Network Working Group
Internet Draft
Intended status: Standard Track
Expires: September 2017

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March 10, 2017

IS-IS Extensions to Support Segment Routing over IPv6 Dataplane
draft-bashandy-isis-srv6-extensions-00

Abstract

Segment Routing (SR) allows for a flexible definition of end-to-end paths by encoding paths as sequences of topological sub-paths, called "segments". Segment routing architecture can be implemented over an MPLS data plane as well as an IPv6 data plane. This draft describes the IS-IS extensions required to support Segment Routing over an IPv6 data plane.

This Internet-Draft will expire on September 10, 2017.

Table of Contents

1. Introduction

With Segment Routing (SR)[9], 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 [10]. SRv6 refers to this SR instantiation on the IPv6 dataplane.

The network programming paradigm [11] is central to SRv6.

It describes how any function can be bound to a SID and how any network program can be expressed as a combination of SID’s.

It defines several well-known functions such as End, End.X, T.Insert, T.Encaps, etc.

This document specifies IS-IS extensions that allow IS-IS protocol to encode some of these functions.

Familiarity with the network programming paradigm [11] is necessary to understand the extensions specified in this document.

This document defines one new top level IS-IS_TLV and three new IS-IS sub-TLVs.

The SRv6 Capabilities sub-TLV announces the ability to support SRv6 and some functions defined in [11] as well as advertising limitations when applying such functions.

The SRv6 SID top level TLV, the P2P SRv6 X-SID sub-TLV, and the LAN SRv6 X-SID sub-TLV are used to advertise which SIDs are instantiated at a node and what function is bound to each instantiated SID.

Only ISIS-related functions such as End and its variants D and X [11] are defined in this document.

1.1. Conventions used in this document

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 [8].

In this document, these words will appear with that interpretation only when in ALL CAPS. Lower case uses of these words are not to be interpreted as carrying RFC-2119 [8] significance.

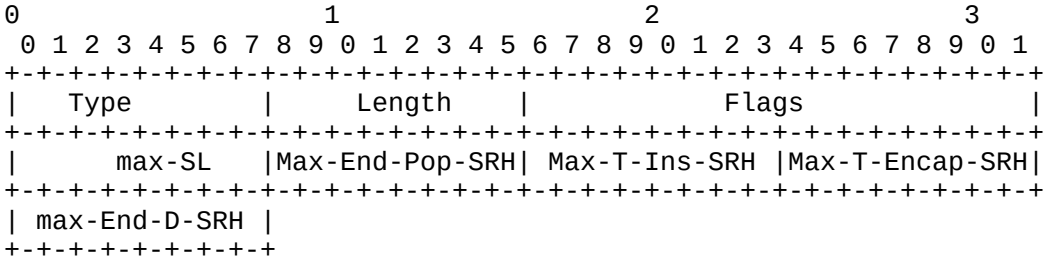
2. SRv6-Capabilities sub-TLV

As described in [10] and [11], the list of Segments is stored in the segment routing header referred hereafter as "SRH".

A router that supports SRv6 MUST be able to process the segment routing header as described in [10] and [11] up to the limitations set by the advertised SRv6-capabilities sub-TLV.

To announce this ability, a router uses the newly defined SRv6-capabilities sub-TLV of the router capabilities TLV [1]. The SRv6-capabilities sub-TLV may contain optional sub-sub-TLVs in the future.

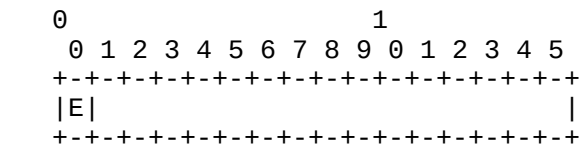
The SRv6 Capabilities sub-TLV has the following format:



Type: Suggested value 22, to be assigned by IANA

Length: 7 + length of sub-sub-TLVs

Flags: 2 octets The following flags are defined:



where:

E-flag: If set, then router is able to apply "T.Encap" operation

Max-SL: 1 octet.

This field specifies the maximum value of the "SL" field [10] in the SRH of a received packet before applying the function associated with a SID.

Max-End-Pop-SRH: 1 Octet

This field specifies the maximum number of SIDs in the top SRH in an SRH stack that the router can apply "PSP" or USP" [11] flavors to. If the value of this field is zero, then the router cannot apply PSP or USP flavors.

Max-T-Ins-SRH: 1 octet

This field specifies the maximum number of SIDs that can be inserted as part of the "T.insert" behavior [11]. If the value of this field is zero, then the router cannot apply any variation of the "T.insert" behavior.

Max-T-Encap-SRH: 1 octet

This field specifies the maximum number of SIDs that can be included as part of the "T.Encap" behavior [11]. If this field is zero and the "E" flag is set, then the router can apply T.Encap by encapsulating the incoming packet in another IPv6 header without SRH the same way IPinIP encapsulation is performed. If the "E" flag is clear, then this field SHOULD be transmitted as zero and MUST be ignored on receipt.

max-End-D-SRH: 1 octet

This field specifies the maximum number of SIDs in an SRH when applying "End.DX6" and "End.DT6" functions. If this field is zero, then the router cannot apply "End.DX6" or "End.DT6" functions if the extension header right underneath the outer IPv6 header is an SRH.

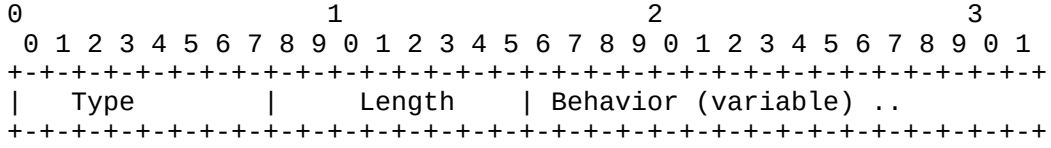
3. SRv6-function Descriptor

The SRv6 SID TLV defined in Section 4, P2P SRv6 X-SID sub-TLV specified in Section 6.1, and LAN SRv6 X-SID sub-TLV specified in section 6.2 MUST include one SRv6 function Descriptor.

When included in the SRv6 SID TLV, the descriptor is encoded as a sub-TLV. When included in a P2P/LAN SRv6 X-SID sub-TLV, the descriptor is encoded as a sub-sub-TLV.

The SRv6-function Descriptor encodes the function (and its flavors) bound to the SRv6 SID advertised in the SRv6 SID TLV [11].

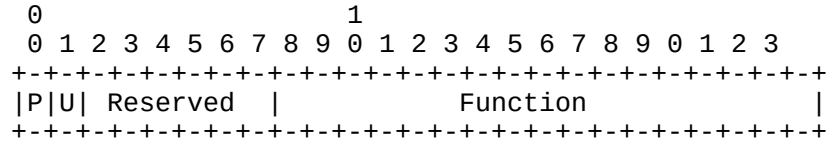
The SRv6 SID function Descriptor has the following format:



Type: See IANA considerations in Section 7.

Length: 3 * (number of functions)

Behavior: One function (with its associated flavors) encoded in 3 octets as shown in the following diagram



The first octet encodes flags. This document defines two flags to specify the flavor(s) [11] associated with the SRv6 function specified in the "Function" field:

P bit: If set, then the PSP flavor [11] is associated with the function encoded in the "function" field

U bit: If set, then the USP flavor [11] is associated with the function encoded in the "function" field

Reserved Bits SHOULD be transmitted as 0 and MUST be ignored on receipt.

The second two octets encode the function. Function code points are defined in Section 5.

For a given SRv6 SID function encoded in the "Function" field, the "P" and "U" bits are set/cleared according to the rules of enabling/disabling the PSP and USP flavors, respectively, for that function as specified in [11].

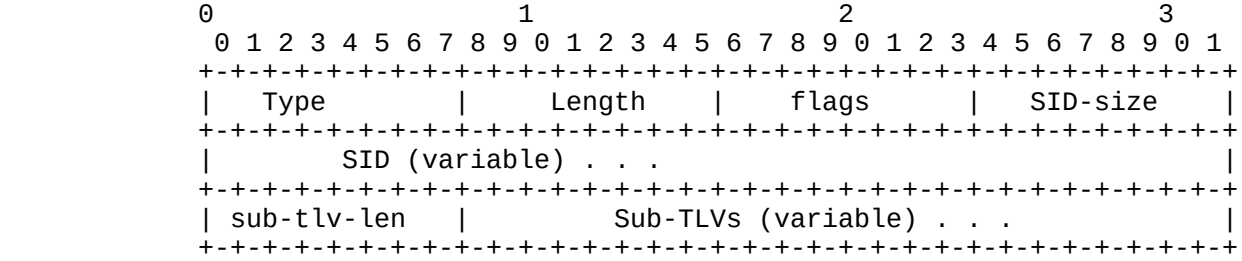
4. SRv6-SID TLV

A new top level TLV is introduced to advertise SRv6 Segment Identifiers (SID) and their attributes.

The new TLV is used to advertise SRv6 SIDs with any of the functions defined in [11] whose code point is defined in this document except those SIDs which must be associated with a particular neighbor in order to be correctly applied [11]. SRv6 SIDs associated with a neighbor are advertised in the sub-TLVs defined in Section 6.

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

The SRv6 SID TLV has the following format



Type: 27 (Suggested value to be assigned by IANA)

Length: variable.

One or more SID entries, each of which has the following format:

Flags: 1 octet. The following flags are defined

where:

D bit: When the SID is leaked from level-2 to level-1, the D bit MUST be set. Otherwise, this bit MUST be clear. SIDs with the D bit set MUST NOT be leaked from level-1 to level-2. This is to prevent looping.

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

SID-Size: 1 octet. Number of bits in the SID field.

SID: 1-16 octets. This field encodes the advertised SRv6 SID. The "SID-size" field can have the values 1-128 and indicates the number of bits in the SID. The SRv6 SID is encoded in the minimal number of octets for the given number of bits. The owning router may associate one or more functions as specified in [11], in other documents, or as locally configured.

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

The function associated with the advertised SID is specified by the SRv6-Function Descriptor sub-TLV specified in Section 3.

5. Function Code points.

This section defines the code points for supported functions associated with SRv6 SIDs. Functions are defined in [11].

- 0: Reserved
- 1: End Function.
- 2: End.DX6 Function.
- 3: End.DT6 Function.
- 4: End.X Function.

6. Advertising SRv6 SIDs associated with a Neighbor.

Certain SRv6 functions [11] must be associated with a particular neighbor, and in case of multiple layer 3 links to the same neighbor, with a particular link in order to be correctly applied.

This document specifies how to advertise two such functions in IS-IS, namely End.X and End.DX6 [11].

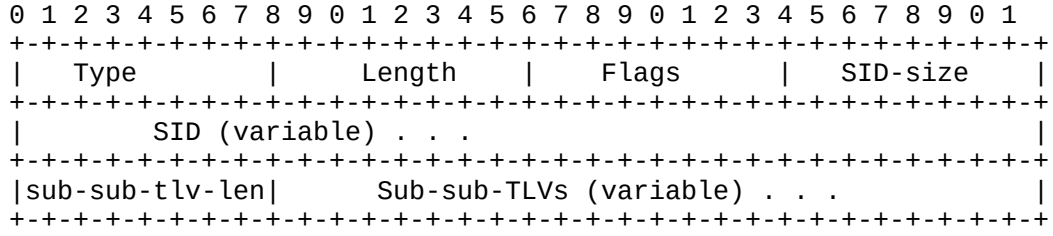
SIDs associated with End.X and End.DX6 functions are advertised within neighbor reachability TLVs.

This document defines two new sub-TLVs of TLV 22 [4], 23 [6], 222 [5], 223[6], and 141 [7] namely "P2P SRv6 X-SID" and "LAN SRv6 X-SID".

6.1. P2P SRv6 X-SID sub-TLV

This sub-TLV is used to advertise one or more SRv6 SIDs associated with End.X and End.DX6 [11] functions over a point to point adjacency.

The "P2P SRv6 X-SID" sub-TLV has the following format



Type: 40 (Suggested value to be assigned by IANA)

Length: variable.

One or more SIDs each of which has the following format:

Flags: 1 octet. No flags defined in this document

SID-Size: 1 octet. Number of bits in the SID field.

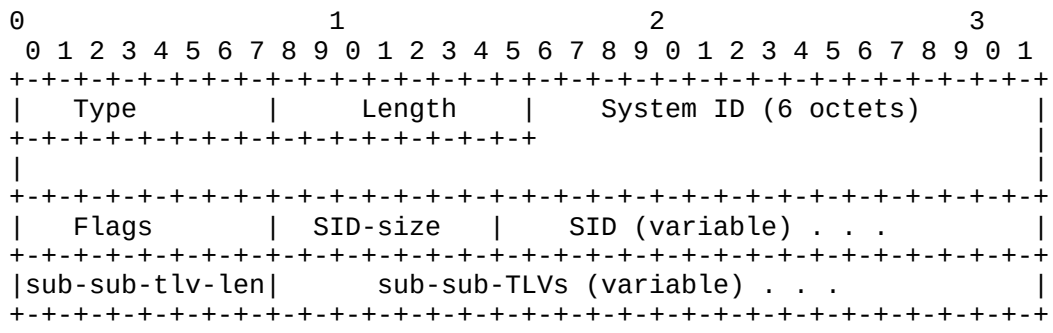
SID: 1-16 octets. This field encodes the advertised SRv6 SID. The "SID-size" field can have the values 1-128 and indicates the number of bits in the SID. The SRv6 SID is encoded in the minimal number of octets for the given number of bits. The owning router may associate one or more functions as specified in [11], in other documents, or as locally configured.

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

The function associated with the advertised SID is specified by the SRv6-Function Descriptor sub-sub-TLV specified in Section 3. If the SRv6-Function Descriptor is encoded in the P2P SRv6 X-SID sub-TLV, then the encoded SRv6 SID function MUST include only the code points of SRv6 SID functions that require the specification of a neighbor to be correctly applied. This document specifies the code points of two such functions, namely End.X and End.DX6 [11].

6.2. LAN SRv6 X-SID sub-TLV

This sub-TLV is used to advertise one or more SRv6 SIDs associated with End.X and End.DX6 [11] functions over a LAN adjacency. The "LAN SRv6 X-SID" sub-TLV has the following format



Type: 41 (Suggested value to be assigned by IANA)

Length: variable.

System-ID: 6 octets of IS-IS System-ID of length "ID Length" as defined in [2].

One or more SIDs each of which has the following format:

Flags 1 Octet. No flags are defined in this document

SID-Size: 1 octet. Number of bits in the SID field.

SID: 1-16 octets. This field encodes the advertised SRv6 SID. The "SID-size" field can have the values 1-128 and indicates the number of bits in the SID. The SRv6 SID is encoded in the minimal number of octets for the given number of bits. The owning router may associate one or more functions as specified in [11], in other documents, or as locally configured.

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

The function associated with the advertised SID is specified by the SRv6-Function Descriptor sub-sub-TLV specified in Section 3. If the SRv6-Function Descriptor is encoded in the P2P SRv6 X-SID sub-TLV, then the encoded SRv6 SID function MUST include only the code points of SRv6 SID functions that require the specification of a neighbor to be correctly applied. This document specifies the code points of two such functions, namely End.X and End.DX6 [11].

7. IANA Considerations

This documents request allocation for the following TLVs, sub-TLVs, and sub-sub-TLVs as well updating the ISIS TLV registry and defining a new registry.

7.1. SRv6 SID TLV and sub-TLVs

This document adds the following new TLV to the IS-IS TLV Codepoints registry.

Value: 27 (suggested - to be assigned by IANA)

Name: SRv6 SID

The name of the "Sub-TLVs for TLVs 135, 235, 236 and 237 registry" needs to be changed to "Sub-TLVs for TLVs 27, 135, 235, 236 and 237 registry".

This document adds a new sub-TLV to the (renamed) "Sub-TLVs for TLVs 27, 135, 235, 236 and 237 registry".

Value: 5 (Suggested - to be assigned by IANA)

Name: SRv6-function Descriptor

The revised table of sub-TLVs in the registry should be:

Type	27	135	235	236	237
1	n	y	y	y	y
2	n	y	y	y	y
3	y	y	y	y	y
4	y	y	y	y	y
5(new)	y	n	n	n	n
11	y	y	y	y	y

12	y	y	y	y	y

7.2. IS-IS SRv6-functions Codepoints Registry

This document requests the creation of a new IANA managed registry to identify SRv6 SID functions. The registration procedure is "Expert Review" as defined in [3]. Suggested registry name is "SRv6 SID Function Types". A function identifier is an unsigned 8 bits value. The following values are defined by this document:

0 Reserved

1 End function.

2 End.DX6 function.

3 End.DT6 function.

4 End.X function.

7.3. SRv6 Capabilities sub-TLV

This document adds the definition of a new sub-TLV in the "Sub-TLVs for TLV 242 registry".

Type: 22 (Suggested - to be assigned by IANA)

Description: SRv6 Capabilities

7.4. P2P SRv6 X-SID and LAN SRv6 X-SID sub-TLVs

This document adds the definition of two new sub-TLVs in the "sub-TLVs for TLV 22, 23, 141, 222 and 223 registry".

Type: 40 (suggested - to be assigned by IANA)

Description: Point-to-Point SRv6 X-SID

Type: 41 (suggested - to be assigned by IANA)

Description: LAN SRv6 X-SID

Type	22	23	141	222	223
40	y	y	y	y	y
41	y	y	y	y	y

7.5. IS-IS SRv6 X-SID sub-sub-TLV Codepoints Registry

This document requests the creation of a new IANA managed registry to identify SRv6 SID functions encoded in P2P/LAN X-SID sub-TLVs. The registration procedure is "Expert Review" as defined in [3]. Suggested registry name is "SRv6 X-SID sub-sub-TLV Codepoints Registry". The following values are defined by this document:

Value: 5 (Suggested - to be assigned by IANA)

Name: SRv6-function Descriptor

This sub-sub-TLV MAY appear in either the Point-to-Point SRv6 X-SID or the LAN SRv6 X-SID sub-TLVs described in Section 7.4.

8. Security Considerations

TBD

9. Contributors

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

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11. Acknowledgments

This document was prepared using 2-Word-v2.0.template.dot.

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Network Working Group
Internet-Draft
Intended status: Standards Track
Expires: September 14, 2017

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Avoiding Traffic Black-Holes for Route Aggregation in IS-IS
draft-chen-isis-black-hole-avoid-00

Abstract

When the Intermediate System to Intermediate System (IS-IS) routing protocol is adopted by a highly symmetric network such as the Leaf-Spine or Fat-Tree network, the Leaf nodes (e.g., Top of Rack switches in datacenters) are recommended to be prevented from receiving other nodes' explicit routes in order to achieve scalability. However, such a setup would cause traffic black-holes or suboptimal routing if link failure happens in the network. This document extends IS-IS to solve this problem.

Requirements Language

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

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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This Internet-Draft will expire on September 14, 2017.

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Table of Contents

1. Introduction

When running the Intermediate System to Intermediate System (IS-IS) routing protocol in a highly symmetric network such as the Leaf-Spine or Fat-Tree network, the Leaf nodes (e.g., Top of Rack switches in datacenters) are recommended to be prevented from receiving other nodes' explicit routes in order to achieve scalability, as proposed in [IS-IS-SL-Extension], [IS-IS-Overhead-Reduction], [RIFT], and [OpenFabric]. In particular, each Leaf node SHOULD simply maintain a default (or aggregated) route (e.g., 0.0.0.0/0) in its routing table, of which the next hop SHOULD be an Equal Cost Multi Path (ECMP) group including all Spines nodes that the Leaf node connects to. However, such a setup would cause traffic black-holes or suboptimal routing if link failure happens in the network, since the Leaf nodes are not aware of any topology information.

To solve this problem, this document extends IS-IS to advertise unreachable prefixes, which are defined as the prefixes that a default (or aggregated) route's next hop can no longer reach. When link failure happens between a Spine node and a Leaf node, the Spine node SHOULD advertise all prefixes attached to the Leaf node (i.e., the unreachable prefixes) to every other Leaf node it connects to. On receiving the unreachable prefixes, each Leaf node SHOULD add the

unreachable prefixes to its routing table, thus avoiding traffic black-holes and suboptimal routing.

2. Problem Description

This section illustrates why link failure would cause traffic black-hole or suboptimal routing when Leaf nodes only maintain default (or aggregated) routes.

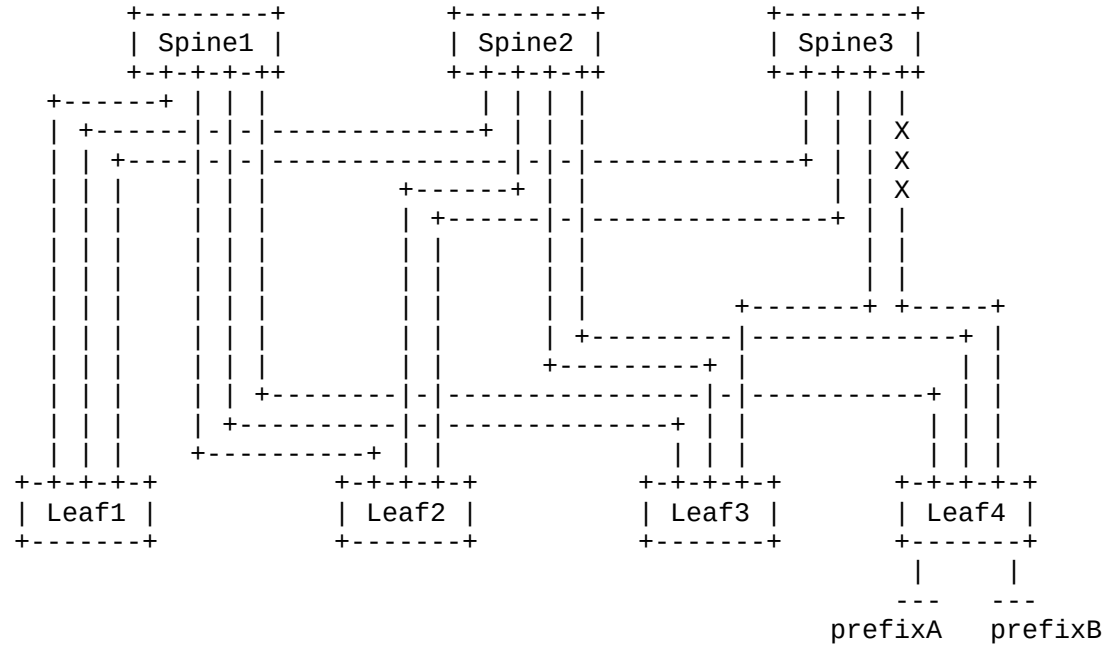


Figure 1: Topology Example

Figure 1 shows a Spine-Leaf topology example where Leaf1 to Leaf4 are connected to Spine1 to Spine3, and prefixA and prefixB are attached to Leaf4. To achieve scalability, as proposed in [IS-IS-SL-Extension], [IS-IS-Overhead-Reduction], [RIFT], and [OpenFabric], Leaf1 to Leaf4 SHOULD NOT receive explict routes from each other nor the Spine nodes. Instead, each of them maintains a default (or aggregated) route (e.g., 0.0.0.0/0) in the routing table, of which the next hop is an ECMP group including Spine1, Spine2, and Spine3. Flows from one Leaf node to another are shared among Spine1, Spine2, and Spine3 based on the well known 5-tuple hashing.

However, such a setup would cause traffic black-hole or suboptimal routing when link failure happens in the network. For example, if

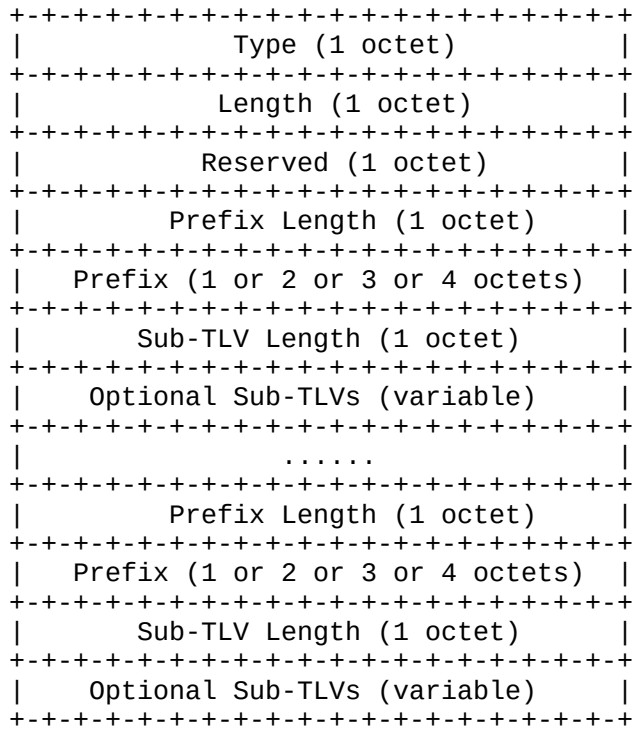
the link between Spine3 and Leaf4 is broken, Leaf1, Leaf2, and Leaf3 could not get aware of the failure. As a result, these Leaf nodes will still send a portion of traffic destined for prefixA or prefixB toward Spine3, which makes the traffic be discarded at Spine3, causing traffic black-hole. On the other hand, if there is a higher tier of switches interconnecting Spine1, Spine2, and Spine3, the traffic will be steered up to the higher-tier switches by Spine3, causing suboptimal routing.

Therefore, this document extends IS-IS to advertise unreachable prefixes thus solving this problem.

3. IS-IS Extensions

3.1. TLV Encoding

This document introduces one IS-IS TLV to advertise unreachable prefixes, called the IP Unreachability TLV, which SHOULD be carried in the IS-IS Link State Packet (LSP). The format of the IP Unreachability TLV is shown as follow:



The fields of this TLV are defined as follows:

Type: TBD.

Length: Length of the Value field of the TLV.

Reserved: Bits reserved for future usage.

Prefix Length: The value can be 0 to 32, indicating the number of effective bits in the Prefix field.

Prefix: Encoding the unreachable prefix in the minimal number of octets for the given number of effective bits (i.e., the Prefix Length field). The remaining bits of prefix SHOULD be set zero and ignored upon receipt.

Sub-TLV Length: Length of Sub-TLVs.

Sub-TLVs: Optional Sub-TLVs for future extension.

Note that the last four fields can appear repeatedly.

3.2. Unreachable Prefixes Advertisement

When link failure happens between a Spine node and a Leaf node, the Spine node SHOULD 1) encode all prefixes attached to the Leaf node (i.e., the unreachable prefixes) into the IP Unreachability TLV, 2) append the IP Unreachability TLV to the IS-IS LSP, and 3) send the LSP to every other Leaf node it connects to.

When a Leaf node receives unreachable prefixes (contained in a LSP) advertised by a Spine node, it SHOULD install each of the unreachable prefixes into its routing table, of which the next hop SHOULD be set an ECMP group including all Spine nodes it connects to except the one who advertises the unreachable prefix.

For example, if the link between Spine3 and Leaf4 in Figure 1 is broken, Spine3 SHOULD advertise prefixA and prefixB to Leaf1, Leaf2, and Leaf3, by sending them an IS-IS LSP containing the IP Unreachability TLV. On receiving the LSP, Leaf1, Leaf2, and Leaf3 SHOULD install prefixA and prefixB into their routing tables, and the next hop of prefixA or prefixB SHOULD be set an ECMP group including Spine1 and Spine2. For instance, the routing table of Leaf1 before and after the link failure is shown in Figure 2 and Figure 3, respectively.

Note that the mechanism described above could achieve minimal signaling latency, which helps to avoid black-hole or suboptimal routing rapidly when link failure happens.

Destination	Proto	Pre	Cost	Flags	NextHop	Interface
0.0.0.0/0	ISIS	15	20	D	Spine1	Ethernet0/0/0
	ISIS	15	20	D	Spine2	Ethernet0/0/1
	ISIS	15	20	D	Spine3	Ethernet0/0/2

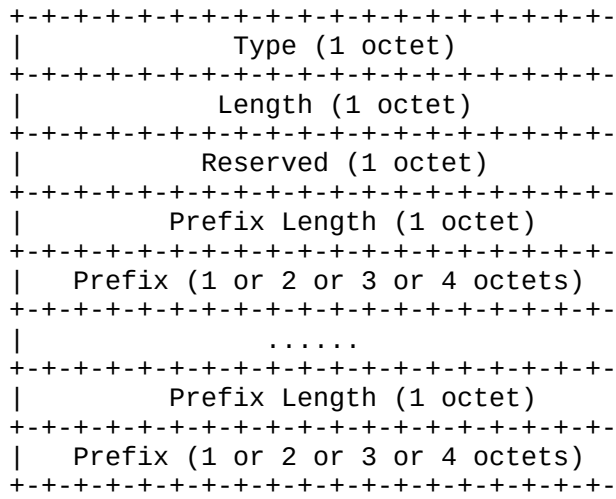
Figure 2: Routing Table of Leaf1 before link failure

Destination	Proto	Pre	Cost	Flags	NextHop	Interface
0.0.0.0/0	ISIS	15	20	D	Spine1	Ethernet0/0/0
	ISIS	15	20	D	Spine2	Ethernet0/0/1
	ISIS	15	20	D	Spine3	Ethernet0/0/2
prefixA	ISIS	15	20	D	Spine1	Ethernet0/0/0
	ISIS	15	20	D	Spine2	Ethernet0/0/1
prefixB	ISIS	15	20	D	Spine1	Ethernet0/0/0
	ISIS	15	20	D	Spine2	Ethernet0/0/1

Figure 3: Routing Table of Leaf1 after link failure

4. Alternative Solution

The unreachable prefixes can alternatively be encoded as a new Sub-TLV of the Extended IP Reachability TLV defined in [RFC 5305]. The format of the Sub-TLV is shown as follow:



The fields of this Sub-TLV are defined as follows:

Type: TBD.

