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IS-IS Topology-Transparent Zone
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Abstract

This document presents a topology-transparent zone in a domain. A zone comprises a group of routers and a number of circuits connecting them. Any router outside of the zone is not aware of the zone. The information about the circuits and routers inside the zone is not distributed to any router outside of the zone. Any link state change such as a circuit down inside the zone is not seen by any router outside of the zone.

Status of this Memo

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

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This Internet-Draft will expire on September 9, 2015.

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1. Introduction

ISO/IEC 10589 describes IS-IS areas or levels in an Autonomous System (AS). Each level 1 area has a number of level 1 and level 2 routers connected to the level 2 area. Each level 1 and level 2 router may summarize the topology of its attached level 1 areas to the level 2 area or vice versa.

The number of routers in a network becomes larger and larger as the Internet traffic keeps growing. Through splitting the network into multiple areas, we can extend the network further. However, there are a number of issues when a network is split further into more areas.

At first, dividing a network from one area into multiple areas or from a number of existing areas to even more areas is a very challenging and time consuming task since it is involved in significant network architecture changes.

Secondly, the services carried by the network may be interrupted while the network is being split from one area into multiple areas or from a number of existing areas into even more areas.

Furthermore, it is complex for a Multi-Protocol Label Switching (MPLS) Traffic Engineering (TE) Label Switching Path (LSP) crossing multiple areas to be setup. In one option, a TE path crossing multiple areas is computed by using collaborating Path Computation Elements (PCEs) [RFC5441] through the PCE Communication Protocol (PCEP)[RFC5440], which is not easy to configure by operators since the manual configuration of the sequence of domains is required. Although this issue can be addressed by using the Hierarchical PCE, this solution may further increase the complexity of network design. Especially, the current PCE standard method may not guarantee that the path found is optimal.

This document presents a topology-transparent zone in a domain or an area and describes extensions to IS-IS for supporting the topology-transparent zone, which is scalable and resolves the issues above.

A topology-transparent zone comprises a group of routers and a number of circuits connecting these routers. Any router outside of the zone is not aware of the zone. The information about the circuits and routers inside the zone is not distributed to any router outside of the zone. Any link state change such as a circuit down inside the zone is not seen by any router outside of the zone.

2. 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.

3. Requirements

Topology-Transparent Zone (TTZ) may be deployed for resolving some critical issues such as scalability in existing networks and future networks. The requirements for TTZ are listed as follows:

- TTZ MUST be backward compatible. When a TTZ is deployed on a set of routers in a network, the routers outside of the TTZ in the network do not need to know or support TTZ.
- TTZ MUST support at least one more levels of network hierarchies, in addition to the hierarchies supported by existing routing protocols.
- Users SHOULD be able to easily set up an end to end service crossing TTZs.
- The configuration for a TTZ in a network SHOULD be minimum.
- The changes on the existing protocols for supporting TTZ SHOULD be minimum.

4. Topology-Transparent Zone

4.1. Overview of Topology-Transparent Zone

A Topology-Transparent Zone (TTZ) is identified by an Identifier (ID), and it includes a group of routers and a number of circuits connecting the routers. A TTZ is in an IS-IS domain (area).

The ID of a TTZ or TTZ ID is a number that is unique for identifying an entity such as a node in an IS-IS domain (area). It is not zero in general.

In addition to having the functions of an IS-IS level or area, an IS-IS TTZ makes some improvements on an IS-IS level or area, which include:

- An IS-IS TTZ is virtualized as the TTZ edge routers connected.

- An IS-IS TTZ receives the link state information about the topology outside of the TTZ, stores the information in the TTZ and floods the information through the TTZ to the routers outside of TTZ.

4.2. An Example of TTZ

The figure below illustrates an example of a routing domain containing a TTZ: TTZ 600.

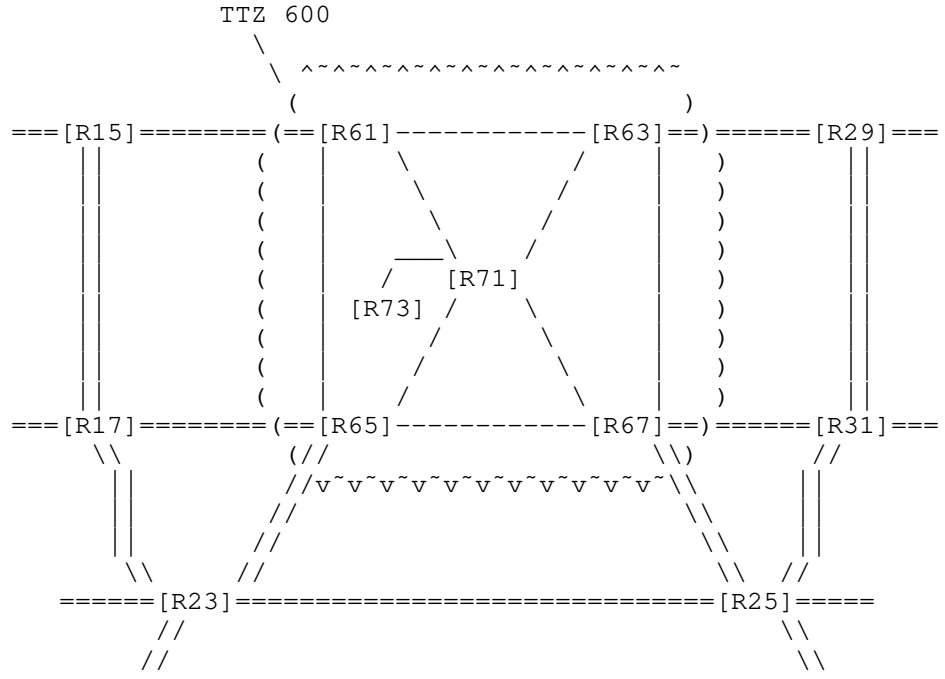


Figure 1: An Example of TTZ

The routing domain comprises routers R15, R17, R23, R25, R29 and R31. It also contains TTZ 600, which comprises routers R61, R63, R65, R67, R71 and R73, and the circuits connecting them.

There are two types of routers in a TTZ: TTZ internal routers and TTZ edge routers. A TTZ internal router is a router inside the TTZ and its adjacent routers are inside the TTZ. A TTZ edge router is a router inside the TTZ and has at least one adjacent router that is outside of the TTZ.

The TTZ in the figure above comprises four TTZ edge routers R61, R63,

R65 and R67. Each TTZ edge router is connected to at least one router outside of the TTZ. For instance, router R61 is a TTZ edge router since it is connected to router R15, which is outside of the TTZ.

In addition, the TTZ comprises two TTZ internal routers R71 and R73. A TTZ internal router is not connected to any router outside of the TTZ. For instance, router R71 is a TTZ internal router since it is not connected to any router outside of the TTZ. It is just connected to routers R61, R63, R65, R67 and R73 inside the TTZ.

A TTZ MUST hide the information inside the TTZ from the outside. It MUST NOT directly distribute any internal information about the TTZ to a router outside of the TTZ.

For instance, the TTZ in the figure above MUST NOT send the information about TTZ internal router R71 to any router outside of the TTZ in the routing domain; it MUST NOT send the information about the circuit between TTZ router R61 and R65 to any router outside of the TTZ.

In order to create a TTZ, we MUST configure the same TTZ ID on the edge routers and identify the TTZ internal circuits on them. In addition, we SHOULD configure the TTZ ID on every TTZ internal router which indicates that every circuit of the router is a TTZ internal circuit.

From a router outside of the TTZ, a TTZ is seen as a group of routers fully connected. For instance, router R15 in the figure above, which is outside of TTZ 600, sees TTZ 600 as a group of TTZ edge routers: R61, R63, R65 and R67. These four TTZ edge routers are fully connected.

In addition, a router outside of the TTZ sees TTZ edge routers having normal connections to the routers outside of the TTZ. For example, router R15 sees four TTZ edge routers R61, R63, R65 and R67, which have the normal connections to R15, R29, R17 and R23, R25 and R31 respectively.

5. Extensions to IS-IS Protocols

5.1. TTZ TLV

A new TLV, which is called TTZ TLV, may be added into a link state PDU(LSP) or a Hello PDU for a TTZ node. It has the following format.

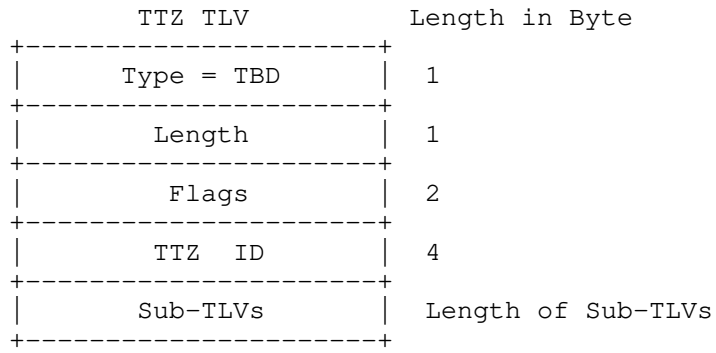
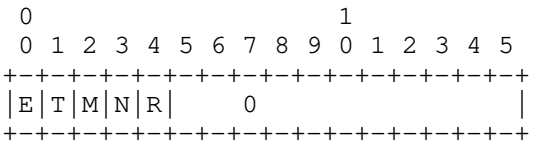


Figure 2: TTZ TLV

A TTZ TLV has 1 byte of Type, 1 byte of Length of the value field of the TLV, which is followed by 2 bytes of Flags and 4 bytes of TTZ ID. A TTZ TLV in an LSP may contains a number of sub TLVs and have Flags defined as follows.



E = 1: Edge router of TTZ
T = 1: Distributing TTZ Topology Information for Migration
M = 1: Migrating to TTZ
N = 1: Distributing Normal Topology Information for Rollback
R = 1: Rolling back from TTZ

When a router in a TTZ receives a CLI command triggering TTZ information distribution for migration, it updates its LSP by adding a TTZ TLV with T set to 1. When a router in a TTZ receives a CLI command activating migration to TTZ, it sets M to 1 in the TTZ TLV in its LSP.

Two new sub-TLVs are defined, which may be added into a TTZ TLV in an LSP. One is TTZ IS Neighbor sub-TLV, or TTZ ISN sub-TLV for short. The other is TTZ ES Neighbor sub-TLV, or TTZ ESN sub-TLV for short. A TTZ ISN sub-TLV contains the information about a number of TTZ IS neighbors connected to a TTZ edge router. It has the format below.

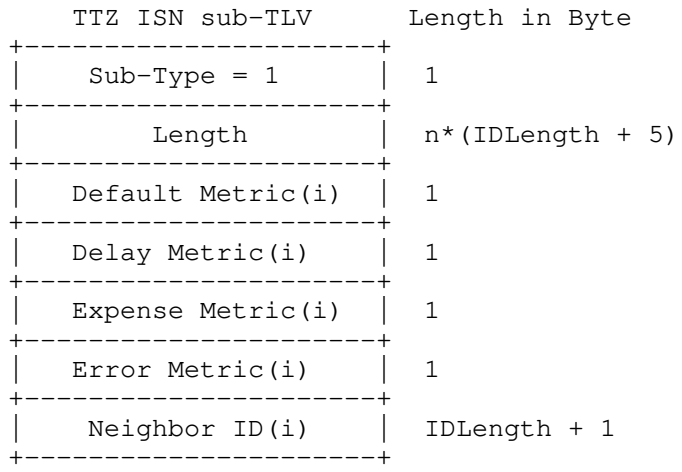


Figure 3: TTZ ISN sub TLV

A TTZ ESN sub-TLV contains the information about a number of TTZ ES neighbors connected to a TTZ edge router. It has the format below.

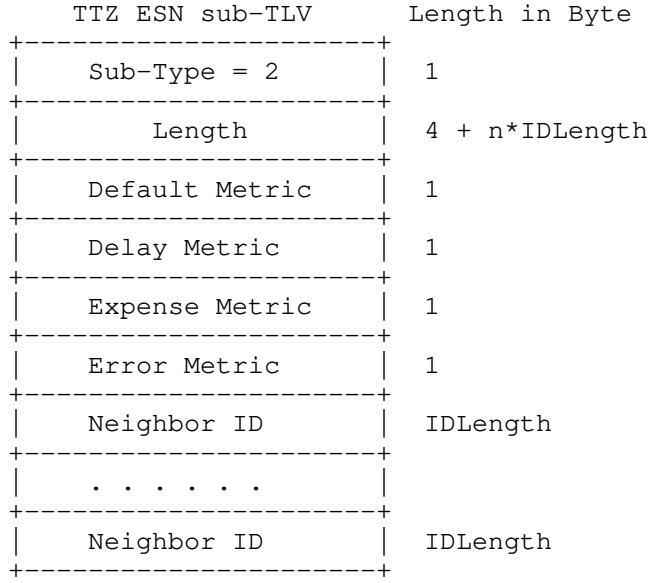


Figure 4: TTZ ESN sub TLV

6. Updating LSPs for TTZ

6.1. Updating LSP for a TTZ Internal Router

A TTZ internal router adds a TTZ TLV into its LSP after it receives an LSP containing a TTZ TLV with T = 1 or a CLI command triggering TTZ information distribution for migration. The TLV has a TTZ ID set to the ID of the TTZ and E bit in Flags set to 0 indicating TTZ internal router. The router floods its LSP to its neighbors in the TTZ.

When a router inside the TTZ receives a link state packet (LSP) containing a TTZ TLV from a neighboring router in the TTZ, it stores the link state and floods the link state to the other neighboring routers in the TTZ.

6.2. Updating LSP for a TTZ Edge Router

For every edge router of a TTZ, it updates its LSP in three steps and floods the LSP to all its neighbors.

At first, a TTZ edge router adds a TTZ TLV into its LSP after it receives an LSP containing a TTZ TLV with T = 1 or a CLI command triggering TTZ information distribution for migration. The TLV has a TTZ ID set to the ID of the TTZ, E bit in Flags set to 1 indicating TTZ edge router and a TTZ ISN sub TLV. The sub TLV contains the information about the TTZ IS neighbors connected to the TTZ edge router. In addition, the TLV may has a TTZ ESN sub TLV comprising the information about the TTZ end systems connected to the TTZ edge router.

Secondly, it adds each of the other TTZ edge routers as an IS neighbor into the Intermediate System Neighbors TLV in the LSP after it receives an LSP containing a TTZ TLV with M = 1 or a CLI command activating migration to TTZ. The metric to the neighbor is the metric of the shortest path to the edge router within the TTZ.

In addition, it adds a Prefix Neighbors TLV into its LSP. The TLV contains a number of address prefixes in the TTZ to be reachable from outside of the TTZ.

And then it removes the IS neighbors corresponding to the IS neighbors in the TTZ TLV (i.e., in the TTZ ISN sub TLV) from Intermediate System Neighbors TLV in the LSP, and the ES neighbors corresponding to the ES neighbors in the TTZ TLV (i.e., in the TTZ ESN sub TLV) from End System Neighbors TLV in the LSP. This SHOULD be done after it receives the LSPs for virtualizing TTZ from the other TTZ edges for a given time.

7. Establishing Adjacencies

7.1. Discover TTZ Neighbor over Normal Adjacency

For two routers A and B connected by a P2P circuit and having a normal adjacency, they discover TTZ each other through including a TTZ TLV containing a TTZ ID in their hello packets. If two ends of the circuit have the same TTZ ID, A and B are TTZ neighbors; otherwise, they are not TTZ neighbors, but normal neighbors.

For a number of routers connected through a broadcast circuit and having normal adjacencies among them, they also discover TTZ each other through including a TTZ TLV containing a TTZ ID in their hello packets. The DIS for the circuit "forms" TTZ adjacency with each of the other routers if all the routers attached to the circuit have the same TTZ ID configured on the connections to the circuit and included in their hello packets; otherwise, they are not TTZ neighbors, but still normal neighbors.

7.2. Establishing TTZ Adjacencies

When a router (say A) is connected via a P2P circuit to another router (say B) and there is not any adjacency between them over the circuit, a user configures TTZ on two ends of the circuit to form a TTZ adjacency.

Routers A and B include a TTZ TLV containing a TTZ ID in their hello packets. If two routers have the same TTZ IDs in their hellos, an adjacency between these two routers is to be formed; otherwise, no adjacency is formed.

For a number of routers connected through a broadcast circuit and having no adjacency among them, they start to form TTZ adjacencies after TTZ is configured on the circuit and a TTZ TLV with a TTZ ID is included in their hello packets. The DIS for the circuit forms TTZ adjacency with each of the other routers if all the routers attached to the circuit have the same TTZ ID configured on the connections to the circuit and included in the hello packets; otherwise, the DIS does not form any adjacency with any router attached to the circuit.

7.3. Adjacency between TTZ Edge and Router outside

For an edge router in a TTZ, in addition to establishing adjacencies with other routers in the TTZ that have connections with the edge router, it forms an adjacency with any router outside of the TTZ that has a connection with the edge router.

When the edge router synchronizes its link state database with the

router outside of the TTZ, it sends the router outside of the TTZ the information about all the LSPs except for the LSPs belong to the TTZ that are hidden from any router outside of the TTZ.

At the end of the link state database synchronization, the edge router originates its own LSP and sends this LSP to the router outside of the TTZ. This LSP contains two groups of circuits.

The first group of circuits are the circuits connecting to the routers outside of the TTZ from this TTZ edge router. The second group of circuits are the "virtual" circuits connecting to the other TTZ edge routers from this TTZ edge router.

From the point of view of the router outside of the TTZ, it sees the other end as a normal router and forms the adjacency in the same way as a normal router. It is not aware of anything about its neighboring TTZ. From the LSPs related to the TTZ edge router in the other end, it knows that the TTZ edge router is connected to each of the other TTZ edge routers and some routers outside of the TTZ.

8. Distribution of LSPs

LSPs can be divided into two classes according to their distributions. One class of LSPs is distributed within a TTZ. The other is distributed through a TTZ.

8.1. Distribution of LSPs within TTZ

Any LSP generated for a TTZ internal router in a TTZ is distributed within the TTZ. It will not be distributed to any router outside of the TTZ.

Any pseudo node LSP generated for a broadcast network inside a TTZ, is distributed within the TTZ. It will not be distributed to any router outside of the TTZ.

8.2. Distribution of LSPs through TTZ

Any LSP about a link state outside of a TTZ received by an edge router of the TTZ is distributed through the TTZ; and any LSP about a link state for the TTZ generated by a TTZ edge router is distributed through the TTZ.

For example, when an edge router of a TTZ receives an LSP for a link state outside of the TTZ from a router outside of the TTZ, it floods it to its neighboring routers both inside the TTZ and outside of the TTZ. This LSP may be any LSP such as a router LSP that is

distributed in a domain.

The routers in the TTZ continue to flood the LSP. When another edge router of the TTZ receives the LSP, it floods the LSP to its neighboring routers both outside of the TTZ and inside the TTZ.

9. Computation of Routing Table

The computation of the routing table on a router outside of a TTZ is the same as that described in ISO/SEC 10589. On a router in a TTZ, the computation of the routing table has the same procedure flow as that described in ISO/SEC 10589, with one exception. A router in a TTZ MUST ignore the circuits in the router LSPs generated by the edge routers of the TTZ for virtualizing the TTZ.

The routing table on a router inside the TTZ is computed through using the link state database (LSDB) containing the LSPs for the topology of the TTZ and the LSPs for the topology outside of the TTZ. That is that the shortest path to every destination both inside the TTZ and outside of the TTZ is computed over all the circuits including the circuits inside the TTZ and the circuits outside of the TTZ.

10. Operations

10.1. Configuring TTZ

This section proposes some options for configuring a TTZ.

1. Configuring TTZ on Every Circuit in TTZ

If every circuit in a TTZ is configured with a same TTZ ID as a TTZ circuit, the TTZ is determined. A router with some TTZ circuits and some normal circuits is a TTZ edge router. A router with only TTZ circuits is a TTZ internal router.

2. Configuring TTZ on Every Router in TTZ

We may configure a same TTZ ID on every router in the TTZ, and on every edge router’s circuits connecting to the routers in the TTZ.

A router configured with the TTZ ID on some of its circuits is a TTZ edge router. A router configured with the TTZ ID only is a TTZ internal router. All the circuits on a TTZ internal router are TTZ circuits. This option is simpler than the above one.

10.2. Smooth Migration to TTZ

For a group of routers and a number of circuits connecting the routers in an area, making them transfer to work as a TTZ without any service interruption may take a few of steps.

At first, users configure the TTZ feature on every router in the TTZ. In this stage, a router does not update its LSPs. It will discover its TTZ neighbors.

Secondly, after configuring the TTZ, users issue a CLI command on one router in the TTZ, which triggers every router in the TTZ to distribute TTZ information among the routers in the TTZ. When the router receives the command, it updates its LSP by adding a TTZ TLV, and distributes the LSP to its TTZ neighbors. The LSP has T = 1 in Flags in the TTZ TLV (indicating TTZ information generation and distribution for migration). When a router in the TTZ receives the LSP with T = 1, it updates its LSP by adding a TTZ TLV. In this stage, every router in the TTZ has dual roles. One is to function as a normal router. The other is to generate and distribute TTZ information.

Thirdly, users may check whether every router in the TTZ is ready for transferring to work as a TTZ router. A router in the TTZ is ready after it has received all the necessary information from all the routers in the TTZ. This information may be displayed on a router through a CLI command.

And then users activate the TTZ through using a CLI command such as migrate to TTZ on one router in the TTZ. The router transfers to work as a TTZ router, updates its LSP with M = 1 in the TTZ TLV (indicating Migrating to TTZ) after it receives the command.

After a router in the TTZ receives the LSP with M = 1, it also transfers to work as a TTZ router. Thus, activating the TTZ on one TTZ router makes every router in the TTZ transfer to work as a TTZ router, which computes routes through using the TTZ topology and the topology outside of the TTZ.

For an edge router of the TTZ, transferring to work as a TTZ router comprises updating its LSP to virtualize the TTZ by adding each of the other TTZ edge routers as an IS neighbor and flooding this LSP to all its direct neighboring routers. And then, the TTZ edge router removes the IS neighbors corresponding to the IS neighbors in the TTZ TLV (i.e., in the TTZ ISN sub TLV) from Intermediate System Neighbors TLV in the LSP

10.3. Adding a Router into TTZ

When a non TTZ router (say R1) is connected via a P2P circuit to a TTZ router (say T1) working as TTZ and there is a normal adjacency between them over the circuit, a user can configure TTZ on two ends of the circuit to add R1 into the TTZ to which T1 belongs. They discover TTZ each other in the same way as described in section 7.1.

When a number of non TTZ routers are connected via a broadcast circuit to a TTZ router (say T1) working as TTZ and there are normal adjacencies among them, a user configures TTZ on the connection to the circuit on every router to add the non TTZ routers into the TTZ to which T1 belongs. The DIS for the circuit "forms" TTZ adjacency with each of the other routers if all the routers have the same TTZ ID configured on the connections to the circuit.

When a router (say R1) is connected via a P2P circuit to a TTZ router (say T1) and there is not any adjacency between them over the circuit, a user can configure TTZ on two ends of the circuit to add R1 into the TTZ to which T1 belongs. R1 and T1 will form an adjacency in the same way as described in section 7.2.

When a router (say R1) is connected via a broadcast circuit to a group of TTZ routers on the circuit and there is not any adjacency between R1 and any over the circuit, a user can configure TTZ on the connection to the circuit on R1 to add R1 into the TTZ to which the TTZ routers belong. R1 starts to form an adjacency with the DIS for the circuit after the configuration.

11. Security Considerations

The mechanism described in this document does not raise any new security issues for the IS-IS protocols.

12. IANA Considerations

This document requires the allocation for a new TLV and a couple of new sub TLVs in the new TLV. IANA is requested to assign a new Type (value 150 is suggested) for new TLV TTZ as follows:

Type	Name	IIH	LSP	SNP	Purge
150	TTZ	Y	Y	N	N

This document defines two new Sub-TLVs in TLV 150. The values below are suggested for them subject to assignment by IANA or Expert review.

Type	Name and Description
1	TTZ ISN, TTZ IS Neighbors
2	TTZ ESN, TTZ ES Neighbors

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14. Acknowledgement

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15. Normative References

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IS-IS Path Computation and Reservation
draft-farkas-isis-pcr-02

Abstract

IEEE 802.1Qca Path Control and Reservation (PCR) specifies explicit path control via IS-IS in Layer 2 networks in order to move beyond the shortest path capabilities provided by IEEE 802.1aq Shortest Path Bridging (SPB). IS-IS PCR provides capabilities for the establishment and control of explicit forwarding trees in a Layer 2 network domain. This document specifies the sub-TLVs for IS-IS PCR.

Status of This Memo

Table of Contents

1. Introduction

IEEE 802.1Qca Path Control and Reservation (PCR) [IEEE8021Qca] specifies extensions to IS-IS for the control of Explicit Trees (ETs). The PCR extensions are compatible with the Shortest Path Bridging (SPB) extensions to IS-IS specified by [RFC6329] and [IEEE8021aq] (already rolled into [IEEE8021Q]). Furthermore, IS-IS with PCR extensions relies on the SPB architecture and terminology; and some of the IS-IS SPB sub-TLVs are also leveraged. IS-IS PCR builds upon IS-IS and uses IS-IS in a similar way to SPB. IS-IS PCR

only addresses point-to-point physical links, although IS-IS also supports shared media LANs.

This document specifies five IS-IS sub-TLVs for the control of explicit trees by IS-IS PCR in a Layer 2 network as specified by IEEE 802.1Qca. In addition to the sub-TLVs specified here, IS-IS PCR relies on the following IS-IS SPB sub-TLVs specified by [RFC6329]:

- SPB Link Metric sub-TLV
- SPB Base VLAN-Identifiers sub-TLV
- SPB Instance sub-TLV
- SPBV MAC address sub-TLV
- SPBM Service Identifier and Unicast Address sub-TLV

These sub-TLVs are used to provide the link metric and the associations among bridges, MAC addresses, VIDs and I-SIDs within an IS-IS domain. The use of these SPB sub-TLVs for PCR is specified by IEEE 802.1Qca. Note that IS-IS PCR does not require the implementation of the full IS-IS SPB protocol but only the support of these SPB sub-TLVs. A bridge can support both IS-IS SPB and IS-IS PCR at the same time but when it supports both they are implemented by the same IS-IS entity on a per instance basis.

The sub-TLVs specified here can be also applied for Fast ReRoute using Maximally Redundant Trees (MRT-FRR) [I-D.ietf-rtgwg-mrt-frr-architecture] in a Layer 2 network. MRTs are computed as specified in [I-D.ietf-rtgwg-mrt-frr-algorithm]. If MRT computation is split such that the Generalized Almost Directed Acyclic Graph (GADAG) is computed centrally, then these sub-TLVs can be used to distribute the GADAG, which is identical for each network node throughout a network domain.

PCR uses IS-IS, the SPB sub-TLVs listed above, and the new sub-TLVs defined here. IS-IS PCR has no impact to IETF protocols.

2. 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 [RFC2119].

The lowercase forms with an initial capital "Must", "Must Not", "Shall", "Shall Not", "Should", "Should Not", "May", and "Optional" in this document are to be interpreted in the sense defined in

[RFC2119], but are used where the normative behavior is defined in documents published by SDOs other than the IETF.

