
   Cisco Systems
   Brussels
   Belgium

   Email: cfilsfil@cisco.com

Ahmed Bashandy
Individual

Email: abashandy.ietf@gmail.com

Bruno Decraene
Orange
Issy-les-Moulineaux
France

Email: bruno.decraene@orange.com

Zhibo Hu
Huawei Technologies

Email: huzhibo@huawei.com