Length: Length of the Value field of the Sub-TLV.

Reserved: Bits reserved for future usage.

Prefix Length: The value can be 0 to 32, indicating the number of effective bits in the Prefix field.

Prefix: Encoding the unreachable prefix in the minimal number of octets for the given number of effective bits (i.e., the Prefix Length field). The remaining bits of prefix SHOULD be set zero and ignored upon receipt.

Note that the last two fields can appear repeatedly.

When link failure happens between a Spine node and a Leaf node, the Spine node SHOULD 1) encode all prefixes attached to the Leaf node (i.e., the unreachable prefixes) into the Sub-TLV described above, 2) encode the Sub-TLV into the Extended IP Reachability TLV, 3) append the Extended IP Reachability TLV to the IS-IS LSP, and 4) send the LSP to every other Leaf node it connects to. The Prefix field of the Extended IP Reachability TLV SHOULD be set the default (or aggregated) route that each of the Leaf nodes already maintains.

When a Leaf node receives unreachable prefixes (contained in a LSP) advertised by a Spine node, it SHOULD install each of the unreachable prefixes into its routing table, of which the next hop SHOULD be set

an ECMP group including all Spine nodes it connects to except the one who advertises the unreachable prefix.

5. IPv6 Support

Will be completed in the next version of the document.

6. IANA Considerations

TBD.

7. Security Considerations

TBD.

8. Acknowledgements

TBD.

9. References

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[IS-IS-SL-Extension]
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Network Working Group
Internet-Draft
Intended status: Standards Track
Expires: January 4, 2018

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Overheads Reduction for IS-IS Enabled Spine-Leaf Networks
draft-chen-isis-sl-overheads-reduction-01

Abstract

When a Spine-Leaf topology adopts the Intermediate System to Intermediate System (IS-IS) routing protocol, the Leaf node receives Link State Packets (LSPs) from all the other nodes thus having the entire routing information of the topology. This is usually considered unnecessary and costly. This document describes a solution to this problem by utilizing IS-IS's inherent multi-level and area partition features, which requires that an IS-IS router SHOULD check a level-1 LSP's area addresses before advertising it to a neighbor.

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

Table of Contents

1. Introduction

Spine-Leaf topology (a.k.a., CLOS topology) is widely used in today's datacenter and campus networks. When the Spine-Leaf topology runs the Intermediate System to Intermediate System (IS-IS) routing protocol, each Leaf node receives Link State Packets (LSPs) from all the other nodes thus having the entire routing information of the topology. This is usually considered unnecessary and costly because the Leaf node only needs to know its default gateways (i.e., the Spine nodes it connects to) and the LSPs generated by the other Leaf nodes bring little benefit for it to forward traffic.

To avoid Leaf nodes from learning the unnecessary LSPs from one another, [IS-IS-SL-Extension] proposes a new TLV attached to the IS-IS Hello (IIH) PDU to carry an router's role (i.e., Spine or Leaf) in the topology. The Spine nodes then prevent all LSPs from being sent

to the Leaf nodes, and each Leaf node sets the Spine nodes it connects to as its default gateways.

This document proposes another solution to this problem, which utilizes IS-IS's inherent multi-level and area partition features. In particular, it requires that each Leaf node (configured as L1 router) SHOULD be assigned with a unique area address and each Spine node (configured as L1/L2 router) MUST NOT advertise level-1 LSPs of a given area to neighbors within another area. This prevents Leaf nodes from receiving routing information from one another, without introducing new message formats.

2. Solution Description

2.1. Area Address Assignment

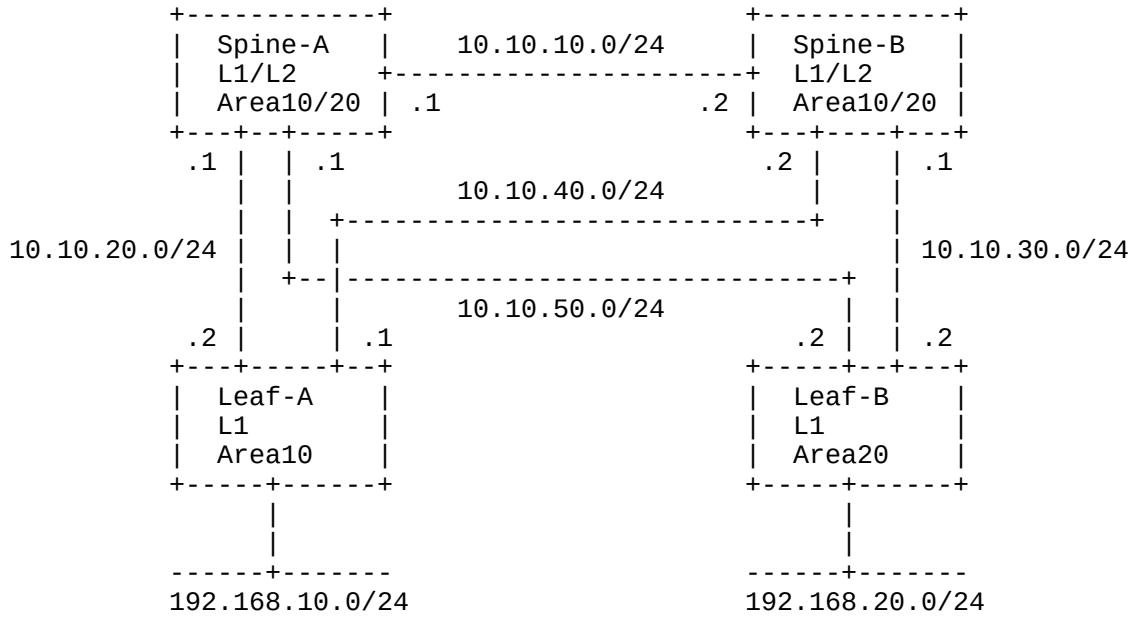

Figure 1: Topology Example

This section describes how to assign area addresses in the Spine-Leaf topology, and illustrates why IS-IS routers SHOULD check the area addresses before advertising level-1 LSPs. As shown in Figure 1, there are two Spine nodes (i.e., Spine-A and Spine-B) and two Leaf nodes (i.e., Leaf-A and Leaf-B). The System IDs of Spine-A, Spine-B, Leaf-A, and Leaf-B are 1111.1111.1111.00 to 4444.4444.4444.00, respectively.

To prevent a Leaf node from learning the routing information of the other ones, the following configurations are REQUIRED:

a. Leaf nodes SHOULD be configured as L1 routers and each of them SHOULD be assigned a unique area address.

b. Spine nodes SHOULD be configured as L1/L2 routers and SHOULD be assigned multiple area addresses with each being that of a given Leaf node connected to it.

As a result, Leaf-A and Leaf-B in Figure 1 are configured as L1 routers and are assigned 10 and 20 as their area addresses, respectively. Spine-A and Spine-B are configured as L1/L2 routers and are assigned both 10 and 20 as their area addresses.

Level-1 Link State Database (Spine-A):

LSPID	Seq Num	Checksum	Holdtime	Length	ATT/P/OL	Area
1111.1111.1111.00-00	0x0000006c	0x540b	743	124	0/0/0	10/20
2222.2222.2222.00-00	0x0000006d	0x933b	1068	124	0/0/0	10/20
3333.3333.3333.00-00	0x0000006b	0x1815	402	122	0/0/0	10
4444.4444.4444.00-00	0x0000006a	0xf543	431	122	0/0/0	20

Level-2 Link State Database (Spine-A):

LSPID	Seq Num	Checksum	Holdtime	Length	ATT/P/OL	Area
1111.1111.1111.00-00	0x0000006f	0x682f	743	150	0/0/0	10/20
2222.2222.2222.00-00	0x00000063	0x30eb	1068	150	0/0/0	10/20

Figure 2: Link State Database of Spine-A

Under such configurations, however, Leaf-A still receives Leaf-B’s LSPs (and vice versa) even though they are in different areas. This is because of the IS-IS definition that all routers in a specific area SHOULD share the same level-1 Link State Database (LSDB). In other words, IS-IS routers check area addresses during neighbor establishment, but are regardless of area addresses when advertising LSPs to a neighbor.

The example in Figure 1 and the LSDB of Spine-A (in Figure 2) further illustrate this. Since Spine-A and Leaf-B are both in area 20, Spine-A will receive LSP 4444.4444.4444.00-00 from Leaf-B and store the LSP into its level-1 LSDB. On the other hand, since Spine-A and Leaf-A are both in area 10, Spine-A will advertise LSP 4444.4444.4444.00-00 to Leaf-A although Leaf-A and Leaf-B (generator of the LSP) are in different areas. As a result, Leaf-A installs the route 192.168.20.0/24 into its routing table (Figure 3), even though it is an external area route.

Leaf-A Routing Table:

Destination	Proto	Pre	Cost	Flags	NextHop	Interface
10.10.10.0/24	ISIS-L1	15	20	D	10.10.20.1	Ethernet0/0/0
	ISIS-L1	15	20	D	10.10.40.2	Ethernet0/0/1
10.10.20.0/24	Direct	0	0	D	127.0.0.1	Ethernet0/0/0
10.10.30.0/24	ISIS-L1	15	20	D	10.10.40.2	Ethernet0/0/1
10.10.40.0/24	Direct	0	0	D	127.0.0.1	Ethernet0/0/1
10.10.50.0/24	ISIS-L1	15	20	D	10.10.20.1	Ethernet0/0/0
192.168.10.0/24	Direct	0	0	D	127.0.0.1	GEthernet0/0/0
192.168.20.0/24	ISIS-L1	15	30	D	10.10.20.1	Ethernet0/0/0
	ISIS-L1	15	30	D	10.10.40.2	Ethernet0/0/1
127.0.0.0/8	Direct	0	0	D	127.0.0.1	InLoopBack0
0.0.0.0/0	ISIS-L1	15	10	D	10.10.20.1	Ethernet0/0/0
	ISIS-L1	15	10	D	10.10.40.2	Ethernet0/0/1

Figure 3: Routing Table of Leaf-A

Therefore, the solution proposed in this document requires that an IS-IS router SHOULD check a level-1 LSP’s area addresses before advertising it to a neighbor (see Section 2.2).

2.2. Area Address Checking

Before advertising a level-1 LSP to a neighbor, an IS-IS router SHOULD compare the area addresses associated with the LSP and the ones associated with the neighbor. If they have at least one area

address in common, the router SHOULD advertise the LSP to the neighbor. Otherwise, the router MUST NOT advertise the LSP to the neighbor.

In the former case, the router SHOULD remove every area addresse in the LSP except the ones associated with the neighbor before the advertisement. This makes the solution more compatible since the Leaf nodes can be unaltered (see Section 3.2).

For instance, before Spine-A advertises LSP 1111.1111.1111.00-00 to Leaf-A, it compares the LSP's area addresses (i.e., 10 and 20) with Leaf-A's area address (i.e., 10). Since they have a common area address 10, Spine-A SHOULD remove area address 20 from the LSP and advertise the LSP to Leaf-A. On the other hand, before Spine-A advertises LSP 4444.4444.4444.00-00 to Leaf-A, it checks their area addresses and finds that they have no area address in common. So Spine-A MUST NOT advertise the LSP to Leaf-A. As a result, Leaf-A would not learn any routing information of Leaf-B, as shown in Figure 4.

Leaf-A Routing Table:

Destination	Proto	Pre	Cost	Flags	NextHop	Interface
10.10.10.0/24	ISIS-L1	15	20	D	10.10.20.1	Ethernet0/0/0
	ISIS-L1	15	20	D	10.10.40.2	Ethernet0/0/1
10.10.20.0/24	Direct	0	0	D	127.0.0.1	Ethernet0/0/0
10.10.30.0/24	ISIS-L1	15	20	D	10.10.40.2	Ethernet0/0/1
10.10.40.0/24	Direct	0	0	D	127.0.0.1	Ethernet0/0/1
10.10.50.0/24	ISIS-L1	15	20	D	10.10.20.1	Ethernet0/0/0
192.168.10.0/24	Direct	0	0	D	127.0.0.1	GEthernet0/0/0
127.0.0.0/8	Direct	0	0	D	127.0.0.1	InLoopBack0
0.0.0.0/0	ISIS-L1	15	10	D	10.10.20.1	Ethernet0/0/0
	ISIS-L1	15	10	D	10.10.40.2	Ethernet0/0/1

Figure 4: Routing Table of Leaf-A

2.3. Default Route Advertising

As defined in [RFC 1195], a L1/L2 router will indicate in its LSPs that it is "attached" by setting the ATT bits. Therefore, each Leaf node would set the Spine nodes as its default gateways and install a default route in its routing table, as shown in Figure 4.

However, a specific IS-IS implementation in this case may not let the L1/L2 router set the ATT bits, because it may speculate that the L1/L2 router has lost connectivity to the level-2 backbone. To solve this problem, operators can manually configure the L1/L2 router to advertise a default route.

3. Compatibility

3.1. Overlapping Areas Use Case

In most deployments, an IS-IS router is assigned only one area address, which will not be influenced by the area checking mechanism proposed in this document. However, an IS-IS router might be assigned more than one area addresses in some practical deployments for the following reasons: 1) it is desirable to change the area address of an area, 2) to merge two areas into one area, or 3) to partition an area into two areas.

For instance, to change an area’s address from X to Y, one can simply add area address Y to all routers in the area, and then remove X from them. Note that such operations would not disrupt live traffic in the network.

Although the solution in this document requires IS-IS router to check LSP’s area addresses before advertising it, the above use cases are still applicable and no compatible issue rises.

3.2. Maximum Area Addresses

The maximumAreaAddresses parameter in today’s IS-IS implementation is set to be 3 (or 0 which indicates 3) on consensus. Therefore, the solution in this document also requires that Spine node SHOULD be modified for supporting more area addresses. However, as LSPs sent to a given neighbor only carry the area address(es) of the neighbor (see Section 2.2), the solution does not require to modify Leaf nodes.

4. IANA Considerations

TBD.

5. Security Considerations

TBD.

6. Acknowledgements

TBD.

7. Normative References

[IS-IS-SL-Extension]
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Networking Working Group
Internet-Draft
Intended status: Standards Track
Expires: December 22, 2017

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IS-IS TE Attributes per application
draft-ginsberg-isis-te-app-03.txt

Abstract

Existing traffic engineering related link attribute advertisements have been defined and are used in RSVP-TE deployments. In cases where multiple applications wish to make use of these link attributes the current advertisements do not support application specific values for a given attribute nor do they support indication of which applications are using the advertised value for a given link.

This draft introduces new link attribute advertisements which address both of these shortcomings. It also discusses backwards compatibility issues and how to minimize duplicate advertisements in the presence of routers which do not support the extensions defined in this document.

Requirements Language

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

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at http://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on December 22, 2017.

Table of Contents

1. Introduction

Advertisement of link attributes by the Intermediate-System-to-Intermediate-System (IS-IS) protocol in support of traffic engineering (TE) was introduced by [RFC5305] and extended by [RFC5307], [RFC6119], and [RFC7810]. Use of these extensions has been associated with deployments supporting Traffic Engineering over Multiprotocol Label Switching (MPLS) in the presence of Resource Reservation Protocol (RSVP) - more succinctly referred to as RSVP-TE.

In recent years new applications have been introduced which have use cases for many of the link attributes historically used by RSVP-TE. Such applications include Segment Routing Traffic Engineering (SRTE) and Loop Free Alternates (LFA). This has introduced ambiguity in that if a deployment includes a mix of RSVP-TE support and SRTE support (for example) it is not possible to unambiguously indicate which advertisements are to be used by RSVP-TE and which advertisements are to be used by SRTE. If the topologies are fully congruent this may not be an issue, but any incongruence leads to ambiguity.

An additional issue arises in cases where both applications are supported on a link but the link attribute values associated with each application differ. Current advertisements do not support advertising application specific values for the same attribute on a specific link.

This document defines extensions which address these issues. Also, as evolution of use cases for link attributes can be expected to continue in the years to come, this document defines a solution which is easily extensible to the introduction of new applications and new use cases.

2. Requirements Discussion

As stated previously, evolution of use cases for link attributes can be expected to continue - so any discussion of existing use cases is limited to requirements which are known at the time of this writing. However, in order to determine the functionality required beyond what already exists in IS-IS, it is only necessary to discuss use cases which justify the key points identified in the introduction - which are:

1. Support for indicating which applications are using the link attribute advertisements on a link

2. Support for advertising application specific values for the same attribute on a link

[RFC7855] discusses use cases/requirements for SR. Included among these use cases is SRTE. If both RSVP-TE and SRTE are deployed in a network, link attribute advertisements can be used by one or both of these applications. As there is no requirement for the link attributes advertised on a given link used by SRTE to be identical to the link attributes advertised on that same link used by RSVP-TE, there is a clear requirement to indicate independently which link attribute advertisements are to be used by each application.

As the number of applications which may wish to utilize link attributes may grow in the future, an additional requirement is that the extensions defined allow the association of additional applications to link attributes without altering the format of the advertisements or introducing new backwards compatibility issues.

Finally, there may still be many cases where a single attribute value can be shared among multiple applications, so the solution must minimize advertising duplicate link/attribute pairs whenever possible.

3. Legacy Advertisements

There are existing advertisements used in support of RSVP-TE. These advertisements include sub-TLVs for TLVs 22, 23, 141, 222, and 223 and TLVs for SRLG advertisement.

3.1. Legacy sub-TLVs

Sub-TLVs for TLVs 22, 23, 141, 222, and 223

Code Point	Attribute Name
3	Administrative group (color)
9	Maximum link bandwidth
10	Maximum reservable link bandwidth
11	Unreserved bandwidth
14	Extended Administrative Group
33	Unidirectional Link Delay
34	Min/Max Unidirectional Link Delay
35	Unidirectional Delay Variation
36	Unidirectional Link Loss
37	Unidirectional Residual Bandwidth
38	Unidirectional Available Bandwidth
39	Unidirectional Utilized Bandwidth

3.2. Legacy SRLG Advertisements

TLV 138 GMPLS-SRLG
Supports links identified by IPv4 addresses and unnumbered links

TLV 139 IPv6 SRLG
Supports links identified by IPv6 addresses

Note that [RFC6119] prohibits the use of TLV 139 when it is possible to use TLV 138.

4. Advertising Application Specific Link Attributes

Two new code points are defined in support of Application Specific Link Attribute Advertisements:

1) Application Specific Link Attributes sub-TLV for TLVs 22, 23, 141, 222, and 223

2)Application Specific Shared Risk Link Group (SRLG) TLV

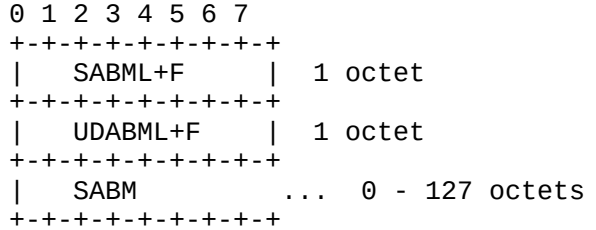
In support of these new advertisements, an application bit mask is defined which identifies the application(s) associated with a given advertisement.

The following sections define the format of these new advertisements.

4.1. Application Identifier Bit Mask

Identification of the set of applications associated with link attribute advertisements utilizes two bit masks. One bit mask is for standard applications where the definition of each bit is defined in a new IANA controlled registry. A second bit mask is for non-standard User Defined Applications(UDAs).

The encoding defined below is used by both the Application Specific Link Attributes sub-TLV and the Application Specific SRLG TLV.



```
|   UDABM        ...  0 - 127 octets
+-+-+-+-+-+-+-+-+
```

SABML+F (1 octet)
Standard Application Bit Mask Length/Flags

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

L-flag: Applications listed (both Standard and User Defined) MUST use the legacy advertisements for the corresponding link found in TLVs 22, 23, 141, 222, and 223 or TLV 138 or TLV 139 as appropriate.

SA-Length: Indicates the length in octets (0-127) of the Bit Mask for Standard Applications.

UDABML+F (1 octet)
User Defined Application Bit Mask Length/Flags

```
 0 1 2 3 4 5 6 7
+-+-+-+-+-+-+-+-+
|R| UDA-Length  |
+-+-+-+-+-+-+-+-+
```

R: Reserved. Transmitted as 0 and ignored on receipt

UDA-Length: Indicates the length in octets (0-127) of the Bit Mask for User Defined Applications.

SABM (variable length)
Standard Application Bit Mask

(SA-Length * 8) bits

This is omitted if SA-Length is 0.

```
 0 1 2 3 4 5 6 7 ...
+-+-+-+-+-+-+-+-+...
|R|S|F|          ...
+-+-+-+-+-+-+-+-+...
```

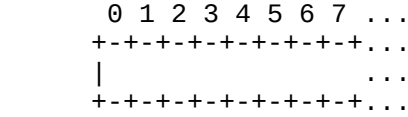
R-bit: RSVP-TE

S-bit: Segment Routing Traffic Engineering

F-bit: Loop Free Alternate

UDABM (variable length)
User Defined Application Bit Mask

(UDA Length * 8) bits



This is omitted if UDA-Length is 0.

NOTE: If both SA-length and UDA-Length are zero, then the attributes associated with this attribute identifier bit mask MAY be used by any Standard Application and any User Defined Application.

Standard Application Bits are defined/sent starting with Bit 0. Additional bit definitions that may be defined in the future SHOULD be assigned in ascending bit order so as to minimize the number of octets that will need to be transmitted. Undefined bits MUST be transmitted as 0 and MUST be ignored on receipt. Bits that are NOT transmitted MUST be treated as if they are set to 0 on receipt.

User Defined Application bits have no relationship to Standard Application bits and are NOT managed by IANA or any other standards body. It is recommended that bits are used starting with Bit 0 so as to minimize the number of octets required to advertise all UDAs.

4.2. Application Specific Link Attributes sub-TLV

A new sub-TLV for TLVs 22, 23, 141, 222, and 223 is defined which supports specification of the applications and application specific attribute values.

Type: 15 (suggested value - to be assigned by IANA)
Length: Variable (1 octet)
Value:

Application Bit Mask (as defined in Section 3.1)

Link Attribute sub-sub-TLVs - format matches the existing formats defined in [RFC5305] and [RFC7810]

When the L-flag is set in the Application Identifiers, all of the applications specified in the bit mask MUST use the link attribute sub-TLV advertisements listed in Section 3.1 for the corresponding link. Application specific link attribute sub-sub-TLVs for the corresponding link attributes MUST NOT be advertised for the set of applications specified in the Standard/User Application Bit Masks and all such advertisements MUST be ignored on receipt.

Multiple sub-TLVs for the same link MAY be advertised. When multiple sub-TLVs for the same link are advertised, they SHOULD advertise non-conflicting application/attribute pairs. A conflict exists when the same application is associated with two different values of the same link attribute for a given link. In cases where conflicting values for the same application/attribute/link are advertised all the conflicting values MUST be ignored.

For a given application, the setting of the L-flag MUST be the same in all sub-TLVs for a given link. In cases where this constraint is violated, the L-flag MUST be considered set for this application.

A new registry of sub-sub-TLVs is to be created by IANA which defines the link attribute sub-sub-TLV code points. A sub-sub-TLV is defined for each of the existing sub-TLVs listed in Section 3.1. Format of the sub-sub-TLVs matches the format of the corresponding legacy sub-TLV and IANA is requested to assign the legacy sub-TLV identifer to the corresponding sub-sub-TLV.

4.3. Application Specific SRLG TLV

A new TLV is defined to advertise application specific SRLGs for a given link. Although similar in functionality to TLV 138 (defined by [RFC5307]) and TLV 139 (defined by [RFC6119], a single TLV provides support for IPv4, IPv6, and unnumbered identifiers for a link. Unlike TLVs 138/139, it utilizes sub-TLVs to encode the link identifiers in order to provide the flexible formatting required to support multiple link identifier types.

Type: 238 (Suggested value - to be assigned by IANA)
Length: Number of octets in the value field (1 octet)
Value:
  Neighbor System-ID + pseudo-node ID (7 octets)
  Application Bit Mask (as defined in Section 3.1)
  Length of sub-TLVs (1 octet)
  Link Identifier sub-TLVs (variable)
  0 or more SRLG Values (Each value is 4 octets)

The following Link Identifier sub-TLVs are defined. The type values are suggested and will be assigned by IANA - but as the formats are identical to existing sub-TLVs defined for TLVs 22, 23, 141, 222, and 223 the use of the suggested sub-TLV types is strongly encouraged.

Type	Description
4	Link Local/Remote Identifiers (see [RFC5307])
6	IPv4 interface address (see [RFC5305])
8	IPv4 neighbor address (see [RFC5305])
12	IPv6 Interface Address (see [RFC6119])
13	IPv6 Neighbor Address (see [RFC6119])

At least one set of link identifiers (IPv4, IPv6, or unnumbered) MUST be present. TLVs which do not meet this requirement MUST be ignored.

Multiple TLVs for the same link MAY be advertised.

When the L-flag is set in the Application Identifiers, SRLG values MUST NOT be included in the TLV. Any SRLG values which are advertised MUST be ignored. Based on the link identifiers advertised the corresponding legacy TLV (see Section 3.2) can be identified and the SRLG values advertised in the legacy TLV MUST be used by the set of applications specified in the Application Bit Mask.

For a given application, the setting of the L-flag MUST be the same in all TLVs for a given link. In cases where this constraint is violated, the L-flag MUST be considered set for this application.

5. Deployment Considerations

If link attributes are advertised associated with zero length application bit masks for both standard applications and user defined applications, then that set of link attributes MAY be used by any application. If support for a new application is introduced on any node in a network in the presence of such advertisements, these advertisements MAY be used by the new application. If this is not what is intended, then existing advertisements MUST be readvertised

with an explicit set of applications specified before a new application is introduced.

6. Attribute Advertisements and Enablement

This document defines extensions to support the advertisement of application specific link attributes. The presence or absence of link attribute advertisements for a given application on a link does NOT indicate the state of enablement of that application on that link. Enablement of an application on a link is controlled by other means.

For some applications, the concept of enablement is implicit. For example, SRTE implicitly is enabled on all links which are part of the Segment Routing enabled topology. Advertisement of link attributes supports constraints which may be applied when specifying an explicit path through that topology.

For other applications enablement is controlled by local configuration. For example, use of a link as an LFA can be controlled by local enablement/disablement and/or the use of administrative tags.

It is an application specific policy as to whether a given link can be used by that application even in the abscence of any application specififc link attributes.

7. Interoperability, Backwards Compatibility and Migration Concerns

Existing deployments of RSVP-TE utilize the legacy advertisements listed in Section 3. Routers which do not support the extensions defined in this document will only process legacy advertisements and are likely to infer that RSVP-TE is enabled on the links for which legacy advertisements exist. It is expected that deployments using the legacy advertisements will persist for a significant period of time - therefore deployments using the extensions defined in this document must be able to co-exist with use of the legacy advertisements by routers which do not support the extensions defined in this document. The following sub-sections discuss interoperability and backwards compatibility concerns for a number of deployment scenarios.

Note that in all cases the defined strategy can be employed on a per link basis.

7.1. RSVP-TE only deployments

In deployments where RSVP-TE is the only application utilizing link attribute advertisements, use of the the legacy advertisements can continue without change.

7.2. Multiple Applications: Common Attributes with RSVP-TE

In cases where multiple applications are utilizing a given link, one of the applications is RSVP-TE, and all link attributes for a given link are common to the set of applications utilizing that link, interoperability is achieved by using legacy advertisements and sending application specific advertisements with L-bit set and no link attribute values. This avoids duplication of link attribute advertisements.

7.3. Multiple Applications: All Attributes Not Shared w RSVP-TE

In cases where one or more applications other than RSVP-TE are utilizing a given link and one or more link attribute values are NOT shared with RSVP-TE, it is necessary to use application specific advertisements as defined in this document. Attributes for applications other than RSVP-TE MUST be advertised using application specific advertisements which have the L-bit clear. In cases where some link attributes are shared with RSVP-TE, this requires duplicate advertisements for those attributes.

The discussion in this section applies to cases where RSVP-TE is NOT using any advertised attributes on a link and to cases where RSVP-TE is using some link attribute advertisements on the link but some link attributes cannot be shared with RSVP-TE.