3. Terminology and Definitions

ADAG: Almost Directed Acyclic Graph - a digraph that can be transformed into a DAG by removing all arcs incoming to the root. [I-D.ietf-rtgwg-mrt-frr-architecture]

B-VID: Backbone VID. [IEEE8021Q]

Base VID: The VID used to identify a VLAN in management operations. [IEEE8021aq]

BLCE: Bridge Local Computation Engine - A computation engine in a bridge that performs path and routing computations. The BLCE implements e.g. SPF, CSPF, or the Maximally Redundant Trees Algorithm. [IEEE8021Qca]

Constrained tree: A tree meeting a certain constraint, e.g. providing a minimal available bandwidth. [IEEE8021Qca]

Cut-node: A node is a cut-node if removing it partitions the network. [I-D.ietf-rtgwg-mrt-frr-architecture]

Cut-link: A link is a cut-link if removing it partitions the network. [I-D.ietf-rtgwg-mrt-frr-architecture]

DAG: Directed Acyclic Graph - a digraph containing no directed cycle. [I-D.ietf-rtgwg-mrt-frr-architecture]

DEI: Drop Eligible Indicator. [IEEE8021Q]

ECT Algorithm: Equal Cost Tree Algorithm - The algorithm and mechanism that is used for the control of the active topology, i.e. forwarding trees. It can be one of the shortest path algorithms specified by IEEE 802.1aq. It can be also one of the explicit path control algorithms specified by IEEE 802.1Qca. Each ECT Algorithm has a 32-bit unique ID. [IEEE8021aq]

ET: Explicit Tree - An explicitly defined tree, which is specified by its end points and the paths among the end points. If only the end points are specified but the paths are not, then it is a loose explicit tree. If the paths are also specified, then it is a strict explicit tree. [IEEE8021Qca]

ETDB: Explicit Tree Database - A database storing explicit trees. [IEEE8021Qca]

FDB: Filtering Database. [IEEE8021Q]

GADAG: Generalized ADAG - a digraph, which has only ADAGs as all of its topology blocks. [I-D.ietf-rtgwg-mrt-frr-architecture]

Hop: A hop is specified by two nodes. A strict hop has no intermediate nodes, whereas a loose hop can have one or more intermediate nodes. IS-IS PCR specifies an explicit tree by an ordered list of hops starting at the root, each successive hop being defined by the next element of the list. [IEEE8021Qca]

I-SID: Backbone Service Instance Identifier - A 24-bit ID. [IEEE8021Q]

Maximally Redundant Trees (MRTs): A pair of trees with a common MRT Root where the path from any leaf node to the MRT Root along the first tree (MRT-Blue) and the path from the same leaf node along the second tree (MRT-Red) share the minimum number of nodes and the minimum number of links. Each such shared node is a cut-node. Any shared links are cut-links.
[I-D.ietf-rtgwg-mrt-frr-architecture]

MRT-Blue: MRT-Blue is one of the two MRTs; specifically, MRT-Blue is the increasing MRT where links in the GADAG are taken in the direction from a lower topologically ordered node to a higher one. [I-D.ietf-rtgwg-mrt-frr-architecture]

MRT-Red: MRT-Red is one of the two MRTs; specifically, MRT-Red is the decreasing MRT where links in the GADAG are taken in the direction from a higher topologically ordered node to a lower one. [I-D.ietf-rtgwg-mrt-frr-architecture]

MRT Root: The common root of the two MRTs: MRT-Blue and MRT-Red. [I-D.ietf-rtgwg-mrt-frr-architecture]

MSRP: Multiple Stream Registration Protocol, standardized as IEEE 802.1Qat, already rolled into [IEEE8021Q].

PCA: Path Control Agent - The agent that is part of the IS-IS domain and thus can perform IS-IS operations on behalf of a PCE, e.g. maintain the LSDB and send LSPs. [IEEE8021Qca]

PCE: Path Computation Element - An entity that is capable of computing a path through a network based on a representation of the topology of the network (obtained by undefined means external to the PCE). [RFC4655]

PCP: Priority Code Point, which identifies a traffic class. [IEEE8021Q]

PTP: Precision Time Protocol specified by [IEEE1588].

Redundant trees: A pair of trees with a common Root where the paths from any leaf node to the Root along the first tree and the second tree are disjoint. [I-D.ietf-rtgwg-mrt-frr-architecture]

SPBM: SPB MAC - The SPB mode where a MAC or its shorthand (SPSourceID: Shortest Path Source ID) is used to identify an SPT. [IEEE8021aq]

SPBV: SPB VID - The SPB mode where a unique VID is assigned to each SPT Root bridge and is used to identify an SPT. [IEEE8021aq]

SPF: Shortest Path First.

SPT: Shortest Path Tree. [IEEE8021aq]

SRLG: Shared Risk Link Group - A set of links that share a resource whose failure affects each link. [RFC5307]

TAI: Temps Atomique International - International Atomic Time. [IEEE1588]

topology block: Either a maximally two-connected cluster, a cut-link with its endpoints, or an isolated node. [I-D.ietf-rtgwg-mrt-frr-architecture]

TED: Traffic Engineering Database - A database storing the traffic engineering information propagated by IS-IS. [RFC5305]

two-connected: A graph that has no cut-nodes. This is a graph that requires at least two nodes to be removed before gets partitioned. [I-D.ietf-rtgwg-mrt-frr-architecture]

VID: VLAN ID. [IEEE8021Q]

VLAN: Virtual Local Area Network. [IEEE8021Q]

4. Explicit Trees

An explicit tree is determined by a Path Computation Element (PCE) [RFC4655] and is not required to follow the shortest path. A PCE is an entity that is capable of computing a topology for forwarding based on a network topology, its corresponding attributes, and potential constraints. A PCE MUST explicitly describe a forwarding

tree as described in Section 6.1. Either a single PCE or multiple PCEs determine explicit trees for a domain. Even if there are multiple PCEs in a domain, each explicit tree MUST be only determined by one PCE, which is referred to as the owner PCE of the tree. PCEs and IS-IS PCR can be used in combination with IS-IS SPB shortest path routing.

The PCE interacts with the active topology control protocol, i.e. with IS-IS. The collaboration with IS-IS can be provided by a Path Control Agent (PCA) on behalf of a PCE. Either the PCE or the corresponding PCA is part of the IS-IS domain. If the PCE is not part of the IS-IS domain, then the PCE MUST be associated with a PCA that is part of the IS-IS domain. The PCE or its PCA MUST establish IS-IS adjacency in order to receive all the LSPs transmitted by the bridges in the domain. The PCE, either on its own or via its PCA, can control the establishment of explicit trees in that domain by injecting an LSP conveying an explicit tree and thus instruct IS-IS to set up the explicit tree determined by the PCE. If instructed to do so by a PCE, IS-IS MAY also record and communicate bandwidth assignments, which MUST NOT be applied if reservation protocol (e.g. Multiple Stream Registration Protocol (MSRP)) is used in the domain. Both MSRP and IS-IS MUST NOT be used to make bandwidth assignments in the same domain.

The operation details of the PCE are not specified by this document or by IEEE 802.1Qca. If the PCE is part of the IS-IS domain, then the PCE uses IS-IS PDUs to communicate with the IS-IS domain and the PCE has a live IS-IS LSDB, (i.e. the PCE implements the PCA functions too). A PCE can instead communicate with the IS-IS domain via a PCA, e.g. to retrieve the LSDB or instruct the creation of an explicit tree. However, the means of communication between the PCE and the PCA is not specified by this document or by IEEE 802.1Qca.

An Explicit Tree (ET) is an undirected loop-free topology, whose use is under the control of the owner PCE by means of associating VIDs and MAC addresses with it. An ET MUST NOT contain Cycles. As it is undirected, an ET contains no assumptions about the direction of any flows that use it; it can be used in either direction as specified by the VIDs and MAC addresses associated with it. It is the responsibility of the PCE to ensure reverse path congruency and multicast-unicast congruency if that is required.

An explicit tree is either strict or loose. A strict explicit tree specifies all bridges and paths it comprises. A loose tree only specifies the bridges as a list of hops that have a special role in the tree, e.g. a traffic end point, and no path or path segment is specified between the bridges, which are therefore loose hops even if traffic end points are adjacent neighbors. The special role of a hop

can be: traffic end point, root, leaf, a bridge to be avoided, or a transit hop in case of a tree with a single leaf. The path for a loose hop is determined by the Bridge Local Computation Engine (BLCE) of the bridges. The shortest path is used for a loose hop unless specified otherwise by the descriptor (Section 6.1) of the tree or by the corresponding ECT Algorithm (Section 5).

A loose explicit tree is constrained if the tree descriptor includes one or more constraints, e.g. the administrative group that the links of the tree have to belong to. The BLCE of the bridges then apply the Constrained Shortest Path First (CSPF) algorithm, which is Shortest Path First (SPF) on the topology that only contains the links meeting the constraint(s).

An explicit tree is specified by a Topology sub-TLV (Section 6.1). The Topology sub-TLV associates one or more VIDs with an explicit tree. The Topology sub-TLV includes two or more Hop sub-TLVs (Section 6.2), and a hop is specified by an IS-IS System ID. A Hop sub-TLV MAY include a delay constraint for a loose hop. A Topology sub-TLV MAY also include further sub-TLVs to constrain loose hops. The bridges involved in an explicit tree store the corresponding Topology sub-TLVs in their Explicit Tree Database (ETDB).

Explicit trees are propagated and set-up by IS-IS PCR in a domain. The PCE or its PCA assembles the Topology sub-TLVs (Section 6.1), and adds it into an LSP, which is flooded throughout the domain. The Topology sub-TLV is flooded by the same techniques used for the SPB LSPs. The bridges then MUST process the Topology sub-TLV upon reception. If the Topology sub-TLV specifies one or more loose trees, then the path for the loose hops is determined by the BLCE of the bridges. The bridges then install the appropriate FDB entries for frame forwarding along the tree described by the Topology sub-TLV, or the trees computed based on the Topology sub-TLV. Dynamic Filtering Entries are maintained by IS-IS for the VID, MAC address tuples associated with an ET.

Due to the LSP aging of IS-IS, the Topology sub-TLVs (Section 6.1) have to be refreshed similar to other IS-IS TLVs in order to keep the integrity of the LSDB. The corresponding Dynamic Filtering Entries are also refreshed in the FDB when a Topology sub-TLV is refreshed. Refreshing Topology sub-TLVs is the task of the entity being part of the IS-IS domain, i.e. either the PCE or the PCA.

There is no precedence order between Explicit Trees. Precedence order among bandwidth assignments recorded by IS-IS PCR is specified in Section 6.4.

If it is not possible to install an explicit tree, e.g. constraint(s) cannot be met or the Topology sub-TLV is ill-formed, then no tree is installed but a management report is generated.

The bridges MAY support the following IS-IS features for the computation of explicit trees. The Extended IS Reachability TLV (type 22) specified in [RFC5305] provides the following link attribute IS-IS sub-TLVs:

- Administrative Group (color, resource class) (sub-TLV type 3),
- Maximum Link Bandwidth (sub-TLV type 9),
- Maximum Reservable Link bandwidth (sub-TLV type 10),
- Unreserved Bandwidth (sub-TLV type 11),
- Traffic Engineering Default Metric (sub-TLV type 18).

When the Unreserved Bandwidth sub-TLV is used in a Layer 2 bridge network, the priority value encoded in the sub-TLV provides the PCP, i.e. identifies a traffic class (not a setup priority level).

Further attributes are provided by the IS-IS TE Metric Extension link attribute sub-TLVs specified in [I-D.ietf-isis-te-metric-extensions]:

- Unidirectional Link Delay,
- Min/Max Unidirectional Link Delay,
- Unidirectional Delay Variation,
- Unidirectional Link Loss,
- Unidirectional Residual Bandwidth,
- Unidirectional Available Bandwidth,
- Unidirectional Utilized Bandwidth.

The Shared Risk Link Group (SRLG) information provided by the SRLG TLV (type 138) [RFC5307] MAY be also used. In order to indicate that the interface is unnumbered in this case, the corresponding flag takes value 0. The Link Local Identifier is an Extended Local Circuit Identifier and the Link Remote Identifier is a Neighbor Extended Local Circuit ID.

5. Explicit ECT Algorithms

The exact IS-IS control mode of operation MUST be selected for a VLAN by associating its Base VID with the appropriate ECT Algorithm in the SPB Base VLAN-Identifiers sub-TLV [RFC6329], in addition to allocating the Base VID to IS-IS control. There are five distinct ECT Algorithms for the five explicit path control modes. The operation details of the explicit ECT Algorithms and their configuration is specified by IEEE 802.1Qca, a high level overview is given here. An ECT Algorithm value consists of the IEEE 802.1 OUI (Organizationally Unique Identifier) value 00-80-C2 concatenated with an index [RFC6329].

The Strict Tree (ST) ECT Algorithm MUST be used for a strict explicit tree. A strict ET is static as no other entity can update it but the owner PCE. In case of a topology change, it is the task of the owner PCE to detect the topology change, e.g. based on the changes in the LSDB, and to update the strict trees if needed. That is, the owner PCE computes the new tree, assembles its descriptor (Section 6.1), and then instructs IS-IS PCR to install it. The value for the ST ECT algorithm is 00-80-C2-17.

The Loose Tree (LT) ECT Algorithm MAY be also supported. It is used for a single loose explicit tree. The path for loose hops is determined by the BLCE of the bridges; therefore, the Topology sub-TLV (Section 6.1) specifying the tree MUST indicate which hop is the Root of the tree. The loose hops are maintained by IS-IS, i.e. restored upon a topology change if a loop-free path is available. If the tree computed by the BLCE visits the same bridge twice (implying that a loop or hairpin has been created), then that loop or hairpin MUST be pruned from the tree even if it contains a hop specified by the Topology sub-TLV. It is a constraint if a bridge is not to be included, which can be specified by the Exclude flag of a Hop sub-TLV (Section 6.2) conveyed by the Topology sub-TLV specifying the tree. The range of values for the LT ECT Algorithms is 00-80-C2-21...00-80-C2-30.

The Loose Tree Set (LTS) ECT Algorithm MAY be also supported. It is used if connectivity among the traffic end points specified by the Topology sub-TLV (Section 6.1) is to be provided by a set of loose trees such that one tree is rooted at each traffic end point. The BLCE of the bridges compute the loose trees, which are maintained by IS-IS, i.e. restored upon a topology change. One constraint can be to avoid some bridges in these trees, which can be specified by the Exclude flag (item c.6. in Section 6.2). Further constraints can be specified by the Topology sub-TLV. The range of values for the LT ECT Algorithms is 00-80-C2-31...00-80-C2-40.

The LT and LTS ECT Algorithms use the shortest paths after pruning the topology according to the constraint(s) if any. The shortest path tie-breaking specified by Section 12 of [RFC6329] is applied (see also subclauses 28.5 - 28.8 of [IEEE8021aq]), that's why range of values are associated with the LT and LTS ECT Algorithms. In case of the LT ECT Algorithm, the indexes are 0x21...0x30, and ECT-MASK{index-0x20} is applied to retrieve the ECT-MASK of Section 12 of [RFC6329]. In case of the LTS ECT Algorithm, the indexes are 0x31...0x40, and ECT-MASK{index-0x30} is applied to retrieve the ECT-MASK for shortest path tie-breaking.

The MRT ECT Algorithm MAY be also supported. It is used for the establishment and maintenance of MRTs in a distributed fashion. The MRT Lowpoint Algorithm specified by [I-D.ietf-rtgwg-mrt-frr-algorithm] MUST be used for the computation of MRTs. The MRT Lowpoint Algorithm first computes the GADAG then produces two MRTs for each MRT Root: MRT-Blue and MRT-Red. If the level of redundancy provided by each bridge being an MRT Root is not required, then the MRT Roots can be specified by a Topology sub-TLV (Section 6.1). Both the GADAG and the MRT computation steps are performed distributed, i.e. by each bridge. The value for the MRT ECT algorithm is 00-80-C2-18.

The MRT GADAG (MRTG) ECT Algorithm MAY be also supported. It splits the computation into two. As the GADAG is identical for each MRT within a domain, it is computed by a single entity, which is the GADAG Computer. The GADAG is then described in a Topology sub-TLV (Section 6.1), which is flooded in the domain. The bridges then compute the MRTs for the MRT Roots based on the GADAG received. Section 7 provides more details on the description of the GADAG. The value for the MRTG ECT algorithm is 00-80-C2-19.

MRTs are loose trees as bridges are involved in their computation and restoration. Thus both the MRT and the MRTG ECT Algorithms provide a set of loose trees: two MRTs for each MRT Root.

6. IS-IS PCR sub-TLVs

The following sub-TLVs are specified for IS-IS PCR. The Topology sub-TLV MUST be carried in an MT-Capability TLV, the rest of the sub-TLVs are conveyed by Topology sub-TLV.

6.1. Topology sub-TLV

The variable length Topology sub-TLV MUST be used to describe an explicit tree. The Topology sub-TLV MAY be also used for describing a Generalized Almost Directed Acyclic Graph (GADAG) as explained in Section 7 in detail. The Topology sub-TLV MUST be carried in an MT-

Capability TLV (type 144) [RFC6329] in a Link State PDU. A Topology sub-TLV specifying an explicit tree conveys one or more Base VIDs, two or more Hop sub-TLVs (Section 6.2). A Topology sub-TLV describing a loose tree MAY also convey further sub-TLVs to specify constraints. Figure 1 shows the format of the Topology sub-TLV.

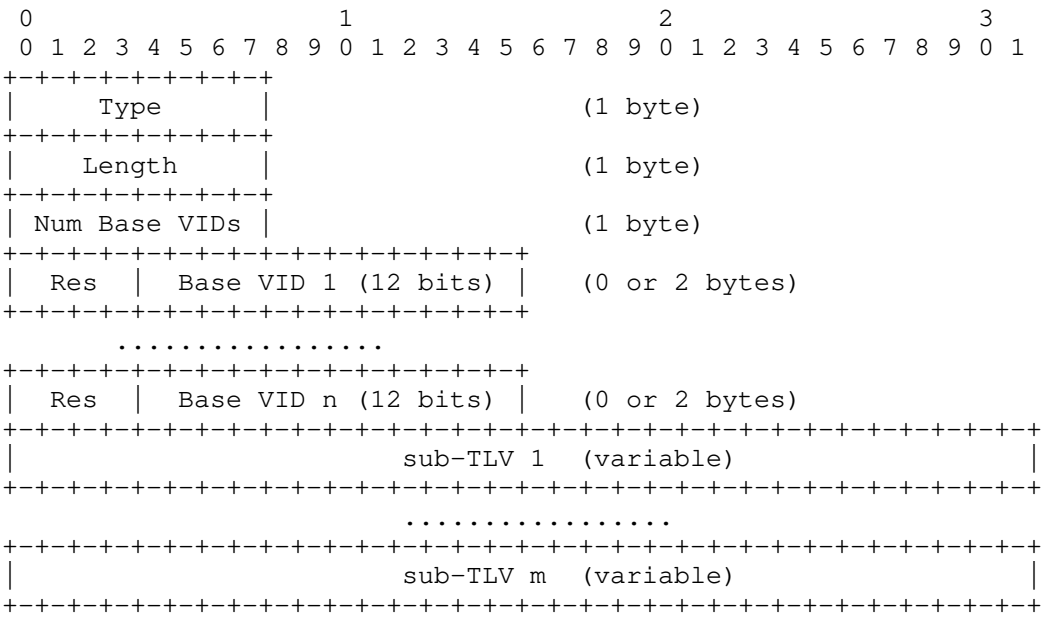

Figure 1: Topology sub-TLV

The parameters of explicit trees are encoded by the Topology sub-TLV as follows:

a. Type (8 bits): The type of the sub-TLV, its value is TBD.

b. Length (8 bits): The total number of bytes contained in the Value field.

c. Number of Base VIDs (8 bits): The number of Base VIDs carried in the Topology sub-TLV. Its minimum value is 1 if the Topology sub-TLV specifies one or more explicit trees. Its value can be 0 if the Topology sub-TLV specifies a GADAG.

d. Reserved (Res) (4 bits): The reserved bits take value 0.

e. Base VID (12 bits): The Base VID parameter provides the Base VID of the VLAN that is associated with the explicit tree. Multiple Base VIDs can be associated with the same explicit tree. In

addition to the Base VID, some of the explicit ECT Algorithms (Section 5) require further VIDs which are associated with the VLAN via the SPB Instance sub-TLV [RFC6329]. A Topology sub-TLV specifying a GADAG can have zero Base VID parameters. In this case, the given GADAG MUST be applied for each VLAN associated with the MRTG ECT Algorithm (Section 5).

f. sub TLVs: The rest conveys further sub-TLVs that specify the hops of the topology and can also specify constraints as described in the following.

A topology is specified by a list of Hop sub-TLVs (Section 6.2), and a hop is specified by an IS-IS System ID. An ill-formed Topology sub-TLV, e.g. specifying an invalid or inconsistent tree is ignored, no tree is installed but a management report is generated.

The Topology sub-TLV specifies a strict tree by decomposing the tree to branches. Each branch is a point-to-point path specified by an ordered list of hops where the end of each branch is a leaf. Each element of a branch is the direct link between adjacent neighbor bridges whose Hop sub-TLV is next to each other in the Topology sub-TLV. The first hop of the Topology sub-TLV is the root, hence, the first branch originates from the root. The rest of the branches fork from another branch. The first hop of a branch is a bridge that is already part of a former branch and the last hop is a leaf bridge. Therefore, the hop after a leaf hop is the beginning of a new branch, if any. A hop of a branch is created if and only if the bridge specified for that hop is directly connected to the preceding bridge of the same branch. The first branch MUST begin with the root and after that the order of the branches does not matter within the Topology sub-TLV. Figure 2 shows an example strict tree and its description.

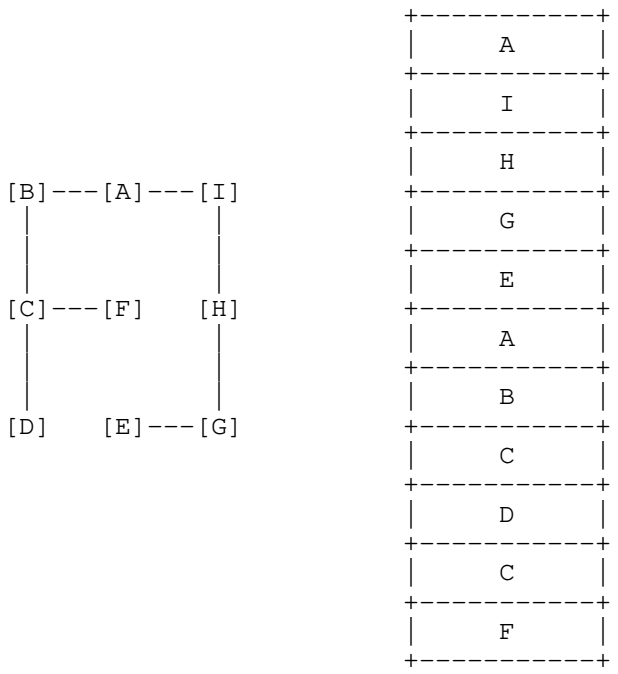

Figure 2: A strict tree and its description; root = Node A

The Topology sub-TLV of a loose tree does not provide any path or path segment, but the hops which are to participate. The root MUST be the first hop. The leaves of a single loose tree MUST be also specified. Hop sub-TLVs can be included in a Topology sub-TLV to specify bridges that have to be avoided. If the Topology sub-TLV only specifies a single leaf, then one or more transit hops can be specified by the Topology sub-TLV to direct the path along a sequence of bridges, specified by the order of hops. If bridges whose respective Hop sub-TLVs are adjacent to each other in the Topology sub-TLV but are not topology neighbors, then it is a loose hop. If a Topology sub-TLV conveys one or more loose hops, then that sub-TLV defines a loose explicit tree and each hop is considered as a loose hop. The path of a loose hop MUST be pruned from the tree if the path would create a loop or hairpin.

If the Base VIDs of the Topology sub-TLV are associated with the LTS ECT Algorithm or the MRT ECT Algorithm, then the Hop sub-TLVs conveyed by the Topology sub-TLV belong to traffic end points or bridges to be excluded. The BLCEs compute the loose trees, e.g. MRTs, such that they span the traffic end points and are rooted at a traffic end point.

The Topology sub-TLV specifies a GADAG if the Base VIDs conveyed by the Topology sub-TLV are associated with the MRTG ECT Algorithm. Section 7 provides the details on the description of a GADAG by a Topology sub-TLV.

Each traffic end point of an explicit tree MUST be always specified in the Topology sub-TLV by the inclusion of the Hop sub-TLVs corresponding to the traffic end points. The traffic end points of a tree are identified by setting the Traffic End Point flag (item c.3. in Section 6.2) in the appropriate Hop sub-TLVs.

If the explicit tree is loose, then the Topology sub-TLV MAY convey further sub-TLVs to specify constraints, e.g. an Administrative Group sub-TLV [RFC5305] or a Bandwidth Constraint (Section 6.3). If it is not possible to meet the constraint(s) specified by the Topology sub-TLV, then no tree is installed but a management report is generated.

If IS-IS PCR is used for recording bandwidth assignment, then the Topology sub-TLV conveys Bandwidth Assignment sub-TLV (Section 6.4) and it can also convey Timestamp sub-TLV (Section 6.5). If the bandwidth assignment specified by the Topology sub-TLV is not possible, e.g. due to overbooking, then bandwidth assignment MUST NOT be performed and a management report is generated. If the Topology sub-TLV specifies a new valid explicit tree, then the tree is installed without bandwidth assignment.

6.2. Hop sub-TLV

The Hop sub-TLV MUST be used to specify a hop of a topology. Each Hop sub-TLV conveys an IS-IS System ID, which specifies a hop. A Hop sub-TLV is conveyed by a Topology sub-TLV (Section 6.1). A strict explicit tree is decomposed to branches where each branch is a point-to-point path specified by an ordered list of Hop sub-TLVs as specified in Section 6.1. A hop of a branch is created if and only if the bridge specified for that hop is directly connected to the preceding bridge in the path. That is, a point-to-point LAN is identified by the two bridges it interconnects; and the LAN is part of the strict tree if and only if the Hop sub-TLVs of the two bridges are next to each other in the Topology sub-TLV. A Hop sub-TLV can convey a Circuit ID in order to distinguish multiple links between adjacent neighbor bridges. A Hop sub-TLV also specifies the role of a bridge, e.g. if it is the root or a traffic end point. The Topology sub-TLV of a loose tree only comprises the Hop sub-TLV of the bridges that have special role in the tree. The Hop sub-TLV MAY also specify a delay budget for a loose hop.

By default, the traffic end points both transmit and receive with respect to each VID associated with an explicit tree, except for an

LTS (Section 5) associated with a learning VLAN, which uses a unidirectional VID per bridge. The Hop sub-TLV allows different configuration by means of the Transmit (T) and Receive (R) flags conveyed in the sub-TLV. The VID and its T/R flags are only present in the Hop sub-TLV if the behavior of the traffic end points differs from the default.

Figure 3 shows the format of the variable length Hop sub-TLV, which MUST be conveyed by a Topology sub-TLV (Section 6.1).