7.4. Deprecating legacy advertisements

The extensions defined in this document support RSVP-TE as one of the supported applications - so a long term goal for deployments would be to deprecate use of the legacy advertisements in support of RSVP-TE. This can be done in the following step-wise manner:

1)Upgrade all routers to support extensions in this document

2)Readvertise all legacy link attributes using application specific advertisements with L-bit clear and R-bit set.

3)Remove legacy advertisements

8. IANA Considerations

This document defines a new sub-TLV for TLVs 22, 23, 141, 222, and 223.

Type	Description	22	23	141	222	223
15	Application Specific Link Attributes	y	y	y	y	y

This document defines one new TLV:

Type	Description	IIH	SNP	LSP	Purge
238	Application Specific SRLG	n	n	y	n

This document requests a new IANA registry be created to control the assignment of sub-sub-TLV codepoints for the Application Specific Link Attributes sub-TLV. The suggested name of the new registry is "sub-sub-TLV code points for application link attributes". The registration procedure is "Expert Review" as defined in [RFC5226]. The following assignments are made by this document:

Type	Description
3	Administrative group (color)
9	Maximum link bandwidth
10	Maximum reservable link bandwidth
11	Unreserved bandwidth
14	Extended Administrative Group
33	Unidirectional Link Delay
34	Min/Max Unidirectional Link Delay
35	Unidirectional Delay Variation
36	Unidirectional Link Loss
37	Unidirectional Residual Bandwidth
38	Unidirectional Available Bandwidth
39	Unidirectional Utilized Bandwidth

This document requests a new IANA registry be created to control the assignment of application bit identifiers. The suggested name of the new registry is "Link Attribute Applications". The registration procedure is "Expert Review" as defined in [RFC5226]. The following assignments are made by this document:

Bit #	Name
0	RSVP-TE (R-bit)
1	Segment Routing Traffic Engineering (S-bit)
2	Loop Free Alternate (F-bit)

This document requests a new IANA registry be created to control the assignment of sub-TLV types for the application specific SRLG TLV. The suggested name of the new registry is "Sub-TLVs for TLV 238". The registration procedure is "Expert Review" as defined in [RFC5226]. The following assignments are made by this document:

Value	Description
4	Link Local/Remote Identifiers (see [RFC5307])
6	IPv4 interface address (see [RFC5305])
8	IPv4 neighbor address (see [RFC5305])
12	IPv6 Interface Address (see [RFC6119])
13	IPv6 Neighbor Address (see [RFC6119])

9. Security Considerations

Security concerns for IS-IS are addressed in [ISO10589, [RFC5304], and [RFC5310].

10. Acknowledgements

The authors would like to thank John Drake and Acee Lindem for their careful review and content suggestions.

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IS-IS Working Group
Internet-Draft
Intended status: Standards Track
Expires: November 6, 2017

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YANG Data Model for IS-IS Segment Routing
draft-ietf-isis-sr-yang-01

Abstract

This document defines a YANG data model that can be used to configure and manage IS-IS Segment Routing ([I-D.ietf-isis-segment-routing-extensions].

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 [RFC2119].

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at http://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on November 6, 2017.

Table of Contents

1. Overview

YANG [RFC6020] [RFC7950] is a data definition language used to define the contents of a conceptual data store that allows networked devices to be managed using NETCONF [RFC6241]. YANG is proving relevant beyond its initial confines, as bindings to other interfaces (e.g., ReST) and encodings other than XML (e.g., JSON) are being defined. Furthermore, YANG data models can be used as the basis for

implementation of other interfaces, such as CLI and programmatic APIs.

This document defines a YANG data model that can be used to configure and manage IS-IS Segment Routing and it is an augmentation to the IS-IS YANG data model.

2. IS-IS Segment Routing

This document defines a model for IS-IS Segment Routing feature. It is an augmentation of the IS-IS base model.

The IS-IS SR YANG module requires support for the base segment routing module [I-D.ietf-spring-sr-yang], which defines the global segment routing configuration independent of any specific routing protocol configuration, and support of IS-IS base model [I-D.ietf-isis-yang-isis-cfg] which defines basic IS-IS configuration and state.

The figure below describes the overall structure of the isis-sr YANG module:

```
module: ietf-isis-sr
  augment /rt:routing/rt:control-plane-protocols
          /rt:control-plane-protocol/isis:isis:
    +--rw segment-routing
    |  +--rw enabled?    boolean
    |  +--rw bindings
    |     +--rw advertise
    |     |  +--rw policies*   string
    |     +--rw receive?     boolean
    +--rw protocol-srgb {sr:protocol-srgb}?
       +--rw srgb* [lower-bound upper-bound]
          +--rw lower-bound    uint32
          +--rw upper-bound    uint32
  augment /rt:routing/rt:control-plane-protocols
          /rt:control-plane-protocol/isis:isis/isis:interfaces
          /isis:interface:
    +--rw segment-routing
       +--rw adjacency-sid
          +--rw advertise-adj-group-sid* [group-id]
          |  +--rw group-id    uint32
          +--rw advertise-protection?      enumeration
  augment /rt:routing/rt:control-plane-protocols
          /rt:control-plane-protocol/isis:isis/isis:interfaces
          /isis:interface/isis:fast-reroute:
    +--rw ti-lfa {ti-lfa}?
       +--rw enable?   boolean
```

```
augment /rt:routing/rt:control-plane-protocols
        /rt:control-plane-protocol/isis:isis/isis:interfaces
        /isis:interface/isis:fast-reroute/isis:lfa/isis:remote-lfa:
  +--rw use-segment-routing-path?   boolean {remote-lfa-sr}?
augment /rt:routing-state/rt:control-plane-protocols
        /rt:control-plane-protocol/isis:isis:
  +--ro segment-routing
  |  +--ro enabled?    boolean
  |  +--ro bindings
  |     +--ro advertise
  |     |  +--ro policies*   string
  |     +--ro receive?     boolean
  +--ro protocol-srgb {sr:protocol-srgb}?
     +--ro srgb* [lower-bound upper-bound]
        +--ro lower-bound    uint32
        +--ro upper-bound    uint32
augment /rt:routing-state/rt:control-plane-protocols
        /rt:control-plane-protocol/isis:isis/isis:interfaces
        /isis:interface:
  +--ro segment-routing
     +--ro adjacency-sid
        +--ro advertise-adj-group-sid* [group-id]
        |  +--ro group-id    uint32
        +--ro advertise-protection?      enumeration
augment /rt:routing-state/rt:control-plane-protocols
        /rt:control-plane-protocol/isis:isis/isis:interfaces
        /isis:interface/isis:adjacencies/isis:adjacency:
  +--ro adjacency-sid* [value]
     +--ro af?                     identityref
     +--ro value                   uint32
     +--ro weight?                 uint8
     +--ro protection-requested?   boolean
augment /rt:routing-state/rt:control-plane-protocols
        /rt:control-plane-protocol/isis:isis/isis:database
        /isis:level-db/isis:lsp/isis:extended-is-neighbor
        /isis:neighbor:
  +--ro sid-list* [value]
     +--ro flags?         bits
     +--ro weight?        uint8
     +--ro neighbor-id?   isis:system-id
     +--ro value          uint32
augment /rt:routing-state/rt:control-plane-protocols
        /rt:control-plane-protocol/isis:isis/isis:database
        /isis:level-db/isis:lsp/isis:mt-is-neighbor/isis:neighbor:
  +--ro sid-list* [value]
     +--ro flags?         bits
     +--ro weight?        uint8
     +--ro neighbor-id?   isis:system-id
```

```
        +--ro value          uint32
     augment /rt:routing-state/rt:control-plane-protocols
             /rt:control-plane-protocol/isis:isis/isis:database
             /isis:level-db/isis:lsp/isis:extended-ipv4-reachability
             /isis:prefixes:
       +--ro sid-list* [value]
          +--ro flags?       bits
          +--ro algorithm?   uint8
          +--ro value        uint32
     augment /rt:routing-state/rt:control-plane-protocols
             /rt:control-plane-protocol/isis:isis/isis:database
             /isis:level-db/isis:lsp/isis:mt-extended-ipv4-reachability
             /isis:prefixes:
       +--ro sid-list* [value]
          +--ro flags?       bits
          +--ro algorithm?   uint8
          +--ro value        uint32
     augment /rt:routing-state/rt:control-plane-protocols
             /rt:control-plane-protocol/isis:isis/isis:database
             /isis:level-db/isis:lsp/isis:ipv6-reachability
             /isis:prefixes:
       +--ro sid-list* [value]
          +--ro flags?       bits
          +--ro algorithm?   uint8
          +--ro value        uint32
     augment /rt:routing-state/rt:control-plane-protocols
             /rt:control-plane-protocol/isis:isis/isis:database
             /isis:level-db/isis:lsp/isis:mt-ipv6-reachability
             /isis:prefixes:
       +--ro sid-list* [value]
          +--ro flags?       bits
          +--ro algorithm?   uint8
          +--ro value        uint32
     augment /rt:routing-state/rt:control-plane-protocols
             /rt:control-plane-protocol/isis:isis/isis:database
             /isis:level-db/isis:lsp:
       +--ro segment-routing-bindings* [fec range]
          +--ro fec        string
          +--ro range      uint16
          +--ro flags?     bits
          +--ro weight?    uint8
          +--ro binding
             +--ro prefix-sid
             |  +--ro sid-list* [value]
             |     +--ro flags?       bits
             |     +--ro algorithm?   uint8
             |     +--ro value        uint32
             +--ro ero-metric?                          uint32
```

```
            +--ro ero
            |  +--ro address-family?   identityref
            |  +--ro loose?            boolean
            |  +--ro address?          string
            +--ro backup-ero
            |  +--ro address-family?   identityref
            |  +--ro loose?            boolean
            |  +--ro address?          string
            +--ro unnumbered-interface-id-ero
            |  +--ro router-id?      string
            |  +--ro interface-id?   uint32
            +--ro backup-unnumbered-interface-id-ero
               +--ro router-id?      string
               +--ro interface-id?   uint32
```

3. IS-IS Segment Routing configuration

3.1. Segment Routing activation

Activation of segment-routing IS-IS is done by setting the "enable" leaf to true. This triggers advertisement of segment-routing extensions based on the configuration parameters that have been setup using the base segment routing module.

3.2. Advertising mapping server policy

The base segment routing module defines mapping server policies. By default, IS-IS will not advertise nor receive any mapping server entry. The IS-IS segment-routing module allows to advertise one or multiple mapping server policies through the "bindings/advertise/ policies" leaf-list. The "bindings/receive" leaf allows to enable the reception of mapping server entries.

3.3. IP Fast reroute

IS-IS SR model augments the fast-reroute container under interface. It brings the ability to activate TI-LFA (topology independent LFA) and also enhances remote LFA to use segment-routing tunneling instead of LDP.

4. IS-IS Segment Routing YANG Module

```
<CODE BEGINS> file "ietf-isis-sr@2017-05-05.yang"
module ietf-isis-sr {
  namespace "urn:ietf:params:xml:ns:"
          + "yang:ietf-isis-sr";
  prefix isis-sr;
```

```
     import ietf-routing {
       prefix "rt";
     }

     import ietf-segment-routing-common {
       prefix "sr-cmn";
     }


     import ietf-segment-routing {
       prefix "sr";
     }

     import ietf-isis {
       prefix "isis";
     }

     organization
      "IETF ISIS Working Group";

     contact
       "WG List:  <mailto:isis@ietf.org>

       Editor:    Stephane Litkowski
             <mailto:stephane.litkowski@orange.com>

           Acee Lindem
             <mailto:acee@cisco.com>
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           Ing-Wher Chen
             <mailto:ng-wher_chen@jabil.com>
           Jeff Tantsura
             <mailto:jefftant.ietf@gmail.com>

       ";
     description
       "The YANG module defines a generic configuration model for
       Segment routing ISIS extensions common across all of the vendor
       implementations.";

     revision 2017-05-05 {
       description
         "Add p-flag in adj-sid.";
       reference "RFC XXXX";
     }
```

```
     /* Identities */


     /* Features */

   feature remote-lfa-sr {
       description
        "Enhance rLFA to use SR path.";
   }

   feature ti-lfa {
       description
        "Enhance IPFRR with ti-lfa
        support";
   }

     /* Groupings */

   grouping adjacency-state {
       description
        "This group will extend adjacency state.";
       list adjacency-sid {
         key value;
         leaf af {
           type identityref {
             base rt:address-family;
           }
           description
            "Address-family associated with the
            segment ID";
         }
         leaf value {
           type uint32;
           description
            "Value of the Adj-SID.";
         }
         leaf weight {
           type uint8;
           description
            "Weight associated with
            the adjacency SID.";
         }
         leaf protection-requested {
           type boolean;
           description
            "Describe if the adjacency SID
            must be protected.";
         }
```

```
        description
         "List of adjacency Segment IDs.";
      }
   }

   grouping prefix-segment-id {
       description
        "This group defines segment routing extensions
        for prefixes.";

       list sid-list {
         key value;

         leaf flags {
           type bits {
             bit readvertisment {
               position 7;
               description
                "If set, then the prefix to
               which this Prefix-SID is attached,
               has been propagated by the
               router either from another level
               or from redistribution.";
             }

             bit php {
               position 5;
               description
               "If set, then the penultimate hop MUST NOT
               pop the Prefix-SID before delivering the packet
               to the node
               that advertised the Prefix-SID.";
             }
             bit explicit-null {
               position 4;
               description
               "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 and 2 for
               IPv6) before forwarding the packet.";
             }
             bit  value {
               position 3;
               description
               "If set, then the Prefix-SID carries a
               value (instead of an index).
```

```
              By default the flag is UNSET.";


             }
             bit  local {
               position 2;
               description
               "If set, then the value/index carried by
               the Prefix-SID has local significance.
               By default the flag is UNSET.";
             }
           }
           description
            "Describes flags associated with the
            segment ID.";
         }

         leaf algorithm {
           type uint8;
           description
            "Algorithm to be used for path computation.";
         }
         leaf value {
           type uint32;
           description
            "Value of the prefix-SID.";
         }
         description
          "List of segments.";
       }
     }

     grouping adjacency-segment-id {
       description
        "This group defines segment routing extensions
        for adjacencies.";
       list sid-list {
         key value;

         leaf flags {
           type bits {
             bit address-family {
               position 7;
               description
                "If unset, then the Adj-SID refers
               to an adjacency with outgoing IPv4 encapsulation.
               If set then the Adj-SID refers to an adjacency
               with outgoing IPv6 encapsulation.";
```

```
            }
            bit backup {
              position 6;
              description
               "If set, the Adj-SID refers to an
              adjacency being protected
              (e.g.: using IPFRR or MPLS-FRR)";
            }
            bit  value {
              position 5;
              description
              "If set, then the SID carries a
              value (instead of an index).
              By default the flag is SET.";


            }
            bit  local {
              position 4;
              description
              "If set, then the value/index carried by
              the SID has local significance.
              By default the flag is SET.";
            }
            bit  set {
              position 3;
              description
              "When set, the S-Flag indicates that the
              Adj-SID refers to a set of adjacencies";
            }
            bit persistent {
              position 2;
              description
                "When set, the P-Flag indicates that the
                 Adj-SID is persistently allocated.";
            }
          }

          description
           "Describes flags associated with the
           segment ID.";
        }
        leaf weight {
          type uint8;
          description
           "The value represents the weight of the Adj-SID
            for the purpose of load balancing.";
        }
```

```
          leaf neighbor-id {
            type isis:system-id;
            description
             "Describes the system ID of the neighbor
             associated with the SID value. This is only
             used on LAN adjacencies.";
          }
          leaf value {
            type uint32;
            description
             "Value of the Adj-SID.";
          }
          description
           "List of segments.";
        }

      }
      grouping segment-routing-binding-tlv {
      list segment-routing-bindings {

          key "fec range";

          leaf fec {
            type string;
            description
            "IP (v4 or v6) range to be bound to SIDs.";
          }

          leaf range {
            type uint16;
            description
             "Describes number of elements to assign
             a binding to.";
          }

          leaf flags {
            type bits {
              bit address-family {
                position 7;
                description
                "If unset, then the Prefix FEC
                carries an IPv4 Prefix.
                If set then the Prefix FEC carries an
                IPv6 Prefix.";
              }
              bit mirror {
                position 6;
                description
```

```
              "Set if the advertised SID/path
              corresponds to a mirrored context.
              ";
            }
            bit flooding {
              position 5;
              description
               "If the S bit is set(1),
               the IS-IS Router CAPABILITY TLV
              MUST be flooded across the entire routing domain.
              If the S bit is
              not set(0), the TLV MUST NOT be leaked between levels.
              This bit MUST NOT be altered during the TLV leaking.";
            }
            bit down {
              position 4;
              description
              "When the IS-IS Router CAPABILITY TLV is
              leaked from level-2 to level-1, the D bit
              MUST be set.  Otherwise, this bit MUST
              be clear.  IS-IS Router capability TLVs
              with the D bit set MUST NOT
              be leaked from level-1 to level-2.
              This is to prevent TLV looping.
              ";
            }
            bit attached {
              position 3;
              description
              "The originator of the SID/Label Binding
              TLV MAY set the A bit in order to signal
              that the prefixes and
              SIDs advertised in the SID/Label Binding
              TLV are directly
              connected to their originators.
              ";
            }

          }
          description
             "Flags of the binding.";
        }
        leaf weight {
          type uint8;
          description
           "Weight of the path for loadbalancing purpose.";
        }
```

```
          container binding {
            container prefix-sid {
              uses prefix-segment-id;
              description
               "Binding prefix SID to the range.";
            }
            leaf ero-metric {
              type uint32;
              description
               "Cost of ERO path.";
            }
            container ero {
              leaf address-family {
                type identityref {
                  base rt:address-family;
                }
                description
                 "Address-family.";
              }

              leaf loose {
                type boolean;
                description
                 "Set to true,
                 if hop is a loose hop.";
              }
              leaf address {
                type string;
                description
                "IP address of a node on the
                path.";
              }

              description
               "Binding ERO path to the range.";
            }
            container backup-ero {
              leaf address-family {
                type identityref {
                  base rt:address-family;
                }
                description
                 "Address-family.";
              }

              leaf loose {
                type boolean;
                description
```

```
                "Set to true,
                 if hop is a loose hop.";
              }
              leaf address {
                type string;
                description
                "IP address of a node on the
                path.";
              }

              description
               "Binding backup ERO path to the range.";
            }
            container unnumbered-interface-id-ero {
              leaf router-id {
                type string;
                description
                 "Router ID of the node owning the interface.";
              }
              leaf interface-id {
                type uint32;
                description
                "Interface ID on which the path is built.";
              }
              description
               "Binding a path over unnumbered interface.";
            }
            container backup-unnumbered-interface-id-ero {
              leaf router-id {
                type string;
                description
                 "Router ID of the node owning the interface.";
              }
              leaf interface-id {
                type uint32;
                description
                "Interface ID on which the path is built.";
              }
              description
               "Binding a backup path over unnumbered interface.";
            }
            description
             "Bindings associated with the range.";
          }

          description
           "This container describes list of SID/Label
           bindings.
```

```
          ISIS reference is TLV 149.";
      }
      description
       "Defines binding TLV for database.";

    }
    /* Cfg */

    augment "/rt:routing/" +
          "rt:control-plane-protocols/rt:control-plane-protocol"+
          "/isis:isis" {
      when "/rt:routing/rt:control-plane-protocols/"+
          "rt:control-plane-protocol/rt:type = 'isis:isis'" {
        description
        "This augment ISIS routing protocol when used";
      }
      description
       "This augments ISIS protocol configuration
        with segment routing.";

      uses sr:controlplane-cfg;
      container protocol-srgb {
           if-feature sr:protocol-srgb;
           uses sr-cmn:srgb-cfg;
           description
             "Per-protocol SRGB.";
         }

    }


     augment "/rt:routing/" +
          "rt:control-plane-protocols/rt:control-plane-protocol"+
          "/isis:isis/isis:interfaces/isis:interface" {
      when "/rt:routing/rt:control-plane-protocols/"+
          "rt:control-plane-protocol/rt:type = 'isis:isis'" {
        description
        "This augment ISIS routing protocol when used";
      }
      description
       "This augments ISIS protocol configuration
        with segment routing.";
      uses sr:igp-interface-cfg;
    }

     augment "/rt:routing/" +
          "rt:control-plane-protocols/rt:control-plane-protocol"+
          "/isis:isis/isis:interfaces/isis:interface"+
```

```
          "/isis:fast-reroute" {
        when "/rt:routing/rt:control-plane-protocols/"+
            "rt:control-plane-protocol/rt:type = 'isis:isis'" {
          description
          "This augment ISIS routing protocol when used";
        }
        description
         "This augments ISIS IP FRR with TILFA.";

        container ti-lfa {
            if-feature ti-lfa;
            leaf enable {
                type boolean;
                description
                 "Enables TI-LFA computation.";
            }
            description
             "TILFA configuration.";
        }

      }

      augment "/rt:routing/" +
            "rt:control-plane-protocols/rt:control-plane-protocol"+
            "/isis:isis/isis:interfaces/isis:interface"+
            "/isis:fast-reroute/isis:lfa/isis:remote-lfa" {
        when "/rt:routing/rt:control-plane-protocols/"+
            "rt:control-plane-protocol/rt:type = 'isis:isis'" {
          description
          "This augment ISIS routing protocol when used";
        }
        description
         "This augments ISIS remoteLFA config with
         use of segment-routing path.";

        leaf use-segment-routing-path {
            if-feature remote-lfa-sr;
            type boolean;
            description
             "force remote LFA to use segment routing
              path instead of LDP path.";
        }
      }



      /* Operational states */
```

```
     augment "/rt:routing-state/" +
           "rt:control-plane-protocols/rt:control-plane-protocol"+
           "/isis:isis" {
       when "/rt:routing-state/rt:control-plane-protocols/"+
           "rt:control-plane-protocol/rt:type = 'isis:isis'" {
         description
         "This augment ISIS routing protocol when used";
       }
       description
        "This augments ISIS protocol configuration
         with segment routing.";

       uses sr:controlplane-cfg;
       container protocol-srgb {
            if-feature sr:protocol-srgb;
            uses sr-cmn:srgb-cfg;
            description
              "Per-protocol SRGB.";
          }

     }

      augment "/rt:routing-state/" +
           "rt:control-plane-protocols/rt:control-plane-protocol"+
           "/isis:isis/isis:interfaces/isis:interface" {
       when "/rt:routing-state/rt:control-plane-protocols/"+
           "rt:control-plane-protocol/rt:type = 'isis:isis'" {
         description
         "This augment ISIS routing protocol when used";
       }
       description
        "This augments ISIS protocol configuration
         with segment routing.";

       uses sr:igp-interface-cfg;
     }

     augment "/rt:routing-state/" +
           "rt:control-plane-protocols/rt:control-plane-protocol"+
           "/isis:isis/isis:interfaces/isis:interface" +
           "/isis:adjacencies/isis:adjacency" {
       when "/rt:routing-state/rt:control-plane-protocols/"+
           "rt:control-plane-protocol/rt:type = 'isis:isis'" {
         description
         "This augment ISIS routing protocol when used";
       }
       description
        "This augments ISIS protocol configuration
```

```
         with segment routing.";


       uses adjacency-state;
     }

     augment "/rt:routing-state/" +
           "rt:control-plane-protocols/rt:control-plane-protocol"+
           "/isis:isis/isis:database/isis:level-db/isis:lsp"+
           "/isis:extended-is-neighbor/isis:neighbor" {
        when "/rt:routing-state/rt:control-plane-protocols/"+
           "rt:control-plane-protocol/rt:type = 'isis:isis'" {
         description
         "This augment ISIS routing protocol when used";
       }
       description
        "This augments ISIS protocol LSDB neighbor.";
       uses adjacency-segment-id;

     }
     augment "/rt:routing-state/" +
           "rt:control-plane-protocols/rt:control-plane-protocol"+
           "/isis:isis/isis:database/isis:level-db/isis:lsp"+
           "/isis:mt-is-neighbor/isis:neighbor" {
               when "/rt:routing-state/rt:control-plane-protocols/"+
           "rt:control-plane-protocol/rt:type = 'isis:isis'" {
         description
         "This augment ISIS routing protocol when used";
       }
           description
        "This augments ISIS protocol LSDB neighbor.";
       uses adjacency-segment-id;

     }
     augment "/rt:routing-state/" +
           "rt:control-plane-protocols/rt:control-plane-protocol"+
           "/isis:isis/isis:database/isis:level-db/isis:lsp"+
           "/isis:extended-ipv4-reachability/isis:prefixes" {
               when "/rt:routing-state/rt:control-plane-protocols/"+
           "rt:control-plane-protocol/rt:type = 'isis:isis'" {
         description
         "This augment ISIS routing protocol when used";
       }
           description
        "This augments ISIS protocol LSDB prefix.";
       uses prefix-segment-id;

     }
```

```
     augment "/rt:routing-state/" +
           "rt:control-plane-protocols/rt:control-plane-protocol"+
           "/isis:isis/isis:database/isis:level-db/isis:lsp"+
           "/isis:mt-extended-ipv4-reachability/isis:prefixes" {
               when "/rt:routing-state/rt:control-plane-protocols/"+
           "rt:control-plane-protocol/rt:type = 'isis:isis'" {
         description
         "This augment ISIS routing protocol when used";
       }
           description
        "This augments ISIS protocol LSDB prefix.";
       uses prefix-segment-id;

     }
     augment "/rt:routing-state/" +
           "rt:control-plane-protocols/rt:control-plane-protocol"+
           "/isis:isis/isis:database/isis:level-db/isis:lsp"+
           "/isis:ipv6-reachability/isis:prefixes" {
               when "/rt:routing-state/rt:control-plane-protocols/"+
           "rt:control-plane-protocol/rt:type = 'isis:isis'" {
         description
         "This augment ISIS routing protocol when used";
       }
           description
        "This augments ISIS protocol LSDB prefix.";
       uses prefix-segment-id;

     }
     augment "/rt:routing-state/" +
           "rt:control-plane-protocols/rt:control-plane-protocol"+
           "/isis:isis/isis:database/isis:level-db/isis:lsp"+
           "/isis:mt-ipv6-reachability/isis:prefixes" {
               when "/rt:routing-state/rt:control-plane-protocols/"+
           "rt:control-plane-protocol/rt:type = 'isis:isis'" {
         description
         "This augment ISIS routing protocol when used";
       }
           description
        "This augments ISIS protocol LSDB prefix.";
       uses prefix-segment-id;

     }
     augment "/rt:routing-state/" +
           "rt:control-plane-protocols/rt:control-plane-protocol"+
           "/isis:isis/isis:database/isis:level-db/isis:lsp" {
           when "/rt:routing-state/rt:control-plane-protocols/"+
           "rt:control-plane-protocol/rt:type = 'isis:isis'" {
         description
```

```
          "This augment ISIS routing protocol when used";
        }
            description
         "This augments ISIS protocol LSDB.";
        uses segment-routing-binding-tlv;

      }


      /* Notifications */


    }
```

<CODE ENDS>

5. Security Considerations

Configuration and state data defined in this document are designed to be accessed via the NETCONF protocol [RFC6241].

As IS-IS is an IGP protocol (critical piece of the network), ensuring stability and security of the protocol is mandatory for the network service.

Authors recommends to implement NETCONF access control model ([RFC6536]) to restrict access to all or part of the configuration to specific users.

6. Contributors

Authors would like to thank Derek Yeung, Acee Lindem, Yi Yang for their major contributions to the draft.

7. Acknowledgements

TBD.

8. IANA Considerations

The IANA is requested to assign two new URIs from the IETF XML registry ([RFC3688]). Authors are suggesting the following URI:

```
        URI: urn:ietf:params:xml:ns:yang:ietf-isis-sr
        Registrant Contact: IS-IS WG
        XML: N/A, the requested URI is an XML namespace
```

This document also requests one new YANG module name in the YANG Module Names registry ([RFC6020]) with the following suggestion :

```
name: ietf-isis-sr
namespace: urn:ietf:params:xml:ns:yang:ietf-isis-sr
prefix: isis-sr
reference: RFC XXXX
```

9. Change log for ietf-isis-sr YANG module

9.1. From isis document version -12 to isis-sr document version -00

- Separate document for IS-IS SR extensions.

9.2. From isis document version -12 to version -13

- Align with new segment routing common module.

9.3. From isis document version -09 to version -11

- Fixed XPATH in 'when' expressions.

9.4. From isis document version -08 to version -09

- Align to draft-ietf-netmod-routing-cfg-23.

9.5. From isis document version -07 to version -08

- Align to draft-ietf-netmod-routing-cfg-21.

9.6. From isis-sr document version -00 to version -01

- Added P-Flag in Adj-SID..

10. Normative References

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IS-IS Working Group
Internet-Draft
Intended status: Standards Track
Expires: October 1, 2017

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YANG Data Model for IS-IS protocol
draft-ietf-isis-yang-isis-cfg-17

Abstract

This document defines a YANG data model that can be used to configure and manage IS-IS protocol on network elements.

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 [RFC2119].

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at http://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on October 1, 2017.

Table of Contents

1. Introduction

This document defines a YANG data model for IS-IS routing protocol.