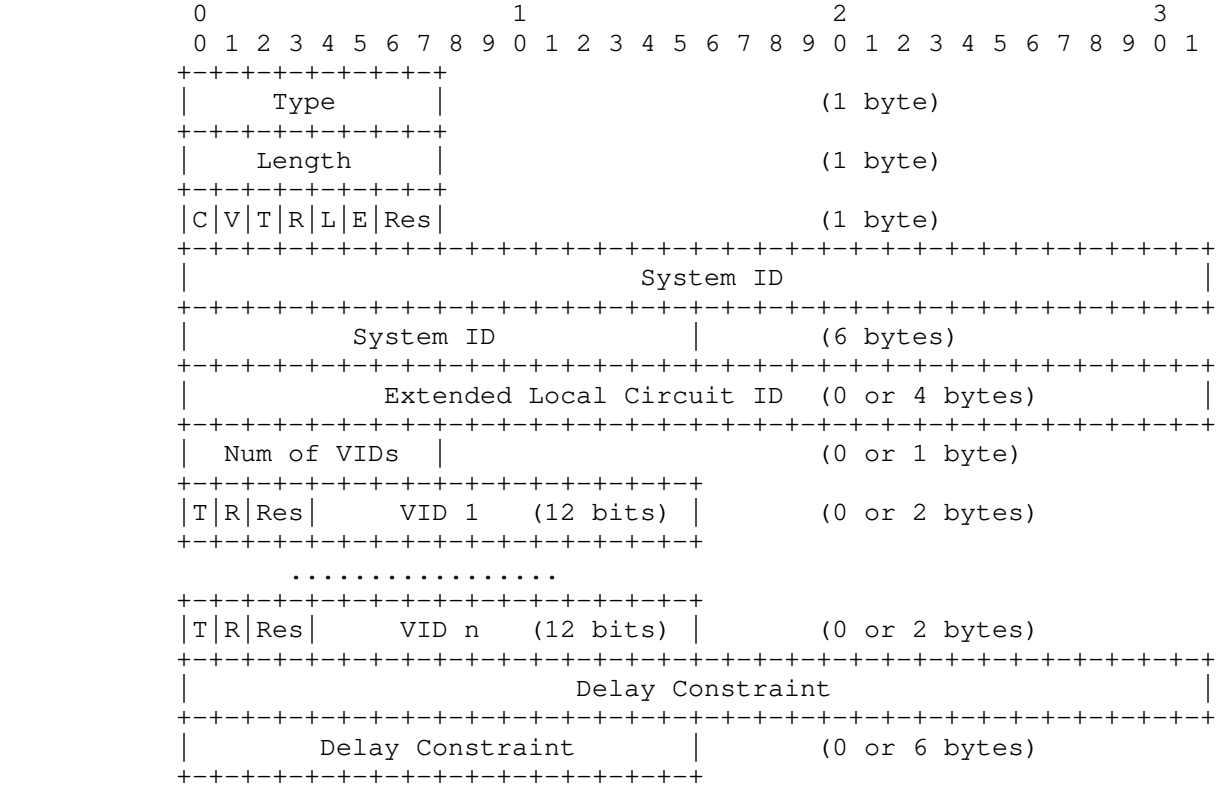

Figure 3: Hop sub-TLV

The parameters of a hop are encoded as follows:

a. Type (8 bits): The type of the sub-TLV, its value is TBD.

b. Length (8 bits): The total number of bytes contained in the Value field.

c. Hop Flags (8 bits): The Hop sub-TLV conveys six one-bit flags. The Circuit and the VID flags influence the length of the Hop sub-TLV. Two bits are reserved for future use, transmitted as 0 and ignored on receipt.

   1. Circuit (C) flag (1 bit): The Circuit flag is a one-bit flag to indicate whether or not the Extended Local Circuit ID parameter is present. If the flag is set, then an Extended Local Circuit ID is also included in the Hop sub-TLV.

   2. VID (V) flag (1 bit): The VID flag is a one-bit flag to indicate whether or not one or more VIDs are conveyed by the Hop sub-TLV. If the flag is set, then the Number of VIDs parameter is present and indicates how many VIDs are conveyed by the Hop sub-TLV. If the VID flag is reset, then neither the Number of VIDs parameter nor VIDs are present in the Hop sub-TLV.

   3. Traffic End Point (T) flag (1 bit): The Traffic End Point flag is a one-bit flag to indicate whether or not the given System is a traffic end point, i.e. transmitter and/or receiver. If the System is a traffic end point, then the Traffic End Point flag MUSt be set. (The Traffic End Point flag indicates whether FDB entries are to be installed for the given hop.)

   4. Root (R) flag (1 bit): The Root flag is a one-bit flag to indicate whether or not the given System is a Root of the explicit tree specified by the Topology sub-TLV. If the System is a root of a tree, then the Root flag MUST be set. If the Topology sub-TLV specifies a single tree, i.e. the Base VIDs conveyed by the Topology sub-TLV are associated with either the ST ECT Algorithm or the LT ECT Algorithm (Section 5), then the Root flag is only set for one of the Systems conveyed by the Topology sub-TLV. Furthermore, the first Hop sub-TLV of the Topology sub-TLV conveys the System that is the root of the tree. If the Topology sub-TLV specifies a Loose Tree Set, i.e. the Base VIDs conveyed by the Topology sub-TLV are associated with the LTS ECT Algorithm (Section 5), then the Root flag is set for each traffic end point as each of them roots a tree. If the Topology sub-TLV is used for MRT operations, i.e. the Base VIDs conveyed by the Topology sub-TLV are associated with either the MRT ECT Algorithm or the MRTG ECT Algorithm (Section 5), then the Root flag is set for each MRT Root. If no MRT Root is specified by a Topology sub-TLV specifying a GADAG, then each SPT Root is an MRT Root as well. If the Base VIDs conveyed by the Topology sub-TLV are associated

with the MRTG ECT Algorithm (Section 5), then the Topology sub-TLV specifies a GADAG and the very first Hop sub-TLV specifies the GADAG Root. There is no flag for indicating the GADAG Root.

5. Leaf (L) flag (1 bit): The Leaf flag is a one-bit flag to indicate whether or not the given System is a Leaf of the explicit tree specified by the Topology sub-TLV. If the System is a Leaf, then the Leaf flag MUST be set. The Leaf flag is only used to mark a leaf of a tree if the Topology sub-TLV specifies a single tree. The Leaf flag MUST be used to indicate the end of a topology block if the Topology sub-TLV specifies a GADAG, see Section 7.

6. Exclude (E) flag (1 bit): The Exclude flag is a one-bit flag to indicate if the given System MUST be excluded from the topology. The Exclude flag and the Root flag cannot be set for a given hop at the same time.

7. Reserved (Res) (2 bits): The reserved bits take value 0.

d. System ID (48 bits): The 6-byte IS-IS System Identifier of the bridge that the Hop sub-TLV refers to.

e. Extended Local Circuit ID (32 bits): The Extended Local Circuit ID [RFC5303] parameter is not necessarily present in the Hop sub-TLV. Its presence is indicated by the Circuit flag. Parallel links corresponding to different IS-IS adjacencies between a pair of neighbor bridges can be distinguished by means of the Extended Local Circuit ID. The Extended Local Circuit ID is conveyed by the Hop sub-TLV specifying the bridge nearer to the root of the tree, and identifies a circuit that attaches the given bridge to its neighbor cited by the next Hop sub-TLV of the Topology sub-TLV. The Extended Local Circuit ID can only be used in strict trees.

f. Number of VIDs (8 bits): The Number of VIDs parameter is not present if the Hop sub-TLV does not convey VIDs, which is indicated by the VID flag.

g. VID and its T/R flags (14 bits): The VID and its T/R flags are only present in the Hop sub-TLV if the given bridge is a traffic end point and it behaves differently from the default with respect to that particular VID.

1. T flag (1 bit): This is the Transmit allowed flag for the VID following the flag.

2. R flag (1 bit): This is the Receive allowed flag for the VID following the flag.

3. Reserved (Res) (2 bits): The reserved bits take value 0.

4. VID (12 bits): A VID.

h. Delay Constraint (48 bits): The last six bytes specify a delay constraint if they convey a Unidirectional Link Delay sub-TLV [I-D.ietf-isis-te-metric-extensions]. The delay constraint MAY be used in a Topology sub-TLV that specifies a single loose tree, i.e. the Base VIDs are associated with the LT ECT Algorithm (Section 5). If delay constraint is applied, then the loose hop MUST fit in the delay budget specified by the Delay parameter of the Unidirectional Link Delay sub-TLV conveyed by the Hop sub-TLV. If the Topology sub-TLV specifies a single leaf, then the path between the preceding Hop sub-TLV and the current Hop sub-TLV MUST meet the delay budget. If the Topology sub-TLV specifies multiple leaves, then the path between the root and the current Hop sub-TLV MUST to meet the delay budget. If the tree is used as a reverse congruent tree, then the delay constraint applies in both directions. If the tree is used as a directed tree, then the delay constraint applies in the direction of the tree. If it is not possible to meet the delay constraint specified by the Topology sub-TLV, then no tree is installed but a management report is generated.

6.3. Bandwidth Constraint sub-TLV

The Bandwidth Constraint sub-TLV MAY be included in a Topology sub-TLV (Section 6.1) in order to specify how much available bandwidth is to be provided by the constrained tree. Each loose hop MUST meet the bandwidth constraint. The bandwidth value of the constraint is a total value or it only refers to a single PCP as specified by the sub-TLV. Figure 4 shows the format of the Bandwidth Constraint sub-TLV.

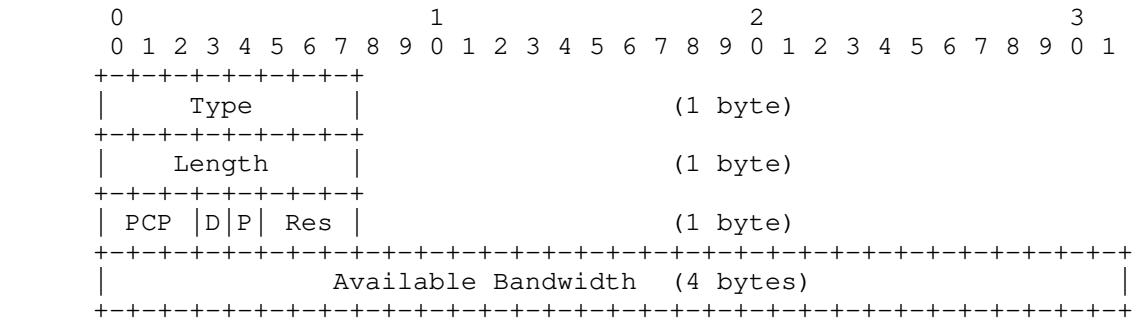

Figure 4: Bandwidth Constraint sub-TLV

The parameters of the bandwidth constraint are encoded as follows:

a. Type (8 bits): The type of the sub-TLV, its value is TBD.

b. Length (8 bits): The total number of bytes contained in the Value field. The value of the Length field is 5 bytes.

c. PCP (4 bits): The Priority Code Point (PCP) parameter identifies the traffic class the Available Bandwidth parameter refers to, if any.

d. DEI (D) (1 bit): This is the Drop Eligible Indicator (DEI) parameter. If the DEI parameter is clear, then the bandwidth constraint refers to committed information rate. If the DEI parameter is set, then the bandwidth constraint refers to peak information rate.

e. PCP (P) flag (1 bit): If this flag is set, then the PCP parameter is taken into account.

f. Reserved (Res) (3 bits): The reserved bits take value 0.

g. Available Bandwidth (32 bits): The Available Bandwidth is specific to the traffic class identified by the PCP parameter if the PCP flag is set, otherwise, it is total bandwidth. In-line with the bandwidth parameters specified in [RFC5305], the Available Bandwidth is encoded as a 32-bit IEEE floating point number, and the units are bytes (not bits!) per second. When the Unreserved Bandwidth sub-TLV (sub-TLV type 11 specified by [RFC5305]) is used in a Layer 2 bridge network, the priority value encoded in the Unreserved Bandwidth sub-TLV provides the PCP, i.e. identifies a traffic class (not a setup priority level). Thus, the Available Bandwidth of a traffic class is easily comparable with the Unreserved Bandwidth stored in the TED

for the given traffic class. The bandwidth constraint applies for both directions in case of symmetric explicit trees. Nevertheless, a VID associated with an explicit tree can be made unidirectional by means of the T/R flags belonging to the VID in the Hop sub-TLV (item g. in Section 6.2) of the traffic end points. If all the VIDs of the Topology sub-TLV (Section 6.1) are unidirectional and all belong to the traffic class identified by the PCP parameter of the Bandwidth Constraint sub-TLV, then it is enough to meet the bandwidth constraint in the direction applied for those VIDs.

6.4. Bandwidth Assignment sub-TLV

IS-IS PCR MAY be used for recording bandwidth assignment for explicitly placed data traffic in a domain if MSRP is not used within the domain. If MSRP is used in a domain, then only MSRP performs reservations. Both MSRP and IS-IS MUST NOT be used to make bandwidth assignments in the same domain.

The Bandwidth Assignment sub-TLV can be used to define the amount of bandwidth whose assignment is to be recorded by IS-IS PCR at each hop of the explicit tree described by the corresponding Topology sub-TLV (Section 6.1). The Bandwidth Assignment sub-TLV is used by IS-IS PCR for the recording of bandwidth assignment for a traffic class identified by the PCP parameter of a VLAN tag. If precedence order has to be determined among bandwidth assignments in a domain with multiple PCEs, then IS-IS PCR does it as described below. If the bandwidth assignment specified by the Topology sub-TLV is not possible, e.g. due to overbooking, then bandwidth recording MUST NOT be performed and a management report is generated. If the Topology sub-TLV specifies a new valid explicit tree, then the tree is installed without bandwidth assignment. The Bandwidth Assignment sub-TLV is conveyed by a Topology sub-TLV (Section 6.1). Figure 5 shows the format of the Bandwidth Assignment sub-TLV.

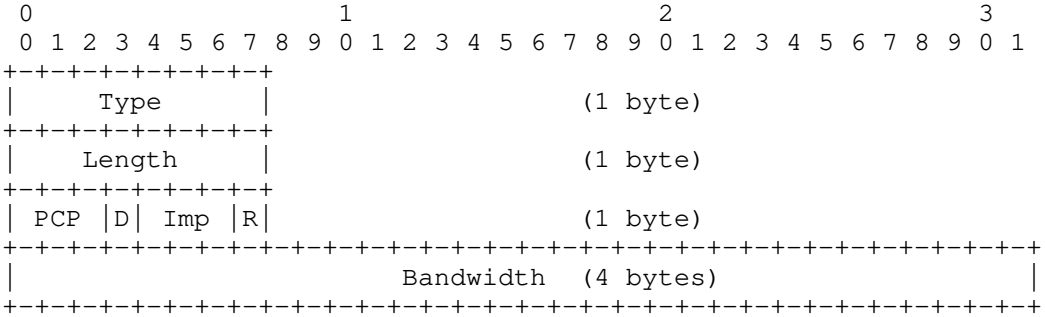

Figure 5: Bandwidth Assignment sub-TLV

The parameters of the bandwidth constraint are encoded as follows:

a. Type (8 bits): The type of the sub-TLV, its value is TBD.

b. Length (8 bits): The total number of bytes contained in the Value field. The value of the Length field is 5 bytes.

c. PCP (3 bits): The PCP parameter identifies the traffic class the bandwidth to be assigned for.

d. DEI (D) (1 bit): This is the Drop Eligible Indicator (DEI) parameter. If the DEI parameter is clear, then the bandwidth assignment is performed for providing committed information rate. If the DEI parameter is set, then the bandwidth assignment is performed for providing peak information rate.

e. Importance (Imp) (3 bits): This is the Importance parameter for determining precedence order among bandwidth assignments within a PCP as described below. Lower numerical value indicates more important bandwidth assignment within a PCP. The default value of the Importance parameter is 7.

f. Reserved (R) (1 bit): The reserved bit takes value 0.

g. Bandwidth (32 bits): This is the amount of bandwidth to be assigned for the traffic class identified by the PCP parameter. In-line with the bandwidth values specified in [RFC5305], the Bandwidth parameter is encoded as a 32-bit IEEE floating point number, and the units are bytes (not bits!) per second. The bandwidth assignment applies for both directions in case of symmetric explicit trees.

The PCEs are collectively responsible for making a consistent set of bandwidth assignments when IS-IS PCR is used for recording bandwidth allocations. If despite of that, precedence ordering is required among bandwidth assignments, then ordering based on the following parameters MUST be applied:

1. PCP parameter of Bandwidth Assignment sub-TLV,

2. Importance parameter of Bandwidth Assignment sub-TLV,

3. Timestamp sub-TLV (if present in the Topology sub-TLV).

A bandwidth assignment takes precedence if it has higher PCP, or higher Importance within a PCP, or earlier timestamp in case of equal Importance within a PCP. A bandwidth assignment associated with a timestamp takes precedence over a bandwidth assignment without

timestamp. If resolution is not possible based on the above parameters or they are not available, e.g. each bandwidth assignment lacks timestamp or the same VID is called for, then the item is granted to the PCE whose LSP has the numerically least LSP ID.

6.5. Timestamp sub-TLV

The Timestamp sub-TLV MAY be included in a Topology sub-TLV (Section 6.1) in order to provide precedence order among equally important bandwidth assignments within a PCP as described in Section 6.4. Figure 6 shows the format of the Timestamp sub-TLV.

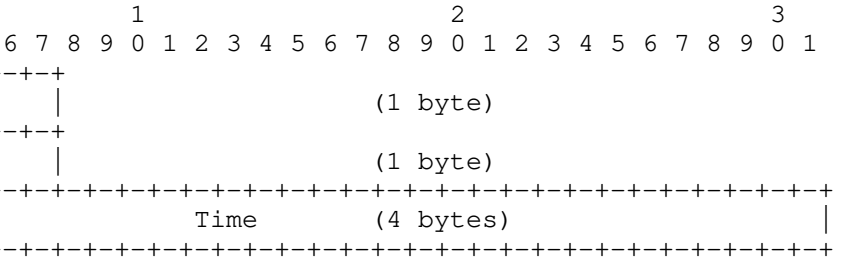

Figure 6: Timestamp sub-TLV

The timestamp represents a positive time with respect to the Precision Time Protocol (PTP) epoch and it is encoded as follows:

a. Type (8 bits): The type of the sub-TLV, its value is TBD.

b. Length (8 bits): The total number of bytes contained in the Value field. The value of the Length field is 4 bytes.

c. Time (32 bits): This is the time in units of seconds with respect to the PTP epoch.

The Timestamp sub-TLV carries the seconds portion of PTP as specified by [IEEE1588]. The epoch is 1970-01-01 00:00:00 TAI (i.e., the PTP time does not include leap seconds).

7. MRT-FRR Application

The application of MRT by [IEEE8021Qca] is discussed in detail in [I-D.bowers-rtgwg-mrt-applicability-to-8021qca]. This section describes some special considerations for the use of the MRT Lowpoint Algorithm [I-D.ietf-rtgwg-mrt-frr-algorithm], which are applicable both to the MRT ECT Algorithm and the MRTG ECT Algorithm. This section also explains details related to the MRTG ECT Algorithm and the application of the Topology sub-TLV in particular.

The SPB Link Metric sub-TLV [RFC6329] specifies the metric of each link for IS-IS PCR including the MRT Algorithms. If the SPB Link Metric values advertised by different ends of an adjacency are different, then the maximum value MUST be used. If equal cost (sub)paths are found during the MRT computation, then the default tie-breaking specified by Section 11 of [RFC6329] MUST be used, which is based on the lower Bridge ID. (The BridgeID is an 8-byte quantity whose upper 2 bytes are the node's BridgePriority and lower 6 bytes are the node's SYSID.) Note also that if MRTs are used for source specific multicast (see [IEEE8021Qca] for details), then the bridges have to compute the MRTs of the other bridges in addition to their own one in order to be able to install the appropriated FDB entries. (This is similar to the need for all pairs shortest path computation instead of Dijkstra for source specific shortest path multicast trees.)

The GADAG is identical for all the MRTs within a network domain, as a consequence of the use of the MRT Lowpoint Algorithm [I-D.ietf-rtgwg-mrt-frr-algorithm]. Therefore, it is beneficial to compute the GADAG by a single entity, which is referred to as the GADAG Computer and is either a PCE or the GADAG Root. If the MRTG ECT Algorithm is applied, then the GADAG MUST be only computed by the GADAG Computer, which then MUST flood the descriptor Topology sub-TLV of the GADAG. The bridges then compute the MRTs based on the received GADAG.

The GADAG computation requires the selection of the GADAG Root. The bridge with the best Bridge Identifier MUST be selected as the GADAG Root, where the numerically lower value indicates the better identifier. The Bridge Priority component of the Bridge Identifier allows the configuration of the GADAG Root by management action. The Bridge Priority is conveyed by the SPB Instance sub-TLV [RFC6329].

The GADAG Computer MUST perform the GADAG computation as specified by the MRT Lowpoint Algorithm [I-D.ietf-rtgwg-mrt-frr-algorithm]. The GADAG Computer then MUST encode the GADAG in a Topology sub-TLV (Section 6.1), which is then flooded throughout the domain. A GADAG is encoded in a Topology sub-TLV by means of directed ear decomposition as follows. A directed ear is a directed point-to-point path whose end points can coincide but no other element of the path is repeated in the ear. Each ear is specified by an ordered list of hops such that the order of hops is according to the direction of the arcs in the GADAG. There are no leaves in a GADAG, hence, the Leaf flag (item c.5. in Section 6.2) is used to mark the end of a topology block. (A GADAG with multiple blocks is illustrated in Figure 8.) The sequence of ears in the Topology sub-TLV is such that the end points of an ear belong to preceding ears. The GADAG Root is not marked by any flag but the GADAG Root is the

first hop in the Topology sub-TLV, correspondingly the first ear starts and ends with the GADAG Root. MRT Roots MUST be marked by the Root flag (item c.4. in Section 6.2) and all other traffic end points are leaves of the given MRTs. If no MRT Root is specified, then each SPT Root is also an MRT Root.

Figure 7 shows an example GADAG. The figure also illustrates the description of the GADAG, it shows the System ID parameter of the Hop sub-TLV (Section 6.2) and the order of hops in the Topology sub-TLV (Section 6.1).

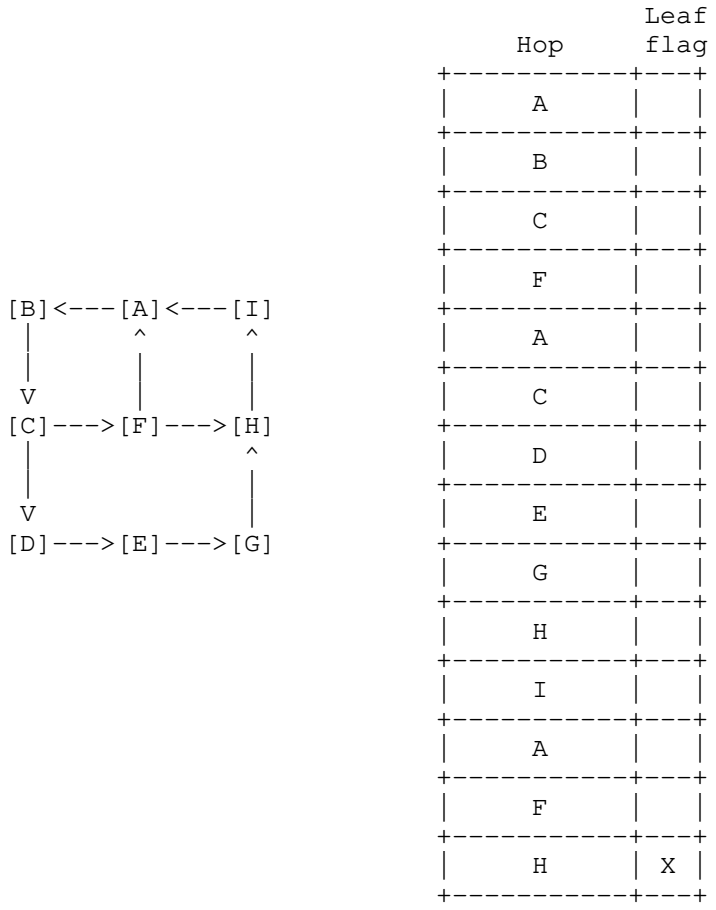

Figure 7: A GADAG and its description; GADAG root = Node A

A topology can be comprised of multiple blocks, like the one illustrated in Figure 8(a). This example topology is comprised of four blocks as each cut-link is a block. A-B-C-D-E-F is a block, D-G

is another block, G-H, and H-J-K are further blocks. The GADAG for this topology is shown in Figure 8(b). Note that the GADAG includes two arcs for each cut-link and the direction of each arc is different, e.g. D->G and G->D. The encoding starts with the Block (ADAG) involving the GADAG Root as illustrated in Figure 8. The first hop in the Topology sub-TLV is the GADAG Root (node A in this example.) The ADAG of the first block is then described using the ear decomposition, as described above. In this example, the first block has been completely traversed at the second occurrence of node A in the GADAG descriptor. The end of a block is indicated by setting the Leaf flag for the last hop of the block, e.g. for the second occurrence of node A in the example GADAG descriptor. The next node that appears in the GADAG descriptor (D in this case) is the localroot for the nodes in the next block. Continuing this process, the Leaf flag is set for the third occurrence of D, the third occurrence of G, and the third occurrence of H, each indicating the end of a block. The first hop of the first block is the GADAG Root, the fist hop in the rest of the blocks is the localroot. The position of the set Leaf flags helps to determine the localroot, which is the next hop. In the example GADAG descriptor, one can determine that A is the localroot for B,C,D,E,F (and A is the GADAG Root). D is the localroot for G. G is the localroot for H. And H is the localroot for J and K. The GADAG Root is assigned a localroot of None.

Block IDs are reconstructed while parsing a Topology sub-TLV specifying a GADAG. The current Block ID starts at 0 and is assigned to the GADAG Root. A node appearing in the GADAG descriptor without a previously-assigned Block ID value is assigned the current Block ID. And the current Block ID is incremented by 1 after processing the localroot of a block. Note that the localroot of a block will keep the Block ID of the first block in which it is assigned a Block ID. In the example in Figure 8, A has Block ID=0. B, C, D, E, and F have Block ID=1. G has Block ID=2. H has Block ID=3. J and K have Block ID=4.

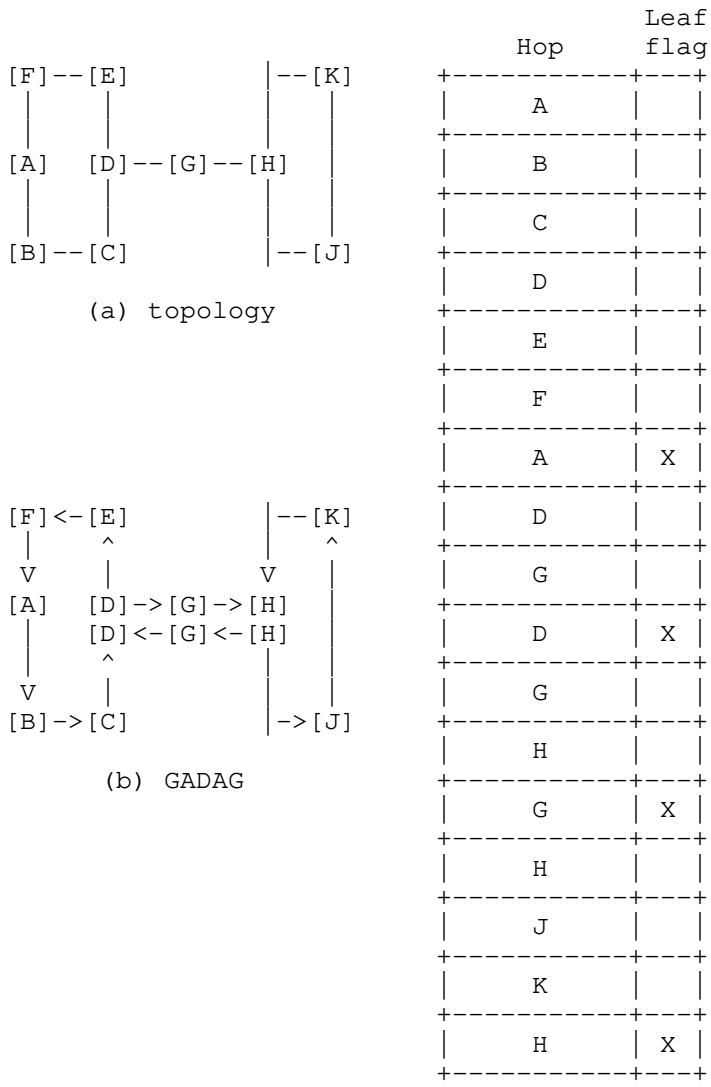

Figure 8: A GADAG with cut-links and its description; GADAG root = Node A

8. Summary

This document specifies IS-IS sub-TLVs for the control of explicit trees in Layer 2 networks. These sub-TLVs can be also used for the

distribution of a centrally computed GADAG or MRTs if MFT-FRR is used.

9. IANA Considerations

Five new code points are required within MT-Capability [RFC6329] for the five new sub-TLVs:

- Topology sub-TLV
- Hop sub-TLV
- Bandwidth Constraint sub-TLV
- Bandwidth Assignment sub-TLV
- Timestamp sub-TLV

10. Security Considerations

This document adds no additional security risks to IS-IS, nor does it provide any additional security for IS-IS when used in a configured environment or a single-operator domain such as a data center. IS-IS PCR is not for zero configuration environments.

However, if IS-IS PCR is used to record bandwidth assignments in a network with multiple PCEs, then race conditions can appear and the precedence can be resolved by Importance parameter of the Bandwidth Assignment sub-TLV and the Time parameter of the Timestamp sub-TLV, especially if the different PCEs are administered by different entities.

11. Acknowledgements

The authors would like to thank Don Fedyk and Eric Gray for their comments and suggestions.

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12.1. Normative References

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IS-IS Prefix Attributes for Extended IP and IPv6 Reachability
draft-ginsberg-isis-prefix-attributes-01.txt

Abstract

This document introduces new sub-TLVs to support advertisement of prefix attribute flags and the source router id of the router which originated a prefix advertisement.

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

There are existing use cases in which knowing additional attributes of a prefix is useful. For example, it is useful to know whether an advertised prefix is directly connected to the advertising router or not. In the case of [SR] knowing whether a prefix is directly connected or not determines what action should be taken as regards

processing of labels associated with an incoming packet. Current formats of the Extended Reachability TLVs for both IP and IPv6 are fixed and do not allow the introduction of additional flags without backwards compatibility issues. Therefore a new sub-TLV is introduced which allows for the advertisement of attribute flags associated with prefix advertisements.

It is also useful to know the source of a prefix advertisement when the advertisement has been leaked to another level. Therefore a new sub-TLV is introduced to advertise the router-id of the originator of a prefix advertisement.

2. New sub-TLVs for Extended Reachability TLVs

The following new sub-TLVs are introduced:

- IPv4/IPv6 Extended Reachability Attributes
- IPv4 Source Router ID
- IPv6 Source Router ID

All sub-TLVs are applicable to TLVs 135, 235, 236, and/or 237.

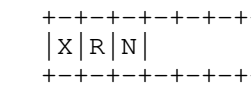
2.1. IPv4/IPv6 Extended Reachability Attribute Flags

This sub-TLV supports the advertisement of additional flags associated with a given prefix advertisement. The behavior of each flag when a prefix advertisement is leaked from one level to another (upwards or downwards) is explicitly defined below.

All flags are applicable to TLVs 135, 235, 236, 237 unless otherwise stated.

Prefix Attribute Flags
Type: 4 (suggested - to be assigned by IANA)
Length: Number of octets to follow
Value

(Length * 8) bits.



Bits are defined/sent starting with Bit #0 defined below. Additional bit definitions which may be defined in the future SHOULD be assigned in ascending bit order so as to minimize the number of bits which will need to be transmitted.

Undefined bits SHOULD be transmitted as 0 and MUST be ignored on receipt.

Bits which are NOT transmitted MUST be treated as if they are set to 0 on receipt.

X-Flag: External Prefix Flag (Bit 0)
Set if the prefix has been redistributed from another protocol. This includes the case where multiple virtual routers are supported and the source of the redistributed prefix is another IS-IS instance.
The flag is preserved when leaked between levels.
In TLVs 236 and 237 this flag SHOULD always be sent as 0 and MUST be ignored on receipt. This is because there is an existing X flag defined in the fixed format of these TLVs as specified in [RFC5308] and [RFC5120].

R-Flag: Re-advertisement Flag (Bit 1)
Set when the prefix has been leaked from one level to another (upwards or downwards).

N-flag: Node Flag (Bit 2)
Set when the prefix identifies the advertising router i.e., the prefix is a host prefix advertising a globally reachable address typically associated with a loopback address.
The advertising router MAY choose to NOT set this flag even when the above conditions are met.
If the flag is set and the prefix length is NOT a host prefix (/32 for IPV4, /128 for IPv6) then the flag MUST be ignored.
The flag is preserved when leaked between levels.

2.2. IPv4/IPv6 Source Router ID

When a reachability advertisement is leaked from one level to another, the source of the original advertisement is unknown. In cases where the advertisement is an identifier for the advertising router (e.g., N-flag set in the Extended Reachability Attribute sub-TLV as described in the previous section) it may be useful for other routers to know the source of the advertisement. The sub-TLVs defined below provide this information.

IPv4 Source Router ID
Type: 11 (suggested - to be assigned by IANA)
Length: 4
Value: IPv4 Router ID of the source of the advertisement

Inclusion of this TLV is optional and MAY occur in TLVs 135, 235, 236, or 237.

If present the sub-TLV MUST be included when the prefix advertisement is leaked to another level.

IPv6 Source Router ID
Type: 12 (suggested - to be assigned by IANA)
Length: 16
Value: IPv6 Router ID of the source of the advertisement

Inclusion of this TLV is optional and MAY occur in TLVs 135, 235, 236, or 237.

If present the sub-TLV MUST be included when the prefix advertisement is leaked to another level.

3. IANA Considerations

This document adds the following new sub-TLVs to the registry of sub-TLVs for TLVs 135, 235, 236, 237.

Value: 4 (suggested - to be assigned by IANA)

Name: Prefix Attribute Flags

Value: 11 (suggested - to be assigned by IANA)

Name: IPv4 Source Router ID

Value: 12 (suggested - to be assigned by IANA)

Name: IPv6 Source Router ID

This document also introduces a new registry for bit values in the Prefix Attribute Flags sub-TLV. Registration policy is Expert Review as defined in [RFC5226]. Defined values are:

Bit #	Name
0	External Prefix Flag
1	Re-advertisement Flag
2	Node Flag

4. Security Considerations

None.

5. Acknowledgements

TBD

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6.2. Informational References

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ISIS Link Overload
draft-hegde-isis-link-overload-00

Abstract

Many ISIS deployments run on overlay networks provisioned by means of pseudo-wires or L2-circuits. when the devices in the underlying network go for maintenance, it is useful to divert the traffic away from the specific node(s), to some alternate paths, before the maintenance is actually scheduled. Since the nodes in the underlying network are not visible to ISIS, existing Avoidance of traffic blackhole mechanism described in [RFC3277] cannot be used. It is useful for routers in IS-IS routing domain to be able to advertise a link being in overload state to indicate impending maintenance activity in the underlying network devices.

This document describes the protocol extensions to disseminate link overload information in IS-IS protocol.

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

It is useful for routers in IS-IS routing domain to be able to advertise a link being in overload state to indicate impending maintenance activity on the link. This document provides mechanisms to advertise link overload state in the Link attributes TLV as defined in [RFC5029]

2. ISIS Link overload bit

The link-attribute sub-TLV is carried within the TLV 22 and has a format identical to the sub-TLV format used by the Traffic Engineering Extensions for IS-IS ([RFC3784]): 1 octet of sub-type, 1 octet of length of the value field of the sub-TLV followed by the value field -- in this case, a 16 bit flags field.

The following bit represents the Link in overload.

Link Overload: 0x04 When set, this indicates that the link is overloaded.

3. Elements of procedure

The Link attributes sub TLV with link-overload bit set indicates that the Link which carries the sub TLV is overloaded. The node that has the link going for maintenance, sets metric of the link to MAX-METRIC and re-originates the LSP. The metric in the reverse direction also need to change to divert the traffic from reverse direction. The node SHOULD originate Link attributes sub TLV and set the overload bit and originate the LSP and flood it in the respective IS-IS level.

When the originator of the Link attributes sub TLV, purges the LSP or re-originates it without the Link Overload bit set, the metric on the remote node SHOULD be changed back to the original value.

Based on the link type of the overloaded link, actions listed below MAY be taken by the receiver.

3.1. Point-to-point links

When a link attributes sub TLV with link overload bit set is received for a point-to-point link the receiver SHOULD identify the local link which corresponds to the overloaded link and set the metric to MAX-METRIC. Receiver node MUST re-originate the LSP with the changed metric and flood into the ISIS level.

3.2. Broadcast links

Broadcast networks in ISIS are represented by a star topology where the Designated Intermediate System (DIS) is the central point to which all other routers on the broadcast network connect. As a result, routers on the broadcast network advertise only their adjacency to the pseudo-node.As a result, routers on the broadcast network advertise only their adjacency to the pseudo- node. Routers that do not act as DIS do not advertise adjacencies with each other. DIS originates pseudo-node which contains adjacenices with all the neighbors. For the Broadcast links, the MAX-METRIC on the outgoing link cannot be changed since all the adjacencies are on same link. Setting the link cost to MAX- METRIC would impact paths going via all neighbors.

When a link-attributes sub TLV with link-overload bit set is received by the remote end for a broadcast link.

- If it's non DIS for that link, SHOULD not take any action.

- If receiving node is DIS for the link, it MUST set the metric from the pseudo-node to the originator of the link overload bit to MAX-METRIC and MUST re-originate the pseudo-node LSP and flood into the ISIS Level.

4. Backward compatibility

The mechanism described in the document is fully backward compatible.It is required that the originator and receiver of link-overload bit understand the extensions defined in this document and in case of broadcast links the originator and the DR need to understand the extensions. Other nodes in the network compute based on increased metric and hence the feature is backward compatible.

5. Security Considerations

This document does not introduce any further security issues other than those discussed in [ISO10589] and [RFC1195].

6. IANA Considerations

This specification updates one ISIS registry: ISIS Link attributes Sub TLV

i) 0x04 - Link overload bit

7. Acknowledgements

8. References

8.1. Normative References

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[RFC3277] McPherson, D., "Intermediate System to Intermediate System (IS-IS) Transient Blackhole Avoidance", RFC 3277, April 2002.

[RFC3784] Smit, H. and T. Li, "Intermediate System to Intermediate System (IS-IS) Extensions for Traffic Engineering (TE)", RFC 3784, June 2004.

[RFC5029] Vasseur, JP. and S. Previdi, "Definition of an IS-IS Link Attribute Sub-TLV", RFC 5029, September 2007.

8.2. Informative References

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IS-IS Route Preference for Extended IP and IPv6 Reachability
draft-ietf-isis-route-preference-02.txt

Abstract

Existing specifications as regards route preference are not explicit when applied to IPv4/IPv6 Extended Reachability Type/Length/Value (TLVs). There are also inconsistencies in the definition of how the up/down bit applies to route preference when the prefix advertisement appears in Level 2 Link State Protocol Data Units (LSPs). This document addresses these issues.

This document, if approved, updates RFC 5308.

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

[RFC5302] defines the route preferences rules as they apply to TLVs 128 and 130. [RFC5305] introduced the IP Extended Reachability TLV 135 but did not explicitly adapt the route preference rules defined in [RFC5302] for the new TLV. [RFC5308] defines the IPv6 Reachability TLV 236 and does include an explicit statement as regards route preference - but the statement introduces use of the up/down bit in advertisements which appear in Level 2 LSPs which is inconsistent with statements made in [RFC5302] and [RFC5305]. This document defines explicit route preference rules for TLV 135, revises the route preferences rules for TLV 236, and clarifies the usage of the up/down bit when it appears in TLVs in Level 2 LSPs. This document is viewed as a clarification (NOT correction) of [RFC5302] and [RFC5305] and a correction of the route preference rules defined in [RFC5308] to be consistent with the rules for IPv4. It also makes explicit that the same rules apply for the Multi-Topology(MT) equivalent TLVs 235 and 237.

2. Use of the up/down Bit in Level 2 LSPs

The up/down bit was introduced in support of leaking prefixes downwards in the IS-IS level hierarchy. Routes which are leaked downwards have the bit set to 1. Such prefixes MUST NOT be leaked upwards in the hierarchy. So long as we confine ourselves to a single IS-IS instance and the current number of supported levels (two) it is impossible to have a prefix advertised in a Level 2 LSP and have the up/down bit set to 1. However, because [RFC5302] anticipated a future extension to IS-IS which might support additional levels it allowed for the possibility that the up/down bit might be set in a Level-2 LSP and in support of easier migration in the event such an extension was introduced Section 3.3 stated:

"...it is RECOMMENDED that implementations ignore the up/down bit in L2 LSPs, and accept the prefixes in L2 LSPs regardless of whether the up/down bit is set."

[RFC5305] addressed an additional case wherein an implementation included support for multiple virtual routers running IS-IS in different areas. In such a case it is possible to redistribute prefixes between two IS-IS instances in the same manner that prefixes are redistributed from other protocols into IS-IS. This introduced the possibility that a prefix could be redistributed from Level 1 to Level 1 (as well as between Level 2 and Level 2) and in the event the redistributed route was leaked from Level 1 to Level 2 two different routers in different areas would be advertising the same prefix into the Level 2 sub-domain. To prevent this [RFC5305] specified in Section 4.1:

"If a prefix is advertised from one area to another at the same level, then the up/down bit SHALL be set to 1."

However, the statement in [RFC5302] that the up/down bit is ignored in Level 2 LSPs is not altered by [RFC5305].

The conclusion then is that there is no "L2 inter-area route" - and indeed no such route type is defined by [RFC5302]. However, [RFC5308] ignored this fact and introduced such a route type in Section 5 when it specified a preference for " Level 2 down prefix". This is an error which this document corrects. As changing the use of the up/down bit in TLVs 236 and 237 may introduce interoperability issues implementors may wish to support transition mechanisms from the [RFC5308] behavior to the behavior specified in this document.

3. Types of Routes in IS-IS Supported by Extended Reachability TLVs

[RFC5302] is the authoritative reference for the types of routes supported by TLVs 128 and 130. However, a number of attributes supported by those TLVs are NOT supported by TLVs 135, 235, 236, 237. Distinction between internal/external metrics is not supported. In the case of IPv4 TLVs (135 and 235) the distinction between internal and external route types is not supported. However the Prefix Attribute Flags sub-TLV defined in [PFXATTR] reintroduces the distinction between internal and external route types. The definitions below include references to the relevant attribute bits from [PFXATTR].

3.1. Types of Routes Supported by TLVs 135 and 235

This section defines the types of route supported for IPv4 when using TLV 135 [RFC5305] and/or TLV 235 [RFC5120]. The text follows as closely as possible the original text from [RFC5302].

L1 intra-area routes: These are advertised in L1 LSPs, in TLV 135 or TLV 235. The up/down bit is set to 0. These IP prefixes are directly connected to the advertising router. If the Prefix Attribute Flags sub-TLV is included both the X-Flag and the R-Flag are set to 0.

L1 external routes: These are advertised in L1 LSPs, in TLV 135 or TLV 235. The up/down bit is set to 0. These IP prefixes are learned from other protocols and are usually not directly connected to the advertising router. If the Prefix Attribute Flags sub-TLV is included the X-Flag is set to 1 and the R-Flag is set to 0.

L2 intra-area routes: These are advertised in L2 LSPs, in TLV 135 or TLV 235. The up/down bit is set to 0. These IP prefixes are

directly connected to the advertising router. If the Prefix Attribute Flags sub-TLV is included both the X-Flag and the R-Flag are set to 0.

L1->L2 inter-area routes: These are advertised in L2 LSPs, in TLV 135 or TLV 235. The up/down bit is set to 0. These IP prefixes are learned via L1 routing and were derived during the L1 Shortest Path First (SPF) computation from prefixes advertised in L1 LSPs in TLV 135 or TLV 235. If the Prefix Attribute Flags sub-TLV is included the R-Flag is set to 1.

L2->L2 inter-area routes: These are advertised in L2 LSPs, in TLV 135 or TLV 235. The up/down bit is set to 1 but is ignored and treated as if it were set to 0. These IP prefixes are learned from another IS-IS instance usually operating in another area. If the Prefix Attribute Flags sub-TLV is included the X-Flag is set to 1 and the R-Flag is set to 0.

L2 external routes: These are advertised in L2 LSPs, in TLV 135 or TLV 235. The up/down bit is set to 0. These IP prefixes are learned from other protocols and are usually not directly connected to the advertising router. If the Prefix Attribute Flags sub-TLV is included the X-Flag is set to 1 and the R-Flag is set to 0.

L2->L1 inter-area routes: These are advertised in L1 LSPs, in TLV 135 or TLV 235. The up/down bit is set to 1. These IP prefixes are learned via L2 routing and were derived during the L2 SPF computation from prefixes advertised in TLV 135 or TLV 235. If the Prefix Attribute Flags sub-TLV is included the R-Flag is set to 1.

L1->L1 inter-area routes: These are advertised in L1 LSPs, in TLV 135 or TLV 235. The up/down bit is set to 1. These IP prefixes are learned from another IS-IS instance usually operating in another area. If the Prefix Attribute Flags sub-TLV is included the X-Flag is set to 1 and the R-Flag is set to 0.

3.2. Types of Routes Supported by TLVs 236 and 237

This section defines the types of route supported for IPv6 when using TLV 236 [RFC5308] and/or TLV 237 [RFC5120].

L1 intra-area routes: These are advertised in L1 LSPs, in TLV 236 or TLV 237. The up/down bit is set to 0. The external bit is set to 0. These IPv6 prefixes are directly connected to the advertising router. If the Prefix Attribute Flags sub-TLV is included the R-Flag is set to 0.

L1 external routes: These are advertised in L1 LSPs, in TLV 236 or TLV 237. The up/down bit is set to 0. The external bit is set to 1. These IPv6 prefixes are learned from other protocols and are usually not directly connected to the advertising router. If the Prefix Attribute Flags sub-TLV is included the R-Flag is set to 0.

L2 intra-area routes: These are advertised in L2 LSPs, in TLV 236 or TLV 237. The up/down bit is set to 0. The external bit is set to 0. These IPv6 prefixes are directly connected to the advertising router. If the Prefix Attribute Flags sub-TLV is included the R-Flag is set to 0.

L1->L2 inter-area routes: These are advertised in L2 LSPs, in TLV 236 or TLV 237. The up/down bit is set to 0. The external bit is set to 0. These IPv6 prefixes are learned via L1 routing and were derived during the L1 Shortest Path First (SPF) computation from prefixes advertised in L1 LSPs in TLV 236 or TLV 237. If the Prefix Attribute Flags sub-TLV is included the R-Flag is set to 1.

L2 external routes: These are advertised in L2 LSPs, in TLV 236 or TLV 237. The up/down bit is set to 0. the external bit is set to 1. These IPv6 prefixes are learned from other protocols and are usually not directly connected to the advertising router. If the Prefix Attribute Flags sub-TLV is included the R-Flag is set to 0.

L1->L2 external routes: These are advertised in L2 LSPs, in TLV 236 or TLV 237. The up/down bit is set to 0. The external bit is set to 1. These IPv6 prefixes are learned via L1 routing and were derived during the L1 Shortest Path First (SPF) computation from L1 external routes advertised in L1 LSPs in TLV 236 or TLV 237. If the Prefix Attribute Flags sub-TLV is included the R-Flag is set to 1.

L2->L2 inter-area routes. These are advertised in L2 LSPs, in TLV 236 or TLV 237. The up/down bit is set to 1 but is ignored and treated as if it were set to 0. The external bit is set to 1. These IP prefixes are learned from another IS-IS instance usually operating in another area. If the Prefix Attribute Flags sub-TLV is included the R-Flag is set to 0.

L2->L1 inter-area routes: These are advertised in L1 LSPs, in TLV 236 or TLV 237. The up/down bit is set to 1. The external bit is set to 0. These IPv6 prefixes are learned via L2 routing and were derived during the L2 SPF computation from prefixes advertised in TLV 236 or TLV 237. If the Prefix Attribute Flags sub-TLV is included the R-Flag is set to 1.

L2->L1 external routes: These are advertised in L1 LSPs, in TLV 236 or TLV 237. The up/down bit is set to 1. The external bit is set to

1. These IPv6 prefixes are learned via L2 routing and were derived during the L2 SPF computation from prefixes advertised in TLV 236 or TLV 237. If the Prefix Attribute Flags sub-TLV is included the R-Flag is set to 1.

L1->L1 inter-area routes. These are advertised in L1 LSPs, in TLV 236 or TLV 237. The up/down bit is set to 1. The external bit is set to 1. These IP prefixes are learned from another IS-IS instance usually operating in another area. If the Prefix Attribute Flags sub-TLV is included the R-Flag is set to 0.

3.3. Order of Preference for all types of routes supported by TLVs 135 and 235

This document defines the following route preferences for IPv4 routes advertised in TLVs 135 or 235. Note that all types of routes listed for a given preference are treated equally.

1. L1 intra-area routes; L1 external routes

2. L2 intra-area routes; L2 external routes; L1->L2 inter-area routes; L2-L2 inter-area routes

3. L2->L1 inter-area routes; L1->L1 inter-area routes

3.4. Order of Preference for all types of routes supported by TLVs 236 and 237

This document defines the following route preferences for IPv6 routes advertised in TLVs 236 or 237. Note that all types of routes listed for a given preference are treated equally.

1. L1 intra-area routes; L1 external routes

2. L2 intra-area routes; L2 external routes; L1->L2 inter-area routes; L1-L2 external routes;L2-L2 inter-area routes

3. L2->L1 inter-area routes; L2->L1 external routes;L1->L1 inter-area routes

4. IANA Considerations

No IANA actions required.

5. Security Considerations

None.

6. Acknowledgements

The authors wish to thank Ahmed Bashandy for his insightful review.

7. References

7.1. Normative References

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[RFC5302] Li, T., Smit, H., and T. Przygienda, "Domain-Wide Prefix Distribution with Two-Level IS-IS", RFC 5302, DOI 10.17487/RFC5302, October 2008, <http://www.rfc-editor.org/info/rfc5302>.

[RFC5305] Li, T. and H. Smit, "IS-IS Extensions for Traffic Engineering", RFC 5305, DOI 10.17487/RFC5305, October 2008, <http://www.rfc-editor.org/info/rfc5305>.

[RFC5308] Hopps, C., "Routing IPv6 with IS-IS", RFC 5308, DOI 10.17487/RFC5308, October 2008, <http://www.rfc-editor.org/info/rfc5308>.

7.2. Informational References

[PFXATTR] "IS-IS Prefix Attributes, draft-ietf-isis-prefix-attributes-01(work in progress)", June 2015.

Appendix A. Example Interoperability Issue

This documents a real world interoperability issue which occurs because implementations from different vendors have interpreted the use of the up/down bit in Level 2 LSPs inconsistently.

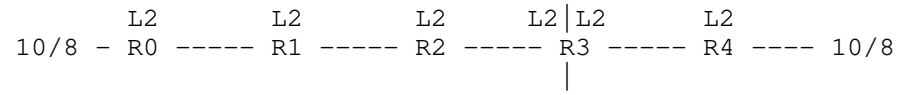

Figure 1

Considering Figure 1, both R0 and R4 are advertising the prefix 10/8. Two ISIS Level 2 instances are running on R3 to separate the network into two areas. R3 is performing route-leaking and advertises prefixes from R4 to the other Level 2 process. The network is using extended metrics (TLV135 defined in [RFC5305]). R0 is advertising 10/8 with metric 2000 and R3 advertises 10/8 with metric 100. All links have a metric of 1. When advertising 10/8 in its Level 2 LSP, R3 sets the down bit as specified in [RFC5305].

R1, R2 and R3 are from three different vendors (R1->Vendor1, R2->Vendor2, R3->Vendor3). During interoperability testing, routing loops are observed in this scenario.

- R2 has two possible paths to reach 10/8, Level 2 route with metric 2002, up/down bit is 0 (from R0) and Level 2 route with metric 101, up/down bit is 1 (from R3). R2 selects R1 as nexthop to 10/8 because it prefers the route which does NOT have up/down bit set.

- R3 has two possible paths to reach 10/8, Level 2 route with metric 2003, up/down bit is 0 (from R0) and Level 2 route with metric 101, up/down bit is 0 (from R4). R3 selects R4 as nexthop due to lowest metric.

- R1 has two possible paths to reach 10/8, Level 2 route with metric 2001, up/down bit is 0 (from R0) and Level 2 metric 102, up/down bit is 1 (from R3). R1 selects R2 as nexthop due to lowest metric.

When R1 or R2 try to send traffic to 10/8, packets are looping due to inconsistent routing decision between R1 and R2.

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Advertising S-BFD Discriminators in IS-IS
draft-ietf-isis-sbfd-discriminator-02.txt

Abstract

This document defines a means of advertising one or more S-BFD Discriminators using the IS-IS Router Capability TLV.

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 September 3, 2015.

Copyright Notice

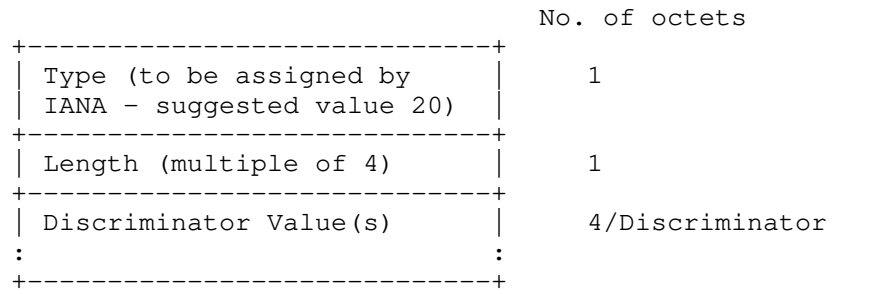
Table of Contents

1. Introduction

[S-BFD] defines a simplified mechanism to use Bidirectional Forwarding Detection (BFD)[RFC5880]. This mechanism depends on network nodes knowing the BFD discriminators which each node in the network has reserved for this purpose. Use of the Intermediate System to Intermediate System (IS-IS)[IS-IS] protocol is one possible means of advertising these discriminators.

2. Encoding Format

The IS-IS Router CAPABILITY TLV as defined in [RFC4971] will be used to advertise S-BFD discriminators. A new sub-TLV is defined as described below. S-BFD Discriminators sub-TLVs are formatted as specified in [RFC5305].



Inclusion of the S-BFD Discriminators sub-TLV in a Router Capability TLV is optional. Multiple S-BFD Discriminators sub-TLVs MAY be advertised by an IS. When multiple S-BFD discriminators are advertised how a given discriminator is mapped to a specific use case is out of scope for this document.