The data model covers configuration of an IS-IS routing protocol instance as well as operational states.

1.1. Tree diagram

A simplified graphical representation of the data model is presented in Section 2.

The meaning of the symbols in these diagrams is as follows:

- Brackets "[" and "]" enclose list keys.
- Curly braces "{" and "}" contain names of optional features that make the corresponding node conditional.
- Abbreviations before data node names: "rw" means configuration (read-write), and "ro" state data (read-only).
- Symbols after data node names: "?" means an optional node and "*" denotes a "list" or "leaf-list".
- Parentheses enclose choice and case nodes, and case nodes are also marked with a colon (":").
- Ellipsis ("...") stands for contents of subtrees that are not shown.

2. Design of the Data Model

The IS-IS YANG module is divided in two main "isis" containers that are augmenting the "control-plane-protocol" lists in ietf-routing module with specific IS-IS parameters.

One container contains the writable parameters, while the other contains the operational states.

The figure below describes the overall structure of the isis YANG module:

```
module: ietf-isis
augment /rt:routing-state/rt:ribs/rt:rib/rt:routes/rt:route:
   +--ro metric?       uint32
   +--ro tag*          uint64
   +--ro route-type?   enumeration
augment /if:interfaces/if:interface:
   +--rw clns-mtu?   uint16
augment /rt:routing/rt:control-plane-protocols/rt:control-plane-protocol
:
   +--rw isis
      +--rw enable?                    boolean {admin-control}?
      +--rw level-type?                level
      +--rw system-id?                 system-id
      +--rw maximum-area-addresses?    uint8 {maximum-area-addresses}?
      +--rw area-address*              area-address
      +--rw mpls
      |  +--rw ipv4-router-id?   inet:ipv4-address {ipv4-router-id}?
      |  +--rw ipv6-router-id?   inet:ipv6-address {ipv6-router-id}?
      |  +--rw ldp
      |        ...
      +--rw auto-cost {auto-cost}?
      |  +--rw reference-bandwidth?   uint32
      |  +--rw enable?                boolean
      +--rw lsp-mtu?                   uint16
      +--rw lsp-lifetime?              uint16
      +--rw lsp-refresh?               rt-types:timer-value-seconds16 {ls
p-refresh}?
      +--rw graceful-restart {graceful-restart}?
      |  +--rw enable?             boolean
      |  +--rw restart-interval?   rt-types:timer-value-seconds16
      |  +--rw helper-enable?      boolean
      +--rw nsr {nsr}?
      |  +--rw enable?   boolean
      +--rw node-tags {node-tag}?
      |  +--rw node-tag* [tag]
      |        ...
      +--rw authentication
      |  +--rw (authentication-type)?
      |  |     ...
      |  +--rw level-1
      |  |     ...
      |  +--rw level-2
      |        ...
      +--rw metric-type
      |  +--rw value?     enumeration
      |  +--rw level-1
      |  |     ...
```

```
      |  +--rw level-2
      |        ...
      +--rw default-metric
      |  +--rw value?     wide-metric
      |  +--rw level-1
      |  |     ...
      |  +--rw level-2
      |        ...
      +--rw afs {nlpid-control}?
      |  +--rw af* [af]
      |        ...
      +--rw preference
      |  +--rw (granularity)?
      |        ...
      +--rw overload
      |  +--rw status?   boolean
      +--rw overload-max-metric {overload-max-metric}?
      |  +--rw timeout?   rt-types:timer-value-seconds16
      +--rw fast-reroute {fast-reroute}?
      |  +--rw lfa {lfa}?
      +--rw spf-control
      |  +--rw ietf-spf-delay {ietf-spf-delay}?
      |        ...
      +--rw topologies {multi-topology}?
      |  +--rw topology* [name]
      |        ...
      +--rw interfaces
         +--rw interface* [name]
               ...
augment /rt:routing-state/rt:control-plane-protocols/rt:control-plane-pr
otocol:
   +--ro isis
      +--ro enable?                   boolean {admin-control}?
      +--ro level-type?               level
      +--ro system-id?                system-id
      +--ro maximum-area-addresses?   uint8 {maximum-area-addresses}?
      +--ro area-address*             area-address
      +--ro mpls
      |  +--ro ipv4-router-id?   inet:ipv4-address {ipv4-router-id}?
      |  +--ro ipv6-router-id?   inet:ipv6-address {ipv6-router-id}?
      |  +--ro ldp
      |        ...
      +--ro auto-cost {auto-cost}?
      |  +--ro reference-bandwidth?   uint32
      |  +--ro enable?                boolean
      +--ro lsp-mtu?                  uint16
      +--ro lsp-lifetime?             uint16
      +--ro lsp-refresh?              rt-types:timer-value-seconds16 {ls
p-refresh}?
      +--ro graceful-restart {graceful-restart}?
```

```
      |  +--ro enable?             boolean
      |  +--ro restart-interval?   rt-types:timer-value-seconds16
      |  +--ro helper-enable?      boolean
      +--ro nsr {nsr}?
      |  +--ro enable?   boolean
      +--ro node-tags {node-tag}?
      |  +--ro node-tag* [tag]
      |        ...
      +--ro authentication
      |  +--ro (authentication-type)?
      |  |     ...
      |  +--ro level-1
      |  |     ...
      |  +--ro level-2
      |        ...
      +--ro metric-type
      |  +--ro value?     enumeration
      |  +--ro level-1
      |  |     ...
      |  +--ro level-2
      |        ...
      +--ro default-metric
      |  +--ro value?     wide-metric
      |  +--ro level-1
      |  |     ...
      |  +--ro level-2
      |        ...
      +--ro afs {nlpid-control}?
      |  +--ro af* [af]
      |        ...
      +--ro preference
      |  +--ro (granularity)?
      |        ...
      +--ro overload
      |  +--ro status?   boolean
      +--ro overload-max-metric {overload-max-metric}?
      |  +--ro timeout?   rt-types:timer-value-seconds16
      +--ro fast-reroute {fast-reroute}?
      |  +--ro lfa {lfa}?
      |  +--ro protected-routes
      |  |     ...
      |  +--ro nonprotected-routes
      |  |     ...
      |  +--ro protection-statistics* [frr-protection-method]
      |        ...
      +--ro spf-control
      |  +--ro ietf-spf-delay {ietf-spf-delay}?
      |        ...
```

```
      +--ro topologies* [name]
      |  +--ro name         leafref
      |  +--ro local-rib
      |        ...
      +--ro local-rib
      |  +--ro route* [prefix]
      |        ...
      +--ro system-counters
      |  +--ro level* [level]
      |        ...
      +--ro interfaces
      |  +--ro interface* [interface]
      |        ...
      +--ro spf-log
      |  +--ro event* [id]
      |        ...
      +--ro lsp-log
      |  +--ro event* [id]
      |        ...
      +--ro hostnames
      |  +--ro hostname* [system-id]
      |        ...
      +--ro database
         +--ro level-db* [level]
               ...
rpcs:
   +---x clear-adjacency
   |  +--ro input
   |     +--ro routing-protocol-instance-name    instance-state-ref
   |     +--ro level?                            level
   |     +--ro interface?                        string
   +---x clear-database
      +--ro input
         +--ro routing-protocol-instance-name    instance-state-ref
         +--ro level?                            level
notifications:
   +---n database-overload
   |  +--ro routing-instance?        string
   |  +--ro routing-protocol-name?   string
   |  +--ro isis-level?              level
   |  +--ro overload?                enumeration
   +---n lsp-too-large
   |  +--ro routing-instance?        string
   |  +--ro routing-protocol-name?   string
   |  +--ro isis-level?              level
   |  +--ro interface-name?          string
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
```

```
   |  +--ro pdu-size?               uint32
   |  +--ro lsp-id?                 lsp-id
   +---n if-state-change
   |  +--ro routing-instance?       string
   |  +--ro routing-protocol-name?  string
   |  +--ro isis-level?             level
   |  +--ro interface-name?         string
   |  +--ro interface-level?        level
   |  +--ro extended-circuit-id?    extended-circuit-id
   |  +--ro state?                  if-state-type
   +---n corrupted-lsp-detected
   |  +--ro routing-instance?       string
   |  +--ro routing-protocol-name?  string
   |  +--ro isis-level?             level
   |  +--ro lsp-id?                 lsp-id
   +---n attempt-to-exceed-max-sequence
   |  +--ro routing-instance?       string
   |  +--ro routing-protocol-name?  string
   |  +--ro isis-level?             level
   |  +--ro lsp-id?                 lsp-id
   +---n id-len-mismatch
   |  +--ro routing-instance?       string
   |  +--ro routing-protocol-name?  string
   |  +--ro isis-level?             level
   |  +--ro interface-name?         string
   |  +--ro interface-level?        level
   |  +--ro extended-circuit-id?    extended-circuit-id
   |  +--ro pdu-field-len?          uint8
   |  +--ro raw-pdu?                binary
   +---n max-area-addresses-mismatch
   |  +--ro routing-instance?       string
   |  +--ro routing-protocol-name?  string
   |  +--ro isis-level?             level
   |  +--ro interface-name?         string
   |  +--ro interface-level?        level
   |  +--ro extended-circuit-id?    extended-circuit-id
   |  +--ro max-area-addresses?     uint8
   |  +--ro raw-pdu?                binary
   +---n own-lsp-purge
   |  +--ro routing-instance?       string
   |  +--ro routing-protocol-name?  string
   |  +--ro isis-level?             level
   |  +--ro interface-name?         string
   |  +--ro interface-level?        level
   |  +--ro extended-circuit-id?    extended-circuit-id
   |  +--ro lsp-id?                 lsp-id
   +---n sequence-number-skipped
   |  +--ro routing-instance?       string
```

```
   |  +--ro routing-protocol-name?   string
   |  +--ro isis-level?              level
   |  +--ro interface-name?          string
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
   |  +--ro lsp-id?                  lsp-id
   +---n authentication-type-failure
   |  +--ro routing-instance?        string
   |  +--ro routing-protocol-name?   string
   |  +--ro isis-level?              level
   |  +--ro interface-name?          string
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
   |  +--ro raw-pdu?                 binary
   +---n authentication-failure
   |  +--ro routing-instance?        string
   |  +--ro routing-protocol-name?   string
   |  +--ro isis-level?              level
   |  +--ro interface-name?          string
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
   |  +--ro raw-pdu?                 binary
   +---n version-skew
   |  +--ro routing-instance?        string
   |  +--ro routing-protocol-name?   string
   |  +--ro isis-level?              level
   |  +--ro interface-name?          string
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
   |  +--ro protocol-version?        uint8
   |  +--ro raw-pdu?                 binary
   +---n area-mismatch
   |  +--ro routing-instance?        string
   |  +--ro routing-protocol-name?   string
   |  +--ro isis-level?              level
   |  +--ro interface-name?          string
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
   |  +--ro raw-pdu?                 binary
   +---n rejected-adjacency
   |  +--ro routing-instance?        string
   |  +--ro routing-protocol-name?   string
   |  +--ro isis-level?              level
   |  +--ro interface-name?          string
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
   |  +--ro raw-pdu?                 binary
   |  +--ro reason?                  string
```

```
   +---n protocols-supported-mismatch
   |  +--ro routing-instance?        string
   |  +--ro routing-protocol-name?   string
   |  +--ro isis-level?              level
   |  +--ro interface-name?          string
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
   |  +--ro raw-pdu?                 binary
   |  +--ro protocols*               uint8
   +---n lsp-error-detected
   |  +--ro routing-instance?        string
   |  +--ro routing-protocol-name?   string
   |  +--ro isis-level?              level
   |  +--ro interface-name?          string
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
   |  +--ro lsp-id?                  lsp-id
   |  +--ro raw-pdu?                 binary
   |  +--ro error-offset?            uint32
   |  +--ro tlv-type?                uint8
   +---n adjacency-state-change
   |  +--ro routing-instance?        string
   |  +--ro routing-protocol-name?   string
   |  +--ro isis-level?              level
   |  +--ro interface-name?          string
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
   |  +--ro neighbor?                string
   |  +--ro neighbor-system-id?      system-id
   |  +--ro state?                   adj-state-type
   |  +--ro reason?                  string
   +---n lsp-received
   |  +--ro routing-instance?        string
   |  +--ro routing-protocol-name?   string
   |  +--ro isis-level?              level
   |  +--ro interface-name?          string
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
   |  +--ro lsp-id?                  lsp-id
   |  +--ro sequence?                uint32
   |  +--ro received-timestamp?      yang:timestamp
   |  +--ro neighbor-system-id?      system-id
   +---n lsp-generation
      +--ro routing-instance?        string
      +--ro routing-protocol-name?   string
      +--ro isis-level?              level
      +--ro lsp-id?                  lsp-id
      +--ro sequence?                uint32
```

```
      +--ro send-timestamp?          yang:timestamp
```

2.1. IS-IS Configuration

The IS-IS configuration container is divided in:

- Global parameters.
- Per interface configuration (see Section 2.4).

Additional modules may be created this to support any additional parameters. These additional modules should augment the ietf-isis module.

The model implements features, thus some of the configuration statement becomes optional. As an example, the ability to control the administrative state of a particular IS-IS instance is optional. By advertising the feature "admin-control", a device communicates to the client that it supports the ability to shutdown a particular IS-IS instance.

The global configuration contains usual IS-IS parameters such as lsp-mtu, lsp-lifetime, lsp-refresh, default-metric...

2.2. Multitopology Parameters

The model supports multitopology (MT) IS-IS as defined in [RFC5120].

The "topologies" container is used to enable support of MT extensions.

The "name" used in the topology list should refer to an existing RIB of the device.

Some specific parameters could be defined on a per topology basis both at global level and at interface level: for example, an interface metric can be defined per topology.

Multiple address families (like IPv4 or IPv6) can also be activated within the default topology. This can be achieved using the "afs" container (requiring "nlpid-control" feature to be advertised).

2.3. Per-Level Parameters

Some parameters allow a per level configuration. In this case, the parameter is modeled as a container with three configuration locations:

- a top level container: corresponds to level-1-2, so the configuration applies to both levels.

- a level-1 container: corresponds to level-1 specific parameters.

- a level-2 container: corresponds to level-2 specific parameters.

```
            +--rw priority
            |  +--rw value?     uint8
            |  +--rw level-1
            |  |  +--rw value?   uint8
            |  +--rw level-2
            |     +--rw value?   uint8
```

Example:

```
        <priority>
            <value>250</value>
            <level-1>
                <value>100</value>
            </level-1>
            <level-2>
                <value>200</value>
            </level-2>
        </priority>
```

An implementation SHOULD prefer a level specific parameter over a level-all parameter. As example, if the priority is 100 for the level-1, 200 for the level-2 and 250 for the top level configuration, the implementation should use 100 for the level-1 and 200 for the level-2.

Some parameters like "overload bit" and "route preference" are not modeled to support a per level configuration. If an implementation supports per level configuration for such parameter, this implementation SHOULD augment the current model by adding both level-1 and level-2 containers and SHOULD reuse existing configuration groupings.

Example of augmentation:

```
   augment "/rt:routing/" +
           "rt:control-plane-protocols/rt:control-plane-protocol"+
           "/isis:isis/isis:overload" {
       when "rt:type = 'isis:isis'" {
         description
         "This augment IS-IS routing protocol when used";
       }
       description
        "This augments IS-IS overload configuration
         with per level configuration.";

       container level-1 {
           uses isis:overload-global-cfg;
           description
            "Level 1 configuration.";
       }
       container level-2 {
           uses isis:overload-global-cfg;
           description
            "Level 2 configuration.";
       }

   }
```

If an implementation does not support per level configuration for a parameter modeled with per level configuration, the implementation SHOULD advertise a deviation to announce the non support of the level-1 and level-2 containers.

Finally, if an implementation supports per level configuration but does not support the level-1-2 configuration, it SHOULD also advertise a deviation.

2.4. Per-Interface Parameters

The per-interface section of the IS-IS instance describes the interface specific parameters.

The interface is modeled as a reference to an existing interface defined in the "ietf-interfaces" YANG model.

Each interface has some interface-specific parameters that may have a different per level value as described in previous section. An interface-specific parameter always override an IS-IS global parameter.

Some parameters like hello-padding are defined as containers to allow easy extension by vendor specific modules.

```
      +--rw interfaces
         +--rw interface* [name]
            +--rw name                        if:interface-ref
            +--rw level-type?                 level
            +--rw lsp-pacing-interval?        rt-types:timer-value-millis
econds
            +--rw lsp-retransmit-interval?    rt-types:timer-value-second
s16
            +--rw passive?                    boolean
            +--rw csnp-interval?              rt-types:timer-value-second
s16
            +--rw hello-padding
            |  +--rw enable?   boolean
            +--rw mesh-group-enable?          mesh-group-state
            +--rw mesh-group?                 uint8
            +--rw interface-type?             interface-type
            +--rw enable?                     boolean {admin-control}?
            +--rw tag*                        uint32 {prefix-tag}?
            +--rw tag64*                      uint64 {prefix-tag64}?
            +--rw node-flag?                  boolean {node-flag}?
            +--rw hello-authentication
            |  +--rw (authentication-type)?
            |  |  +--:(key-chain) {key-chain}?
            |  |  |  +--rw key-chain?          key-chain:key-chain-ref
            |  |  +--:(password)
            |  |     +--rw key?                string
            |  |     +--rw crypto-algorithm?   identityref
            |  +--rw level-1
            |  |  +--rw (authentication-type)?
            |  |     +--:(key-chain) {key-chain}?
            |  |     |  +--rw key-chain?          key-chain:key-chain-re
f
            |  |     +--:(password)
            |  |        +--rw key?                string
            |  |        +--rw crypto-algorithm?   identityref
            |  +--rw level-2
            |     +--rw (authentication-type)?
            |        +--:(key-chain) {key-chain}?
            |        |  +--rw key-chain?          key-chain:key-chain-re
f
            |        +--:(password)
            |           +--rw key?                string
            |           +--rw crypto-algorithm?   identityref
            +--rw hello-interval
            |  +--rw value?     rt-types:timer-value-seconds16
            |  +--rw level-1
            |  |  +--rw value?   rt-types:timer-value-seconds16
            |  +--rw level-2
            |     +--rw value?   rt-types:timer-value-seconds16
            +--rw hello-multiplier
            |  +--rw value?     uint16
            |  +--rw level-1
            |  |  +--rw value?   uint16
```

```
|  +--rw level-2
|     +--rw value?   uint16
+--rw priority
|  +--rw value?     uint8
|  +--rw level-1
|  |  +--rw value?   uint8
|  +--rw level-2
|     +--rw value?   uint8
+--rw metric
|  +--rw value?     wide-metric
|  +--rw level-1
|  |  +--rw value?   wide-metric
|  +--rw level-2
|     +--rw value?   wide-metric
+--rw bfd {bfd}?
|  +--rw enable?   boolean
+--rw afs {nlpid-control}?
|  +--rw af* [af]
|     +--rw af    identityref
+--rw mpls
|  +--rw ldp
|     +--rw igp-sync?   boolean {ldp-igp-sync}?
+--rw fast-reroute {fast-reroute}?
|  +--rw lfa {lfa}?
|     +--rw candidate-disabled?   boolean
|     +--rw enable?               boolean
|     +--rw remote-lfa {remote-lfa}?
|     |  +--rw enable?   boolean
|     +--rw level-1
|     |  +--rw candidate-disabled?   boolean
|     |  +--rw enable?               boolean
|     |  +--rw remote-lfa {remote-lfa}?
|     |     +--rw enable?   boolean
|     +--rw level-2
|        +--rw candidate-disabled?   boolean
|        +--rw enable?               boolean
|        +--rw remote-lfa {remote-lfa}?
|           +--rw enable?   boolean
+--rw topologies {multi-topology}?
   +--rw topology* [name]
      +--rw name      leafref
      +--rw metric
         +--rw value?     wide-metric
         +--rw level-1
         |  +--rw value?   wide-metric
         +--rw level-2
            +--rw value?   wide-metric
```

2.5. Authentication Parameters

The module enables authentication configuration through the IETF key-chain module ([I-D.ietf-rtgwg-yang-key-chain]). The IS-IS module imports the "ietf-key-chain" module and reuses some groupings to allow global and per interface configuration of authentication. If a global authentication is configured, an implementation SHOULD authenticate PSNPs, CSNPs and LSPs with the authentication parameters supplied. The authentication of hello PDUs can be activated on a per interface basis.

2.6. IGP/LDP synchronization

[RFC5443] defines a mechanism where IGP needs to be synchronized with LDP. An "ldp-igp-sync" feature has been defined in the model to support this mechanism. The "mpls/ldp/igp-sync" leaf under "interface" allows activation of the mechanism on a per interface basis. The "mpls/ldp/igp-sync" container in the global configuration is empty on purpose and is not required for the activation. The goal of this empty container is to allow easy augmentation with additional parameters like timers for example.

2.7. ISO parameters

As IS-IS protocol is based on ISO protocol suite, some ISO parameters may be required.

This module augments interface configuration model to support ISO configuration parameters.

The clns-mtu can be defined under the interface.

2.8. IP FRR

This YANG model supports LFA ([RFC5286]) and remote LFA ([RFC7490]) as IP FRR techniques. The "fast-reroute" container may be augmented by other models to support other IPFRR flavors (MRT, TILFA ...).

The current version of the model supports activation of LFA and remote LFA at interface only. The global "lfa" container is present but kept empty to allow augmentation with vendor specific properties like policies.

Remote LFA is considered as a child of LFA. Remote LFA cannot be enabled if LFA is not enabled.

The "candidate-disabled" allows to mark an interface to not be used as a backup.

2.9. Operational States

An "isis" container provides operational states for IS-IS. This container is divided in multiple components:

- system-counters : provides statistical informations about the global system.
- interface : provides configuration state informations for each interface.
- adjacencies: provides state informations about current IS-IS adjacencies.
- spf-log: provides informations about SPF events on the node. This SHOULD be implemented as a wrapping buffer.
- lsp-log: provides informations about LSP events on the node (reception of an LSP or modification of local LSP). This SHOULD be implemented as a wrapping buffer and an implementation MAY decide to log refresh LSPs or not.
- local-rib: provides the IS-IS internal routing table view.
- database: provides details on the current LSDB.
- hostnames: provides informations about system-id to hostname mappings.
- fast-reroute: provides informations about IP FRR.

3. RPC Operations

The "ietf-isis" module defines two RPC operations:

- clear-isis-database: reset the content of a particular IS-IS database and restart database synchronization with the neighbors.
- clear-isis-adjacency: restart a particular set of IS-IS adjacencies.

```
   rpcs:
      +---x clear-adjacency
      |  +--ro input
      |     +--ro routing-protocol-instance-name    instance-state-ref
      |     +--ro level?                            level
      |     +--ro interface?                        string
      +---x clear-database
         +--ro input
            +--ro routing-protocol-instance-name    instance-state-ref
            +--ro level?                            level
```

4. Notifications

The "ietf-isis" module introduces some notifications :

database-overload : raised when overload condition is changed.

lsp-too-large : raised when the system tries to propagate a too large PDU.

corrupted-lsp-detected : raised when the system find that an LSP that was stored in memory has become corrupted.

attempt-to-exceed-max-sequence : This notification is sent when the system wraps the 32-bit sequence counter of an LSP.

id-len-mismatch : This notification is sent when we receive a PDU with a different value for the System ID length.

max-area-addresses-mismatch : This notification is sent when we receive a PDU with a different value for the Maximum Area Addresses.

own-lsp-purge : This notification is sent when the system receives a PDU with its own system ID and zero age.

sequence-number-skipped : This notification is sent when the system receives a PDU with its own system ID and different contents. The system has to reissue the LSP with a higher sequence number.

authentication-type-failure : This notification is sent when the system receives a PDU with the wrong authentication type field.

authentication-failure : This notification is sent when the system receives a PDU with the wrong authentication information.

version-skew : This notification is sent when the system receives a PDU with a different protocol version number.

area-mismatch : This notification is sent when the system receives a Hello PDU from an IS that does not share any area address.

rejected-adjacency : This notification is sent when the system receives a Hello PDU from an IS but does not establish an adjacency for some reason.

protocols-supported-mismatch : This notification is sent when the system receives a non pseudonode LSP that has no matching protocol supported.

lsp-error-detected : This notification is sent when the system receives a LSP with a parse error.

adjacency-change : This notification is sent when an IS-IS adjacency moves to Up state or to Down state.

lsp-received : This notification is sent when a LSP is received.

lsp-generation : This notification is sent when a LSP is regenerated.

```
   notifications:
      +---n database-overload
      |  +--ro routing-instance?        string
      |  +--ro routing-protocol-name?   string
      |  +--ro isis-level?              level
      |  +--ro overload?                enumeration
      +---n lsp-too-large
      |  +--ro routing-instance?        string
      |  +--ro routing-protocol-name?   string
      |  +--ro isis-level?              level
      |  +--ro interface-name?          string
      |  +--ro interface-level?         level
      |  +--ro extended-circuit-id?     extended-circuit-id
      |  +--ro pdu-size?                uint32
      |  +--ro lsp-id?                  lsp-id
      +---n if-state-change
      |  +--ro routing-instance?        string
      |  +--ro routing-protocol-name?   string
      |  +--ro isis-level?              level
      |  +--ro interface-name?          string
      |  +--ro interface-level?         level
      |  +--ro extended-circuit-id?     extended-circuit-id
      |  +--ro state?                   if-state-type
```

```
      +---n corrupted-lsp-detected
      |  +--ro routing-instance?        string
      |  +--ro routing-protocol-name?   string
      |  +--ro isis-level?              level
      |  +--ro lsp-id?                  lsp-id
      +---n attempt-to-exceed-max-sequence
      |  +--ro routing-instance?        string
      |  +--ro routing-protocol-name?   string
      |  +--ro isis-level?              level
      |  +--ro lsp-id?                  lsp-id
      +---n id-len-mismatch
      |  +--ro routing-instance?        string
      |  +--ro routing-protocol-name?   string
      |  +--ro isis-level?              level
      |  +--ro interface-name?          string
      |  +--ro interface-level?         level
      |  +--ro extended-circuit-id?     extended-circuit-id
      |  +--ro pdu-field-len?           uint8
      |  +--ro raw-pdu?                 binary
      +---n max-area-addresses-mismatch
      |  +--ro routing-instance?        string
      |  +--ro routing-protocol-name?   string
      |  +--ro isis-level?              level
      |  +--ro interface-name?          string
      |  +--ro interface-level?         level
      |  +--ro extended-circuit-id?     extended-circuit-id
      |  +--ro max-area-addresses?      uint8
      |  +--ro raw-pdu?                 binary
      +---n own-lsp-purge
      |  +--ro routing-instance?        string
      |  +--ro routing-protocol-name?   string
      |  +--ro isis-level?              level
      |  +--ro interface-name?          string
      |  +--ro interface-level?         level
      |  +--ro extended-circuit-id?     extended-circuit-id
      |  +--ro lsp-id?                  lsp-id
      +---n sequence-number-skipped
      |  +--ro routing-instance?        string
      |  +--ro routing-protocol-name?   string
      |  +--ro isis-level?              level
      |  +--ro interface-name?          string
      |  +--ro interface-level?         level
      |  +--ro extended-circuit-id?     extended-circuit-id
      |  +--ro lsp-id?                  lsp-id
      +---n authentication-type-failure
      |  +--ro routing-instance?        string
      |  +--ro routing-protocol-name?   string
      |  +--ro isis-level?              level
```

```
      |  +--ro interface-name?          string
      |  +--ro interface-level?         level
      |  +--ro extended-circuit-id?     extended-circuit-id
      |  +--ro raw-pdu?                 binary
      +---n authentication-failure
      |  +--ro routing-instance?        string
      |  +--ro routing-protocol-name?   string
      |  +--ro isis-level?              level
      |  +--ro interface-name?          string
      |  +--ro interface-level?         level
      |  +--ro extended-circuit-id?     extended-circuit-id
      |  +--ro raw-pdu?                 binary
      +---n version-skew
      |  +--ro routing-instance?        string
      |  +--ro routing-protocol-name?   string
      |  +--ro isis-level?              level
      |  +--ro interface-name?          string
      |  +--ro interface-level?         level
      |  +--ro extended-circuit-id?     extended-circuit-id
      |  +--ro protocol-version?        uint8
      |  +--ro raw-pdu?                 binary
      +---n area-mismatch
      |  +--ro routing-instance?        string
      |  +--ro routing-protocol-name?   string
      |  +--ro isis-level?              level
      |  +--ro interface-name?          string
      |  +--ro interface-level?         level
      |  +--ro extended-circuit-id?     extended-circuit-id
      |  +--ro raw-pdu?                 binary
      +---n rejected-adjacency
      |  +--ro routing-instance?        string
      |  +--ro routing-protocol-name?   string
      |  +--ro isis-level?              level
      |  +--ro interface-name?          string
      |  +--ro interface-level?         level
      |  +--ro extended-circuit-id?     extended-circuit-id
      |  +--ro raw-pdu?                 binary
      |  +--ro reason?                  string
      +---n protocols-supported-mismatch
      |  +--ro routing-instance?        string
      |  +--ro routing-protocol-name?   string
      |  +--ro isis-level?              level
      |  +--ro interface-name?          string
      |  +--ro interface-level?         level
      |  +--ro extended-circuit-id?     extended-circuit-id
      |  +--ro raw-pdu?                 binary
      |  +--ro protocols*               uint8
      +---n lsp-error-detected
```

```
      |  +--ro routing-instance?        string
      |  +--ro routing-protocol-name?   string
      |  +--ro isis-level?              level
      |  +--ro interface-name?          string
      |  +--ro interface-level?         level
      |  +--ro extended-circuit-id?     extended-circuit-id
      |  +--ro lsp-id?                  lsp-id
      |  +--ro raw-pdu?                 binary
      |  +--ro error-offset?            uint32
      |  +--ro tlv-type?                uint8
      +---n adjacency-state-change
      |  +--ro routing-instance?        string
      |  +--ro routing-protocol-name?   string
      |  +--ro isis-level?              level
      |  +--ro interface-name?          string
      |  +--ro interface-level?         level
      |  +--ro extended-circuit-id?     extended-circuit-id
      |  +--ro neighbor?                string
      |  +--ro neighbor-system-id?      system-id
      |  +--ro state?                   adj-state-type
      |  +--ro reason?                  string
      +---n lsp-received
      |  +--ro routing-instance?        string
      |  +--ro routing-protocol-name?   string
      |  +--ro isis-level?              level
      |  +--ro interface-name?          string
      |  +--ro interface-level?         level
      |  +--ro extended-circuit-id?     extended-circuit-id
      |  +--ro lsp-id?                  lsp-id
      |  +--ro sequence?                uint32
      |  +--ro received-timestamp?      yang:timestamp
      |  +--ro neighbor-system-id?      system-id
      +---n lsp-generation
         +--ro routing-instance?        string
         +--ro routing-protocol-name?   string
         +--ro isis-level?              level
         +--ro lsp-id?                  lsp-id
         +--ro sequence?                uint32
         +--ro send-timestamp?          yang:timestamp
```

5. Interaction with Other YANG Modules

The "isis" configuration container augments the "/rt:routing/ rt:control-plane-protocols/control-plane-protocol" container of the ietf-routing [I-D.ietf-netmod-routing-cfg] module by defining IS-IS specific parameters.