S-BFD discriminator advertisements MAY be flooded within an area or throughout the domain using the procedures specified in [RFC4971]. The appropriate flooding scope depends on the intended use of S-BFD. If S-BFD use will be exclusively within a Level-1 area then area scope is appropriate. If S-BFD usage will span different L1 areas then domain scope is appropriate.

3. IANA Considerations

This document requires the definition of a new sub-TLV in the Sub-TLVs for TLV 242 registry. The value written below is a suggested value subject to assignment by IANA.

Value	Description
20	S-BFD Discriminators

4. Security Considerations

Security concerns for IS-IS are addressed in [IS-IS], [RFC5304], and [RFC5310]. Introduction of the S-BFD Discriminators sub-TLV introduces no new security risks for IS-IS.

Advertisement of the S-BFD discriminators does make it possible for attackers to initiate S-BFD sessions using the advertised information. The vulnerabilities this poses and how to mitigate them are discussed in the Security Considerations section of [S-BFD].

5. Acknowledgements

The authors wish to thank Sam Aldrin, Manav Bhatia, and Carlos Pignataro for input essential to defining the needed functionality.

6. Normative References

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YANG Data Model for IS-IS Protocol
draft-ietf-isis-yang-isis-cfg-42

Abstract

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

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

Status of This Memo

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

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This Internet-Draft will expire on April 17, 2020.

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1. Introduction

This document defines a YANG [RFC7950] data model for IS-IS routing protocol.

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

A simplified tree representation of the data model is presented in Section 2. Tree diagrams used in this document follow the notation defined in [RFC8340].

The module is designed as per the NMDA (Network Management Datastore Architecture) [RFC8342].

2. Design of the Data Model

The IS-IS YANG module augments the "control-plane-protocol" list in the ietf-routing module [RFC8349] with specific IS-IS parameters.

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

```
module: ietf-isis
augment /rt:routing/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 {osi-interface}?
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 lsp-mtu?                   uint16
     +--rw lsp-lifetime?              uint16
     +--rw lsp-refresh?               rt-types:timer-value-seconds16
     |                                    {lsp-refresh}?
     +--rw poi-tlv?                   boolean {poi-tlv}?
     +--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 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 auto-cost {auto-cost}?
     |  +--rw enable?                boolean
     |  +--rw reference-bandwidth?   uint32
     +--rw authentication
     |  +--rw (authentication-type)?
     |  |     ...
     |  +--rw level-1
     |  |     ...
     |  +--rw level-2
     |        ...
     +--rw address-families {nlpid-control}?
     |  +--rw address-family-list* [address-family]
     |        ...
     +--rw mpls
     |  +--rw te-rid {te-rid}?
     |  |     ...
     |  +--rw ldp
     |        ...
     +--rw spf-control
     |  +--rw paths?            uint16 {max-ecmp}?
     |  +--rw ietf-spf-delay {ietf-spf-delay}?
     |        ...
     +--rw fast-reroute {fast-reroute}?
     |  +--rw lfa {lfa}?
     +--rw preference
     |  +--rw (granularity)?
     |        ...
     +--rw overload
     |  +--rw status?   boolean
     +--rw overload-max-metric {overload-max-metric}?
     |  +--rw timeout?   rt-types:timer-value-seconds16
     +--ro spf-log
     |  +--ro event* [id]
     |        ...
     +--ro lsp-log
     |  +--ro event* [id]
```

```
     |        ...
     +--ro hostnames
     |  +--ro hostname* [system-id]
     |        ...
     +--ro database
     |  +--ro levels* [level]
     |        ...
     +--ro local-rib
     |  +--ro route* [prefix]
     |        ...
     +--ro system-counters
     |  +--ro level* [level]
     |        ...
     +--ro protected-routes
     |  +--ro address-family-stats* [address-family prefix alternate]
     |        ...
     +--ro unprotected-routes
     |  +--ro prefixes* [address-family prefix]
     |        ...
     +--ro protection-statistics* [frr-protection-method]
     |  +--ro frr-protection-method    identityref
     |  +--ro address-family-stats* [address-family]
     |        ...
     +--rw discontinuity-time?       yang:date-and-time
     +--rw topologies {multi-topology}?
     |  +--rw topology* [name]
     |        ...
     +--rw interfaces
        +--rw interface* [name]
              ...

rpcs:
  +---x clear-adjacency
  |  +---w input
  |     +---w routing-protocol-instance-name -> /rt:routing/
  |     |                                     control-plane-protocols/
  |     |                                     control-plane-protocol/name
  |     +---w level?                             level
  |     +---w interface?                         if:interface-ref
  +---x clear-database
     +---w input
        +---w routing-protocol-instance-name -> /rt:routing/
        |                                     control-plane-protocols/
        |                                     control-plane-protocol/name
        +---w level?                             level

notifications:
  +---n database-overload
```

```
  |  +--ro routing-protocol-name?   -> /rt:routing/
  |  |                                 control-plane-protocols/
  |  |                                 control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro overload?                enumeration
  +---n lsp-too-large
  |  +--ro routing-protocol-name?   -> /rt:routing/
  |  |                                 control-plane-protocols/
  |  |                                 control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro interface-name?          if:interface-ref
  |  +--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-protocol-name?   -> /rt:routing/
  |  |                                 control-plane-protocols/
  |  |                                 control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro interface-name?          if:interface-ref
  |  +--ro interface-level?         level
  |  +--ro extended-circuit-id?     extended-circuit-id
  |  +--ro state?                   if-state-type
  +---n corrupted-lsp-detected
  |  +--ro routing-protocol-name?   -> /rt:routing/
  |  |                                 control-plane-protocols/
  |  |                                 control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro lsp-id?                  lsp-id
  +---n attempt-to-exceed-max-sequence
  |  +--ro routing-protocol-name?   -> /rt:routing/
  |  |                                 control-plane-protocols/
  |  |                                 control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro lsp-id?                  lsp-id
  +---n id-len-mismatch
  |  +--ro routing-protocol-name?   -> /rt:routing/
  |  |                                 control-plane-protocols/
  |  |                                 control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro interface-name?          if:interface-ref
  |  +--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-protocol-name?   -> /rt:routing/
```

```
  |   |                                  control-plane-protocols/
  |   |                                  control-plane-protocol/name
  |   +--ro isis-level?              level
  |   +--ro interface-name?          if:interface-ref
  |   +--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-protocol-name?   -> /rt:routing/
  |   |                                  control-plane-protocols/
  |   |                                  control-plane-protocol/name
  |   +--ro isis-level?              level
  |   +--ro interface-name?          if:interface-ref
  |   +--ro interface-level?         level
  |   +--ro extended-circuit-id?     extended-circuit-id
  |   +--ro lsp-id?                  lsp-id
  +---n sequence-number-skipped
  |   +--ro routing-protocol-name?   -> /rt:routing/
  |   |                                  control-plane-protocols/
  |   |                                  control-plane-protocol/name
  |   +--ro isis-level?              level
  |   +--ro interface-name?          if:interface-ref
  |   +--ro interface-level?         level
  |   +--ro extended-circuit-id?     extended-circuit-id
  |   +--ro lsp-id?                  lsp-id
  +---n authentication-type-failure
  |   +--ro routing-protocol-name?   -> /rt:routing/
  |   |                                  control-plane-protocols/
  |   |                                  control-plane-protocol/name
  |   +--ro isis-level?              level
  |   +--ro interface-name?          if:interface-ref
  |   +--ro interface-level?         level
  |   +--ro extended-circuit-id?     extended-circuit-id
  |   +--ro raw-pdu?                 binary
  +---n authentication-failure
  |   +--ro routing-protocol-name?   -> /rt:routing/
  |   |                                  control-plane-protocols/
  |   |                                control-plane-protocol/name
  |   +--ro isis-level?              level
  |   +--ro interface-name?          if:interface-ref
  |   +--ro interface-level?         level
  |   +--ro extended-circuit-id?     extended-circuit-id
  |   +--ro raw-pdu?                 binary
  +---n version-skew
  |   +--ro routing-protocol-name?   -> /rt:routing/
  |   |                                  control-plane-protocols/
  |   |                                  control-plane-protocol/name
```

```
   |  +--ro isis-level?              level
   |  +--ro interface-name?          if:interface-ref
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
   |  +--ro protocol-version?        uint8
   |  +--ro raw-pdu?                 binary
   +---n area-mismatch
   |  +--ro routing-protocol-name?   -> /rt:routing/
   |  |                                 control-plane-protocols/
   |  |                                 control-plane-protocol/name
   |  +--ro isis-level?              level
   |  +--ro interface-name?          if:interface-ref
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
   |  +--ro raw-pdu?                 binary
   +---n rejected-adjacency
   |  +--ro routing-protocol-name?   -> /rt:routing/
   |  |                                  control-plane-protocols/
   |  |                                  control-plane-protocol/name
   |  +--ro isis-level?              level
   |  +--ro interface-name?          if:interface-ref
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
   |  +--ro raw-pdu?                 binary
   |  +--ro reason?                  string
   +---n protocols-supported-mismatch
   |  +--ro routing-protocol-name?   -> /rt:routing/
   |  |                                 control-plane-protocols/
   |  |                                 control-plane-protocol/name
   |  +--ro isis-level?              level
   |  +--ro interface-name?          if:interface-ref
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
   |  +--ro raw-pdu?                 binary
   |  +--ro protocols*               uint8
   +---n lsp-error-detected
   |  +--ro routing-protocol-name?   -> /rt:routing/
   |  |                                 control-plane-protocols/
   |  |                                 control-plane-protocol/name
   |  +--ro isis-level?              level
   |  +--ro interface-name?          if:interface-ref
   |  +--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-protocol-name?   -> /rt:routing/
   |  |                                 control-plane-protocols/
   |  |                                 control-plane-protocol/name
   |  +--ro isis-level?              level
   |  +--ro interface-name?          if:interface-ref
   |  +--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-protocol-name?   -> /rt:routing/
   |  |                                 control-plane-protocols/
   |  |                                 control-plane-protocol/name
   |  +--ro isis-level?              level
   |  +--ro interface-name?          if:interface-ref
   |  +--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-protocol-name?   -> /rt:routing/
      |                                 control-plane-protocols/
      |                                 control-plane-protocol/name
      +--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 is divided into:

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

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

The model includes optional features, for which the corresponding configuration data nodes are also 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, etc.

2.2. Multi-topology Parameters

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

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

The "name" used in the topology list should refer to an existing Routing Information Base (RIB) defined for the device [RFC8349].

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

Multiple address families (such as, IPv4 or IPv6) can also be enabled within the default topology. This can be achieved using the address-families container (requiring the "nlpid-control" feature to be supported).

2.3. Per-Level Parameters

Some parameters allow a per-level configuration. For such parameters, 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>
        </priority>
```

An implementation MUST prefer a level-specific parameter over a top-level parameter. For example, if the priority is 100 for the level-1 and 250 for the top-level configuration, the implementation must use 100 for the level-1 priority and 250 for the level-2 priority.

Some parameters, such as, "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 MUST augment the current model by adding both level-1 and level-2 containers and MUST 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 ([RFC8343].

Each interface has some interface-specific parameters that may have a different per-level value as described in the previous section. An interface-specific parameter MUST be preferred over an IS-IS global parameter.

Some parameters, such as, 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 enable?                       boolean {admin-control}?
       +--rw level-type?                   level
       +--rw lsp-pacing-interval?          rt-types:
       |                                      timer-value-milliseconds
       +--rw lsp-retransmit-interval?      rt-types:
       |                                      timer-value-seconds16
       +--rw passive?                      boolean
       +--rw csnp-interval?                rt-types:
       |                                      timer-value-seconds16
       +--rw hello-padding
       |  +--rw enable?   boolean
       +--rw mesh-group-enable?            mesh-group-state
       +--rw mesh-group?                   uint8
       +--rw interface-type?               interface-type
       +--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-ref
          |  |     +--:(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-ref
          |        +--:(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 local-multiplier?                    multiplier
          |  +--rw (interval-config-type)?
          |     +--:(tx-rx-intervals)
          |     |  +--rw desired-min-tx-interval?       uint32
          |     |  +--rw required-min-rx-interval?      uint32
          |     +--:(single-interval) {single-minimum-interval}?
          |        +--rw min-interval?                  uint32
          +--rw address-families {nlpid-control}?
          |  +--rw address-family-list* [address-family]
```

```
|     +--rw address-family    iana-rt-types:address-family
+--rw mpls
|  +--rw ldp
|     +--rw igp-sync?   boolean {ldp-igp-sync}?
+--rw fast-reroute {fast-reroute}?
|  +--rw lfa {lfa}?
|     +--rw candidate-enable?   boolean
|     +--rw enable?             boolean
|     +--rw remote-lfa {remote-lfa}?
|     |  +--rw enable?   boolean
|     +--rw level-1
|     |  +--rw candidate-enable?   boolean
|     |  +--rw enable?             boolean
|     |  +--rw remote-lfa {remote-lfa}?
|     |     +--rw enable?   boolean
|     +--rw level-2
|        +--rw candidate-enable?   boolean
|        +--rw enable?             boolean
|        +--rw remote-lfa {remote-lfa}?
|           +--rw enable?   boolean
+--ro adjacencies
|  +--ro adjacency* []
|     +--ro neighbor-sys-type?             level
|     +--ro neighbor-sysid?                system-id
|     +--ro neighbor-extended-circuit-id?  extended-circuit-id
|     +--ro neighbor-snpa?                 snpa
|     +--ro usage?                         level
|     +--ro hold-timer?                    rt-types:
|     |                                   timer-value-seconds16
|     +--ro neighbor-priority?             uint8
|     +--ro lastuptime?                    yang:timestamp
|     +--ro state?                         adj-state-type
+--ro event-counters
|  +--ro adjacency-changes?             uint32
|  +--ro adjacency-number?              uint32
|  +--ro init-fails?                    uint32
|  +--ro adjacency-rejects?             uint32
|  +--ro id-len-mismatch?               uint32
|  +--ro max-area-addresses-mismatch?   uint32
|  +--ro authentication-type-fails?     uint32
|  +--ro authentication-fails?          uint32
|  +--ro lan-dis-changes?               uint32
+--ro packet-counters
|  +--ro level* [level]
|     +--ro level      level-number
|     +--ro iih
|     |  +--ro in?    uint32
|     |  +--ro out?   uint32
```

```
          |      +--ro ish
          |      |  +--ro in?    uint32
          |      |  +--ro out?   uint32
          |      +--ro esh
          |      |  +--ro in?    uint32
          |      |  +--ro out?   uint32
          |      +--ro lsp
          |      |  +--ro in?    uint32
          |      |  +--ro out?   uint32
          |      +--ro psnp
          |      |  +--ro in?    uint32
          |      |  +--ro out?   uint32
          |      +--ro csnp
          |      |  +--ro in?    uint32
          |      |  +--ro out?   uint32
          |      +--ro unknown
          |         +--ro in?   uint32
          +--rw discontinuity-time?        yang:date-and-time
          +--rw topologies {multi-topology}?
             +--rw topology* [name]
                +--rw name      ->
                |              ../../../../../../../../rt:ribs/rib/name
                +--rw metric
                   +--rw value?     wide-metric
                   +--rw level-1
                   |  +--rw value?   wide-metric
                   +--rw level-2
                      +--rw value?   wide-metric

rpcs:
  +---x clear-adjacency
  |  +---w input
  |     +---w routing-protocol-instance-name    -> /rt:routing/
  |     |                                        control-plane-protocols/
  |     |                                        control-plane-protocol/name
  |     +---w level?                              level
  |     +---w interface?                          if:interface-ref
  +---x clear-database
     +---w input
        +---w routing-protocol-instance-name    -> /rt:routing/
        |                                        control-plane-protocols/
        |                                        control-plane-protocol/name
        +---w level?                              level

notifications:
  +---n database-overload
  |  +--ro routing-protocol-name?   -> /rt:routing/
  |  |                                 control-plane-protocols/
```

```
  |  |                                      control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro overload?                enumeration
  +---n lsp-too-large
  |  +--ro routing-protocol-name?   -> /rt:routing/
  |  |                                   control-plane-protocols/
  |  |                                   control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro interface-name?          if:interface-ref
  |  +--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-protocol-name?   -> /rt:routing/
  |  |                                   control-plane-protocols/
  |  |                                   control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro interface-name?          if:interface-ref
  |  +--ro interface-level?         level
  |  +--ro extended-circuit-id?     extended-circuit-id
  |  +--ro state?                   if-state-type
  +---n corrupted-lsp-detected
  |  +--ro routing-protocol-name?   -> /rt:routing/
  |  |                                   control-plane-protocols/
  |  |                                   control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro lsp-id?                  lsp-id
  +---n attempt-to-exceed-max-sequence
  |  +--ro routing-protocol-name?   -> /rt:routing/
  |  |                                   control-plane-protocols/
  |  |                                   control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro lsp-id?                  lsp-id
  +---n id-len-mismatch
  |  +--ro routing-protocol-name?   -> /rt:routing/
  |  |                                   control-plane-protocols/
  |  |                                   control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro interface-name?          if:interface-ref
  |  +--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-protocol-name?   -> /rt:routing/
  |  |                                   control-plane-protocols/
  |  |                                   control-plane-protocol/name
```

```
   |  +--ro isis-level?              level
   |  +--ro interface-name?          if:interface-ref
   |  +--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-protocol-name?   -> /rt:routing/
   |  |                                     control-plane-protocols/
   |  |                                     control-plane-protocol/name
   |  +--ro isis-level?              level
   |  +--ro interface-name?          if:interface-ref
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
   |  +--ro lsp-id?                  lsp-id
   +---n sequence-number-skipped
   |  +--ro routing-protocol-name?   -> /rt:routing/
   |  |                                     control-plane-protocols/
   |  |                                     control-plane-protocol/name
   |  +--ro isis-level?              level
   |  +--ro interface-name?          if:interface-ref
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
   |  +--ro lsp-id?                  lsp-id
   +---n authentication-type-failure
   |  +--ro routing-protocol-name?   -> /rt:routing/
   |  |                                     control-plane-protocols/
   |  |                                     control-plane-protocol/name
   |  +--ro isis-level?              level
   |  +--ro interface-name?          if:interface-ref
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
   |  +--ro raw-pdu?                 binary
   +---n authentication-failure
   |  +--ro routing-protocol-name?   -> /rt:routing/
   |  |                                     control-plane-protocols/
   |  |                                     control-plane-protocol/name
   |  +--ro isis-level?              level
   |  +--ro interface-name?          if:interface-ref
   |  +--ro interface-level?         level
   |  +--ro extended-circuit-id?     extended-circuit-id
   |  +--ro raw-pdu?                 binary
   +---n version-skew
   |  +--ro routing-protocol-name?   -> /rt:routing/
   |  |                                     control-plane-protocols/
   |  |                                     control-plane-protocol/name
   |  +--ro isis-level?              level
   |  +--ro interface-name?          if:interface-ref
```

```
  |  +--ro interface-level?         level
  |  +--ro extended-circuit-id?     extended-circuit-id
  |  +--ro protocol-version?        uint8
  |  +--ro raw-pdu?                 binary
  +---n area-mismatch
  |  +--ro routing-protocol-name?   -> /rt:routing/
  |  |                                     control-plane-protocols/
  |  |                                     control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro interface-name?          if:interface-ref
  |  +--ro interface-level?         level
  |  +--ro extended-circuit-id?     extended-circuit-id
  |  +--ro raw-pdu?                 binary
  +---n rejected-adjacency
  |  +--ro routing-protocol-name?   -> /rt:routing/
  |  |                                     control-plane-protocols/
  |  |                                     control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro interface-name?          if:interface-ref
  |  +--ro interface-level?         level
  |  +--ro extended-circuit-id?     extended-circuit-id
  |  +--ro raw-pdu?                 binary
  |  +--ro reason?                  string
  +---n protocols-supported-mismatch
  |  +--ro routing-protocol-name?   -> /rt:routing/
  |  |                                     control-plane-protocols/
  |  |                                     control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro interface-name?          if:interface-ref
  |  +--ro interface-level?         level
  |  +--ro extended-circuit-id?     extended-circuit-id
  |  +--ro raw-pdu?                 binary
  |  +--ro protocols*               uint8
  +---n lsp-error-detected
  |  +--ro routing-protocol-name?   -> /rt:routing/
  |  |                                     control-plane-protocols/
  |  |                                     control-plane-protocol/name
  |  +--ro isis-level?              level
  |  +--ro interface-name?          if:interface-ref
  |  +--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-protocol-name?   -> /rt:routing/
  |  |                                     control-plane-protocols/
```

```
   |  |                                    control-plane-protocol/name
   |  +--ro isis-level?              level
   |  +--ro interface-name?          if:interface-ref
   |  +--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-protocol-name?   -> /rt:routing/
   |  |                                    control-plane-protocols/
   |  |                                    control-plane-protocol/name
   |  +--ro isis-level?              level
   |  +--ro interface-name?          if:interface-ref
   |  +--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-protocol-name?   -> /rt:routing/
      |                                    control-plane-protocols/
      |                                    control-plane-protocol/name
      +--ro isis-level?              level
      +--ro lsp-id?                  lsp-id
      +--ro sequence?                uint32
      +--ro send-timestamp?          yang:timestamp
```

2.5. Authentication Parameters

The module enables authentication configuration through the IETF key-chain module [RFC8177]. The IS-IS module imports the "ietf-key-chain" module and reuses some groupings to allow global and per-interface configuration of authentication. If global authentication is configured, an implementation SHOULD authenticate PSNPs (Partial Sequence Number Packets), CSNPs (Complete Sequence Number Packets) and LSPs (Link State Packets) with the authentication parameters supplied. The authentication of HELLO PDUs (Protocol Data Units) can be activated on a per-interface basis.

2.6. IGP/LDP synchronization

[RFC5443] defines a mechanism where IGP (Interior Gateway Protocol) needs to be synchronized with LDP (Label Distribution Protocol). An "ldp-igp-sync" feature has been defined in the model to support this functionality. The "mpls/ldp/igp-sync" leaf under "interface" allows

activation of the functionality on a per-interface basis. The "mpls/ldp/igp-sync" container in the global configuration is intentionally empty and is not required for feature activation. The goal of this empty container is to facilitate augmentation with additional parameters, e.g., timers.

2.7. ISO parameters

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

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

The clns-mtu can be configured for an interface.

2.8. IP FRR

This YANG module supports LFA (Loop Free Alternates) [RFC5286] and remote LFA [RFC7490] as IP Fast Re-Route (FRR) techniques. The "fast-reroute" container may be augmented by other models to support other IP FRR flavors (MRT as defined in [RFC7812], TI-LFA as defined in [I-D.ietf-rtgwg-segment-routing-ti-lfa], etc.).

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

Remote LFA is considered as an extension of LFA. Remote LFA cannot be enabled if LFA is not enabled.

The "candidate-enable" data leaf designates that an interface can be used as a backup.

2.9. Operational States

Operational state is defined in module in various containers at various levels:

- system-counters: Provides statistical information about the global system.
- interface: Provides configuration state information for each interface.
- adjacencies: Provides state information about current IS-IS adjacencies.

- spf-log: Provides information about SPF events for an IS-IS instance. This SHOULD be implemented as a wrapping buffer.

- lsp-log: Provides information about LSP events for an IS-IS instance (reception of an LSP or modification of a local LSP). This SHOULD be implemented as a wrapping buffer and the implementation MAY optionally log LSP refreshes.

- local-rib: Provides the IS-IS internal routing table.

- database: Provides contents of the current Link State Database.

- hostnames: Provides the system-id to hostname mappings [RFC5301].

- fast-reroute: Provides IP FRR state information.

3. RPC Operations

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

- clear-database: Reset the content of a particular IS-IS database and restart database synchronization with all neighbors.

- clear-adjacency: Restart a particular set of IS-IS adjacencies.

4. Notifications

The "ietf-isis" module defines the following notifications:

database-overload: This notification is sent when the IS-IS Node overload condition changes.

lsp-too-large: This notification is sent when the system tries to propagate a PDU that is too large.

if-state-change: This notification is sent when an interface's state changes.

corrupted-lsp-detected: This notification is sent when the IS-IS node discovers that an LSP that was previously stored in the Link State Database, i.e., local 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 an LSP with a parse error.

adjacency-state-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 an LSP is received.

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

5. Interaction with Other YANG Modules

The "isis" container augments the "/rt:routing/rt:control-plane-protocols/control-plane-protocol" container of the ietf-routing [RFC8349] module with IS-IS-specific parameters.

The "isis" module augments "/if:interfaces/if:interface" defined by [RFC8343] 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 with IS-IS-specific operational states.

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

The modules defined in this document uses some groupings from ietf-keychain [RFC8177].

The module reuses types from [RFC6991] and [RFC8294].

To support BFD for fast detection, the module relies on [I-D.ietf-bfd-yang].

6. IS-IS YANG Module

The following RFCs, drafts and external standards are not referenced in the document text but are referenced in the ietf-isis.yang module: [ISO-10589], [RFC1195], [RFC4090],[RFC5029], [RFC5130], [RFC5302], [RFC5305], [RFC5306], [RFC5307], [RFC5308], [RFC5880], [RFC5881], [RFC6119], [RFC6232], [RFC7794], [RFC7981], [RFC8570], [RFC7917], [RFC8405].

```
<CODE BEGINS> file "ietf-isis@2019-10-15.yang"
module ietf-isis {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-isis";

  prefix isis;

  import ietf-routing {
    prefix "rt";
    reference "RFC 8349 - A YANG Data Model for Routing
               Management (NMDA Version)";
  }

  import ietf-inet-types {
    prefix inet;
    reference "RFC 6991 - Common YANG Data Types";
  }

  import ietf-yang-types {
```

```
      prefix yang;
      reference "RFC 6991 - Common YANG Data Types";
    }

    import ietf-interfaces {
      prefix "if";
      reference "RFC 8343 - A YANG Data Model for Interface
                 Management (NDMA Version)";
    }

    import ietf-key-chain {
      prefix "key-chain";
      reference "RFC 8177 - YANG Data Model for Key Chains";
    }

    import ietf-routing-types {
      prefix "rt-types";
      reference "RFC 8294 - Common YANG Data Types for the
                 Routing Area";
    }

    import iana-routing-types {
      prefix "iana-rt-types";
      reference "RFC 8294 - Common YANG Data Types for the
                 Routing Area";
    }

    import ietf-bfd-types {
      prefix "bfd-types";
      reference "RFC YYYY - YANG Data Model for Bidirectional
                 Forwarding Detection (BFD).

   -- Note to RFC Editor Please replace YYYY with published RFC
     number for draft-ietf-bfd-yang.";

    }

    organization
      "IETF LSR Working Group";

    contact
      "WG Web:   <https://datatracker.ietf.org/group/lsr/>
       WG List:  <mailto:lsr@ietf.org>

       Editor:   Stephane Litkowski
                 <mailto:slitkows.ietf@gmail.com>
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```

```
        Author:   Acee Lindem
                  <mailto:acee@cisco.com>
        Author:   Jeffrey Zhang
                  <mailto:zzhang@juniper.net>
        Author:   Ladislav Lhotka
                  <mailto:llhotka@nic.cz>";

    description
     "This YANG module defines the generic configuration and
      operational state for the IS-IS protocol common to all
      vendor implementations. It is intended that the module
      will be extended by vendors to define vendor-specific
      IS-IS configuration parameters and policies,
      for example, route maps or route policies.

      This YANG model conforms to the Network Management
      Datastore Architecture (NMDA) as described in RFC 8242.

      Copyright (c) 2018 IETF Trust and the persons identified as
      authors of the code.  All rights reserved.

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      without modification, is permitted pursuant to, and subject to
      the license terms contained in, the Simplified BSD License set
      forth in Section 4.c of the IETF Trust's Legal Provisions
      Relating to IETF Documents
      (https://trustee.ietf.org/license-info).

      This version of this YANG module is part of RFC XXXX
      (https://www.rfc-editor.org/info/rfcXXXX); see the RFC itself
      for full legal notices.

      The key words 'MUST', 'MUST NOT', 'REQUIRED', 'SHALL', 'SHALL
      NOT', 'SHOULD', 'SHOULD NOT', 'RECOMMENDED', 'NOT RECOMMENDED',
      'MAY', and 'OPTIONAL' in this document are to be interpreted as
      described in BCP 14 (RFC 2119) (RFC 8174) when, and only when,
      they appear in all capitals, as shown here.

      This version of this YANG module is part of RFC XXXX;
      see the RFC itself for full legal notices.";

    revision 2019-10-15 {
      description
        "Initial revision.";
      reference "RFC XXXX";
    }

    /* Identities */
```

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

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.";
}

identity frr-protection-method {
  description
    "Base identity for a Fast Reroute protection method.";
}
identity frr-protection-method-lfa {
  base frr-protection-method;
  description "Loop Free Alternate as defined in RFC5286.";
}
identity frr-protection-method-rlfa {
  base frr-protection-method;
  description "Remote Loop Free Alternate as defined in RFC7490.";
}
identity frr-protection-method-rsvpte {
  base frr-protection-method;
  description "RSVP-TE as defined in RFC4090.";
}

identity frr-protection-available-type {
  description "Base identity for Fast Reroute protection types
               provided by an alternate path.";
}
identity frr-protection-available-node-type {
  base frr-protection-available-type;
  description "Node protection is provided by the alternate.";
}
```

```
    identity frr-protection-available-link-type {
      base frr-protection-available-type;
      description "Link protection is provided by the alternate.";
    }
    identity frr-protection-available-srlg-type {
      base frr-protection-available-type;
      description "SRLG protection is provided by the alternate.";
    }
    identity frr-protection-available-downstream-type {
      base frr-protection-available-type;
      description "The alternate is downstream of node in the path.";
    }
    identity frr-protection-available-other-type {
      base frr-protection-available-type;
      description "The level of protection is unknown.";
    }

    identity frr-alternate-type {
      description "Base identity for IP Fast Reroute alternate type.";
    }
    identity frr-alternate-type-equal-cost {
      base frr-alternate-type;
          description "ECMP alternate.";
    }
    identity frr-alternate-type-lfa {
      base frr-alternate-type;
          description "LFA alternate.";
    }
    identity frr-alternate-type-remote-lfa {
      base frr-alternate-type;
          description "Remote LFA alternate.";
    }
    identity frr-alternate-type-tunnel {
      base frr-alternate-type;
          description "Tunnel based alternate (such as,
                   RSVP-TE or GRE).";
    }
    identity frr-alternate-mrt {
      base frr-alternate-type;
          description "MRT alternate.";
    }
    identity frr-alternate-tilfa {
      base frr-alternate-type;
          description "TILFA alternate.";
    }
    identity frr-alternate-other {
      base frr-alternate-type;
          description "Other alternate.";
```

```
    }


    identity unidirectional-link-delay-subtlv-flag {
        description "Base identity for unidirectional-link-delay
                     subTLV flags. Flags are defined in RFC8570.";
    }
    identity unidirectional-link-delay-subtlv-a-flag {
        base unidirectional-link-delay-subtlv-flag;
        description
            "The A bit represents the Anomalous (A) bit.
             The A bit is set when the measured value of
             this parameter exceeds its configured
             maximum threshold.
             The A bit is cleared when the measured value
             falls below its configured reuse threshold.
             If the A bit is clear,
             the value represents steady-state link performance.";
    }
    identity min-max-unidirectional-link-delay-subtlv-flag {
        description
          "Base identity for min-max-unidirectional-link-delay
           subTLV flags. Flags are defined in RFC8570.";
    }
    identity min-max-unidirectional-link-delay-subtlv-a-flag {
        base min-max-unidirectional-link-delay-subtlv-flag;
        description
            "The A bit represents the Anomalous (A) bit.
             The A bit is set when the measured value of
             this parameter exceeds its configured
             maximum threshold.
             The A bit is cleared when the measured value
             falls below its configured reuse threshold.
             If the A bit is clear,
             the value represents steady-state link performance.";
    }
    identity unidirectional-link-loss-subtlv-flag {
        description "Base identity for unidirectional-link-loss
                     subTLV flags. Flags are defined in RFC8570.";
    }

    identity unidirectional-link-loss-subtlv-a-flag {
        base unidirectional-link-loss-subtlv-flag;
        description
            "The A bit represents the Anomalous (A) bit.
             The A bit is set when the measured value of
             this parameter exceeds its configured
             maximum threshold.
```

```
                The A bit is cleared when the measured value
                falls below its configured reuse threshold.
                If the A bit is clear,
                the value represents steady-state link performance.";
        }
        identity tlv229-flag {
            description "Base identity for TLV229 flags. Flags are defined
                         in RFC5120.";
        }
        identity tlv229-overload-flag {
            base tlv229-flag;
            description
                "If set, the originator is overloaded,
                and must be avoided in path calculation.";
        }
        identity tlv229-attached-flag {
            base tlv229-flag;
            description
                "If set, the originator is attached to
                another area using the referred metric.";
        }
        identity router-capability-flag {
            description "Base identity for router capability flags.
              Flags are defined in RFC7981.";
        }
        identity router-capability-flooding-flag {
            base router-capability-flag;
            description
                "Quote from RFC7981: 'If the S bit is set,
                 the IS-IS Router CAPABILITY
                 TLV MUST be flooded across the entire routing
                 domain. If the S bit is clear, the TLV MUST NOT
                 be leaked between levels. This bit MUST NOT
                 be altered during the TLV leaking'.";
        }
        identity router-capability-down-flag {
            base router-capability-flag;
            description
                "Quote from RFC7981: '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 in to prevent
                 TLV looping'.";
        }

        identity lsp-flag {
            description "Base identity for LSP attributes.
```

```
                    Attributes are defined in ISO 10589";
    }
    identity lsp-partitioned-flag {
        base lsp-flag;
        description "Originator partition repair supported";
    }
    identity lsp-attached-error-metric-flag {
        base lsp-flag;
        description "Set when originator is attached to
             another area using the error metric.";
    }
    identity lsp-attached-delay-metric-flag {
        base lsp-flag;
        description "Set when originator is attached to
             another area using the delay metric.";
    }
    identity lsp-attached-expense-metric-flag {
        base lsp-flag;
        description "Set when originator is attached to
             another area using the expense metric.";
    }
    identity lsp-attached-default-metric-flag {
        base lsp-flag;
        description "Set when originator is attached to
             another area using the default metric.";
    }
    identity lsp-overload-flag {
        base lsp-flag;
        description
            "If set, the originator is overloaded,
             and must be avoided in path calculation.";
    }
    identity lsp-l1system-flag {
        base lsp-flag;
        description
            "Set when the Intermediate System has an L1 type.";
    }
    identity lsp-l2system-flag {
        base lsp-flag;
        description
            "Set when the Intermediate System has an L2 type.";
    }


    /* Feature definitions */

    feature osi-interface {
      description "Support of OSI specific parameters on an
```

```
                interface.";
      }
      feature poi-tlv {
        description "Support of Purge Originator Identification.";
        reference "RFC 6232 - Purge Originator Identification TLV
                   for IS-IS";
      }
      feature ietf-spf-delay {
        description
          "Support for IETF SPF delay algorithm.";
        reference "RFC 8405 - SPF Back-off algorithm for link
                   state IGPs";
      }
      feature bfd {
        description
          "Support for BFD detection of IS-IS neighbor reachability.";
        reference "RFC 5880 - Bidirectional Forwarding Detection (BFD)
                   RFC 5881 - Bidirectional Forwarding Detection
                   (BFD) for IPv4 and IPv6 (Single Hop)";
      }
      feature key-chain {
        description
          "Support of keychain for authentication.";
        reference "RFC8177 - YANG Data Model for Key Chains";
      }
      feature node-flag {
        description
          "Support for node-flag for IS-IS prefixes.";
        reference "RFC7794 - IS-IS Prefix Attributes for
                   Extended IP and IPv6 Reachability";
      }
      feature node-tag {
        description
          "Support for node admin tag for IS-IS routing instances.";
        reference "RFC7917 - Advertising Node Administrative Tags
                   in IS-IS";
      }
      feature ldp-igp-sync {
        description
          "Support for LDP IGP synchronization.";
        reference "RFC5443 - LDP IGP Synchronization.";
      }
      feature fast-reroute {
        description
          "Support for IP Fast Reroute (IP-FRR).";
      }
      feature nsr {
        description
```

```
        "Support for Non-Stop-Routing (NSR). The IS-IS NSR feature
            allows  a router with redundant control-plane capability
            (e.g., dual Route-Processor (RP) cards) to maintain its
            state and adjacencies during planned and unplanned
            IS-IS instance restarts. It differs from graceful-restart
            or Non-Stop Forwarding (NSF) in that no protocol signaling
            or assistance from adjacent IS-IS neighbors is required to
            recover control-plane state.";
    }
    feature lfa {
      description
        "Support for Loop-Free Alternates (LFAs).";
      reference "RFC5286 - Basic Specification of IP Fast-Reroute:
                 Loop-free Alternates";
    }
    feature remote-lfa {
      description
        "Support for Remote Loop-Free Alternates (R-LFAs).";
      reference "RFC7490 - Remote Loop-Free Alternate Fast Reroute";
    }

    feature overload-max-metric {
      description
        "Support of overload by setting all links to max metric.
          In IS-IS, the overload bit is usually used to signal that
          a node cannot be used as a transit. The overload-max-metric
          feature brings a similar behavior leveraging on setting all
          the link metrics to MAX_METRIC.";
    }
    feature prefix-tag {
      description
        "Support for 32-bit prefix tags";
      reference "RFC5130 - A Policy Control Mechanism in
                 IS-IS Using Administrative Tags";
    }
    feature prefix-tag64 {
      description
        "Support for 64-bit prefix tags";
      reference "RFC5130 - A Policy Control Mechanism in
                 IS-IS Using Administrative Tags";
    }
    feature auto-cost {
      description
        "Support for IS-IS interface metric computation
         according to a reference bandwidth.";
    }

    feature te-rid {
```

```
      description
        "Traffic-Engineering Router-ID.";
      reference "RFC5305 - IS-IS Extensions for Traffic Engineering
                 RFC6119 - IPv6 Traffic Engineering in IS-IS";
    }
    feature max-ecmp {
      description
        "Setting maximum number of ECMP paths.";
    }
    feature multi-topology {
      description
        "Support for Multiple-Topology Routing (MTR).";
      reference "RFC5120 - M-IS-IS: Multi Topology Routing in IS-IS";
    }
    feature nlpid-control {
      description
        "Support for the advertisement
         of a Network Layer Protocol Identifier within IS-IS
         configuration.";
    }
    feature graceful-restart {
      description
        "IS-IS Graceful restart support.";
      reference "RFC5306 - Restart Signaling in IS-IS";
    }

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

    feature maximum-area-addresses {
      description
        "Support for maximum-area-addresses configuration.";
    }

    feature admin-control {
      description
        "Administrative control of the protocol state.";
    }

    /* Type definitions */

    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 for the interface.
         The interface-type determines the type
         of hello message that is used.";

    }

    typedef level {
      type enumeration {
        enum "level-1" {
          description
            "This enum indicates L1-only capability.";
        }
        enum "level-2" {
          description
            "This enum indicates L2-only capability.";
        }
        enum "level-all" {
          description
            "This enum indicates capability for both levels.";
        }
      }
      default "level-all";
      description
        "This type defines IS-IS level of an object.";

    }
```

```
     typedef adj-state-type {
       type enumeration {
         enum "up" {
           description
             "State indicates the adjacency is established.";
         }
         enum "down" {
           description
             "State indicates the adjacency is NOT established.";
         }
         enum "init" {
           description
             "State indicates the adjacency is establishing.";
         }
         enum "failed" {
           description
             "State indicates the 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 the state of an interface";
     }

     typedef level-number {
       type uint8 {
         range "1 .. 2";
       }
       description
         "This type defines the current IS-IS 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 the IS-IS LSP ID format using a
         pattern. An example LSP ID is 0143.0438.AEF0.02-01";
    }

    typedef area-address {
      type string {
        pattern '[0-9A-Fa-f]{2}(\.[0-9A-Fa-f]{4}){0,6}';
      }
      description
        "This type defines the area address format.";
    }

    typedef snpa {
      type string {
        length "0 .. 20";
      }
      description
        "This type defines the Subnetwork Point
         of Attachment (SNPA) format.
         The SNPA should be encoded according to the rules
         specified for the particular type of subnetwork
         being used. As an example, for an ethernet subnetwork,
         the SNPA is encoded as a MAC address, such as,
         '00aa.bbcc.ddee'.";
    }

    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 IS-IS system-id using pattern,
         An example system-id is 0143.0438.AEF0";
    }
    typedef extended-system-id {
      type string {
        pattern
          '[0-9A-Fa-f]{4}\.[0-9A-Fa-f]{4}\.[0-9A-Fa-f]{4}\.'
          +'[0-9][0-9]';
      }
      description
        "This type defines IS-IS system-id using pattern. The extended
         system-id contains the pseudonode number in addition to the
```

```
          system-id.
          An example system-id is 0143.0438.AEF0.00";
      }

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

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

      typedef mesh-group-state {
        type enumeration {
          enum "mesh-inactive" {
            description
              "Interface is not part of a mesh group.";
          }
          enum "mesh-set" {
            description
              "Interface is part of a mesh group.";
          }
          enum "mesh-blocked" {
            description
              "LSPs must not be flooded over this interface.";
          }
        }
        description
          "This type describes mesh group state of an interface";
      }

      /* Grouping for notifications */

      grouping notification-instance-hdr {
        description
          "Instance specific IS-IS notification data grouping";
        leaf routing-protocol-name {
          type leafref {
            path "/rt:routing/rt:control-plane-protocols/"
               + "rt:control-plane-protocol/rt:name";
```

```
        }
        description "Name of the IS-IS instance.";
      }
      leaf isis-level {
        type level;
        description "IS-IS level of the instance.";
      }
    }

    grouping notification-interface-hdr {
      description
        "Interface specific IS-IS notification data grouping";
      leaf interface-name {
        type if:interface-ref;
        description "IS-IS interface name";
      }
      leaf interface-level {
        type level;
        description "IS-IS level of the interface.";
      }
      leaf extended-circuit-id {
        type extended-circuit-id;
        description "Extended circuit-id of the interface.";
      }
    }


   /* Groupings for IP Fast Reroute */

   grouping instance-fast-reroute-config {
      description
        "This group defines global configuration of IP
         Fast ReRoute (FRR).";
      container fast-reroute {
        if-feature fast-reroute;
        description
          "This container may be augmented with global
           parameters for IP-FRR.";
        container lfa {
          if-feature lfa;
          description
            "This container may be augmented with
             global parameters for Loop-Free Alternatives (LFA).
             Container creation has no effect on LFA activation.";
        }
      }
    }
```

```
    grouping interface-lfa-config {
       leaf candidate-enable {
         type boolean;
         default "true";
         description
           "Enable the interface to be used as backup.";
       }
       leaf enable {
         type boolean;
         default false;
         description
           "Activates LFA - Per-prefix LFA computation
            is assumed.";
       }
       container remote-lfa {
         if-feature remote-lfa;
         leaf enable {
           type boolean;
           default false;
           description
             "Activates Remote LFA (R-LFA).";
         }
         description
           "Remote LFA configuration.";
       }
       description "Grouping for LFA interface configuration";
     }
     grouping interface-fast-reroute-config {
       description
         "This group defines interface configuration of IP-FRR.";
       container fast-reroute {
         if-feature fast-reroute;
         container lfa {
           if-feature lfa;
           uses interface-lfa-config;
           container level-1 {
             uses interface-lfa-config;
             description
               "LFA level 1 config";
           }
           container level-2 {
           uses interface-lfa-config;
            description
             "LFA level 2 config";
           }
           description
             "LFA configuration.";
         }
```

```
        description
          "Interface IP Fast-reroute configuration.";
      }
    }
    grouping instance-fast-reroute-state {
      description "IPFRR state data grouping";
      container protected-routes {
        config false;
        list address-family-stats {
          key "address-family prefix alternate";

          leaf address-family {
            type iana-rt-types:address-family;
            description
              "Address-family";
          }
          leaf prefix {
            type inet:ip-prefix;
            description
              "Protected prefix.";
          }
          leaf alternate {
            type inet:ip-address;
            description
              "Alternate next hop for the prefix.";
          }
          leaf alternate-type {
                    type identityref {
                      base frr-alternate-type;
                    }
            description
              "Type of alternate.";
          }
          leaf best {
            type boolean;
            description
              "Is set when the alternate is the preferred one,
               is clear otherwise.";
          }
          leaf non-best-reason {
            type string {
              length "1..255";
            }
            description
              "Information field to describe why the alternate
               is not best. The length should be limited to 255
               unicode characters. The expected format is a single
               line text.";
```

```
          }
          container protection-available {
            leaf-list protection-types {
              type identityref {
                base frr-protection-available-type;
              }
              description "This list contains a set of protection
                           types defined as identities.
                           An identity must be added for each type of
                           protection provided by the alternate.
                           As an example, if an alternate provides
                           SRLG, node and link protection, three
                           identities must be added in this list:
                           one for SRLG protection, one for node
                           protection, one for link protection.";
            }
            description "Protection types provided by the alternate.";
          }
          leaf alternate-metric1 {
            type uint32;
            description
              "Metric from Point of Local Repair (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 protected prefix statistics.";
        }
        description
          "List of prefixes that are protected.";
      }

      container unprotected-routes {
        config false;
        list prefixes {
          key "address-family prefix";

          leaf address-family {
            type iana-rt-types:address-family;
```

```
            description "Address-family";
          }
          leaf prefix {
            type inet:ip-prefix;
            description "Unprotected prefix.";
          }
          description
            "Per-AF unprotected prefix statistics.";
        }
        description
          "List of prefixes that are not protected.";
      }

      list protection-statistics {
        key frr-protection-method;
        config false;
        leaf frr-protection-method {
          type identityref {
            base frr-protection-method;
          }
          description "Protection method used.";
        }
        list address-family-stats {
          key address-family;

          leaf address-family {
            type iana-rt-types:address-family;

            description "Address-family";
          }
          leaf total-routes {
            type yang:gauge32;
            description "Total prefixes.";
          }
          leaf unprotected-routes {
            type yang:gauge32;
            description
              "Total prefixes that are not protected.";
          }
          leaf protected-routes {
            type yang:gauge32;
            description
              "Total prefixes that are protected.";
          }
          leaf link-protected-routes {
            type yang:gauge32;
            description
              "Total prefixes that are link protected.";
```

```
          }
          leaf node-protected-routes {
            type yang:gauge32;
            description
              "Total prefixes that are node protected.";
          }
          description
            "Per-AF protected prefix statistics.";
        }

        description "Global protection statistics.";
      }
    }

          /* Route table and local RIB groupings */

    grouping local-rib {
      description "Local-rib - RIB for Routes computed by the local
                   IS-IS routing instance.";
      container local-rib {
        config false;
        description "Local-rib.";
        list route {
          key "prefix";
          description "Routes";
          leaf prefix {
            type inet:ip-prefix;
            description "Destination prefix.";
          }
          container next-hops {
            description "Next hops for the route.";
            list next-hop {
              key "next-hop";
              description "List of next hops for the route";
              leaf outgoing-interface {
                type if:interface-ref;
                description
                  "Name of the outgoing interface.";
              }
              leaf next-hop {
               type inet:ip-address;
               description "Next hop 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 route-content {
      description
        "IS-IS protocol-specific route properties grouping.";
      leaf metric {
        type uint32;
        description "IS-IS metric of a route.";
      }
      leaf-list tag {
        type uint64;
        description
          "List of tags associated with the route.
           This list provides a consolidated view of both
           32-bit and 64-bit tags (RFC5130) available for the prefix.";
      }
      leaf route-type {
        type enumeration {
          enum l2-intra-area {
            description "Level 2 internal route. As per RFC5302,
                         the prefix is directly connected to the
                         advertising router. It cannot be
                         distinguished from an L1->L2 inter-area
                         route.";
          }
          enum l1-intra-area {
            description "Level 1 internal route. As per RFC5302,
                         the prefix is directly connected to the
                         advertising router.";
          }
          enum l2-external {
            description "Level 2 external route. As per RFC5302,
                         such a route is learned from other IGPs.
                         It cannot be distinguished from an L1->L2
                         inter-area external route.";
          }
          enum l1-external {
```

```
            description "Level 1 external route. As per RFC5302,
                         such a route is learned from other IGPs.";
          }
          enum l1-inter-area {
            description "These prefixes are learned via L2 routing.";
          }
          enum l1-inter-area-external {
            description "These prefixes are learned via L2 routing
                         towards an l2-external route.";
          }
        }
        description "IS-IS route type.";
      }
    }


        /* Grouping definitions for configuration and ops state */


    grouping adjacency-state {
      container adjacencies {
        config false;
        list adjacency {
          leaf neighbor-sys-type {
            type level;
            description
              "Level capability 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
              "Define the level(s) activated for the adjacency.
               On a p2p link this might be level 1 and 2,
```

```
              but on a LAN, the usage will be level 1
              between neighbors at level 1 or level 2 between
              neighbors at level 2.";
          }
          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 admin-control {
      leaf enable {
        if-feature admin-control;
        type boolean;
        default "true";
        description
          "Enable/Disable the protocol.";
      }
      description
        "Grouping for admin control.";
    }

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

      leaf hold-down {
        type rt-types:timer-value-milliseconds;
        units msec;
        description
          "Timer used to consider an IGP stability period
                                (milliseconds).";
      }
      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 (milliseconds).";
      }
      leaf current-state {
        type enumeration {
```

```
            enum "quiet" {
              description "QUIET state";
            }
            enum "short-wait" {
              description "SHORT_WAIT state";
            }
            enum "long-wait" {
              description "LONG_WAIT state";
            }
          }
          config false;
          description
            "Current SPF back-off algorithm state.";
        }
        leaf remaining-time-to-learn {
          type rt-types:timer-value-milliseconds;
          units "msec";
          config false;
          description
            "Remaining time until time-to-learn timer fires.";
        }
        leaf remaining-hold-down {
          type rt-types:timer-value-milliseconds;
          units "msec";
          config false;
          description
            "Remaining time until hold-down timer fires.";
        }
        leaf last-event-received {
          type yang:timestamp;
          config false;
          description
            "Time of last IGP event received";
        }
        leaf next-spf-time {
          type yang:timestamp;
          config false;
          description
            "Time when next SPF has been scheduled.";
        }
        leaf last-spf-time {
          type yang:timestamp;
          config false;
          description
            "Time of last SPF computation.";
        }
        description
          "Grouping for IETF SPF delay configuration and state.";
```

```
    }


    grouping node-tag-config {
      description
        "IS-IS node tag config state.";
      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 admin 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 specifies the authentication key. The
               length of the key may be dependent on the
               cryptographic algorithm.";
          }
          leaf crypto-algorithm {
            type identityref {
              base key-chain:crypto-algorithm;
            }
            description
              "Cryptographic algorithm associated with key.";
```

```
          }
        }
        description "Choice of authentication.";
      }
      description "Grouping for global authentication 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
          "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,
           - both means that both are advertised.
           This leaf is only affecting IPv4 metrics.";
      }
      description
        "Grouping for global metric style config.";
    }

    grouping metric-type-global-cfg-with-default {
      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";
```

```
          }
        }
        default wide-only;
        description
          "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,
           - 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;
        description  "Value of the metric";
      }
      description
        "Global default metric config grouping.";
    }
    grouping default-metric-global-cfg-with-default {
      leaf value {
        type wide-metric;
        default "10";
        description  "Value of the metric";
      }
      description
        "Global default metric config grouping.";
    }


    grouping overload-global-cfg {
      leaf status {
        type boolean;
        default false;
        description
          "This leaf specifies 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
          "Timeout (in seconds) of the overload condition.";
      }
      description
        "Overload maximum metric configuration grouping";
    }

    grouping route-preference-global-cfg {
      choice granularity {
        case detail {
          leaf internal {
            type uint8;
            description
              "Protocol preference for internal routes.";
          }
          leaf external {
            type uint8;
            description
              "Protocol preference for external routes.";
          }
        }
        case coarse {
          leaf default {
            type uint8;
            description
              "Protocol preference for all IS-IS routes.";
          }
        }
        description
          "Choice for implementation of route preference.";
      }
      description
        "Global route preference grouping";
    }

    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 "Authentication key specification - The
                         length of the key may be dependent on the
                         cryptographic algorithm.";
          }
          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";
        description
          "Interval (in seconds) between successive hello
           messages.";
      }

      description "Interval between hello messages.";
    }
    grouping hello-interval-cfg-with-default {
      leaf value {
        type rt-types:timer-value-seconds16;
        units "seconds";
        default 10;
        description
          "Interval (in seconds) between successive hello
           messages.";
      }

      description "Interval between hello messages.";
    }

    grouping hello-multiplier-cfg {
      leaf value {
        type uint16;
        description
          "Number of missed hello messages prior to
           declaring the adjacency down.";
      }
```

```
      description
          "Number of missed hello messages prior to
           adjacency down grouping.";
    }
    grouping hello-multiplier-cfg-with-default {
      leaf value {
        type uint16;
        default 3;
        description
          "Number of missed hello messages prior to
           declaring the adjacency down.";
      }
      description
          "Number of missed hello messages prior to
           adjacency down grouping.";
    }

    grouping priority-cfg {
      leaf value {
        type uint8 {
          range "0 .. 127";
        }
        description
          "Priority of interface for DIS election.";
      }

      description "Interface DIS election priority grouping";
    }
    grouping priority-cfg-with-default {
      leaf value {
        type uint8 {
          range "0 .. 127";
        }
        default 64;
        description
          "Priority of interface for DIS election.";
      }

      description "Interface DIS election priority grouping";
    }

    grouping metric-cfg {
      leaf value {
        type wide-metric;
        description "Metric value.";
      }
      description "Interface metric grouping";
    }
```

```
    grouping metric-cfg-with-default {
      leaf value {
        type wide-metric;
        default "10";
        description "Metric value.";
      }
      description "Interface metric grouping";
    }


    grouping metric-parameters {
      container metric-type {
        uses metric-type-global-cfg-with-default;
        container level-1 {
          uses metric-type-global-cfg;
          description "level-1 specific configuration";
        }
        container level-2 {
          uses metric-type-global-cfg;
          description "level-2 specific configuration";
        }
        description "Metric style global configuration";
      }

      container default-metric {
        uses default-metric-global-cfg-with-default;
        container level-1 {
          uses default-metric-global-cfg;
          description "level-1 specific configuration";
        }
        container level-2 {
          uses default-metric-global-cfg;
          description "level-2 specific configuration";
        }
        description "Default metric global configuration";
      }
      container auto-cost {
        if-feature auto-cost;
        description
          "Interface Auto-cost configuration state.";
        leaf enable {
          type boolean;
          description
            "Enable/Disable interface auto-cost.";
        }
        leaf reference-bandwidth {
          when "../enable = 'true'" {
            description "Only when auto cost is enabled";
```