The "isis" module augments "/if:interfaces/if:interface" with ISO specific parameters.

The "isis" operational state container augments the "/rt:routing-state/rt:control-plane-protocols/control-plane-protocol" container of the ietf-routing module by defining IS-IS specific operational states.

Some IS-IS specific routes attributes are added to route objects of the ietf-routing module by augmenting "/rt:routing-state/rt:ribs/rt:rib/rt:routes/rt:route".

The modules defined in this document use some groupings from ietf-keychain [I-D.ietf-rtgwg-yang-key-chain].

6. IS-IS YANG Module

<CODE BEGINS> file "ietf-isis@2017-03-30.yang"

```
module ietf-isis {
  namespace "urn:ietf:params:xml:ns:yang:ietf-isis";

  prefix isis;

  import ietf-routing {
    prefix "rt";
  }

  import ietf-inet-types {
    prefix inet;
  }

  import ietf-yang-types {
    prefix yang;
  }

  import ietf-interfaces {
    prefix "if";
  }

  import ietf-key-chain {
    prefix "key-chain";
  }

  import ietf-routing-types {
    prefix "rt-types";
  }
```

```
    organization
     "IETF ISIS Working Group";

    contact
      "WG List:  &lt;mailto:isis-wg@ietf.org&gt;

      Editor:    Stephane Litkowski
            &lt;mailto:stephane.litkowski@orange.com&gt;

          Derek Yeung
            &lt;mailto:derek@arrcus.com&gt;
          Acee Lindem
            &lt;mailto:acee@cisco.com&gt;
          Jeffrey Zhang
            &lt;mailto:zzhang@juniper.net&gt;
          Ladislav Lhotka
            &lt;mailto:llhotka@nic.cz&gt;
          Yi Yang
            &lt;mailto:yiya@cisco.com&gt;
          Dean Bogdanovic
            &lt;mailto:deanb@juniper.net&gt;
          Kiran Agrahara Sreenivasa
            &lt;mailto:kkoushik@brocade.com&gt;
          Yingzhen Qu
            &lt;mailto:yiqu@cisco.com&gt;
          Jeff Tantsura
            &lt;mailto:jefftant.ietf@gmail.com&gt;

      ";

    description
      "The YANG module defines a generic configuration model for
      ISIS common across all of the vendor implementations.";

    revision 2017-03-30 {
      description
       "Initial revision.";
       reference "RFC XXXX";
    }

   /* Identities */

    identity isis {
      base rt:routing-protocol;
      description "Identity for the ISIS routing protocol.";
    }

    identity isis-adjacency-change {
```

```
      description "Identity for the ISIS routing protocol
        adjacency state.";
    }

    identity clear-isis-database {
      description "Identity for the ISIS routing protocol
        database reset action.";
    }

    identity clear-isis-adjacency {
      description "Identity for the ISIS routing protocol
        adjacency reset action.";
    }

    identity lsp-log-reason {
      description "Base identity for an LSP change
               log reason.";
    }

    identity refresh {
      base lsp-log-reason;
      description
       "Identity used when the LSP log reason is
       a refresh LSP received.";
    }

    identity content-change {
      base lsp-log-reason;
      description
       "Identity used when the LSP log reason is
       a change in the content of the LSP.";
    }


    /* Feature definitions */

    feature ietf-spf-delay {
      description
       "Support of IETF SPF delay algorithm.";
    }
    feature bfd {
      description
       "Support of BFD for IS-IS links.";
    }
    feature key-chain {
      description
        "Support of keychain for authentication.";
    }
```

```
    feature segment-routing {
      description
       "Support of segment-routing.";
    }
    feature node-flag {
      description
       "Support of node-flag advertisement
       as prefix attribute";
    }
    feature node-tag {
      description
        "Support of node tag.";
    }
    feature ldp-igp-sync {
      description
        "Support of RFC5443.";
    }
    feature fast-reroute {
      description
        "Support of IPFRR.";
    }
    feature nsr {
      description
       "Support of
          Non Stop Routing.";
    }
    feature  lfa {
      description
        "Support of Loop Free Alternates.";
    }
    feature remote-lfa {
      description
        "Support of remote Loop Free Alternates.";
    }

    feature overload-max-metric {
      description
        "Support of overload by setting
         all links to max metric.";
    }
    feature prefix-tag {
      description
        "Add 32bit tag to prefixes";
    }
    feature prefix-tag64 {
      description
        "Add 64bit tag to prefixes";
    }
```

```
    feature auto-cost {
      description
        "Use an automated assignment of metrics.";
    }
    feature ipv4-router-id {
      description
       "Support of IPv4 router ID configuration under ISIS.";
    }

    feature ipv6-router-id {
      description
       "Support of IPv6 router ID configuration under ISIS.";
    }

    feature multi-topology {
      description
       "Multitopology routing support.";
    }
    feature nlpid-control {
      description
       "This feature controls the advertisement
        of support NLPID within ISIS configuration.";
    }
    feature graceful-restart {
      description
        "Graceful restart support as per RFC5306.";
    }

    feature lsp-refresh {
      description
        "Configuration of LSP refresh interval.";
    }

    feature maximum-area-addresses {
      description
        "Support of maximum-area-addresses config.";
    }

    feature admin-control {
      description
       "Control administrative state of ISIS.";
    }

    /* Type definitions */


    typedef instance-state-ref {
      type leafref {
```

```
        path "/rt:routing-state/"
        +"rt:control-plane-protocols/rt:control-plane-protocol/"
        +"rt:name";
      }
      description
         "This type is used for leaves that reference state data of
          an ISIS protocol instance.";
    }

    typedef circuit-id {
      type uint8;
      description
       "This type defines the circuit ID
       associated with an interface.";
    }

    typedef extended-circuit-id {
      type uint32;
      description
       "This type defines the extended circuit ID
       associated with an interface.";
    }

    typedef interface-type {
      type enumeration {
        enum broadcast {
          description
          "Broadcast interface type.";
        }
        enum point-to-point {
          description
           "Point to point interface type.";
        }
      }
      description
       "This type defines the type of adjacency
       to be established on the interface.
       This is affecting the type of hello
       message that would be used.";

    }

    typedef level {
      type enumeration {
        enum "level-1" {
          description
           "This enum describes L1 only capability.";
        }
```

```
        enum "level-2" {
          description
           "This enum describes L2 only capability.";
        }
        enum "level-all" {
          description
           "This enum describes both levels capability.";
        }
      }
      default "level-all";
      description
       "This type defines ISIS level of an object.";

    }

    typedef adj-state-type {
       type enumeration {
          enum "Up" {
            description
             "This state describes that
              adjacency is established.";
          }
          enum "Down" {
            description
             "This state describes that
              adjacency is NOT established.";
          }
          enum "Init" {
            description
             "This state describes that
              adjacency is establishing.";
          }
          enum "Failed" {
            description
             "This state describes that
              adjacency is failed.";
          }
        }
        description
        "This type defines states of an adjacency";
    }

    typedef if-state-type {
       type enumeration {
          enum "Up" {
            description
             "Up state.";
```

```
          }
          enum "Down" {
            description
             "Down state";
          }
        }
        description
        "This type defines states of an interface";
    }

    typedef level-number {
      type uint8 {
        range "1 .. 2";
      }
      description
       "This type defines a current ISIS level.";
    }

    typedef lsp-id {
      type string {
        pattern
         '[0-9A-Fa-f]{4}\.[0-9A-Fa-f]{4}\.[0-9A-Fa-f]'
              +'{4}\.[0-9][0-9]-[0-9][0-9]';
      }
      description
       "This type defines ISIS LSP ID using pattern,
        system id looks like : 0143.0438.AeF0.02-01";
    }

    typedef area-address {
      type string {
        pattern '[0-9A-Fa-f]{2}\.([0-9A-Fa-f]{4}\.){0,3}';
      }
      description
       "This type defines the area address format.";
    }

    typedef snpa {
      type string {
        length "0 .. 20";
      }
      description
       "This type defines Subnetwork Point
        of Attachement format.";
    }

    typedef system-id {
      type string {
```

```
        pattern
         '[0-9A-Fa-f]{4}\.[0-9A-Fa-f]{4}\.[0-9A-Fa-f]{4}';
      }
      description
       "This type defines ISIS system id using pattern,
        system id looks like : 0143.0438.AeF0";
    }

    typedef wide-metric {
      type uint32 {
        range "0 .. 16777215";
      }
      description
       "This type defines wide style format
        of ISIS metric.";
    }

    typedef std-metric {
      type uint8 {
        range "0 .. 63";
      }
      description
       "This type defines old style format
        of ISIS metric.";
    }

    typedef mesh-group-state {
      type enumeration {
        enum "meshInactive" {
          description
           "Interface is not part of a mesh group.";
        }
        enum "meshSet" {
          description
           "Interface is part of a mesh group.";
        }
        enum "meshBlocked" {
          description
           "LSPs must not be flooded over that interface.";
        }
      }
      description
       "This type describes meshgroup state of an interface";
    }


    /* Grouping definitions for configuration and ops state */
```

```
    grouping adjacency-state {
     container adjacencies {
        list adjacency {
          leaf neighbor-systype {
            type level;
            description
             "Type of neighboring system";
          }
          leaf neighbor-sysid {
            type system-id;
            description
             "The system-id of the neighbor";
          }
          leaf neighbor-extended-circuit-id {
            type extended-circuit-id;
            description
             "Circuit ID of the neighbor";
          }
          leaf neighbor-snpa {
            type snpa;
            description
             "SNPA of the neighbor";
          }
          leaf usage {
            type level;
            description
            "How is the adjacency used ?
            On a p2p link this might be level 1 and 2,
            but on a LAN, the usage will be level 1
            between peers at L1 or level 2 between
            peers at L2.";
          }
          leaf hold-timer {
            type rt-types:timer-value-seconds16;
            units seconds;
            description
             "The holding time in seconds for this
              adjacency. This value is based on
              received hello PDUs and the elapsed
              time since receipt.";
          }
          leaf neighbor-priority {
            type uint8 {
              range "0 .. 127";
            }
            description
             "Priority of the neighboring IS for becoming
              the DIS.";
```

```
          }
          leaf lastuptime {
            type yang:timestamp;
            description
             "When the adjacency most recently entered
              state 'up', measured in hundredths of a
              second since the last reinitialization of
              the network management subsystem.
              The value is 0 if the adjacency has never
              been in state 'up'.";
          }
          leaf state {
            type adj-state-type;
            description
             "This leaf describes the state of the
             interface.";
          }

          description
           "List of operational adjacencies.";
        }
        description
         "This container lists the adjacencies of
         the local node.";
      }
      description
       "Adjacency state";
    }

    grouping fast-reroute-global-state {
        container protected-routes {
          list af-stats {
            key "af prefix alternate";

            leaf af {
              type identityref {
                base rt-types:address-family;
              }
              description
               "Address-family";
            }
            leaf prefix {
              type string;
              description
               "Protected prefix.";
            }
            leaf alternate {
              type string;
```

```
            description
             "Alternate nexthop for the prefix.";
          }
          leaf alternate-type {
            type enumeration {
              enum equalcost {
                description
                 "ECMP alternate.";
              }
              enum lfa {
                description
                 "LFA alternate.";
              }
              enum remote-lfa {
                description
                 "Remote LFA alternate.";
              }
              enum tunnel {
                description
                 "Tunnel based alternate
                 (like RSVP-TE or GRE).";
              }
              enum ti-lfa {
                description
                 "TI LFA alternate.";
              }
              enum mrt {
                description
                 "MRT alternate.";
              }
              enum other {
                description
                 "Unknown alternate type.";
              }
            }
            description
             "Type of alternate.";
          }
          leaf best {
            type boolean;
            description
             "describes if the alternate is the best one.";
          }
          leaf non-best-reason {
            type string;
            description
             "Information field to describe why the alternate
             is not best.";
```

```
            }
            leaf protection-available {
              type bits {
                bit nodeprotect {
                  position 0;
                  description
                  "Node protection available.";
                }
                bit linkprotect {
                  position 1;
                  description
                  "Link protection available.";
                }
                bit srlgprotect {
                  position 2;
                  description
                  "SRLG protection available.";
                }
                bit downstreamprotect {
                  position 3;
                  description
                  "Downstream protection available.";
                }
                bit other {
                  position 4;
                  description
                  "Other protection available.";
                }
              }
              description
              "Describes protection provided by the alternate.";
            }
            leaf alternate-metric1 {
              type uint32;
              description
               "Metric from PLR to destination
                through the alternate path.";
            }
            leaf alternate-metric2 {
              type uint32;
              description
               "Metric from PLR to the alternate node";
            }
            leaf alternate-metric3 {
              type uint32;
              description
               "Metric from alternate node to the destination";
            }
```

```
            description
             "Per AF statistics.";
          }
          description
           "List of prefixes that are protected.";
        }

        container nonprotected-routes {
           list af-stats {
            key "af prefix";

            leaf af {
              type identityref {
                base rt-types:address-family;
              }
              description
               "Address-family";
            }
            leaf prefix {
              type string;
              description
               "Protected prefix.";
            }
            description
             "Per AF statistics.";
          }
          description
           "List of prefixes that are not protected.";
        }

        list protection-statistics {
          key frr-protection-method;

          leaf frr-protection-method {
            type string;
            description
             "Protection method used.";
          }
          list af-stats {
            key af;

            leaf af {
              type identityref {
                base rt-types:address-family;
              }
              description
               "Address-family";
            }
```

```
            leaf total-routes {
              type uint32;
              description
               "Total prefixes.";
            }
            leaf unprotected-routes {
              type uint32;
              description
                "Total of prefixes who are
                not protected.";
            }
            leaf protected-routes {
              type uint32;
              description
                "Total of prefixes who are
                protected.";
            }
            leaf linkprotected-routes {
              type uint32;
              description
                "Total of prefixes who are
                link protected.";
            }
            leaf nodeprotected-routes {
              type uint32;
              description
                "Total of prefixes who are
                node protected.";
            }
            description
             "Per AF statistics.";
          }

          description
           "Global protection statistics.";
        }
        description
         "IPFRR states.";
    }

    grouping notification-instance-hdr {
      description
       "This group describes common instance specific
       data for notifications.";
      leaf routing-instance {
        type string;
        description
         "Describes the name of the routing-instance instance.";
```

```
      }
      leaf routing-protocol-name {
        type string;
        description
         "Describes the name of the ISIS instance.";
      }
      leaf isis-level {
        type level;
        description
         "Describes the ISIS level of the instance.";
      }
    }

    grouping notification-interface-hdr {
      description
       "This group describes common interface specific
        data for notifications.";
      leaf interface-name {
        type string;
        description
         "Describes the name of the ISIS interface.";
      }
      leaf interface-level {
        type level;
        description
         "Describes the ISIS level of the interface.";
      }
      leaf extended-circuit-id {
        type extended-circuit-id;
        description
         "Describes the extended circuit-id of the interface.";
      }
    }

    grouping route-content {
      description
       "This group add isis-specific route properties.";
      leaf metric {
        type uint32;
        description
         "This leaf describes ISIS metric of a route.";
      }
      leaf-list tag {
        type uint64;
        description
         "This leaf describes list of tags associated
          with the route. The leaf describes both
          32bits and 64bits tags.";
```

```
      }
      leaf route-type {
        type enumeration {
          enum l2-up-internal {
            description "Level 2 internal route
             and not leaked to a lower level";
          }
          enum l1-up-internal {
            description "Level 1 internal route
             and not leaked to a lower level";
          }
          enum l2-up-external {
            description "Level 2 external route
             and not leaked to a lower level";
          }
          enum l1-up-external {
            description "Level 1 external route
             and not leaked to a lower level";
          }
          enum l2-down-internal {
            description "Level 2 internal route
             and leaked to a lower level";
          }
          enum l1-down-internal {
            description "Level 1 internal route
             and leaked to a lower level";
          }
          enum l2-down-external {
            description "Level 2 external route
             and leaked to a lower level";
          }
          enum l1-down-external {
            description "Level 1 external route
             and leaked to a lower level";
          }
        }
        description
         "This leaf describes the type of ISIS route.";
      }
    }

    grouping admin-control {
      leaf enable {
          if-feature admin-control;
          type boolean;
          default true;
          description
               "Control the administrative
```

```
              state.";
      }
      description
       "Grouping for admin control.";
    }

    grouping fast-reroute-global-cfg {
      description
       "This group defines global
       configuration of IPFRR.";
      container lfa {
        if-feature lfa;
        description
          "This container may be
          augmented with global parameters
          for LFA.
          Creating the container has no effect on
          LFA activation.";
      }
    }

    grouping fast-reroute-if-cfg {
      description
       "This group defines interface
       configuration of IPFRR.";
        container lfa {
          if-feature lfa;
          uses lfa-if-cfg;
          container level-1 {
              uses lfa-if-cfg;
              description
               "LFA level 1 config";
          }
          container level-2 {
              uses lfa-if-cfg;
              description
               "LFA level 2 config";
          }
          description
              "LFA config";
        }
    }

    grouping ietf-spf-delay-cfg {
      leaf initial-delay {
          type rt-types:timer-value-milliseconds;
          units msec;
          description
```

```
            "Delay used while in QUIET state.";
        }
        leaf short-delay {
            type rt-types:timer-value-milliseconds;
            units msec;
            description
             "Delay used while in SHORT_WAIT state.";
        }
        leaf long-delay {
            type rt-types:timer-value-milliseconds;
            units msec;
            description
             "Delay used while in LONG_WAIT state.";
        }

        leaf hold-down {
            type rt-types:timer-value-milliseconds;
            units msec;
            description
             "Timer used to consider an IGP stability period.";
        }
        leaf time-to-learn {
            type rt-types:timer-value-milliseconds;
            units msec;
            description
             "Duration used to learn all the IGP events
             related to a single component failure.";
        }

        description
         "Grouping for IETF SPF delay configuration.";
      }

      grouping ietf-spf-delay-state {
        leaf current-state {
            type enumeration {
                enum "QUIET" {
                    description "QUIET state";
                }
                enum "SHORT_WAIT" {
                    description "SHORT_WAIT state";
                }
                enum "LONG_WAIT" {
                    description "LONG_WAIT state";
                }
            }
            description
             "Current state of the algorithm.";
```

```
      }
      leaf remaining-time-to-learn {
          type rt-types:timer-value-milliseconds;
          units "msec";
          description
           "Remaining time until time-to-learn timer fires.";
      }
      leaf remaining-hold-down {
          type rt-types:timer-value-milliseconds;
          units "msec";
          description
           "Remaining time until hold-down timer fires.";
      }
      leaf last-event-received {
          type yang:timestamp;
          description
           "Time of last IGP event received";
      }
      leaf next-spf-time {
          type yang:timestamp;
          description
           "Time when next SPF has been scheduled.";
      }
      leaf last-spf-time {
          type yang:timestamp;
          description
           "Time of last SPF computation.";
      }
      description
       "Grouping for IETF SPF delay operational states.";
    }

     grouping local-rib {
      description "Local-rib grouping.";
      container local-rib {
        description "Local-rib.";
        list route {
          key "prefix";
          description "Routes";
          leaf prefix {
            type inet:ip-prefix;
            description "Destination prefix.";
          }
          container next-hops {
            description "All next hops for the route.";
            list next-hop {
              key "next-hop";
              description "List of next hop for the route";
```

```
              leaf outgoing-interface {
                type if:interface-ref;
                description
                  "Name of the outgoing interface.";
              }
              leaf next-hop {
               type inet:ip-address;
               description "Nexthop address.";
              }
            }
          }
          leaf metric {
            type uint32;
            description "Metric for this route.";
          }
          leaf level {
            type level-number;
            description "Level number for this route.";
          }
          leaf route-tag {
            type uint32;
            description "Route tag for this route.";
          }
        }
      }
    }

    grouping isis-node-tag-cfg {
      description
       "ISIS node tag config.";
      container node-tags {
          if-feature node-tag;
          list node-tag {
            key tag;
            leaf tag {
              type uint32;
              description
               "Node tag value.";
            }
            description
             "List of tags.";
          }
          description
            "Container for node tags.";
        }
    }

    grouping authentication-global-cfg {
```

```
      choice authentication-type {
          case key-chain {
            if-feature key-chain;
            leaf key-chain {
              type key-chain:key-chain-ref;
              description
                "Reference to a key-chain.";
            }
          }
          case password {
            leaf key {
              type string;
              description
               "This leaf describes the
                 authentication key.";
            }
            leaf crypto-algorithm {
              type identityref {
                  base key-chain:crypto-algorithm;
              }
              description
                "Cryptographic algorithm associated with key.";
            }
          }
          description
             "Choice of authentication.";
       }
      description
       "Grouping for global auth config.";
    }

    grouping metric-type-global-cfg {
      leaf value {
          type enumeration {
            enum wide-only {
              description
               "Advertise new metric style only
               (RFC5305)";
            }
            enum old-only {
              description
               "Advertise old metric style only
               (RFC1195)";
            }
            enum both {
              description "Advertise both metric
              styles";
            }
```

```
          }
          description
           "This leaf describes the type of metric
           to be generated.
           Wide-only means only new metric style
           is generated,
           old-only means that only old style metric
           is generated,
           and both means that both are advertised.
           This leaf is only affecting IPv4 metrics.";
        }
         description
        "Grouping for global metric style config.";
    }

    grouping default-metric-global-cfg {
      leaf value {
          type wide-metric;
          default "10";
          description
            "Value of the metric";
      }
      description
            "Grouping for global default metric config.";
    }


    grouping overload-global-cfg {
      leaf status {
          type boolean;
          description
           "This leaf defines the overload status.";
      }
            description
        "Grouping for overload bit config.";
    }

    grouping overload-max-metric-global-cfg {
      leaf timeout {
          type rt-types:timer-value-seconds16;
          units "seconds";
          description
           "This leaf defines the timeout in seconds
            of the overload condition.";
        }
        description
        "Grouping for overload-max-metric config.";
    }
```

```
    grouping route-preference-global-cfg {
      choice granularity {
              case detail {
                leaf internal {
                  type uint8;
                  description
                    "This leaf defines the protocol
                     preference for internal routes.";
                }
                leaf external {
                  type uint8;
                  description
                    "This leaf defines the protocol
                     preference for external routes.";
                }
              }
              case coarse {
                leaf default {
                  type uint8;
                  description
                    "This leaf defines the protocol
                     preference for all ISIS routes.";
                }
              }
              description
               "Choice for implementation of route preference.";
            }
      description
       "This grouping defines how route preference is configured.";
    }

    grouping hello-authentication-cfg {
      choice authentication-type {
          case key-chain {
            if-feature key-chain;
            leaf key-chain {
              type key-chain:key-chain-ref;
              description
                "Reference to a key-chain.";
            }
          }
          case password {
            leaf key {
              type string;
              description
               "This leaf describes the
                 authentication key.";
            }
```

```
            leaf crypto-algorithm {
              type identityref {
                  base key-chain:crypto-algorithm;
              }
              description
                "Cryptographic algorithm associated with key.";
            }
          }
          description
             "Choice of authentication.";
        }
        description
         "Grouping for hello authentication.";
    }

    grouping hello-interval-cfg {
      leaf value {
      type rt-types:timer-value-seconds16;
      units "seconds";
      default 10;
      description
       "This leaf defines the interval of
       hello messages.";
      }

      description
       "Interval between
       hello messages.";
    }

    grouping hello-multiplier-cfg {
      leaf value {
      type uint16;
      description
       "This leaf defines the number of
       hello failed to be received before
       declaring the adjacency down.";
      }
      description
       "This grouping defines the number of
        hello failed to be received before
        declaring the adjacency down.";
    }

    grouping priority-cfg {
      leaf value {
          type uint8 {
            range "0 .. 127";
```

```
      }
      default 64;
      description
       "This leaf describes the priority of
       the interface
       for DIS election.";
      }

      description
       "This grouping leaf describes the
       priority of
       the interface
       for DIS election.";
    }

    grouping metric-cfg {
        leaf value {
          type wide-metric;
          description
           "Metric value.";
        }
        description
         "Grouping for interface metric";
    }

    grouping lfa-if-cfg {
      leaf candidate-disabled {
        type boolean;
        default false;
        description
         "Prevent the interface to be used as backup.";
      }
      leaf enable {
        type boolean;
        description
         "Activates LFA.
         This model assumes activation
         of per-prefix LFA.";
      }

      container remote-lfa {
        if-feature remote-lfa;
        leaf enable {
          type boolean;
          description
          "Activates rLFA.";
        }
        description
```

```
         "remote LFA configuration.";
      }
      description
       "Grouping for LFA
       interface configuration";
    }

    grouping isis-global-cfg {
      description
       "Defines the ISIS global configuration.";

          uses admin-control;

          leaf level-type {
            type level;
            default "level-all";
            description
             "This leaf describes the type of ISIS node.
             A node can be level-1-only, level-2-only
             or level-1-2.
             ";
          }

          leaf system-id {
            type system-id;
            description
             "This leaf defines the system-id of the node.";
          }

          leaf maximum-area-addresses {
            if-feature maximum-area-addresses;
            type uint8;
            default 3;
            description
             "Defines the maximum areas supported.";
          }

          leaf-list area-address {
            type area-address;
            description
             "List of areas supported by the
             protocol instance.";
          }

          container mpls {
            leaf ipv4-router-id {
              if-feature ipv4-router-id;
              type inet:ipv4-address;
```

```
            description
             "Router ID value that would be used in
             TLV 134.";
          }
          leaf ipv6-router-id {
            if-feature ipv6-router-id;
            type inet:ipv6-address;
            description
             "Router ID value that would be used in
             TLV 140.";
          }
          container ldp {
            container igp-sync {
                if-feature ldp-igp-sync;
                description
                "This container may be augmented
                with global parameters for igp-ldp-sync.";
            }
            description
             "LDP related configuration.";
          }
          description
            "This container handles mpls config.";
        }
        container auto-cost {
            if-feature auto-cost;
            leaf reference-bandwidth {
              type uint32;
              units "bps";
              description
               "This leaf defines the bandwidth for calculating
                metric.";
            }
            leaf enable {
                type boolean;
                default false;
                description
                "Enable/disable auto-cost.";
            }
            description
             "This container defines the auto-cost configuration.";
        }
        leaf lsp-mtu {
          type uint16;
          units "bytes";
          default 1492;
          description
           "This leaf describes the maximum size of a
```

```
            LSP PDU in bytes.";
          }
          leaf lsp-lifetime {
            type uint16 {
              range "1..65535";
              }
            units "seconds";
            description
             "This leaf describes the lifetime of the router
              LSP in seconds.";
          }
          leaf lsp-refresh {
            if-feature lsp-refresh;
            type rt-types:timer-value-seconds16;
            units "seconds";
            description
             "This leaf describes the refresh interval of the
              router LSP in seconds.";
          }
          container graceful-restart {
            if-feature graceful-restart;
            leaf enable {
              type boolean;
              description
               "Control enabling the feature.";
            }
            leaf restart-interval {
              type rt-types:timer-value-seconds16;
              units "seconds";
              description
              "Interval in seconds to attempt graceful restart prior
             to failing";
            }
            leaf helper-enable {
              type boolean;
              description
              "If enabled, the local router can act as restart helper.";
            }
            description
             "This container activates graceful restart.";
          }

          container nsr {
              if-feature nsr;
              description
              "Non-Stop Routing (NSR) config state.";
              leaf enable {
                  type boolean;
```

```
                description
                 "Enable/Disable NSR.";
            }
        }

        uses isis-node-tag-cfg;

        container authentication {
            uses authentication-global-cfg;

            container level-1 {
                uses authentication-global-cfg;
                description "level-1 specific cfg";
            }
            container level-2 {
                uses authentication-global-cfg;
                description "level-2 specific cfg";
            }
            description "authentication global cfg.
            It covers both LSPs and SNPs.";
        }

        container metric-type {
            uses metric-type-global-cfg;
            container level-1 {
                uses metric-type-global-cfg;
                description "level-1 specific cfg";
            }
            container level-2 {
                uses metric-type-global-cfg;
                description "level-2 specific cfg";
            }
            description "Metric style global cfg.";
        }

        container default-metric {
            uses default-metric-global-cfg;
            container level-1 {
                uses default-metric-global-cfg;
                description "level-1 specific cfg";
            }
            container level-2 {
                uses default-metric-global-cfg;
                description "level-2 specific cfg";
            }
            description "Default metric global cfg.";
        }
```

```
          container afs {
              if-feature nlpid-control;
              list af {
                key af;
                leaf af {
                  type identityref {
                    base rt-types:address-family;
                  }
                  description
                   "Address-family";
                }
                leaf enable {
                  type boolean;
                  description
                    "Describes the activation state of the
                     AF.";
                }
                description
                 "This list permits activation
                  of new address families.";
              }
              description
               "Container for address-families";
          }

          container preference {
              uses route-preference-global-cfg;
              description
               "This container defines the protocol preference.";
          }

          container overload {
              uses overload-global-cfg;
              description
             "This container describes if the router is
              set to overload state.";
          }

          container overload-max-metric {
              if-feature overload-max-metric;
              uses overload-max-metric-global-cfg;
              description
             "This container describes if the router is
              set to overload state using max-metric
              advertisement.";
          }
      }
```

```
    grouping isis-global-topologies-cfg {
     description
      "Per topology config.";
      container default-metric {
          uses default-metric-global-cfg;
          container level-1 {
              uses default-metric-global-cfg;
              description "level-1 specific cfg";
          }
          container level-2 {
              uses default-metric-global-cfg;
              description "level-2 specific cfg";
          }
          description "Default metric per
          topology cfg.";
      }
      uses isis-node-tag-cfg;
    }

    grouping isis-if-cfg {
      description
       "Grouping for interface cfg.";

      leaf level-type {
        type level;
        default "level-all";
        description
         "This leaf defines the associated ISIS
         level of the interface.";
      }
      leaf lsp-pacing-interval {
        type rt-types:timer-value-milliseconds;
        units "milliseconds";
        default 33;
        description
         "This leaf defines the interval between
          LSP transmissions in milli-seconds";
      }
      leaf lsp-retransmit-interval {
        type rt-types:timer-value-seconds16;
        units "seconds";
        description
         "This leaf defines the interval between
         retransmission of LSP";
      }
      leaf passive {
        type boolean;
        default "false";
```

```
        description
         "This leaf defines if interface is in
          passive mode (ISIS not running,
          but network is advertised).";
      }
      leaf csnp-interval {
        type rt-types:timer-value-seconds16;
        units "seconds";
        default 10;
        description
         "This leaf defines the interval of CSNP
          messages.";
      }
      container hello-padding {
        leaf enable {
          type boolean;
          default "true";
          description
           "Status of Hello-padding activation.
            By default, the implementation shall
            pad HELLOs.";
        }
        description
         "This container handles ISIS hello padding
          configuration.";
      }
      leaf mesh-group-enable {
        type mesh-group-state;
        description
         "Describes the mesh group state of
          the interface.";
      }
      leaf mesh-group {
        when "../mesh-group-enable = 'meshSet'" {
          description
           "Only valid when mesh-group-enable
            equals meshSet";
        }
        type uint8;
        description
         "Describes the mesh group ID of
          the interface.";
      }
      leaf interface-type {
        type interface-type;
        description
         "This leaf defines the type of adjacency
         to be established on the interface.
```

```
         This is affecting the type of hello
         message that would be used.";
       }

       uses admin-control;

       leaf-list tag {
         if-feature prefix-tag;
         type uint32;
         description
          "This leaf defines list of tags associated
           with the interface.";
       }
       leaf-list tag64 {
         if-feature prefix-tag64;
         type uint64;
         description
          "This leaf defines list of 64bits tags
          associated with the interface.";
       }
       leaf node-flag {
           if-feature node-flag;
           type boolean;
           default false;
           description
            "Set prefix as a node
            representative prefix.";
       }
       container hello-authentication {
           uses hello-authentication-cfg;
           container level-1 {
               uses hello-authentication-cfg;
               description "level-1 specific cfg";
           }
           container level-2 {
               uses hello-authentication-cfg;
               description "level-2 specific cfg";
           }
           description "Authentication type
          to be used in hello messages.";
       }
       container hello-interval {
           uses hello-interval-cfg;
           container level-1 {
               uses hello-interval-cfg;
               description "level-1 specific cfg";
           }
           container level-2 {
```

```
            uses hello-interval-cfg;
            description "level-2 specific cfg";
        }
        description "Interval between
         hello messages.";
      }
      container hello-multiplier {
        uses hello-multiplier-cfg;
        container level-1 {
            uses hello-multiplier-cfg;
            description "level-1 specific cfg";
        }
        container level-2 {
            uses hello-multiplier-cfg;
            description "level-2 specific cfg";
        }
        description "Hello multiplier
        configuration.";
      }
      container priority {
        must '../interface-type = "broadcast"' {
            error-message
             "Priority only applies to broadcast
             interfaces.";
            description
             "Check for broadcast interface.";
        }
        uses priority-cfg;
        container level-1 {
            uses priority-cfg;
            description "level-1 specific cfg";
        }
        container level-2 {
            uses priority-cfg;
            description "level-2 specific cfg";
        }
        description "Priority for DIS election.";
      }
      container metric {
        uses metric-cfg;
        container level-1 {
            uses metric-cfg;
            description "level-1 specific cfg";
        }
        container level-2 {
            uses metric-cfg;
            description "level-2 specific cfg";
        }
```

```
          description "Metric configuration.";
      }
      container bfd {
          if-feature bfd;
          leaf enable {
              type boolean;
              default false;
              description "
                  Enables BFD on the interface
              ";
          }
          description
           "BFD configuration.";
      }
      container afs {
          if-feature nlpid-control;
          list af {
            key af;
            leaf af {
              type identityref {
                base rt-types:address-family;
              }
              description
                "Address-family";
            }
            description
             "List of AFs.";
          }
          description
               "Container for address-families";
      }
      container mpls {
        container ldp {
          leaf igp-sync {
              if-feature ldp-igp-sync;
              type boolean;
              description
               "Enables IGP/LDP sync.";
          }
          description
           "LDP protocol related configurations.";
        }
        description
         "Container for MPLS specific configuration
         for ISIS.";
      }
    }
```

```
    grouping isis-if-topologies-cfg {
      description
       "ISIS interface topology cfg.";
      container metric {
          uses metric-cfg;
          container level-1 {
              uses metric-cfg;
              description "level-1 specific cfg";
          }
          container level-2 {
              uses metric-cfg;
              description "level-2 specific cfg";
          }
          description "Metric configuration.";
      }
    }

    grouping system-counters {
     container system-counters {
        list level {
          key level;

          leaf level {
            type level-number;
            description
             "This leaf describes the ISIS level.";
          }
          leaf corrupted-lsps {
            type uint32;
            description
             "Number of corrupted in-memory LSPs detected.
             LSPs received from the wire with a bad
             checksum are silently dropped and not counted.
             LSPs received from the wire with parse errors
             are counted by lsp-errors.";
          }
          leaf authentication-type-fails {
            type uint32;
            description
             "Number of authentication type mismatches.";
          }
          leaf authentication-fails {
            type uint32;
            description
             "Number of authentication key failures.";
          }
          leaf database-overload {
            type uint32;
```

```
            description
             "Number of times the database has become
             overloaded.";
          }
          leaf own-lsp-purge {
            type uint32;
            description
             "Number of times a zero-aged copy of the
             system's own LSP is received from some
             other node.";
          }
          leaf manual-address-drop-from-area {
            type uint32;
            description
             "Number of times a manual address
              has been dropped from the area.";
          }
          leaf max-sequence {
            type uint32;
            description
             "Number of times the system has attempted
              to exceed the maximum sequence number.";
          }
          leaf sequence-number-skipped {
            type uint32;
            description
             "Number of times a sequence number skip has
             occured.";
          }
          leaf id-len-mismatch {
            type uint32;
            description
             "Number of times a PDU is received with
              a different value for ID field length
              from that of the receiving system.";
          }
          leaf partition-changes {
            type uint32;
            description
             "Number of partition changes detected.";
          }
          leaf lsp-errors {
            type uint32;
            description
             "Number of LSPs with errors we have
             received.";
          }
          leaf spf-runs {
```

```
            type uint32;
            description
             "Number of times we ran SPF at this level.";
          }
          description
           "List of supported levels.";
        }
        description
         "The container defines a list of counters
          for the IS.";
      }
      description
       "Grouping for system counters.";
    }

    grouping event-counters {
        container event-counters {
            leaf adjacency-changes {
              type uint32;
              description