```
          }
          type uint32 {
            range "1..4294967";
          }
          units Mbits;
          description
            "Configure reference bandwidth used to automatically
             determine interface cost (Mbits). The cost is the
             reference bandwidth divided by the interface speed
             with 1 being the minimum cost.";
        }
      }

      description "Grouping for global metric parameters.";
    }

    grouping high-availability-parameters {
      container graceful-restart {
        if-feature graceful-restart;
        leaf enable {
          type boolean;
          default false;
          description "Enable graceful restart.";
        }
        leaf restart-interval {
          type rt-types:timer-value-seconds16;
          units "seconds";
          description
            "Interval (in seconds) to attempt graceful restart prior
             to failure.";
        }
        leaf helper-enable {
          type boolean;
          default "true";
          description
            "Enable local IS-IS router as graceful restart helper.";
        }
        description "Graceful-Restart Configuration.";
      }
      container nsr {
        if-feature nsr;
        description "Non-Stop Routing (NSR) configuration.";
        leaf enable {
          type boolean;
          default false;
          description "Enable/Disable Non-Stop Routing (NSR).";
        }
      }
```

```
      description "Grouping for High Availability parameters.";
    }

    grouping authentication-parameters {
      container authentication {
        uses authentication-global-cfg;

        container level-1 {
          uses authentication-global-cfg;
          description "level-1 specific configuration";
        }
        container level-2 {
          uses authentication-global-cfg;
          description "level-2 specific configuration";
        }
        description "Authentication global configuration for
                     both LSPs and SNPs.";
      }
      description "Grouping for authentication parameters";
    }
    grouping address-family-parameters {
      container address-families {
        if-feature nlpid-control;
        list address-family-list {
          key address-family;
          leaf address-family {
            type iana-rt-types:address-family;
            description "Address-family";
          }
          leaf enable {
            type boolean;
            description "Activate the address family.";
          }
          description
            "List of address families and whether or not they
             are activated.";
        }
        description "Address Family configuration";
      }
      description "Grouping for address family parameters.";
    }

    grouping mpls-parameters {
      container mpls {
        container te-rid {
          if-feature te-rid;
          description
            "Stable ISIS Router IP Address used for Traffic
```

```
             Engineering";
          leaf ipv4-router-id {
            type inet:ipv4-address;
            description
              "Router ID value that would be used in TLV 134.";
          }
          leaf 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 configuration.";
        }
        description "MPLS configuration";
      }
      description "Grouping for MPLS global parameters.";
    }

    grouping lsp-parameters {
      leaf lsp-mtu {
        type uint16;
        units "bytes";
        default 1492;
        description
          "Maximum size of an LSP PDU in bytes.";
      }
      leaf lsp-lifetime {
        type uint16 {
          range "1..65535";
        }
        units "seconds";
        description
          "Lifetime of the router's LSPs in seconds.";
      }
      leaf lsp-refresh {
        if-feature lsp-refresh;
        type rt-types:timer-value-seconds16;
        units "seconds";
        description
          "Refresh interval of the router's LSPs in seconds.";
```

```
      }
      leaf poi-tlv {
        if-feature poi-tlv;
        type boolean;
        default false;
        description
          "Enable advertisement of IS-IS Purge Originator
                  Identification TLV.";
      }
      description "Grouping for LSP global parameters.";
    }
    grouping spf-parameters {
      container spf-control {
          leaf paths {
            if-feature max-ecmp;
            type uint16 {
              range "1..65535";
            }
            description
              "Maximum number of Equal-Cost Multi-Path (ECMP) paths.";
          }
          container ietf-spf-delay {
            if-feature ietf-spf-delay;
            uses ietf-spf-delay;
            description "IETF SPF delay algorithm configuration.";
          }
          description
            "SPF calculation control.";
      }
      description "Grouping for SPF global parameters.";
    }
    grouping instance-config {
      description "IS-IS global configuration grouping";

      uses admin-control;

      leaf level-type {
        type level;
        default "level-all";
        description
          "Level of an IS-IS node - can be level-1,
           level-2 or level-all.";
      }

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

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

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

      uses lsp-parameters;
      uses high-availability-parameters;
      uses node-tag-config;
      uses metric-parameters;
      uses authentication-parameters;
      uses address-family-parameters;
      uses mpls-parameters;
      uses spf-parameters;
      uses instance-fast-reroute-config;

      container preference {
        uses route-preference-global-cfg;
        description "Router preference configuration for IS-IS
                     protocol instance route installation";
      }

      container overload {
        uses overload-global-cfg;
        description "Router protocol instance overload state
                     configuration";
      }

      container overload-max-metric {
        if-feature overload-max-metric;
        uses overload-max-metric-global-cfg;
        description
          "Router protocol instance overload maximum
           metric advertisement configuration.";
      }
    }

    grouping instance-state {
      description
        "IS-IS instance operational state.";
      uses spf-log;
```

```
      uses lsp-log;
      uses hostname-db;
      uses lsdb;
      uses local-rib;
      uses system-counters;
      uses instance-fast-reroute-state;
      leaf discontinuity-time {
        type yang:date-and-time;
        description
          "The time of the most recent occasion at which any one
           or more of this IS-IS instance's counters suffered a
           discontinuity.  If no such discontinuities have occurred
           since the IS-IS instance was last re-initialized, then
           this node contains the time the IS-IS instance was
           re-initialized which normally occurs when it was
           created.";
      }
    }

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

    grouping interface-config {
      description "Interface configuration grouping";

      uses admin-control;

      leaf level-type {
        type level;
        default "level-all";
        description "IS-IS level of the interface.";
      }
      leaf lsp-pacing-interval {
        type rt-types:timer-value-milliseconds;
```

```
        units "milliseconds";
        default 33;
        description
          "Interval (in milli-seconds) between LSP
           transmissions.";
      }
      leaf lsp-retransmit-interval {
        type rt-types:timer-value-seconds16;
        units "seconds";
        description
          "Interval (in seconds) between LSP
           retransmissions.";
      }
      leaf passive {
        type boolean;
        default "false";
        description
          "Indicates whether the interface is in passive mode (IS-IS
           not running but network is advertised).";
      }
      leaf csnp-interval {
        type rt-types:timer-value-seconds16;
        units "seconds";
        default 10;
        description
           "Interval (in seconds) between CSNP messages.";
      }
      container hello-padding {
        leaf enable {
          type boolean;
          default "true";
          description
            "IS-IS Hello-padding activation - enabled by default.";
        }
        description "IS-IS hello padding configuration.";
      }
      leaf mesh-group-enable {
        type mesh-group-state;
        description "IS-IS interface mesh-group state";
      }
      leaf mesh-group {
        when "../mesh-group-enable = 'mesh-set'" {
          description
            "Only valid when mesh-group-enable equals mesh-set";
        }
        type uint8;
        description "IS-IS interface mesh-group ID.";
      }
```

```
      leaf interface-type {
        type interface-type;
        default "broadcast";
        description
          "Type of adjacency to be established for the interface. This
           dictates the type of hello messages that are used.";
      }

      leaf-list tag {
        if-feature prefix-tag;
        type uint32;
        description
          "List of tags associated with the interface.";
      }
      leaf-list tag64 {
        if-feature prefix-tag64;
        type uint64;
        description
          "List of 64-bit 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 configuration";
        }
        container level-2 {
          uses hello-authentication-cfg;
          description "level-2 specific configuration";
        }
        description
          "Authentication type to be used in hello messages.";
      }
      container hello-interval {
        uses hello-interval-cfg-with-default;
        container level-1 {
          uses hello-interval-cfg;
          description "level-1 specific configuration";
        }
        container level-2 {
          uses hello-interval-cfg;
```

```
          description "level-2 specific configuration";
        }
        description "Interval between hello messages.";
      }
      container hello-multiplier {
        uses hello-multiplier-cfg-with-default;
        container level-1 {
          uses hello-multiplier-cfg;
          description "level-1 specific configuration";
        }
        container level-2 {
          uses hello-multiplier-cfg;
          description "level-2 specific configuration";
        }
        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-with-default;
        container level-1 {
          uses priority-cfg;
          description "level-1 specific configuration";
        }
        container level-2 {
          uses priority-cfg;
          description "level-2 specific configuration";
        }
        description "Priority for DIS election.";
      }
      container metric {
        uses metric-cfg-with-default;
        container level-1 {
          uses metric-cfg;
          description "level-1 specific configuration";
        }
        container level-2 {
          uses metric-cfg;
          description "level-2 specific configuration";
        }
        description "Metric configuration.";
      }
      container bfd {
        if-feature bfd;
        description "BFD Client Configuration.";
```

```
        uses bfd-types:client-cfg-parms;

        reference "RFC YYYY - YANG Data Model for Bidirectional
                  Forwarding Detection (BFD).

   -- Note to RFC Editor Please replace YYYY with published FC
      number for draft-ietf-bfd-yang.";

       }
       container address-families {
         if-feature nlpid-control;
         list address-family-list {
           key address-family;
           leaf address-family {
             type iana-rt-types:address-family;
             description  "Address-family";
           }
           description "List of AFs.";
         }
         description "Interface address-families";
       }
       container mpls {
         container ldp {
           leaf igp-sync {
             if-feature ldp-igp-sync;
             type boolean;
             default false;
             description "Enables IGP/LDP synchronization";
           }
           description "LDP protocol related configuration.";
         }
         description "MPLS configuration for IS-IS interfaces";
       }
       uses interface-fast-reroute-config;
     }

     grouping multi-topology-interface-config {
       description "IS-IS interface topology configuration.";
       container metric {
         uses metric-cfg;
         container level-1 {
           uses metric-cfg;
           description "level-1 specific configuration";
         }
         container level-2 {
           uses metric-cfg;
           description "level-2 specific configuration";
         }
```

```
        description "Metric IS-IS interface configuration.";
      }
    }
    grouping interface-state {
      description
        "IS-IS interface operational state.";
      uses adjacency-state;
      uses event-counters;
      uses packet-counters;
      leaf discontinuity-time {
        type yang:date-and-time;
        description
          "The time of the most recent occasion at which any one
           or more of this IS-IS interface's counters suffered a
           discontinuity.  If no such discontinuities have occurred
           since the IS-IS interface was last re-initialized, then
           this node contains the time the IS-IS interface was
           re-initialized which normally occurs when it was
           created.";
        }
    }

   /* Grouping for the hostname database */

    grouping hostname-db {
      container hostnames {
        config false;
        list hostname {
          key system-id;
          leaf system-id {
            type system-id;
            description
              "system-id associated with the hostname.";
          }
          leaf hostname {
            type string {
              length "1..255";
            }
            description
              "Hostname associated with the system-id
               as defined in RFC5301.";
          }
          description
            "List of system-id/hostname associations.";
        }
        description
          "Hostname to system-id mapping database.";
      }
```

```
    description
      "Grouping for hostname to system-id mapping database.";
  }

  /* Groupings for counters */

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

        leaf level {
          type level-number;
          description "IS-IS 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 IS-IS 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
               occurred.";
          }
          leaf id-len-mismatch {
            type uint32;
            description
              "Number of times a PDU is received with a
               different value for the ID field length
               than 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
          "List counters for the IS-IS protocol instance";
      }
      description
        "Grouping for IS-IS system counters";
    }
```

```
    grouping event-counters {
      container event-counters {
        config false;
        leaf adjacency-changes {
          type uint32;
          description
            "The number of times an adjacency state change has
             occurred 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 has been
             received on this interface with the
             max area address field differing from that of
             this system.";
        }
        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 "IS-IS interface event counters.";
      }
      description
        "Grouping for IS-IS interface event counters";
    }

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

          leaf level {
            type level-number;
            description "IS-IS level.";
          }
          container iih {
            leaf in {
              type uint32;
              description "Received IIH PDUs.";
            }
            leaf out {
              type uint32;
              description "Sent IIH PDUs.";
            }
            description "Number of IIH PDUs received/sent.";
          }
          container ish {
            leaf in {
              type uint32;
              description "Received ISH PDUs.";
            }
            leaf out {
              type uint32;
              description "Sent ISH PDUs.";
            }
```

```
            description
              "ISH PDUs received/sent.";
          }
          container esh {
            leaf in {
              type uint32;
              description "Received ESH PDUs.";
            }
            leaf out {
              type uint32;
              description "Sent ESH PDUs.";
            }
            description "Number of ESH PDUs received/sent.";
          }
          container lsp {
            leaf in {
              type uint32;
              description "Received LSP PDUs.";
            }
            leaf out {
              type uint32;
              description "Sent LSP PDUs.";
            }
            description "Number of LSP PDUs received/sent.";
          }
          container psnp {
            leaf in {
              type uint32;
              description "Received PSNP PDUs.";
            }
            leaf out {
              type uint32;
              description "Sent PSNP PDUs.";
            }
            description "Number of PSNP PDUs received/sent.";
          }
          container csnp {
            leaf in {
              type uint32;
              description "Received CSNP PDUs.";
            }
            leaf out {
              type uint32;
              description "Sent CSNP PDUs.";
            }
            description "Number of CSNP PDUs received/sent.";
          }
          container unknown {
```

```
            leaf in {
              type uint32;
              description "Received unknown PDUs.";
            }
            description "Number of unknown PDUs received/sent.";
          }
          description
            "List of packet counter for supported levels.";
        }
        description "Packet counters per IS-IS level.";
      }
      description
        "Grouping for per IS-IS Level packet counters.";
    }

        /* Groupings for various log buffers */
    grouping spf-log {
      container spf-log {
        config false;
        list event {
          key id;

          leaf id {
            type yang:counter32;
            description
              "Event identifier -  purely internal value.
               It is expected the most recent events to have the bigger
               id number.";
          }
          leaf spf-type {
            type enumeration {
              enum full {
                description "Full SPF computation.";
              }
              enum route-only {
                description
                  "Route reachability only SPF computation";
              }
            }
            description "Type of SPF computation performed.";
          }
          leaf level {
            type level-number;
            description
              "IS-IS level number for SPF computation";
          }
          leaf schedule-timestamp {
            type yang:timestamp;
```

```
            description
              "Timestamp of when the SPF computation was
               scheduled.";
          }
          leaf start-timestamp {
            type yang:timestamp;
            description
              "Timestamp of when the SPF computation started.";
          }
          leaf end-timestamp {
            type yang:timestamp;
            description
              "Timestamp of when the SPF computation ended.";
          }
          list trigger-lsp {
            key "lsp";
            leaf lsp {
              type lsp-id;
              description
                "LSP ID of the LSP triggering SPF computation.";
            }
            leaf sequence {
              type uint32;
              description
                "Sequence number of the LSP triggering SPF
                 computation";
            }
            description
              "This list includes the LSPs that triggered the
               SPF computation.";
          }
          description
            "List of computation events - implemented as a
             wrapping buffer.";
        }

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

    grouping lsp-log {
      container lsp-log {
        config false;
        list event {
          key id;
```

```
          leaf id {
            type yang:counter32;
            description
              "Event identifier -  purely internal value.
               It is expected the most recent events to have the bigger
               id number.";
          }
          leaf level {
            type level-number;
            description
              "IS-IS level number for LSP";
          }
          container lsp {
            leaf lsp {
              type lsp-id;
              description
                "LSP ID of the LSP.";
            }
            leaf sequence {
              type uint32;
              description
                "Sequence number of the LSP.";
            }
            description
              "LSP identification container - either the received
               LSP or the locally generated LSP.";
          }

          leaf received-timestamp {
            type yang:timestamp;
            description
              "This is the timestamp when the LSA was received.
               In case of local LSA update, the timestamp refers
               to the LSA origination time.";
          }

          leaf reason {
            type identityref {
              base lsp-log-reason;
            }
            description "Type of LSP change.";
          }

          description
            "List of LSP events - implemented as a
             wrapping buffer.";
        }
```

```
        description
          "This container lists the LSP log.
           Local LSP modifications are also included
           in the list.";

      } description "Grouping for LSP log.";
    }



    /* Groupings for the LSDB description */

    /* Unknown TLV and sub-TLV description */
    grouping tlv {
      description
        "Type-Length-Value (TLV)";
      leaf type {
        type uint16;
        description "TLV type.";
      }
      leaf length {
        type uint16;
        description "TLV length (octets).";
      }
      leaf value {
        type yang:hex-string;
        description "TLV value.";
      }
    }

    grouping unknown-tlvs {
      description
        "Unknown TLVs grouping - Used for unknown TLVs or
         unknown sub-TLVs.";
      container unknown-tlvs {
        description "All unknown TLVs.";
        list unknown-tlv {
          description "Unknown TLV.";
          uses tlv;
        }
      }
    }

    /* TLVs and sub-TLVs for prefixes */

    grouping prefix-reachability-attributes {
      description
        "Grouping for 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 "Re-advertisement flag.";
        }
        leaf node-flag {
          type boolean;
          description "Node flag.";
        }
      }

      grouping prefix-ipv4-source-router-id {
        description
          "Grouping for 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
          "Grouping for 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
                     as defined in RFC7794.";

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

      grouping prefix-ipv4-std {
```

```
      description
        "Grouping for attributes of an IPv4 standard prefix
         as defined in RFC1195.";
      leaf ip-prefix {
        type inet:ipv4-address;
        description "IPv4 prefix address";
      }
      leaf prefix-len {
        type uint8;
        description "IPv4 prefix length (in bits)";
      }
      leaf i-e {
        type boolean;
        description
          "Internal or External (I/E) Metric bit value.
           Set to 'false' to indicate an internal metric.";
      }
      container default-metric {
        leaf metric {
          type std-metric;
          description "Default IS-IS metric for IPv4 prefix";
        }
        description "IS-IS default metric container.";
      }
      container delay-metric {
        leaf metric {
          type std-metric;
          description "IS-IS delay metric for IPv4 prefix";
        }
        leaf supported {
          type boolean;
          default "false";
          description
            "Indicates whether IS-IS delay metric is supported.";
        }
        description "IS-IS delay metric container.";
      }
      container expense-metric {
        leaf metric {
          type std-metric;
          description "IS-IS expense metric for IPv4 prefix";
        }
        leaf supported {
          type boolean;
          default "false";
          description
            "Indicates whether IS-IS expense metric is supported.";
        }
```

```
        description "IS-IS expense metric container.";
      }
      container error-metric {
        leaf metric {
          type std-metric;
          description
            "This leaf describes the IS-IS error metric value";
        }
        leaf supported {
          type boolean;
          default "false";
          description
            "Indicates whether IS-IS error metric is supported.";
        }
        description "IS-IS error metric container.";
      }
    }

    grouping prefix-ipv4-extended {
      description
        "Grouping for attributes of an IPv4 extended prefix
         as defined in RFC5305.";
      leaf up-down {
        type boolean;
        description  "Value of up/down bit.
            Set to true when the prefix has been advertised down
            the hierarchy.";
      }
      leaf ip-prefix {
        type inet:ipv4-address;
        description "IPv4 prefix address";
      }
      leaf prefix-len {
        type uint8;
        description "IPv4 prefix length (in bits)";
      }
      leaf metric {
        type wide-metric;
        description "IS-IS wide metric value";
      }
      leaf-list tag {
        type uint32;
        description
          "List of 32-bit tags associated with the IPv4 prefix.";
      }
      leaf-list tag64 {
        type uint64;
        description
```

```
            "List of 64-bit tags associated with the IPv4 prefix.";
        }
        uses prefix-attributes-extension;
      }

      grouping prefix-ipv6-extended {
        description "Grouping for attributes of an IPv6 prefix
                     as defined in RFC5308.";
        leaf up-down {
          type boolean;
          description "Value of up/down bit.
              Set to true when the prefix has been advertised down
              the hierarchy.";
        }
        leaf ip-prefix {
          type inet:ipv6-address;
          description "IPv6 prefix address";
        }
        leaf prefix-len {
          type uint8;
          description  "IPv6 prefix length (in bits)";
        }
        leaf metric {
          type wide-metric;
          description  "IS-IS wide metric value";
        }
        leaf-list tag {
          type uint32;
          description
            "List of 32-bit tags associated with the IPv4 prefix.";
        }
        leaf-list tag64 {
          type uint64;
          description
            "List of 64-bit tags associated with the IPv4 prefix.";
        }
        uses prefix-attributes-extension;
      }

      /* TLVs and sub-TLVs for neighbors */

      grouping neighbor-link-attributes {
        description
          "Grouping for link attributes as defined
          in RFC5029";
        leaf link-attributes-flags {
          type uint16;
          description
```

```
            "Flags for the link attributes";
        }
      }
      grouping neighbor-gmpls-extensions {
        description
          "Grouping for GMPLS attributes of a neighbor as defined
          in RFC5307";
        leaf link-local-id {
          type uint32;
          description
            "Local identifier of the link.";
        }
        leaf remote-local-id {
          type uint32;
          description
            "Remote identifier of the link.";
        }
        leaf protection-capability {
          type uint8;
          description
            "Describes the protection capabilities
            of the link. This is the value of the
            first octet of the sub-TLV type 20 value.";
        }
        container interface-switching-capability {
          description
            "Interface switching capabilities of the link.";
          leaf switching-capability {
            type uint8;
            description
              "Switching capability of the link.";
          }
          leaf encoding {
            type uint8;
            description
              "Type of encoding of the LSP being used.";
          }
          container max-lsp-bandwidths {
            description "Per-priority max LSP bandwidths.";
            list max-lsp-bandwidth {
              leaf priority {
                type uint8 {
                  range "0 .. 7";
                }
                description "Priority from 0 to 7.";
              }
              leaf bandwidth {
                type rt-types:bandwidth-ieee-float32;
```

```
              description "max LSP bandwidth.";
            }
            description
              "List of max LSP bandwidths for different
               priorities.";
          }
        }
        container tdm-specific {
          when "../switching-capability = 100";
          description
            "Switching Capability-specific information applicable
            when switching type is TDM.";

          leaf minimum-lsp-bandwidth {
            type rt-types:bandwidth-ieee-float32;
            description "minimum LSP bandwidth.";
          }
          leaf indication {
            type uint8;
            description
              "The indication whether the interface supports Standard
              or Arbitrary SONET/SDH.";
          }
        }
        container psc-specific {
          when "../switching-capability >= 1 and
                ../switching-capability <= 4";
          description
            "Switching Capability-specific information applicable
            when switching type is PSC1,PSC2,PSC3 or PSC4.";

          leaf minimum-lsp-bandwidth {
            type rt-types:bandwidth-ieee-float32;
            description "minimum LSP bandwidth.";
          }
          leaf mtu {
            type uint16;
            units bytes;
            description
              "Interface MTU";
          }
        }
      }
    }

    grouping neighbor-extended-te-extensions {
      description
        "Grouping for TE attributes of a neighbor as defined
```

```
          in RFC8570";

        container unidirectional-link-delay {
          description
            "Container for the average delay
            from the local neighbor to the remote one.";
          container flags {
            leaf-list unidirectional-link-delay-subtlv-flags {
                type identityref {
                    base unidirectional-link-delay-subtlv-flag;
                }
               description
                     "This list contains identities for the bits
                      which are set.";
            }
            description
              "unidirectional-link-delay subTLV flags.";
          }
          leaf value {
            type uint32;
            units usec;
            description
              "Delay value expressed in microseconds.";
          }
        }
        container min-max-unidirectional-link-delay {
          description
            "Container for the min and max delay
            from the local neighbor to the remote one.";
          container flags {
            leaf-list min-max-unidirectional-link-delay-subtlv-flags {
                type identityref {
                    base min-max-unidirectional-link-delay-subtlv-flag;
                }
                description
                    "This list contains identities for the bits which are
                    set.";
            }
            description
              "min-max-unidirectional-link-delay subTLV flags.";
          }
          leaf min-value {
            type uint32;
            units usec;
            description
              "Minimum delay value expressed in microseconds.";
          }
          leaf max-value {
```

```
          type uint32;
          units usec;
          description
            "Maximum delay value expressed in microseconds.";
        }
      }
      container unidirectional-link-delay-variation {
        description
          "Container for the average delay variation
          from the local neighbor to the remote one.";
        leaf value {
          type uint32;
          units usec;
          description
            "Delay variation value expressed in microseconds.";
        }
      }
      container unidirectional-link-loss {
        description
          "Container for the packet loss
          from the local neighbor to the remote one.";
        container flags {
          leaf-list unidirectional-link-loss-subtlv-flags {
              type identityref {
                  base unidirectional-link-loss-subtlv-flag;
              }
              description
                  "This list contains identities for the bits which are
                  set.";
          }
          description
            "unidirectional-link-loss subTLV flags.";
        }
        leaf value {
          type uint32;
          units percent;
          description
            "Link packet loss expressed as a percentage
            of the total traffic sent over a configurable interval.";
        }
      }
      container unidirectional-link-residual-bandwidth {
        description
          "Container for the residual bandwidth
          from the local neighbor to the remote one.";
        leaf value {
          type rt-types:bandwidth-ieee-float32;
          units Bps;
```

```
          description
            "Residual bandwidth.";
        }
      }
      container unidirectional-link-available-bandwidth {
        description
          "Container for the available bandwidth
          from the local neighbor to the remote one.";
        leaf value {
          type rt-types:bandwidth-ieee-float32;
          units Bps;
          description
            "Available bandwidth.";
        }
      }
      container unidirectional-link-utilized-bandwidth {
        description
          "Container for the utilized bandwidth
          from the local neighbor to the remote one.";
        leaf value {
          type rt-types:bandwidth-ieee-float32;
          units Bps;
          description
            "Utilized bandwidth.";
        }
      }
    }

    grouping neighbor-te-extensions {
      description
        "Grouping for TE attributes of a neighbor as defined
        in RFC5305";
      leaf admin-group {
        type uint32;
        description
          "Administrative group/Resource Class/Color.";
      }
      container local-if-ipv4-addrs {
        description "All local interface IPv4 addresses.";
        leaf-list local-if-ipv4-addr {
          type inet:ipv4-address;
          description
            "List of local interface IPv4 addresses.";
        }
      }
      container remote-if-ipv4-addrs {
        description "All remote interface IPv4 addresses.";
        leaf-list remote-if-ipv4-addr {
```

```
          type inet:ipv4-address;
          description
            "List of remote interface IPv4 addresses.";
        }
      }
      leaf te-metric {
        type uint32;
        description "TE metric.";
      }
      leaf max-bandwidth {
        type rt-types:bandwidth-ieee-float32;
        description "Maximum bandwidth.";
      }
      leaf max-reservable-bandwidth {
        type rt-types:bandwidth-ieee-float32;
        description "Maximum reservable bandwidth.";
      }
      container unreserved-bandwidths {
        description "All unreserved bandwidths.";
        list unreserved-bandwidth {
          leaf priority {
            type uint8 {
              range "0 .. 7";
            }
            description "Priority from 0 to 7.";
          }
          leaf unreserved-bandwidth {
            type rt-types:bandwidth-ieee-float32;
            description "Unreserved bandwidth.";
          }
          description
            "List of unreserved bandwidths for different
             priorities.";
        }
      }
    }

    grouping neighbor-extended {
      description
       "Grouping for attributes of an IS-IS extended neighbor.";
      leaf neighbor-id {
        type extended-system-id;
        description "system-id of the extended neighbor.";
      }
     container instances {
        description "List of all adjacencies between the local
                     system and the neighbor system-id.";
        list instance {
```