               "The number of times an adjacency state
                change has occured on this interface.";
            }
            leaf adjacency-number {
              type uint32;
              description
               "The number of adjacencies on this
                interface.";
            }
            leaf init-fails {
              type uint32;
              description
               "The number of times initialization of
                this interface has failed. This counts
                events such as PPP NCP failures.
                Failures to form an adjacency are counted
                by adjacency-rejects.";
            }
            leaf adjacency-rejects {
              type uint32;
              description
               "The number of times an adjacency has been
                rejected on this interface.";
            }
            leaf id-len-mismatch {
              type uint32;
              description
               "The number of times an IS-IS PDU with an ID
```

```
                field length different from that for this
                system has been received on this interface.";
            }
            leaf max-area-addresses-mismatch {
              type uint32;
              description
               "The number of times an IS-IS PDU with
                according max area address field
                differs from that for
                this system has been received on this
                interface.";
            }
            leaf authentication-type-fails {
              type uint32;
              description
               "Number of authentication type mismatches.";
            }
            leaf authentication-fails {
              type uint32;
              description
               "Number of authentication key failures.";
            }
            leaf lan-dis-changes {
              type uint32;
              description
               "The number of times the DIS has changed
                on this interface at this level.
                If the interface type is point to point,
                the count is zero.";
            }
            description
             "Provides protocol event counters.";
        }
        description
         "Grouping for event counters";
    }

    grouping packet-counters {
      container packet-counters {
        list level {
          key level;

          leaf level {
            type level-number;
            description
             "This leaf describes the ISIS level.";
          }
          container iih {
```

```
            leaf in {
              type uint32;
              description
               "Received PDUs.";
            }
            leaf out {
              type uint32;
              description
               "Sent PDUs.";
            }
            description
             "The number of IIH PDUs received/sent.";
          }
          container ish {
            leaf in {
              type uint32;
              description
               "Received PDUs.";
            }
            leaf out {
              type uint32;
              description
               "Sent PDUs.";
            }
            description
             "The number of ISH PDUs received/sent.";
          }
          container esh {
            leaf in {
              type uint32;
              description
               "Received PDUs.";
            }
            leaf out {
              type uint32;
              description
               "Sent PDUs.";
            }
            description
             "The number of ESH PDUs received/sent.";
          }
          container lsp {
            leaf in {
              type uint32;
              description
               "Received PDUs.";
            }
            leaf out {
```

```
            type uint32;
            description
             "Sent PDUs.";
          }
          description
           "The number of LSP PDUs received/sent.";
        }
        container psnp {
          leaf in {
            type uint32;
            description
             "Received PDUs.";
          }
          leaf out {
            type uint32;
            description
             "Sent PDUs.";
          }
          description
           "The number of PSNP PDUs received/sent.";
        }
        container csnp {
          leaf in {
            type uint32;
            description
             "Received PDUs.";
          }
          leaf out {
            type uint32;
            description
             "Sent PDUs.";
          }
          description
           "The number of CSNP PDUs received/sent.";
        }
        container unknown {
          leaf in {
            type uint32;
            description
             "Received PDUs.";
          }
          leaf out {
            type uint32;
            description
             "Sent PDUs.";
          }
          description
           "The number of unknown PDUs received/sent.";
```

```
          }
          description
           "List of supported levels.";
        }
        description
         "Provides packet counters per level.";
      }
      description
       "Grouping for packet counters.";
    }

    grouping spf-log {
      container spf-log {
        list event {
          key id;

          leaf id {
            type uint32;
            description
             "This leaf defines the event identifier.
              This is a purely internal value.";
          }
          leaf spf-type {
            type enumeration {
              enum full {
                description
                 "Computation done is a Full SPF.";
              }
              enum route-only {
                description
                 "Computation done is a
                  reachability computation
                  only.";
              }
            }
            description
             "This leaf describes the type of computation
             used.";
          }
          leaf level {
            type level-number;
            description
             "This leaf describes the level affected by the
             the computation.";
          }
          leaf schedule-timestamp {
            type yang:timestamp;
            description
```

```
            "This leaf describes the timestamp
             when the computation was scheduled.";
          }
          leaf start-timestamp {
            type yang:timestamp;
            description
             "This leaf describes the timestamp
              when the computation was started.";
          }
          leaf end-timestamp {
            type yang:timestamp;
            description
             "This leaf describes the timestamp
              when the computation was ended.";
          }
          list trigger-lsp {
            key "lsp";
            leaf lsp {
              type lsp-id;
              description
               "This leaf describes the LSPID
                of the LSP.";
            }
            leaf sequence {
              type uint32;
              description
               "This leaf describes the sequence
                number of the LSP.";
            }
            description
             "This leaf describes list of LSPs
              that triggered the computation.";
          }
          description
           "List of computation events.
            It is used as a wrapping buffer.";
        }

        description
         "This container lists the SPF computation events.";
      }
      description
       "Grouping for spf-log events.";
    }

    grouping lsp-log {
      container lsp-log {
        list event {
```

```
          key id;

          leaf id {
            type uint32;
            description
             "This leaf defines the event identifier.
              This is a purely internal value.";
          }
          leaf level {
            type level-number;
            description
             "This leaf describes the level affected by the
             the computation.";
          }
          container lsp {
            leaf lsp {

              type lsp-id;
              description
               "This leaf describes the LSPID
                of the LSP.";
            }
            leaf sequence {
              type uint32;
              description
               "This leaf describes the sequence
                number of the LSP.";
            }
            description
             "This container describes the received LSP
             , in case of local LSP update the local
             LSP ID is referenced.";
          }

          leaf received-timestamp {
            type yang:timestamp;

            description
             "This leaf describes the timestamp
             when the LSP was received. In case of
             local LSP update, the timestamp refers
             to the local LSP update time.";
          }

          leaf change {
            type identityref {
              base lsp-log-reason;
            }
```

```
            description
             "This leaf describes the type of change
             in the LSP.";
          }

          description
           "List of LSP events.
           It is used as a wrapping buffer.";
        }

        description
         "This container lists the LSP reception events.
         Local LSP modification are also contained in the
         list.";
      }
      description
       "Grouping for LSP log.";
    }

    grouping hostname-db {
      container hostnames {
        list hostname {
          key system-id;
          leaf system-id {
            type system-id;
            description
             "This leaf describes the system-id
             associated with the hostname.";
          }
          leaf hostname {
            type string;
            description
             "This leaf describes the hostname
              associated with the system ID.";
          }
          description
           "List of system-id/hostname associations";
        }
        description
         "This container describes the list
         of binding between system-id and
         hostnames.";
      }
      description
       "Grouping for hostname to systemid mapping database.";
    }

    /* Groupings for the LSDB description */
```

```
    grouping prefix-reachability-attributes {
      description
       "This group defines extended reachability attributes of an
        IPv4 or IPv6 prefix.";

      leaf external-prefix-flag {
          type boolean;
          description
           "External prefix flag.";
      }
      leaf readvertisement-flag {
          type boolean;
          description
           "Readvertisement flag.";
      }
      leaf node-flag {
          type boolean;
          description
           "Node flag.";
      }
    }

    grouping prefix-ipv4-source-router-id {
      description
       "This group defines the IPv4 source router ID of
       a prefix advertisement.";

      leaf ipv4-source-router-id {
          type inet:ipv4-address;
          description
           "IPv4 Source router ID address.";
      }
    }

    grouping prefix-ipv6-source-router-id {
      description
       "This group defines the IPv6 source router ID of
       a prefix advertisement.";

      leaf ipv6-source-router-id {
          type inet:ipv6-address;
          description
           "IPv6 Source router ID address.";
      }
    }

    grouping prefix-attributes-extension {
      description
```

```
       "Prefix extended attributes.";

      uses prefix-reachability-attributes;
      uses prefix-ipv4-source-router-id;
      uses prefix-ipv6-source-router-id;
    }

    grouping prefix-ipv4-std {
      description
       "This group defines attributes of an
        IPv4 standard prefix.";
      leaf up-down {
        type boolean;
        description
         "This leaf expresses the value of up/down bit.";
      }
      leaf i-e {
        type boolean;
        description
         "This leaf expresses the value of I/E bit.";
      }
      leaf ip-prefix {
        type inet:ipv4-address;
        description
         "This leaf describes the IPv4 prefix";
      }
      leaf prefix-len {
        type uint8;
        description
         "This leaf describes the IPv4 prefix len in bits";
      }
      leaf default-metric {
        type std-metric;
        description
         "This leaf describes the ISIS default metric value";
      }
      container delay-metric {
        leaf metric {
          type std-metric;
          description
           "This leaf describes the ISIS delay metric value";
        }
        leaf supported {
          type boolean;
          default "false";
          description
           "This leaf describes if the metric is supported.";
        }
```

```
        description
         "This container defines the ISIS delay metric.";
      }
      container expense-metric {
        leaf metric {
          type std-metric;
          description
           "This leaf describes the ISIS expense metric value";
        }
        leaf supported {
          type boolean;
          default "false";
          description
           "This leaf describes if the metric is supported.";
        }
        description
         "This container defines the ISIS expense metric.";
      }
      container error-metric {
        leaf metric {
          type std-metric;
          description
           "This leaf describes the ISIS error metric value";
        }
        leaf supported {
          type boolean;
          default "false";
          description
           "This leaf describes if the metric is supported.";
        }

        description
         "This container defines the ISIS error metric.";
      }
    }

    grouping prefix-ipv4-extended {
      description
       "This group defines attributes of an
        IPv4 extended prefix.";
      leaf up-down {
        type boolean;
        description
         "This leaf expresses the value of up/down bit.";
      }
      leaf ip-prefix {
        type inet:ipv4-address;
        description
```

```
         "This leaf describes the IPv4 prefix";
      }
      leaf prefix-len {
        type uint8;
        description
         "This leaf describes the IPv4 prefix len in bits";
      }

      leaf metric {
        type wide-metric;
        description
         "This leaf describes the ISIS metric value";
      }
      leaf-list tag {
        type uint32;
        description
         "This leaf describes a list of tags associated with
         the prefix.";
      }
      leaf-list tag64 {
        type uint64;
        description
         "This leaf describes a list of 64-bit tags associated with
         the prefix.";
      }
      uses prefix-attributes-extension;
    }

    grouping prefix-ipv6-extended {
      description
       "This group defines attributes of an
        IPv6 prefix.";
      leaf up-down {
        type boolean;
        description
         "This leaf expresses the value of up/down bit.";
      }
      leaf ip-prefix {
        type inet:ipv6-address;
        description
         "This leaf describes the IPv6 prefix";
      }
      leaf prefix-len {
        type uint8;
        description
         "This leaf describes the IPv4 prefix len in bits";
      }
      leaf metric {
```

```
        type wide-metric;
        description
         "This leaf describes the ISIS metric value";
      }
      leaf-list tag {
        type uint32;
        description
         "This leaf describes a list of tags associated with
         the prefix.";
      }
      leaf-list tag64 {
        type uint64;
        description
         "This leaf describes a list of 64-bit tags associated with
         the prefix.";
      }
      uses prefix-attributes-extension;
    }

    grouping neighbor-extended {
      description
       "This group defines attributes of an
        ISIS extended neighbor.";
      leaf neighbor-id {
        type system-id;
        description
         "This leaf describes the system-id of the neighbor.";
      }
      leaf metric {
        type wide-metric;
        description
         "This leaf describes the ISIS metric value";
      }
    }

    grouping neighbor {
      description
       "This group defines attributes of an
        ISIS standard neighbor.";
      leaf neighbor-id {
        type system-id;
        description
         "This leaf describes the system-id of the neighbor.";
      }
      leaf i-e {
        type boolean;
        description
         "This leaf expresses the value of I/E bit.";
```

```
      }
      leaf default-metric {
        type std-metric;
        description
         "This leaf describes the ISIS default metric value";
      }
      container delay-metric {
        leaf metric {
          type std-metric;
          description
           "This leaf describes the ISIS delay metric value";
        }
        leaf supported {
          type boolean;
          default "false";
          description
           "This leaf describes if the metric is supported.";
        }
        description
         "This container defines the ISIS delay metric.";
      }
      container expense-metric {
        leaf metric {
          type std-metric;
          description
           "This leaf describes the ISIS delay expense value";
        }
        leaf supported {
          type boolean;
          default "false";
          description
           "This leaf describes if the metric is supported.";
        }
        description
         "This container defines the ISIS expense metric.";
      }
      container error-metric {
        leaf metric {
          type std-metric;
          description
           "This leaf describes the ISIS error metric value";
        }
        leaf supported {
          type boolean;
          default "false";
          description
           "This leaf describes if the metric is supported.";
        }
```

```
        description
         "This container defines the ISIS error metric.";
      }
    }

    grouping lsp-entry {
     description
       "This group defines attributes of an
        ISIS LSP database entry.";

      leaf decoded-completed {
        type boolean;
        description
          "The IS-IS body is fully decoded.";
      }
      leaf raw-data {
        type yang:hex-string;
        description
          "The complete LSP in network byte
           order hexadecimal as received or originated.";
      }
      leaf lsp-id {
        type lsp-id;
        description
         "This leaf describes the LSP ID of the LSP.";
      }
      leaf checksum {
        type uint16;
        description
         "This leaf describes the checksum of the LSP.";
      }
      leaf remaining-lifetime {
        type uint16;
        units "seconds";
        description
         "This leaf describes the remaining lifetime
          in seconds before the LSP expiration.";
      }
      leaf sequence {
        type uint32;
        description
         "This leaf describes the sequence number of the LSP.";
      }
      leaf attributes {
        type bits {
          bit PARTITIONNED {
            description
             "If set, the originator supports partition
```

```
            repair.";
          }
          bit ATTACHED-ERROR {
            description
             "If set, the originator is attached to
              another area using the referred metric.";
          }
          bit ATTACHED-EXPENSE {
            description
             "If set, the originator is attached to
              another area using the referred metric.";
          }
          bit ATTACHED-DELAY {
            description
             "If set, the originator is attached to
              another area using the referred metric.";
          }
          bit ATTACHED-DEFAULT {
            description
             "If set, the originator is attached to
              another area using the referred metric.";
          }
          bit OVERLOAD {
            description
             "If set, the originator is overloaded,
              and must be avoided in path calculation.";
          }
        }
        description
         "This leaf describes attributes of the LSP.";
      }

      leaf-list ipv4-addresses {
        type inet:ipv4-address;
        description
          "This leaf describes the IPv4 addresses of the node.
          ISIS reference is TLV 132.";
      }

      leaf-list ipv6-addresses {
        type inet:ipv6-address;
        description
         "This leaf describes the IPv6 interface
         addresses of the node.
         ISIS reference is TLV 232.";
      }

      leaf ipv4-te-routerid {
```

```
        type inet:ipv4-address;
        description
          "This leaf describes the IPv4 Traffic Engineering
          router ID of the node.
          ISIS reference is TLV 134.";
      }

      leaf ipv6-te-routerid {
        type inet:ipv6-address;
        description
         "This leaf describes the IPv6 Traffic Engineering
          router ID of the node.
          ISIS reference is TLV 140.";
      }

      leaf-list protocol-supported {
        type uint8;
        description
         "This leaf describes the list of
         supported protocols.
         ISIS reference is TLV 129.";
      }

      leaf dynamic-hostname {
        type string;
        description
         "This leaf describes the name of the node.
         ISIS reference is TLV 137.";
      }

      container authentication {
        leaf authentication-type {
          type string;
          description
           "This leaf describes the authentication type
            to be used.";
        }
        leaf authentication-key {
          type string;
          description
           "This leaf describes the authentication key
            to be used. For security reason, the
            authentication key MUST NOT be presented
            in plaintext format. Authors recommends
            to use MD5 hash to present the authentication-key.";
        }
        description "This container describes authentication
        information of the node. ISIS reference is TLV 10.";
```

```
      }

      container mt-entries {
        list topology {

          leaf MT-ID {
            type uint16 {
              range "0 .. 4095";
            }
            description
             "This leaf defines the identifier
              of a topology.";
          }

          leaf attributes {
            type bits {
              bit OVERLOAD {
                description
                 "If set, the originator is overloaded,
                  and must be avoided in path
                  calculation.";
              }
              bit ATTACHED {
                description
                 "If set, the originator is attached to
                  another area using the referred metric.";
              }
            }
            description
             "This leaf describes attributes of the LSP
              for the associated topology.";
          }
          description
           "List of topologies supported.";
        }
        description
         "This container describes the topology supported.
         ISIS reference is TLV 229.";
      }

      list router-capabilities {
        leaf flags {
          type bits {
            bit flooding {
              position 0;
              description
               "If the S bit is set(1),
               the IS-IS Router CAPABILITY TLV
```

```
              MUST be flooded across the entire routing domain.
              If the S bit is
              not set(0), the TLV MUST NOT be leaked between levels.
              This bit MUST NOT be altered during the TLV leaking.";
            }
            bit down {
              position 1;
              description
              "When the IS-IS Router CAPABILITY TLV is
              leaked from level-2 to level-1, the D bit
              MUST be set.  Otherwise, this bit MUST
              be clear.  IS-IS Router capability TLVs
              with the D bit set MUST NOT
              be leaked from level-1 to level-2.
              This is to prevent TLV looping.
              ";
            }
          }
          description
           "Flags associated with router capability.";
        }
        container node-tags {
          if-feature node-tag;
          list node-tag {
            leaf tag {
              type uint32;
              description
               "Node tag value.";
            }
            description
             "List of tags.";
          }
          description
           "Container for node tags.";
        }

        leaf binary {
          type binary;
          description
           "This leaf describes the capability of the node.
           Format is binary according to the protocol encoding.";
        }
        description
         "This container describes the capabilities of the node.
         This container may be extended with detailed
         information.
         ISIS reference is TLV 242.";
      }
```

```
      container is-neighbor {
        list neighbor {
          uses neighbor;
          description
           "List of neighbors.";
        }
        description
         "This leaf describes list of ISIS neighbors.
         ISIS reference is TLV 2.";
      }

      container extended-is-neighbor {
        list neighbor {
          uses neighbor-extended;
          description
           "List of neighbors.";
        }
        description
         "This container describes list of ISIS extended
         neighbors.
         ISIS reference is TLV 22.";
      }

      container ipv4-internal-reachability {
        list prefixes {
          uses prefix-ipv4-std;
          description
           "List of prefixes.";
        }
        description
         "This container describes list of IPv4 internal
         reachability information.
         ISIS reference is TLV 128.";
      }

      container ipv4-external-reachability {
        list prefixes {
          uses prefix-ipv4-std;
          description
           "List of prefixes.";
        }
        description
         "This container describes list of IPv4 external
         reachability information.
         ISIS reference is TLV 130.";
      }

      container extended-ipv4-reachability {
```

```
        list prefixes {
          uses prefix-ipv4-extended;
          description
           "List of prefixes.";
        }
        description
         "This container describes list of IPv4 extended
         reachability information.
         ISIS reference is TLV 135.";
      }

      container mt-is-neighbor {
        list neighbor {
          leaf MT-ID {
            type uint16 {
              range "0 .. 4095";
            }
            description
             "This leaf defines the identifier
              of a topology.";
          }
          uses neighbor-extended;
          description
           "List of neighbors.";
        }
        description
         "This container describes list of ISIS multi-topology
          neighbors.
          ISIS reference is TLV 223.";
      }

      container mt-extended-ipv4-reachability {
        list prefixes {
          leaf MT-ID {
            type uint16 {
              range "0 .. 4095";
            }
            description
             "This leaf defines the identifier
              of a topology.";
          }
          uses prefix-ipv4-extended;
          description
           "List of prefixes.";

        }
        description
         "This container describes list of IPv4
```

```
         reachability information in multi-topology
         environment.
         ISIS reference is TLV 235.";
      }

      container mt-ipv6-reachability {
        list prefixes {
          leaf MT-ID {
            type uint16 {
              range "0 .. 4095";
            }
            description
             "This leaf defines the identifier
              of a topology.";
          }
          uses prefix-ipv6-extended;
          description
           "List of prefixes.";
        }
        description
         "This container describes list of IPv6
         reachability information in multi-topology
         environment.
         ISIS reference is TLV 237.";
      }

      container ipv6-reachability {
        list prefixes {
          uses prefix-ipv6-extended;
          description
           "List of prefixes.";
        }
        description
         "This container describes list of IPv6
         reachability information.
         ISIS reference is TLV 236.";
      }
    }

    grouping lsdb {
      container database {
        list level-db {
          key level;

          leaf level {
            type level-number;
            description
             "Current level number";
```

```
          }
          list lsp {
            key lsp-id;
            uses lsp-entry;
            description
             "List of LSPs in LSDB.";
          }
          description
           "This container describes the list of LSPs
           in the level x database.";
        }
        description
         "This container describes ISIS Link State
          databases.";
      }
      description
       "Grouping for LSDB description.";
    }



    /* Augmentations */

    augment "/rt:routing-state/"
      +"rt:ribs/rt:rib/rt:routes/rt:route" {
      when "rt:source-protocol = 'isis:isis'" {
        description "ISIS-specific route attributes.";
      }
      uses route-content;
      description
       "This augments route object in RIB with ISIS-specific
        attributes.";
    }


    augment "/if:interfaces/if:interface" {
      leaf clns-mtu {
        type uint16;
        description
         "Defines CLNS MTU of the interface.";
      }
      description "ISO interface config.";
    }

    augment "/rt:routing/rt:control-plane-protocols/"
        +"rt:control-plane-protocol" {
      when "rt:type = 'isis:isis'" {
```

```
        description
         "This augment is only valid when routing protocol
          instance type is isis.";
      }
      description
       "This augments a routing protocol instance with ISIS
        specific parameters.";
      container isis {
          must "count(area-address) > 0" {
            error-message "At least one area-address
            must be configured.";
            description
             "Enforce configuration of at least one area.";
          }

          uses isis-global-cfg;

          container fast-reroute {
           if-feature fast-reroute;
           uses fast-reroute-global-cfg;
           description
                "IPFRR.";
          }
          container spf-control {
              container ietf-spf-delay {
                  if-feature ietf-spf-delay;
                  uses ietf-spf-delay-cfg;
                  description
                   "IETF spf delay algorithm configuration.";
              }
              description
               "Container for all SPF computation related
               operations.";
          }
          container topologies {
              if-feature multi-topology;
              list topology {
                key "name";
                leaf enable {
                  type boolean;
                  description
                   "Control enabling of topologies";
                }
                leaf name {
                  type leafref {
                     path "../../../../../../rt:ribs/rt:rib/rt:name";
                   }
```

```
                description "RIB";
              }

              uses isis-global-topologies-cfg;

              description
                "List of topologies";
            }
            description
             "Container for multi-topology";
          }
          container interfaces {
            list interface {
              key "name";
              leaf name {
                type if:interface-ref;

                description
                 "Reference to the interface within
                  the routing-instance.";
            }
            uses isis-if-cfg;
            container fast-reroute {
              if-feature fast-reroute;
              uses fast-reroute-if-cfg;
              description
                "IPFRR.";
            }
            container topologies {
                if-feature multi-topology;
                list topology {
                    key name;

                    leaf name {
                      type leafref {
                          path "../../../../../../../../"+
                          "rt:ribs/rt:rib/rt:name";
                      }

                      description
                       "Name of RIB.";
                    }
                    uses isis-if-topologies-cfg;
                    description
                     "List of topologies.";
                }
              description
               "Container for multi-topology";
```

```
            }
            description
              "List of ISIS interfaces.";
            }
            description
             "This container defines ISIS interface specific
             configuration objects.";
          }

          description
           "This container defines ISIS specific configuration
            objects.";
        }
      }

      augment "/rt:routing-state/"
        +"rt:control-plane-protocols/rt:control-plane-protocol" {
        when "rt:type = 'isis:isis'" {
          description
           "This augment is only valid when routing protocol
            instance type is isis.";
        }
        description
         "This augments routing protocol instance states with ISIS
          specific parameters.";

        container isis {
          config false;
            uses isis-global-cfg;
            container fast-reroute {
              if-feature fast-reroute;
              uses fast-reroute-global-cfg;
              uses fast-reroute-global-state;
              description
               "IPFRR states.";
            }
            container spf-control {
                container ietf-spf-delay {
                    if-feature ietf-spf-delay;
                    uses ietf-spf-delay-cfg;
                    uses ietf-spf-delay-state;
                    description
                     "IETF spf delay algorithm configuration.";
                }
                description
                 "Container for all SPF computation related
                  operations.";
            }
```

```
          list topologies {
            key name;

            leaf name {
              type leafref {
                 path "../../../../../"
                 +"rt:ribs/rt:rib/rt:name";
               }

              description
                "Name of RIB.";
            }
            uses local-rib;
            description
             "List of topologies.";
          }
          uses local-rib;
          uses system-counters;

          container interfaces {
            list interface {
              key interface;

              leaf interface {
                type string;
                description
                 "This leaf describes the name
                  of the interface.";
              }
              uses isis-if-cfg;
              container fast-reroute {
               if-feature fast-reroute;
               uses fast-reroute-if-cfg;
               description
                "IPFRR.";
              }
              list topologies {
                key name;

                leaf name {
                  type leafref {
                      path "../../../../../"
                      +"../../rt:ribs/rt:rib/rt:name";
                  }
                  description
                    "Name of RIB.";
                }
```

```
              uses isis-if-topologies-cfg;
              uses adjacency-state;

              description
               "List of topologies.";
            }

            uses adjacency-state;
            uses event-counters;
            uses packet-counters;

            description
             "List of interfaces.";
          }
          description
           "The container defines operational parameters
            of interfaces.";
        }

        uses spf-log;
        uses lsp-log;
        uses hostname-db;
        uses lsdb;

      description
         "This container defines various ISIS states objects.";
    }
  }

  /* RPC methods */

  rpc clear-adjacency {
    description
     "This RPC request clears a particular
      set of ISIS adjacencies. If the operation
      fails for ISIS internal reason, then
      error-tag and error-app-tag should be set
      to a meaningful value.";
    input {

      leaf routing-protocol-instance-name {
        type instance-state-ref;
        mandatory "true";
        description
         "Name of the ISIS protocol instance whose ISIS
          information is being queried.

          If the ISIS instance with name equal to the
```

```
            value of this parameter doesn't exist, then this
            operation SHALL fail with error-tag 'data-missing'
            and error-app-tag
            'routing-protocol-instance-not-found'.";
        }
        leaf level {
          type level;
          description
           "ISIS level of the adjacency to be cleared.
           If ISIS level is level-1-2, both level 1 and level 2
           adjacencies would be cleared.

           If the value provided is different from the one
           authorized in the enum type, then this
            operation SHALL fail with error-tag 'data-missing'
            and error-app-tag
            'bad-isis-level'.
           ";
        }
        leaf interface {
          type string;
          description
           "Name of the ISIS interface.

            If the ISIS interface with name equal to the
            value of this parameter doesn't exist, then this
            operation SHALL fail with error-tag 'data-missing'
            and error-app-tag
            'isis-interface-not-found'.";
        }
      }
    }

    rpc clear-database {
      description
       "This RPC request clears a particular
        ISIS database. If the operation
        fails for ISIS internal reason, then
        error-tag and error-app-tag should be set
        to a meaningful value.";
      input {
        leaf routing-protocol-instance-name {
          type instance-state-ref;
          mandatory "true";
          description
           "Name of the ISIS protocol instance whose ISIS
            information is being queried.
```

```
            If the ISIS instance with name equal to the
            value of this parameter doesn't exist, then this
            operation SHALL fail with error-tag 'data-missing'
            and error-app-tag
            'routing-protocol-instance-not-found'.";
        }
        leaf level {
          type level;
          description
           "ISIS level of the adjacency to be cleared.
           If ISIS level is level-1-2, both level 1 and level 2
           adjacencies would be cleared.

           If the value provided is different from the one
           authorized in the enum type, then this
            operation SHALL fail with error-tag 'data-missing'
            and error-app-tag
            'bad-isis-level'.
           ";
        }
      }
    }


    /* Notifications */

    notification database-overload {
      uses notification-instance-hdr;

      leaf overload {
        type enumeration {
          enum "off" {
            description
             "The system has left overload condition.";
          }
          enum "on" {
            description
             "The system is in overload condition.";
          }

        }
        description
           "Describes the new overload state of the instance.";
      }
      description
        "This notification is sent when an ISIS instance
         overload condition changes.";
    }
```

```
    notification lsp-too-large {
      uses notification-instance-hdr;
      uses notification-interface-hdr;

      leaf pdu-size {
        type uint32;
        description
         "Size of the PDU";
      }
      leaf lsp-id {
        type lsp-id;
        description
         "LSP ID.";
      }
      description
        "This notification is sent when we attempt
         to propagate an LSP that is larger than the
         dataLinkBlockSize for the circuit.
         The notification generation must be throttled
         with at least a 5 second gap.
         ";
    }

    notification if-state-change {
      uses notification-instance-hdr;
      uses notification-interface-hdr;

      leaf state {
        type if-state-type;
        description "Interface state.";
      }
      description
        "This notification is sent when an interface
        state change is detected.";
    }

    notification corrupted-lsp-detected {
      uses notification-instance-hdr;
      leaf lsp-id {
        type lsp-id;
        description
         "LSP ID.";
      }
      description
        "This notification is sent when we find
         that an LSP that was stored in memory has
         become corrupted.
         ";
```

```
    }

    notification attempt-to-exceed-max-sequence {
      uses notification-instance-hdr;
      leaf lsp-id {
        type lsp-id;
        description
         "LSP ID.";
      }
      description
        "This notification is sent when the system
        wraps the 32-bit sequence counter of an LSP.
         ";
    }

    notification id-len-mismatch {
      uses notification-instance-hdr;
      uses notification-interface-hdr;

      leaf pdu-field-len {
        type uint8;
        description
         "Size of the ID length in the received PDU";
      }
      leaf raw-pdu {
        type binary;
        description
         "Received raw PDU.";
      }
      description
        "This notification is sent when we receive a PDU
        with a different value for the System ID length.
        The notification generation must be throttled
        with at least a 5 second gap.
         ";
    }

    notification max-area-addresses-mismatch {
      uses notification-instance-hdr;
      uses notification-interface-hdr;

      leaf max-area-addresses {
        type uint8;
        description
         "Received number of supported areas";
      }
      leaf raw-pdu {
        type binary;
```

```
        description
         "Received raw PDU.";
      }
      description
        "This notification is sent when we receive a PDU
        with a different value for the Maximum Area Addresses.
        The notification generation must be throttled
        with at least a 5 second gap.
         ";
    }

    notification own-lsp-purge {
      uses notification-instance-hdr;
      uses notification-interface-hdr;
      leaf lsp-id {
        type lsp-id;
        description
         "LSP ID.";
      }
      description
        "This notification is sent when the system
        receives a PDU with its own system ID and zero age.
         ";
    }

    notification sequence-number-skipped {
      uses notification-instance-hdr;
      uses notification-interface-hdr;
      leaf lsp-id {
        type lsp-id;
        description
         "LSP ID.";
      }
      description
        "This notification is sent when the system
        receives a PDU with its own system ID and
        different contents. The system has to reissue
        the LSP with a higher sequence number.
         ";
    }

    notification authentication-type-failure {
      uses notification-instance-hdr;
      uses notification-interface-hdr;
      leaf raw-pdu {
        type binary;
        description
         "Received raw PDU.";
```

```
      }
      description
        "This notification is sent when the system
        receives a PDU with the wrong authentication type
        field.
        The notification generation must be throttled with
        at least a 5 second gap.
         ";
    }

    notification authentication-failure {
      uses notification-instance-hdr;
      uses notification-interface-hdr;
      leaf raw-pdu {
        type binary;
        description
         "Received raw PDU.";
      }
      description
        "This notification is sent when the system
        receives a PDU with the wrong authentication
        information.
        The notification generation must be throttled with
        at least a 5 second gap.
         ";
    }

    notification version-skew {
      uses notification-instance-hdr;
      uses notification-interface-hdr;
      leaf protocol-version {
        type uint8;
        description
         "Protocol version received in the PDU.";
      }
      leaf raw-pdu {
        type binary;
        description
         "Received raw PDU.";
      }
      description
        "This notification is sent when the system
        receives a PDU with a different protocol version
        number.
        The notification generation must be throttled with at least
         a 5 second gap.
         ";
    }
```

```
    notification area-mismatch {
      uses notification-instance-hdr;
      uses notification-interface-hdr;
      leaf raw-pdu {
        type binary;
        description
         "Received raw PDU.";
      }
      description
        "This notification is sent when the system
        receives a Hello PDU from an IS that does
        not share any area address.
        The notification generation must be throttled with at least
         a 5 second gap.
         ";
    }

    notification rejected-adjacency {
      uses notification-instance-hdr;
      uses notification-interface-hdr;
      leaf raw-pdu {
        type binary;
        description
         "Received raw PDU.";
      }
      leaf reason {
        type string;
        description
         "The system may provide a reason to reject the
          adjacency. If the reason is not available,
          the system use an empty string.";
      }
      description
        "This notification is sent when the system
        receives a Hello PDU from an IS but does not
        establish an adjacency for some reason.
        The notification generation must be throttled with at least
         a 5 second gap.
         ";
    }


    notification protocols-supported-mismatch {
      uses notification-instance-hdr;
      uses notification-interface-hdr;
      leaf raw-pdu {
        type binary;
        description
```

```
         "Received raw PDU.";
      }
      leaf-list protocols {
        type uint8;
        description
         "The list of protocols supported by the
          remote system.";
      }
      description
        "This notification is sent when the system
        receives a non pseudonode LSP that has no matching
        protocol supported.
        The notification generation must be throttled with at least
         a 5 second gap.
         ";
    }

    notification lsp-error-detected {
      uses notification-instance-hdr;
      uses notification-interface-hdr;
      leaf lsp-id {
        type lsp-id;
        description
         "LSP ID.";
      }
      leaf raw-pdu {
        type binary;
        description
         "Received raw PDU.";
      }
      leaf error-offset {
        type uint32;
        description
         "If the problem is a malformed TLV,
         the error-offset points to the start of the TLV.
         If the problem is with the LSP header,
         the error-offset points to the suspicious byte";
      }
      leaf tlv-type {
        type uint8;
        description
         "if the problem is a malformed TLV, the tlv-type is set
         to the type value of the suspicious TLV.
         Otherwise this leaf is not present.";
      }
      description
        "This notification is sent when the system
        receives a  LSP with a parse error.
```

```
        The notification generation must be throttled with at least
         a 5 second gap.
         ";
    }

    notification adjacency-state-change {
      uses notification-instance-hdr;
      uses notification-interface-hdr;
      leaf neighbor {
        type string;
        description
         "Describes the name of the neighbor. If the
         name of the neighbor is not available, the
         field would be empty.";
      }
      leaf neighbor-system-id {
        type system-id;
        description
         "Describes the system-id of the neighbor.";
      }
      leaf state {
        type adj-state-type;

        description
         "This leaf describes the new state of the
          ISIS adjacency.";
      }
      leaf reason {
        type string;
        description
         "If the adjacency is going to DOWN,
         this leaf provides a reason for the adjacency
         going down. The reason is provided as a text.
         If the adjacency is going to UP, no reason is
         provided.";
      }
      description
        "This notification is sent when an ISIS adjacency
         moves to Up state or to Down state.";
    }

    notification lsp-received {
      uses notification-instance-hdr;
      uses notification-interface-hdr;

      leaf lsp-id {
        type lsp-id;
        description
```

```
         "LSP ID.";
      }
      leaf sequence {
        type uint32;
        description
         "Sequence number of the received LSP.";
      }
      leaf received-timestamp {
        type yang:timestamp;

        description
         "This leaf describes the timestamp
         when the LSP was received. ";
      }
      leaf neighbor-system-id {
        type system-id;
        description
         "Describes the system-id of the neighbor
         that sent the LSP.";
      }
      description
        "This notification is sent when a LSP
        is received.
        The notification generation must be throttled with at least
         a 5 second gap. ";
    }

    notification lsp-generation {
      uses notification-instance-hdr;

      leaf lsp-id {
        type lsp-id;
        description
         "LSP ID.";
      }
      leaf sequence {
        type uint32;
        description
         "Sequence number of the received LSP.";
      }
      leaf send-timestamp {
        type yang:timestamp;

        description
         "This leaf describes the timestamp
         when our LSP was regenerated. ";
      }
      description
```

```
        "This notification is sent when a LSP
        is regenerated.
        The notification generation must be throttled with at least
         a 5 second gap. ";
    }
  }
```

<CODE ENDS>

7. Security Considerations

Configuration and state data defined in this document are designed to be accessed via the NETCONF protocol [RFC6241].

As IS-IS is an IGP protocol (critical piece of the network), ensuring stability and security of the protocol is mandatory for the network service.

Authors recommends to implement NETCONF access control model ([RFC6536]) to restrict access to all or part of the configuration to specific users. Access control to RPCs is also critical as RPC allows to clear protocol datastructures that would definitively impact the network service. This kind of RPC needs only to be used in specific cases by well-known experienced users.

Authors consider that all the configuration is considered as sensitive/vulnerable as well as RPCs. But security teams can decide to open some part of the configuration to less experienced users depending on the internal organization, for example:

- User FullWrite: would access to the whole data model. This kind of profile may be restricted to few experienced people.
- User PartialWrite: would only access to configuration part within /isis/interfaces/interface. So this kind of profile is restricted to creation/modification/deletion of interfaces. This profile does not have access to RPC.
- User Read: would only access to the operational states.

Unauthorized access to configuration or RPC may cause high damages to the network service.

The "isis/database" may contain authentication information. As presented in the description of the "/isis/database/level-1/lsp/authentication/authentication-key", the authentication MUST never be displayed in a plaintext format for security reason.

Authors recommend the usage of MD5 to display or return the authentication-key.

Some authentication-key may also be required in the "isis" writable container. When configuring IS-IS using the NETCONF protocol, authors recommends the usage of secure transport of NETCONF using SSH ([RFC6242]).

8. Contributors

Authors would like to thank Kiran Agrahara Sreenivasa, Dean Bogdanovic, Yingzhen Qu, Yi Yang for their major contributions to the draft.

9. Acknowledgements

TBD.

10. IANA Considerations

The IANA is requested to assign two new URIs from the IETF XML registry ([RFC3688]). Authors are suggesting the following URI:

```
URI: urn:ietf:params:xml:ns:yang:ietf-isis
Registrant Contact: IS-IS WG
XML: N/A, the requested URI is an XML namespace
```

This document also requests one new YANG module name in the YANG Module Names registry ([RFC6020]) with the following suggestion:

```
name: ietf-isis
namespace: urn:ietf:params:xml:ns:yang:ietf-isis
prefix: isis
reference: RFC XXXX
```

11. Change log for ietf-isis YANG module

11.1. From version -16 to version -17

- Cosmetic fixes.
- Use of rt-types model.

11.2. From version -15 to version -16

- Alignment with last IETF key chain model.
- lsp-log "change" leaf moved as an identity.

- Incremental SPF removed from spf-log types.

11.3. From version -14 to version -15

- Alignment with OSPF model done:
  - Added spf-control container with IETF SPF delay algorithm as a feature.
  - Added graceful-restart options.
  - Added nsr as a feature.
  - Removed per topology FRR. Need to be augmented if necessary.
  - Created an ldp container within mpls.
  - Renamed igp-ldp-sync to igp-sync.
  - Added auto-cost container.
  - Moved reference-bandwidth under auto-cost container.
  - Added IS-IS local RIB as operational state.
  - Added decode-completed and raw-data leaves in the LSDB model.
  - Modified the notification header.

11.4. From version -13 to version -14

- Segment Routing extensions are now in a separate document.

11.5. From version -12 to version -13

- Move feature nlpid-control to container rather than list.
- Rename multi-topology to topologies to align with OSPF.
- Rename bfd/enabled to bfd/enable for consistency reason.
- Add support for NSR with a feature.

11.6. From version -09 to version -12

- Rename node-tag container to node-tags.

11.7. From version -08 to version -09

- Added container before af list.
- Added container before topology list.
- Aligned LFA if per level cfg.
- Align to draft-ietf-netmod-routing-cfg-23.

11.8. From version -07 to version -08

- Remove selector from system-id type.
- Add some default values.
- Moved lists to containers+groupings for per level configuration.
- remove routing-instance as per core routing model v21.
- added BFD leaf (no more BFD protocol model).
- changed keychain module reference.

11.9. From version -05 to version -07

- Move Overload config from list to container.
- Move Overload-max-metric config from list to container.
- Move preference config from list to container.
- Add Node flag in config.
- Removed BFD config => moved to isis-bfd module.
- Remove call to routing policy model.

11.10. From version -03 to version -05

- Correct invalid references to previous versions of core routing model.
- Remove BFD config and replace by groupings from ietf-bfd.
- Adding routing-policy support through routing-policy model.

11.11. From version -02 to version -03

- Reviewed config and op state groupings.
- Add default value to lfa candidate-disabled.
- Add enable leaf to isis container to reflect admin state.
- Move to VRF centric only.
- Segment routing is part os a separate module.

11.12. From version -01 to version -02

- Adding IPFRR.
- Adding igp-ldp-sync.
- Adding segment-routing.
- Adding instance reference to operational states.
- Move AF type from string to identity.
- Updated router-capability in LSDB description.
- packet counters moved to interface-packet-counters.
- Added modification information in lsp-log.
- Removing igp-ldp-sync timer in IS-IS.
- Defining hierarchy for operational states.
- Adding clns-mtu.
- Adding key-chain.

11.13. From version -00 to version -01

- Interface metric move from af container to interface container.
- Hello-padding on interface moved to hello-padding-disable with empty type.
- three-way-handshake removed.
- route preference changed to a choice.

- csnp-authentication/psnp-authentication merged to authentication container.
- lsp-gen-interval-exp-delay removed.
- Added overload-max-metric feature.
- overload-max-metric is in a separate container.
- Change hello-padding to container.
- Change bfd to container.
- Make BFD a feature.
- Create mpls-te container and put router-id inside.
- Remove GR helper disable and timers.

12. Normative References

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Appendix A. Example of IS-IS configuration in XML

This section gives an example of configuration of an IS-IS instance on a device. The example is written in XML.

```
<?xml version="1.0" encoding="utf-8"?>
<data xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <routing xmlns="urn:ietf:params:xml:ns:yang:ietf-routing">
      <name>SLI</name>
      <router-id>1.1.1.1</router-id>
      <description/>
      <interfaces>
        <interface>
          <name>Loopback0</name>
        </interface>
```

```
          <interface>
            <name>Eth1</name>
          </interface>
        </interfaces>
        <control-plane-protocols>
          <control-plane-protocol>
            <name>ISIS</name>
            <description/>
            <type>isis:isis</type>
            <isis xmlns="urn:ietf:params:xml:ns:yang:ietf-isis">
                <enable>true</enable>
                <level-type>level-2</level-type>
                <system-id>87FC.FCDF.4432</system-id>
                <area-address>49.0001</area-address>
                <mpls-te>
                  <ipv4-router-id>1.1.1.1</ipv4-router-id>
                </mpls-te>
                <lsp-lifetime>65535</lsp-lifetime>
                <lsp-refresh>65000</lsp-refresh>
                <metric-type>
                  <value>wide</value>
                </metric-type>
                <default-metric>
                  <value>111111</value>
                </default-metric>
                <afs>
                  <af>
                      <af>ipv4-unicast</af>
                      <enabled>true</enabled>
                  </af>
                </afs>
                <interfaces>
                  <interface>
                    <name>Loopback0</name>
                    <tag>200</tag>
                    <metric>
                      <value>0</value>
                    </metric>
                    <passive>true</passive>
                  </interface>
                  <interface>
                    <name>Eth1</name>
                    <level-type>level-2</level-type>
                    <interface-type>point-to-point</interface-type>
                    <metric>
                      <value>167890</value>
                    </metric>
                  </interface>
```

```
                </interfaces>
              </isis>
            </control-plane-protocol>
          </control-plane-protocols>
      </routing>
      <interfaces xmlns="urn:ietf:params:xml:ns:yang:ietf-interfaces">
        <interface>
          <name>Loopback0</name>
          <description/>
          <type/>
          <link-up-down-trap-enable/>
          <ipv4 xmlns="urn:ietf:params:xml:ns:yang:ietf-ip">
            <mtu/>
            <address>
              <ip>1.1.1.1</ip>
              <prefix-length>32</prefix-length>
            </address>
          </ipv4>

        </interface>
        <interface>
          <name>Eth1</name>
          <description/>
          <type/>
          <link-up-down-trap-enable/>
          <ipv4 xmlns="urn:ietf:params:xml:ns:yang:ietf-ip">
            <mtu/>
            <address>
              <ip>10.0.0.1</ip>
              <prefix-length>30</prefix-length>
            </address>
          </ipv4>

        </interface>
      </interfaces>
    </data>
```

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June 30, 2017

IS-IS Routing for Spine-Leaf Topology
draft-shen-isis-spine-leaf-ext-04

Abstract

This document describes a mechanism for routers and switches in a Spine-Leaf type topology to have non-reciprocal Intermediate System to Intermediate System (IS-IS) routing relationships between the leafs and spines. The leaf nodes do not need to have the topology information of other nodes and exact prefixes in the network. This extension also has application in the Internet of Things (IoT).

Table of Contents

1. Introduction

The IS-IS routing protocol defined by [ISO10589] has been widely deployed in provider networks, data centers and enterprise campus environments. In the data center and enterprise switching networks, a Spine-Leaf topology is commonly used. This document describes a mechanism where IS-IS routing can be optimized for a Spine-Leaf topology.

In a Spine-Leaf topology, normally a leaf node connects to a number of spine nodes. Data traffic going from one leaf node to another leaf node needs to pass through one of the spine nodes. Also, the decision to choose one of the spine nodes is usually part of equal cost multi-path (ECMP) load sharing. The spine nodes can be considered as gateway devices to reach destinations on other leaf nodes. In this type of topology, the spine nodes have to know the topology and routing information of the entire network, but the leaf nodes only need to know how to reach the gateway devices to which are the spine nodes they are uplinked.

This document describes the IS-IS Spine-Leaf extension that allows the spine nodes to have all the topology and routing information, while keeping the leaf nodes free of topology information other than the default gateway routing information. The leaf nodes do not even need to run a Shortest Path First (SPF) calculation since they have no topology information.

1.1. 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].

2. Motivations

- The leaf nodes in a Spine-Leaf topology do not require complete topology and routing information of the entire domain since their forwarding decision is to use ECMP with spine nodes as default gateways

- The spine nodes in a Spine-Leaf topology are richly connected to leaf nodes, which introduces significant flooding duplication if they flood all Link State PDUs (LSPs) to all the leaf nodes. It saves both spine and leaf nodes' CPU and link bandwidth resources if flooding is blocked to leaf nodes. For small Top of the Rack (ToR) leaf switches in data centers, it is meaningful to prevent full topology routing information and massive database flooding through those devices.

- When a spine node advertises a topology change, every leaf node connected to it will flood the update to all the other spine nodes, and those spine nodes will further flood them to all the leaf nodes, causing a O(n^2) flooding storm which is largely redundant.

- Similar to some of the overlay technologies which are popular in data centers, the edge devices (leaf nodes) may not need to contain all the routing and forwarding information on the device's control and forwarding planes. "Conversational Learning" can be utilized to get the specific routing and forwarding information in the case of pure CLOS topology and in the events of link and node down.

- Small devices and appliances of Internet of Things (IoT) can be considered as leafs in the routing topology sense. They have CPU and memory constrains in design, and those IoT devices do not have to know the exact network topology and prefixes as long as there are ways to reach the cloud servers or other devices.

3. Spine-Leaf (SL) Extension

3.1. Topology Examples

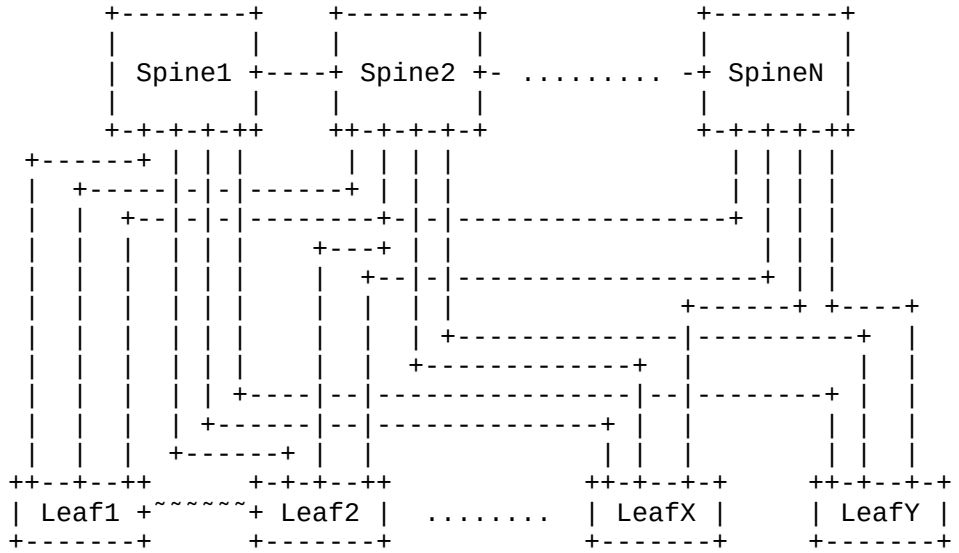


Figure 1: A Spine-Leaf Topology

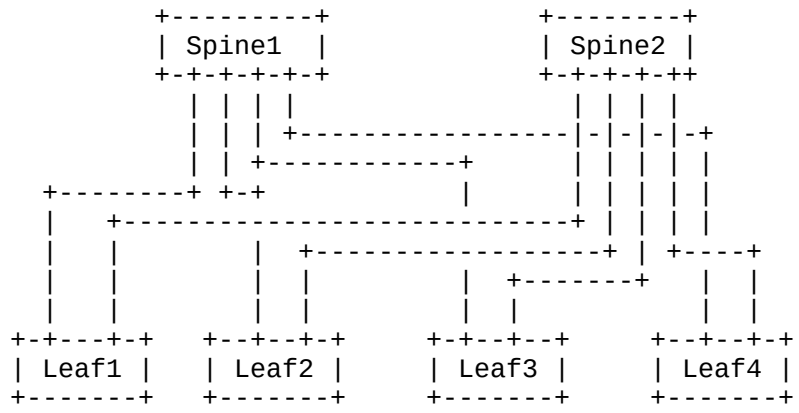


Figure 2: A CLOS Topology

3.2. Applicability Statement

This extension assumes the network is a Spine-Leaf topology, and it should not be applied in an arbitrary network setup. The spine nodes can be viewed as the aggregation layer of the network, and the leaf nodes as the access layer of the network. The leaf nodes use a load sharing algorithm with spine nodes as nexthops in routing and forwarding.

This extension works when the spine nodes are inter-connected, and it works with a pure CLOS or Fat Tree topology based network where the spines are NOT horizontally interconnected.

Although the example diagram in Figure 1 shows a fully meshed Spine-Leaf topology, this extension also works in the case where they are partially meshed. For instance, leaf1 through leaf10 may be fully meshed with spine1 through spine5 while leaf11 through leaf20 is fully meshed with spine4 through spine8, and all the spines are inter-connected in a redundant fashion.

This extension can also work in multi-level spine-leaf topology. The lower level spine node can be a 'leaf' node to the upper level spine node. A spine-leaf 'Tier' can be exchanged with IS-IS hello packets to allow tier X to be connected with tier X+1 using this extension. Normally tier-0 will be the TOR routers and switches if provisioned.

This extension also works with normal IS-IS routing in a topology with more than two layers of spine and leaf. For instance, in example diagrams Figure 1 and Figure 2, there can be another Core layer of routers/switches on top of the aggregation layer. From an IS-IS routing point of view, the Core nodes are not affected by this

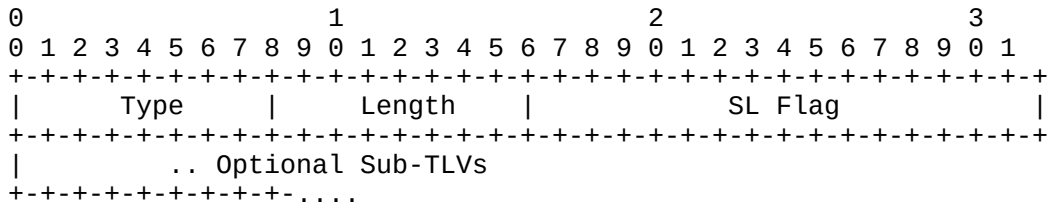
extension and will have the complete topology and routing information just like the spine nodes. To make the network even more scalable, the Core layer can operate as a level-2 IS-IS sub-domain while the Spine and Leaf layers operate as stays at the level-1 IS-IS domain.

This extension also supports the leaf nodes having local connections to other leaf nodes, in the example diagram Figure 1 there is a connection between 'Leaf1' node and 'Leaf2' node, and an external host can be dual homed into both of the leaf nodes.

This extension assumes the link between the spine and leaf nodes are point-to-point, or point-to-point over LAN [RFC5309]. The links connecting among the spine nodes or the links between the leaf nodes can be any type.

3.3. Extension Encoding

This extension introduces one new TLV which may be used in IS-IS Hello (IIH) PDUs, LSPs, or in Circuit Scoped Link State PDUs (CS-LSP) [RFC7356]. It is used by both spine and leaf nodes in this Spine-Leaf mechanism.

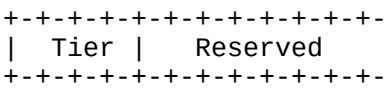


The fields of this TLV are defined as follows:

Type: 1 octet Suggested value 150 (to be assigned by IANA)

Length: 1 octet (2 + length of sub-TLVs).

Flags 16 bits



Tier: A 4 bits value range from 0 to 15. It is used to represent the spine-leaf tier level when the 'T' bit is set. If the 'T' is cleared, this value MUST be set to zero from the sender, and it MUST be ignored on the receiver. The value 15 is reserved to indicate the tier level is unknown or not configured.

L bit (0x01): Only leaf node sets this bit. If the L bit is set in the SL flag, the node indicates it is in 'Leaf-Mode'.

R bit (0x02): Only Spine node sets this bit. If the R bit is set, the node indicates to the leaf neighbor that it can be used as the default route gateway.

B bit (0x04): Only leaf node sets this bit on Leaf-Leaf link, in additional to the 'L' bit setting. If the B bit is set, the node indicates to its leaf neighbor that it can be used as the backup default route gateway.

T bit (0x08): If set, the value in the 'Tier' field represents the spine-leaf tier level in the topology.

Optional Sub-TLV: Not defined in this document, for future extension

sub-TLVs MAY be included when the TLV is in a CS-LSP.
sub-TLVs MUST NOT be included when the TLV is in an IIH

3.3.1. Spine-Leaf Sub-TLVs

If the data center topology is a pure CLOS or Fat Tree, there are no link connections among the spine nodes. If we also assume there is not another Core layer on top of the aggregation layer, then the traffic from one leaf node to another may have a problem if there is a link outage between a spine node and a leaf node. For instance, in the diagram of Figure 2, if Leaf1 sends data traffic to Leaf3 through Spine1 node, and the Spine1-Leaf3 link is down, the data traffic will be dropped on the Spine1 node.

To address this issue spine and leaf nodes may send/request specific reachability information via the sub-TLVs defined below.

Two Spine-Leaf sub-TLVs are defined. The Leaf-Set sub-TLV and the Info-Req sub-TLV.

3.3.1.1. Leaf-Set Sub-TLV

This sub-TLV is used by spine nodes to optionally advertise Leaf neighbors to other Leaf nodes. The fields of this sub-TLV are defined as follows:

Type: 1 octet Suggested value 1 (to be assigned by IANA)

Length: 1 octet MUST be a multiple of 6 octets.

Leaf-Set: A list of IS-IS System-ID of the leaf node neighbors of this spine node.

3.3.1.2. Info-Req Sub-TLV

This sub-TLV is used by leaf nodes to request more specific prefix information from a selected spine node, upon detecting one of the spine node has lost the connection to a leaf node. The fields of this sub-TLV are defined as follows:

Type: 1 octet Suggested value 2 (to be assigned by IANA)

Length: 1 octet. It MUST be a multiple of 6 octets.

Info-Req: List of IS-IS System-IDs of leaf nodes for which connectivity information is being requested.

3.3.2. Advertising IPv4/IPv6 Reachability

In cases where connectivity between a leaf node and a spine node is down, the leaf node MAY request reachability information from a spine node as described in Section 3.3.1.2. The spine node utilizes TLVs 135 [RFC5305] and TLVs 236 [RFC5308] to advertise this information. These TLVs MAY be included either in IIHs or CS-LSPs sent from the spine to the requesting leaf node. Sending such information in IIHs has limited scale - all reachability information MUST fit within a single IIH. It is therefore recommended that CS-LSPs be used.

3.4. Mechanism

Leaf nodes in a spine-leaf application using this extension are provisioned with two attributes:

1)Tier level of 0. This indicates the node is a Leaf Node. The value 0 is advertised in the Tier field of Spine-Leaf TLV defined above.

2)Flooding reduction enabled/disabled. If flooding reduction is enabled the L-bit is set to one in the Spine-Leaf TLV defined above

A spine node does not need explicit configuration. Spine nodes can dynamically discover their tier level by computing the number of hops to a leaf node. Until a spine node determines its tier level it MUST advertise level 15 (unknown tier level) in the Spine-Leaf TLV defined above.

When a spine node receives an IIH which includes the Spine-Leaf TLV with Tier level 0 and 'L' bit set, it labels the point-to-point interface and adjacency to be a 'Reduced Flooding Leaf-Peer (RF-Leaf)'. IIHs sent by a spine node on a link to an RF-Leaf include the Spine-Leaf TLV with the 'R' bit set in the flags field. The 'R' bit indicates to the RF-Leaf neighbor that the spine node can be used as a default routing nexthop.

There is no change to the IS-IS adjacency bring-up mechanism for Spine-Leaf peers.

A spine node blocks LSP flooding to RF-Leaf adjacencies, except for the LSP PDUs in which the IS-IS System-ID matches the System-ID of the RF-Leaf neighbor. This exception is needed since when the leaf node reboots, the spine node needs to forward to the leaf node non-purged LSPs from the RF-Leaf's previous incarnation.

Leaf nodes will perform IS-IS LSP flooding as normal over all of its IS-IS adjacencies, but in the case of RF-Leafs only self-originated LSPs will exist in its LSP database.

Spine nodes will receive all the LSP PDUs in the network, including all the spine nodes and leaf nodes. It will perform Shortest Path First (SPF) as a normal IS-IS node does. There is no change to the route calculation and forwarding on the spine nodes.

RF-Leaf nodes do not have any LSP in the network except for its own. Therefore there is no need to perform SPF calculation on the RF-Leaf node. It only needs to download the default route with the nexthops of those Spine Neighbors which have the 'R' bit set in the Spine-Leaf TLV in IIH PDUs. IS-IS can perform equal cost or unequal cost load sharing while using the spine nodes as nexthops. The aggregated metric of the outbound interface and the 'Reverse Metric' [REVERSE-METRIC] can be used for this purpose.

3.4.1. Pure CLOS Topology

In a data center where the topology is pure CLOS or Fat Tree, there is no interconnection among the spine nodes, and there is not another Core layer above the aggregation layer with reachability to the leaf nodes. When flooding reduction to RF-Leafs is in use, if the link between a spine and a leaf goes down, there is then a possibility of black holing the data traffic in the network.

As in the diagram Figure 2, if the link Spine1-Leaf3 goes down, there needs to be a way for Leaf1, Leaf2 and Leaf4 to avoid the Spine1 if the destination of data traffic is to Leaf3 node.

In the above example, the Spine1 and Spine2 are provisioned to advertise the Leaf-Set sub-TLV of the Spine-Leaf TLV. Originally both Spines will advertise Leaf1 through Leaf4 as their Leaf-Set. When the Spine1-Leaf3 link is down, Spine1 will only have Leaf1, Leaf2 and Leaf4 in its Leaf-Set. This allows the other leaf nodes to know that Spine1 has lost connectivity to the leaf node of Leaf3.

Each RF-Leaf node can select another spine node to request for some prefix information associated with the lost leaf node. In this diagram of Figure 2, there are only two spine nodes (Spine-Leaf topology can have more than two spine nodes in general). Each RF-Leaf node can independently select a spine node for the leaf information. The RF-Leaf nodes will include the Info-Req sub-TLV in the Spine-Leaf TLV in hellos sent to the selected spine node, Spine2 in this case.

The spine node, upon receiving the request from one or more leaf nodes, will find the IPv6/IPv4 prefixes advertised by the leaf nodes listed in the Info-Req sub-TLV. The spine node will use the mechanism defined in Section 3.3.2 to advertise these prefixes to the RF-Leaf node. For instance, it will include the IPv4 loopback prefix of leaf3 based on the policy configured or administrative tag attached to the prefixes. When the leaf nodes receive the more specific prefixes, they will install the advertised prefixes towards the other spine nodes (Spine2 in this example).

For instance in the data center overlay scenario, when any IP destination or MAC destination uses the leaf3’s loopback as the tunnel nexthop, the overlay tunnel from leaf nodes will only select Spine2 as the gateway to reach leaf3 as long as the Spine1-Leaf3 link is still down.

This negative routing is only relevant between tier 0 and tier 1 spine-leaf levels in a multi-level spine-leaf topology when the

reduced flooding extension is in use. Nodes in tiers 1 or greater have the full topology information.

3.5. Implementation and Operation

3.5.1. CSNP PDU

In Spine-Leaf extension, Complete Sequence Number PDU (CSNP) does not need to be transmitted over the Spine-Leaf link to an RF-Leaf. Some IS-IS implementations send periodic CSNPs after the initial adjacency bring-up over a point-to-point interface. There is no need for this optimization here since the RF-Leaf does not need to receive any other LSPs from the network, and the only LSPs transmitted across the Spine-Leaf link is the leaf node LSP.

Also in the graceful restart case[RFC5306], for the same reason, there is no need to send the CSNPs over the Spine-Leaf interface to an RF-Leaf. Spine nodes only need to set the SRMflag on the LSPs belonging to the RF-Leaf.

3.5.2. Leaf to Leaf connection

Leaf to leaf node links are useful in host redundancy cases in switching networks, and normally there is no flooding extensions are required in this case. Each leaf node will set tier level = 0 in the Spine-Leaf TLV included in hellos to leaf neighbors. LSP will be exchanged over this link. In the example diagram Figure 1, the Leaf1 will get Leaf2’s LSP and Leaf2 will get Leaf1’s LSP. They will install more specific routes towards each other using this local Leaf-Leaf link. SPF will be performed in this case just like when the entire network only involves with those two IS-IS nodes. This does not affect the normal Spine-Leaf mechanism they perform toward the spine nodes.

Besides the local leaf-to-leaf traffic, the leaf node can serve as a backup gateway for its leaf neighbor. It needs to remove the ’Overload-Bit’ setting in its LSP, and it sets both the ’L’ bit and the ’B’ bit in the SL-flag with a high ’Reverse Metric’ value.

3.5.3. Overload Bit

The leaf node SHOULD set the ’overload’ bit on its LSP PDU, since if the spine nodes were to forward traffic not meant for the local node, the leaf node does not have the topology information to prevent a routing/forwarding loop.

3.5.4. Spine Node Hostname

This extension creates a non-reciprocal relationship between the spine node and leaf node. The spine node will receive leaf's LSP and will know the leaf's hostname, but the leaf does not have spine's LSP. This extension allows the Dynamic Hostname TLV [RFC5301] to be optionally included in spine's IIH PDU when sending to a 'Leaf-Peer'. This is useful in troubleshooting cases.

3.5.5. IS-IS Reverse Metric

This metric is part of the aggregated metric for leaf's default route installation with load sharing among the spine nodes. When a spine node is in 'overload' condition, it should use the IS-IS Reverse Metric TLV in IIH [REVERSE-METRIC] to set this metric to maximum to discourage the leaf using it as part of the loadsharing.

In some cases, certain spine nodes may have less bandwidth in link provisioning or in real-time condition, and it can use this metric to signal to the leaf nodes dynamically.

In other cases, such as when the spine node loses a link to a particular leaf node, although it can redirect the traffic to other spine nodes to reach that destination leaf node, but it MAY want to increase this metric value if the inter-spine connection becomes over utilized, or the latency becomes an issue.

In the leaf-leaf link as a backup gateway use case, the 'Reverse Metric' SHOULD always be set to very high value.

3.5.6. Spine-Leaf Traffic Engineering

Besides using the IS-IS Reverse Metric by the spine nodes to affect the traffic pattern for leaf default gateway towards multiple spine nodes, the IPv6/IPv4 Info-Advertise sub-TLVs can be selectively used by traffic engineering controllers to move data traffic around the data center fabric to alleviate congestion and to reduce the latency of a certain class of traffic pairs. By injecting more specific leaf node prefixes, it will allow the spine nodes to attract more traffic on some underutilized links.

3.5.7. Other End-to-End Services

Losing the topology information will have an impact on some of the end-to-end network services, for instance, MPLS TE or end-to-end segment routing. Some other mechanisms such as those described in PCE [RFC4655] based solution may be used. In this Spine-Leaf extension, the role of the leaf node is not too much different from

the multi-level IS-IS routing while the level-1 IS-IS nodes only have the default route information towards the node which has the Attach Bit (ATT) set, and the level-2 backbone does not have any topology information of the level-1 areas. The exact mechanism to enable certain end-to-end network services in Spine-Leaf network is outside the scope of this document.

3.5.8. Address Family and Topology

IPv6 Address families[RFC5308], Multi-Topology (MT)[RFC5120] and Multi-Instance (MI)[RFC8202] information is carried over the IIH PDU. Since the goal is to simplify the operation of IS-IS network, for the simplicity of this extension, the Spine-Leaf mechanism is applied the same way to all the address families, MTs and MIs.

3.5.9. Migration

For this extension to be deployed in existing networks, a simple migration scheme is needed. To support any leaf node in the network, all the involved spine nodes have to be upgraded first. So the first step is to migrate all the involved spine nodes to support this extension, then the leaf nodes can be enabled with 'Leaf-Mode' one by one. No flag day is needed for the extension migration.

4. IANA Considerations

A new TLV codepoint is defined in this document and needs to be assigned by IANA from the "IS-IS TLV Codepoints" registry. It is referred to as the Spine-Leaf TLV and the suggested value is 150. This TLV is only to be optionally inserted either in the IIH PDU or in the Circuit Flooding Scoped LSP PDU. IANA is also requested to maintain the SL-flag bit values in this TLV, and 0x01, 0x02 and 0x04 bits are defined in this document.

Value	Name	IIH	LSP	SNP	Purge	CS-LSP
150	Spine-Leaf	y	y	n	n	y

This extension also proposes to have the Dynamic Hostname TLV, already assigned as code 137, to be allowed in IIH PDU.

Value	Name	IIH	LSP	SNP	Purge
137	Dynamic Name	y	y	n	y

Two new sub-TLVs are defined in this document and needs to be added assigned by IANA from the "IS-IS TLV Codepoints". They are referred

to in this document as the Leaf-Set sub-TLV and the Info-Req sub-TLV. It is suggested to have the values 1 and 2 respectively.

5. Security Considerations

Security concerns for IS-IS are addressed in [ISO10589], [RFC5304], [RFC5310], and [RFC7602]. This extension does not raise additional security issues.

6. Acknowledgments

TBD.

7. Document Change Log

7.1. Changes to draft-shen-isis-spine-leaf-ext-04.txt

- Submitted April 2017.
- Added the Tier level information to handle the multi-level spine-leaf topology using this extension.

7.2. Changes to draft-shen-isis-spine-leaf-ext-03.txt

- Submitted March 2017.
- Added the Spine-Leaf sub-TLVs to handle the case of data center pure CLOS topology and mechanism.
- Added the Spine-Leaf TLV and sub-TLVs can be optionally inserted in either IIH PDU or CS-LSP PDU.
- Allow use of prefix Reachability TLVs 135 and 236 in IIHs/CS-LSPs sent from spine to leaf.

7.3. Changes to draft-shen-isis-spine-leaf-ext-02.txt

- Submitted October 2016.
- Removed the ’Default Route Metric’ field in the Spine-Leaf TLV and changed to using the IS-IS Reverse Metric in IIH.

7.4. Changes to draft-shen-isis-spine-leaf-ext-01.txt

- Submitted April 2016.
- No change. Refresh the draft version.

7.5. Changes to draft-shen-isis-spine-leaf-ext-00.txt

- Initial version of the draft is published in November 2015.

8. References

8.1. Normative References

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8.2. Informative References

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Network Working Group
Internet-Draft
Intended status: Standards Track
Expires: November 3, 2017

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May 2, 2017

IS-IS Flooding Reduction in MSDC
draft-xu-isis-flooding-reduction-in-msdc-01

Abstract

IS-IS is commonly used as an underlay routing protocol for MSDC (Massively Scalable Data Center) networks. For a given IS-IS router within the CLOS topology, it would receive multiple copies of exactly the same LSP from multiple IS-IS neighbors. In addition, two IS-IS neighbors may send each other the same LSP simultaneously. The unneccessary link-state information flooding wastes the precious process resource of IS-IS routers greatly due to the fact that there are too many IS-IS neighbors for each IS-IS router within the CLOS topology. This document proposes some extensions to IS-IS so as to reduce the IS-IS flooding within MSDC networks greatly. The reduction of the IS-IS flooding is much beneficial to improve the scalability of MSDC networks.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at http://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on November 3, 2017.

Table of Contents

1. Introduction

IS-IS is commonly used as an underlay routing protocol for Massively Scalable Data Center (MSDC) networks where CLOS is the most popular toplogy. For a given IS-IS router within the CLOS topology, it would receive multiple copies of exactly the same LSP from multiple IS-IS neighbors. In addition, two IS-IS neighbors may send each other the same LSP simultaneously. The unnecessary link-state information flooding wastes the precious process resource of IS-IS routers greatly and therefore IS-IS could not scale very well in MSDC networks.

To simplify the network management task, centralized controllers are becoming fundamental network elements in most MSDCs. One or more controllers are usually connected to all routers within the MSDC network via a Local Area Network (LAN) which is dedicated for network management purpose (called management LAN), as shown in Figure 1.

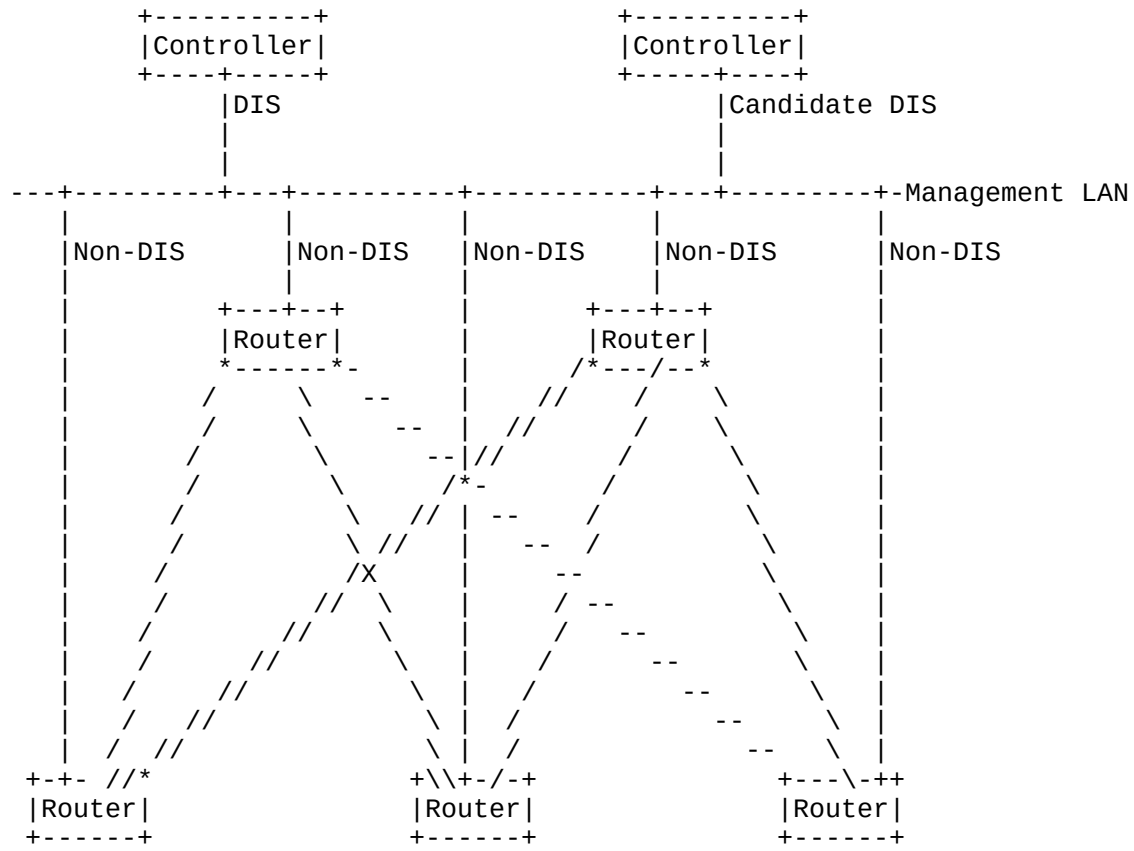

Figure 1

With the assistance of a controller acting as IS-IS Designated Intermediate System (DIS) for the management LAN, IS-IS routers within the MSDC network don't need to exchange any IS-IS Protocl Datagram Units (PDUs) other than Hello packets among them. In order to obtain the full topology information (i.e., the fully synchronized link-state database) of the MSDC's network, these IS-IS routers would exchange the link-state information with the controller being elected as IS-IS DIS for the management LAN instead.

To further suppress the flooding of multicast IS-IS PDUs originated from IS-IS routers over the management LAN, IS-IS routers would not send multicast IS-IS Hello packets over the management LAN. Insteads, they just wait for IS-IS Hello packets originated from the controller being elected as IS-IS DIS initially. Once an IS-IS DIS for the management LAN has been discovered, they start to send IS-IS Hello packets directly (as unicasts) to the IS-IS DIS periodically.

In addition, IS-IS routers would send IS-IS PDUs to the IS-IS DIS for the management LAN as unicasts as well. In contrast, the controller being elected as IS-IS DIS would send IS-IS PDUs as before. As a result, IS-IS routers would not receive IS-IS PDUs from one another unless these IS-IS PDUs are forwarded as unknown unicasts over the management LAN. Through the above modifications to the current IS-IS router behaviors, the IS-IS flooding is greatly reduced, which is much beneficial to improve the scalability of MSDC networks.

1.1. 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].

2. Terminology

This memo makes use of the terms defined in [RFC1195].

3. Modifications to Current IS-IS Behaviors

3.1. IS-IS Routers as Non-DIS

After the bidirectional exchange of IS-IS Hello packets among IS-IS routers, IS-IS routers would originate Link State PDUs (LSPs) accordingly. However, these self-originated LSPs need not to be exchanged directly among them anymore. Instead, these LSPs just need to be sent solely to the controller being elected as IS-IS DIS for the management LAN.

To further reduce the flood of multicast IS-IS PDUs over the management LAN, IS-IS routers SHOULD send IS-IS PDUs as unicasts. More specifically, IS-IS routers SHOULD send unicast IS-IS Hello packets periodically to the controller being elected as IS-IS DIS. In other words, IS-IS routers would not send any IS-IS Hello packet over the management LAN until they have found an IS-IS DIS for the management LAN. Note that IS-IS routers SHOULD NOT be elected as IS-IS DIS for the management LAN (This is done by setting the DIS Priority of those IS-IS routers to zero). As a result, IS-IS routers would not see each other over the management LAN. In other word, IS-IS routers would not establish adjacencies with one other. Furthermore, IS-IS routers SHOULD send all the types of IS-IS PDUs to the controller being elected as IS-IS DIS as unicasts as well.

To advoid the data traffic from being forwarded across the management LAN, the cost of all IS-IS routers' interfaces to the management LAN SHOULD be set to the maximum value.

When a given IS-IS router lost its connection to the management LAN, it SHOULD actively establish adjacency with all of its IS-IS neighbors within the CLOS network. As such, it could obtain the full LSDB of the CLOS network while flooding its self-originated LSPs to the remaining part of the whole CLOS network through these IS-IS neighbor.

3.2. Controllers as DIS

The controller being elected as IS-IS DIS would send IS-IS PDUs as multicasts or unicasts as before. And it SHOULD accept and process those unicast IS-IS PDUs originated from IS-IS routers. Upon receiving any new LSP from a given IS-IS router, the controller being elected as DIS MUST flood it immediately to the management LAN for two purposes: 1) implicitly acknowledging the receipt of that LSP; 2) synchronizing that LSP to all the other IS-IS routers.

Furthermore, to decrease the frequency of advertising Complete Sequence Number PDU (CSNP) on the controller being elected as DIS, it’s RECOMMENDED that IS-IS routers SHOULD send an explicit acknowledgement with a Partial Sequence Number PDU (PSNP) upon receiving a new LSP from the controller being elected as DIS.

4. Acknowledgements

The authors would like to thank Peter Lothberg for his valuable comments and suggestions on this document.

5. IANA Considerations

TBD.

6. Security Considerations

TBD.

7. References

7.1. Normative References

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