```
          key id;

          leaf id {
            type uint32;
            description "Unique identifier of an instance of a
                         particular neighbor.";
          }
          leaf metric {
            type wide-metric;
            description "IS-IS wide metric for extended neighbor";
          }
          uses neighbor-gmpls-extensions;
          uses neighbor-te-extensions;
          uses neighbor-extended-te-extensions;
          uses neighbor-link-attributes;
          uses unknown-tlvs;
          description "Instance of a particular adjacency.";
        }
      }
    }

    grouping neighbor {
      description  "IS-IS standard neighbor grouping.";
      leaf neighbor-id {
        type extended-system-id;
        description "IS-IS neighbor system-id";
      }
     container instances {
        description "List of all adjacencies between the local
                     system and the neighbor system-id.";
        list instance {
          key id;

          leaf id {
            type uint32;
            description "Unique identifier of an instance of a
                         particular neighbor.";
          }
          leaf i-e {
            type boolean;
            description
              "Internal or External (I/E) Metric bit value.
               Set to 'false' to indicate an internal metric.";
          }
          container default-metric {
            leaf metric {
              type std-metric;
              description "IS-IS default metric value";
```

```
            }
           description "IS-IS default metric container";
          }
          container delay-metric {
            leaf metric {
              type std-metric;
              description "IS-IS delay metric value";
            }
            leaf supported {
              type boolean;
              default "false";
              description "IS-IS delay metric supported";
            }
            description "IS-IS delay metric container";
          }
          container expense-metric {
            leaf metric {
              type std-metric;
              description "IS-IS expense metric value";
            }
            leaf supported {
              type boolean;
              default "false";
              description "IS-IS expense metric supported";
            }
            description "IS-IS expense metric container";
          }
          container error-metric {
            leaf metric {
              type std-metric;
              description "IS-IS error metric value";
            }
            leaf supported {
              type boolean;
              default "false";
              description "IS-IS error metric supported";
            }
            description "IS-IS error metric container";
          }
          description "Instance of a particular adjacency
                       as defined in ISO10589.";
        }
      }
    }

    /* Top-level TLVs */

    grouping tlv132-ipv4-addresses {
```

```
      leaf-list ipv4-addresses {
        type inet:ipv4-address;
        description
          "List of IPv4 addresses of the IS-IS node - IS-IS
           reference is TLV 132.";
      }
      description "Grouping for TLV132.";
    }
    grouping tlv232-ipv6-addresses {
      leaf-list ipv6-addresses {
        type inet:ipv6-address;
        description
          "List of IPv6 addresses of the IS-IS node - IS-IS
           reference is TLV 232.";
      }
      description "Grouping for TLV232.";
    }
    grouping tlv134-ipv4-te-rid {
      leaf ipv4-te-routerid {
        type inet:ipv4-address;
        description
          "IPv4 Traffic Engineering router ID of the IS-IS node -
           IS-IS reference is TLV 134.";
      }
      description "Grouping for TLV134.";
    }
    grouping tlv140-ipv6-te-rid {
      leaf ipv6-te-routerid {
        type inet:ipv6-address;
        description
          "IPv6 Traffic Engineering router ID of the IS-IS node -
           IS-IS reference is TLV 140.";
      }
      description "Grouping for TLV140.";
    }
    grouping tlv129-protocols {
      leaf-list protocol-supported {
        type uint8;
        description
        "List of supported protocols of the IS-IS node -
         IS-IS reference is TLV 129.";
      }
      description "Grouping for TLV129.";
    }
    grouping tlv137-hostname {
      leaf dynamic-hostname {
        type string;
        description
```

```
            "Host Name of the IS-IS node - IS-IS reference
             is TLV 137.";
        }
        description "Grouping for TLV137.";
      }
      grouping tlv10-authentication {
        container authentication {
          leaf authentication-type {
            type identityref {
                base key-chain:crypto-algorithm;
            }
            description
              "Authentication type to be used with IS-IS node.";
          }
          leaf authentication-key {
            type string;
            description
              "Authentication key to be used. For security reasons,
               the authentication key MUST NOT be presented in
               a clear text format in response to any request
              (e.g., via get, get-config).";
          }
          description
            "IS-IS node authentication information container -
             IS-IS reference is TLV 10.";
        }
        description "Grouping for TLV10.";
      }
      grouping tlv229-mt {
        container mt-entries {
          list topology {
            description
              "List of topologies supported";

            leaf mt-id {
              type uint16 {
                range "0 .. 4095";
              }
              description
                "Multi-Topology identifier of topology.";
            }
            container attributes {
                leaf-list flags {
                    type identityref {
                        base tlv229-flag;
                    }
                    description
                    "This list contains identities for the bits which are
```

```
                    set.";
                }
                description
                    "TLV 229 flags.";
            }
          }
          description
            "IS-IS node topology information container -
             IS-IS reference is TLV 229.";
        }
        description "Grouping for TLV229.";
      }

      grouping tlv242-router-capabilities {
        container router-capabilities {
          list router-capability {
              container flags {
                leaf-list router-capability-flags {
                    type identityref {
                        base router-capability-flag;
                    }
                    description
                    "This list contains identities for the bits which are
                    set.";
                }
                description
                    "Router capability flags.";
              }
              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 admin tags";
              }

              uses unknown-tlvs;

              description
                "IS-IS node capabilities. This list element may
                 be extended with detailed information -  IS-IS
                 reference is TLV 242.";
            }
            description "List of router capability TLVs.";
```

```
        }
        description "Grouping for TLV242.";
    }

    grouping tlv138-srlg {
      description
        "Grouping for TLV138.";
      container links-srlgs {
        list links {
          leaf neighbor-id {
            type extended-system-id;
            description "system-id of the extended neighbor.";
          }
          leaf flags {
            type uint8;
            description
              "Flags associated with the link.";
          }
          leaf link-local-id {
            type union {
              type inet:ip-address;
              type uint32;
            }
            description
              "Local identifier of the link.
              It could be an IPv4 address or a local identifier.";
          }
          leaf link-remote-id {
            type union {
              type inet:ip-address;
              type uint32;
            }
            description
              "Remote identifier of the link.
              It could be an IPv4 address or a remotely learned
              identifier.";
          }
          container srlgs {
            description "List of SRLGs.";
            leaf-list srlg {
              type uint32;
              description
                "SRLG value of the link.";
            }
          }
          description
            "SRLG attribute of a link.";
        }
```

```
        description
          "List of links with SRLGs";
      }
    }

    /* Grouping for LSDB description */

    grouping lsp-entry {
      description "IS-IS LSP database entry grouping";

      leaf decoded-completed {
        type boolean;
        description "IS-IS LSP body fully decoded.";
      }
      leaf raw-data {
        type yang:hex-string;
        description
          "The hexadecimal representation of the complete LSP in
           network-byte order (NBO) as received or originated.";
      }
      leaf lsp-id {
        type lsp-id;
        description "LSP ID of the LSP";
      }
      leaf checksum {
        type uint16;
        description "LSP checksum";
      }
      leaf remaining-lifetime {
        type uint16;
        units "seconds";
        description
          "Remaining lifetime (in seconds) until LSP expiration.";
      }
      leaf sequence {
        type uint32;
        description
          "This leaf describes the sequence number of the LSP.";
      }
      container attributes {
          leaf-list lsp-flags {
              type identityref {
                  base lsp-flag;
              }
              description
                  "This list contains identities for the bits which are
                  set.";
          }
```

```
          description "LSP attributes.";
        }

        uses tlv132-ipv4-addresses;
        uses tlv232-ipv6-addresses;
        uses tlv134-ipv4-te-rid;
        uses tlv140-ipv6-te-rid;
        uses tlv129-protocols;
        uses tlv137-hostname;
        uses tlv10-authentication;
        uses tlv229-mt;
        uses tlv242-router-capabilities;
        uses tlv138-srlg;
        uses unknown-tlvs;

        container is-neighbor {
          list neighbor {
            key neighbor-id;

            uses neighbor;
            description "List of neighbors.";
          }
          description
            "Standard IS neighbors container - IS-IS reference is
             TLV 2.";
        }

        container extended-is-neighbor {
          list neighbor {
            key neighbor-id;

            uses neighbor-extended;
            description
              "List of extended IS neighbors";
          }
          description
            "Standard IS extended neighbors container - IS-IS
             reference is TLV 22";
        }

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

```
      }

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

      container extended-ipv4-reachability {
        list prefixes {
          uses prefix-ipv4-extended;
          uses unknown-tlvs;
          description "List of prefixes.";
        }
        description
          "IPv4 extended reachability information container -
           IS-IS reference is TLV 135.";
      }

      container mt-is-neighbor {
        list neighbor {
          leaf mt-id {
            type uint16 {
              range "0 .. 4095";
            }
            description "Multi-topology (MT) identifier";
          }
          uses neighbor-extended;
          description "List of neighbors.";
        }
        description
          "IS-IS multi-topology neighbor container - IS-IS
           reference is TLV 223.";
      }

      container mt-extended-ipv4-reachability {
        list prefixes {
          leaf mt-id {
            type uint16 {
              range "0 .. 4095";
            }
            description  "Multi-topology (MT) identifier";
          }
          uses prefix-ipv4-extended;
```

```
          uses unknown-tlvs;
          description "List of extended prefixes.";
        }
        description
          "IPv4 multi-topology (MT) extended reachability
           information container - IS-IS reference is TLV 235.";
      }

      container mt-ipv6-reachability {
        list prefixes {
          leaf MT-ID {
            type uint16 {
              range "0 .. 4095";
            }
            description "Multi-topology (MT) identifier";
          }
          uses prefix-ipv6-extended;
          uses unknown-tlvs;
          description "List of IPv6 extended prefixes.";
        }
        description
          "IPv6 multi-topology (MT) extended reachability
           information container - IS-IS reference is TLV 237.";
      }

      container ipv6-reachability {
        list prefixes {
          uses prefix-ipv6-extended;
          uses unknown-tlvs;
          description "List of IPv6 prefixes.";
        }
        description
          "IPv6 reachability information container - IS-IS
           reference is TLV 236.";
      }
    }

    grouping lsdb {
      description "Link State Database (LSDB) grouping";
      container database {
        config false;
        list levels {
          key level;

          leaf level {
            type level-number;
            description "LSDB level number (1 or 2)";
          }
```

```
        list lsp {
          key lsp-id;
          uses lsp-entry;
          description "List of LSPs in LSDB";
        }
        description "List of LSPs for the LSDB level container";
      }
      description "IS-IS Link State database container";
    }
  }



  /* Augmentations */

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


  augment "/if:interfaces/if:interface" {
    leaf clns-mtu {
      if-feature osi-interface;
      type uint16;
      description "CLNS MTU of the interface";
    }
    description "ISO specific interface parameters.";
  }

  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 IS-IS
       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 instance-config;
        uses instance-state;

        container topologies {
          if-feature multi-topology;
          list topology {
            key "name";
            leaf enable {
              type boolean;
              description "Topology enable configuration";
            }
            leaf name {
              type leafref {
                path "../../../../../../rt:ribs/rt:rib/rt:name";
              }
              description
                "Routing Information Base (RIB) corresponding
                 to topology.";
            }

            uses multi-topology-config;

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

              description
                "Reference to the interface within
                 the routing-instance.";
            }
            uses interface-config;
            uses interface-state;
            container topologies {
              if-feature multi-topology;
              list topology {
```

```
                key name;

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

                  description
                    "Routing Information Base (RIB) corresponding
                     to topology.";
                }
                uses multi-topology-interface-config;
                description "List of interface topologies";
              }
              description "Multi-topology container";
            }
            description "List of IS-IS interfaces.";
          }
          description
            "IS-IS interface specific configuration container";
        }

        description
          "IS-IS configuration/state top-level container";
      }
    }


    /* RPC methods */

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

        leaf routing-protocol-instance-name {
          type leafref {
            path "/rt:routing/rt:control-plane-protocols/"
               + "rt:control-plane-protocol/rt:name";
          }
          mandatory "true";
          description
            "Name of the IS-IS protocol instance whose IS-IS
             adjacency is being cleared.
```

```
            If the corresponding IS-IS instance doesn't exist,
            then the operation will fail with an error-tag of
            'data-missing' and an error-app-tag of
            'routing-protocol-instance-not-found'.";
        }
        leaf level {
          type level;
          description
            "IS-IS level of the adjacency to be cleared. If the
             IS-IS 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 the operation
             SHALL fail with an error-tag of 'data-missing' and
             an error-app-tag of 'bad-isis-level'.";
        }
        leaf interface {
          type if:interface-ref;
          description
            "IS-IS interface name.

             If the corresponding IS-IS interface doesn't exist,
             then the operation SHALL fail with an error-tag of
             'data-missing' and an error-app-tag of
             'isis-interface-not-found'.";
        }
      }
    }

    rpc clear-database {
      description
        "This RPC request clears a particular  IS-IS database. If
         the operation fails for an IS-IS internal reason, then
         the error-tag and error-app-tag should be set
         indicating the reason for the failure.";
      input {
        leaf routing-protocol-instance-name {
          type leafref {
            path "/rt:routing/rt:control-plane-protocols/"
               + "rt:control-plane-protocol/rt:name";
          }
          mandatory "true";
          description
            "Name of the IS-IS protocol instance whose IS-IS
             database(s) is/are being cleared.

             If the corresponding IS-IS instance doesn't exist,
```

```
            then the operation will fail with an error-tag of
            'data-missing' and an error-app-tag of
            'routing-protocol-instance-not-found'.";
        }
        leaf level {
          type level;
          description
            "IS-IS level of the adjacency to be cleared. If the
             IS-IS level is level-1-2, both level 1 and level 2
             databases would be cleared.

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


    /* Notifications */

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

      leaf overload {
        type enumeration {
          enum off {
            description
              "Indicates IS-IS instance has left overload state";
          }
          enum on {
            description
              "Indicates IS-IS instance has entered overload state";
          }

        }
        description "New overload state of the IS-IS instance";
      }
      description
        "This notification is sent when an IS-IS instance
         overload state changes.";
    }

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

```
      leaf pdu-size {
        type uint32;
        description "Size of the LSP 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 (ISO10589)
         for the circuit.  The notification generation must be
         throttled with at least 5 seconds between successive
         notifications.";
    }

    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 5 seconds between successive
         notifications.";
    }

    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 5 seconds between successive
         notifications.";
    }

    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 originate 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 5 seconds between successive
         notifications.";
    }

    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 5 seconds between successive
          notifications.";
      }

      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 5 seconds between successive
           notifications.";
      }

      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 5 seconds between successive
           notifications.";
      }

      notification rejected-adjacency {
        uses notification-instance-hdr;
        uses notification-interface-hdr;
        leaf raw-pdu {
          type binary;
          description
            "Received raw PDU.";
        }
        leaf reason {
          type string {
```

```
          length "0..255";
        }
        description
          "The system may provide a reason to reject the
           adjacency. If the reason is not available,
           the reason string will not be returned.
           The expected format is a single line text.";
      }
      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 5 seconds between successive
         notifications.";
    }


    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
          "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 protocols
         supported. The notification generation must be throttled
         with at least 5 seconds between successive
         notifications.";
    }

    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 errant
           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 an
         LSP with a parse error. The notification generation must
         be throttled with at least 5 seconds between successive
         notifications.";
    }

    notification adjacency-state-change {
      uses notification-instance-hdr;
      uses notification-interface-hdr;
      leaf neighbor {
        type string {
          length "1..255";
        }
        description
          "Name of the neighbor.
           It corresponds to the hostname associated
           with the system-id of the neighbor in the
           mapping database (RFC5301).
           If the name of the neighbor is
           not available, it is not returned.";
      }
      leaf neighbor-system-id {
        type system-id;
        description "Neighbor system-id";
      }
      leaf state {
        type adj-state-type;

        description "New state of the IS-IS adjacency.";
      }
      leaf reason {
        type string {
```

```
          length "1..255";
        }
        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. The expected format is a single line
           text.";
      }
      description
        "This notification is sent when an IS-IS 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 "Timestamp when the LSP was received.";
      }
      leaf neighbor-system-id {
        type system-id;
        description "Neighbor system-id of LSP sender";
      }
      description
        "This notification is sent when an LSP is received.
         The notification generation must be throttled with at
         least 5 seconds between successive notifications.";
     }

    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 "Timestamp when our LSP was regenerated.";
      }
      description
        "This notification is sent when an LSP is regenerated.
         The notification generation must be throttled with at
         least 5 seconds between successive notifications.";
    }
  }
  <CODE ENDS>
```

7. Security Considerations

The YANG modules specified in this document define a schema for data that is designed to be accessed via network management protocols such as NETCONF [RFC6241] or RESTCONF [RFC8040]. The lowest NETCONF layer is the secure transport layer, and the mandatory-to-implement secure transport is Secure Shell (SSH) [RFC6242]. The lowest RESTCONF layer is HTTPS, and the mandatory-to-implement secure transport is TLS [RFC8446].

The NETCONF Access Control Model (NACM) [RFC8341] provides the means to restrict access for particular NETCONF or RESTCONF users to a pre-configured subset of all available NETCONF or RESTCONF protocol operations and content.

There are a number of data nodes defined in ietf-isis.yang module that are writable/creatable/deletable (i.e., config true, which is the default). These data nodes may be considered sensitive or vulnerable in some network environments. Write operations (e.g., edit-config) to these data nodes without proper protection can have a negative effect on network operations. Writable data node represent configuration of each instance and interface. These correspond to the following schema nodes:

/isis

/isis/interfaces/interface[name]

For IS-IS, the ability to modify IS-IS configuration will allow the entire IS-IS domain to be compromised including forming adjacencies with unauthorized routers to misroute traffic or mount a massive

Denial-of-Service (DoS) attack. For example, adding IS-IS on any unprotected interface could allow an IS-IS adjacency to be formed with an unauthorized and malicious neighbor. Once an adjacency is formed, traffic could be hijacked. As a simpler example, a Denial-Of-Service attack could be mounted by changing the cost of an IS-IS interface to be asymmetric such that a hard routing loop ensues. In general, unauthorized modification of most IS-IS features will pose their own set of security risks and the "Security Considerations" in the respective reference RFCs should be consulted.

Some of the readable data nodes in the ietf-isis.yang module may be considered sensitive or vulnerable in some network environments. It is thus important to control read access (e.g., via get, get-config, or notification) to these data nodes. The exposure of the Link State Database (LSDB) will expose the detailed topology of the network. Similarly, the IS-IS local RIB exposes the reachable prefixes in the IS-IS routing domain. The Link State Database (LSDB) and local RIB are represented by the following schema nodes:

/isis/database

/isis/local-rib

Exposure of the Link State Database and local RIB include information beyond the scope of the IS-IS router and this may be undesirable since exposure may facilitate other attacks. Additionally, the complete IP network topology and, if deployed, the traffic engineering topology of the IS-IS domain can be reconstructed from the Link State Database. Though not as straightforward, the IS-IS local RIB can also be discover topological information. Network operators may consider their topologies to be sensitive confidential data.

For IS-IS authentication, configuration is supported via the specification of key-chain [RFC8177] or the direct specification of key and authentication algorithm. Hence, authentication configuration using the "auth-table-trailer" case in the "authentication" container inherits the security considerations of [RFC8177]. This includes the considerations with respect to the local storage and handling of authentication keys.

Some of the RPC operations in this YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control access to these operations. The IS-IS YANG module support the "clear-adjacency" and "clear-database" RPCs. If access to either of these is compromised, they can result in temporary network outages be employed to mount DoS attacks.

The actual authentication key data (whether locally specified or part of a key-chain) is sensitive and needs to be kept secret from unauthorized parties; compromise of the key data would allow an attacker to forge IS-IS traffic that would be accepted as authentic, potentially compromising the entirety IS-IS domain.

The model describes several notifications, implementations must rate-limit the generation of these notifications to avoid creating significant notification load. Otherwise, this notification load may have some side effects on the system stability and may be exploited as an attack vector.

8. Contributors

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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: The IESG
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
```

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11.1. 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>192.0.2.1</router-id>
      <control-plane-protocols>
        <control-plane-protocol>
          <name>ISIS-example</name>
          <description/>
          <type>
            <type xmlns:isis="urn:ietf:params:xml:ns:yang:ietf-isis">
            isis:isis
            </type>
          </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-rid>
                    <ipv4-router-id>192.0.2.1</ipv4-router-id>
                  </te-rid>
                </mpls>
                <lsp-lifetime>65535</lsp-lifetime>
                <lsp-refresh>65000</lsp-refresh>
                <metric-type>
                  <value>wide-only</value>
                </metric-type>
                <default-metric>
                  <value>111111</value>
                </default-metric>
                <address-families>
                  <address-family-list>
                    <address-family>ipv4</address-family>
                    <enable>true</enable>
                  </address-family-list>
                  <address-family-list>
                    <address-family>ipv6</address-family>
                    <enable>true</enable>
                  </address-family-list>
                </address-families>
                <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 xmlns:ianaift="urn:ietf:params:xml:ns:yang:iana-if-type">
        ianaift:softwareLoopback
        </type>
        <link-up-down-trap-enable>enabled</link-up-down-trap-enable>
        <ipv4 xmlns="urn:ietf:params:xml:ns:yang:ietf-ip">
          <address>
            <ip>192.0.2.1</ip>
            <prefix-length>32</prefix-length>
          </address>
        </ipv4>
        <ipv6 xmlns="urn:ietf:params:xml:ns:yang:ietf-ip">
          <address>
            <ip>2001:DB8::1</ip>
            <prefix-length>128</prefix-length>
          </address>
        </ipv6>
      </interface>
      <interface>
        <name>Eth1</name>
        <description/>
        <type xmlns:ianaift="urn:ietf:params:xml:ns:yang:iana-if-type">
        ianaift:ethernetCsmacd
        </type>
        <link-up-down-trap-enable>enabled</link-up-down-trap-enable>
        <ipv4 xmlns="urn:ietf:params:xml:ns:yang:ietf-ip">
          <address>
            <ip>198.51.100.1</ip>
            <prefix-length>30</prefix-length>
          </address>
        </ipv4>
        <ipv6 xmlns="urn:ietf:params:xml:ns:yang:ietf-ip">
          <address>
            <ip>2001:DB8:0:0:FF::1</ip>
            <prefix-length>64</prefix-length>
          </address>
        </ipv6>
      </interface>
    </interfaces>
  </data>
```

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January 30, 2015

BIER support via ISIS
draft-przygienda-bier-isis-ranges-02

Abstract

Specification of an ISIS extension to support BIER domains and sub-domains.

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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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 August 3, 2015.

Copyright Notice

Table of Contents

1. Introduction

Bit Index Explicit Replication (BIER) [I-D.draft-wijnands-bier-architecture-02] defines an architecture where all intended multicast receivers are encoded as bitmask in the Multicast packet header within different encapsulations such as [I-D.draft-wijnands-mpls-bier-encapsulation-02]. A router that receives such a packet will forward the packet based on the Bit Position in the packet header towards the receiver(s), following a precomputed tree for each of the bits in the packet. Each receiver is represented by a unique bit in the bitmask.

This document presents necessary extensions to the currently deployed ISIS for IP [RFC1195] protocol to support distribution of information necessary for operation of BIER domains and sub-domains. This document defines a new TLV to be advertised by every router participating in BIER signaling.

2. Terminology

Some of the terminology specified in [I-D.draft-wijnands-bier-architecture-02] is replicated here and extended by necessary definitions:

BIER: Bit Index Explicit Replication (The overall architecture of forwarding multicast using a Bit Position).

BIER-OL: BIER Overlay Signaling. (The method for the BFIR to learn about BFER's).

BFR: Bit Forwarding Router (A router that participates in Bit Index Multipoint Forwarding). A BFR is identified by a unique BFR-prefix in a BIER domain.

BFIR: Bit Forwarding Ingress Router (The ingress border router that inserts the BM into the packet).

BFER: Bit Forwarding Egress Router. A router that participates in Bit Index Forwarding as leaf. Each BFER must be a BFR. Each BFER must have a valid BFR-id assigned.

BFT: Bit Forwarding Tree used to reach all BFERs in a domain.

BIFT: Bit Index Forwarding Table.

BMS: Bit Mask Set. Set containing bit positions of all BFER participating in a set.

BMP: Bit Mask Position, a given bit in a BMS.

Invalid BMP: Unassigned Bit Mask Position, consisting of all 0s.

IGP signalled BIER domain: A BIER underlay where the BIER synchronization information is carried in IGP. Observe that a multi-topology is NOT a separate BIER domain in IGP.

BIER sub-domain: A further distinction within a BIER domain identified by its unique sub-domain identifier. A BIER sub-domain can support multiple BitString Lengths.

BFR-id: An optional, unique identifier for a BFR within a BIER sub-domain.

Invalid BFR-id: Unassigned BFR-id, consisting of all 0s.

3. IANA Considerations

This document adds the following new sub-TLVs to the registry of sub-TLVs for TLVs 235, 237 [RFC5120] and TLVs 135,236 [RFC5305],[RFC5308].

Value: 32 (suggested - to be assigned by IANA)

Name: BIER Info

4. Concepts

4.1. BIER Domains and Sub-Domains

An ISIS signalled BIER domain is aligned with the scope of distribution of BFR-prefixes that identify the BFRs within ISIS. ISIS acts in such a case as the according BIER underlay.

Within such a domain, ISIS extensions are capable of carrying BIER information for multiple BIER sub-domains. Each sub-domain is uniquely identified by its subdomain-id and each subdomain can reside in any of the ISIS topologies [RFC5120]. The mapping of sub-domains to topologies is a local decision of each BFR currently but is advertised throughout the domain to ensure routing consistency.

Each BIER sub-domain has as its unique attributes the encapsulation used and the type of tree it is using to forward BIER frames (currently always SPF). Additionally, per supported bitstring length in the sub-domain, each router will advertise the necessary label ranges to support it.

This RFC introduces a sub-TLV in the extended reachability TLVs to distribute such information about BIER sub-domains. To satisfy the requirements for BIER prefixes per [I-D.draft-wijnands-bier-architecture-02] additional information will be carried in [I-D.draft-ginsberg-isis-prefix-attributes].

5. Procedures

5.1. Enabling a BIER Sub-Domain

A given sub-domain with identifier BS with supported bitstring lengths MLs in a multi-topology MT [RFC5120] is denoted further as <MT,SD,MLs> and is normally not advertised to preserve the scaling of the protocol (i.e. ISIS carries no TLVs containing any of the elements related to <MT,SD>) and is enabled by a first BIER sub-TLV (Section 6.1) containing <MT,SD> being advertised into the area. The trigger itself is outside the scope of this RFC but can be for example a VPN desiring to initiate a BIER sub-domain as MI-PMSI [RFC6513] tree. It is outside the scope of this document to describe what trigger for a router capable of participating in <MT,SD> is used to start the origination of the necessary information to join into it.

5.2. Multi Topology and Sub-Domain

All routers in the flooding scope of the BIER TLVs MUST advertise a sub-domain within the same multi-topology. A router discovering a sub-domain advertised within a topology that is different from its own MUST report a misconfiguration of a specific sub-domain. Each router MUST compute BFTs for a sub-domain using only routers advertising it in the same topology.

5.3. Encapsulation

All routers in the flooding scope of the BIER TLVs MUST advertise the same encapsulation for a given <MT,SD>. A router discovering encapsulation advertised that is different from its own MUST report a misconfiguration of a specific <MT,SD>. Each router MUST compute BFTs for <MT,SD> using only routers having the same encapsulation as its own advertised encapsulation in BIER sub-TLV for <MT,SD>.

5.4. Tree Type

All routers in the flooding scope of the BIER TLVs MUST advertise the same tree type for a given <MT,SD>. In case of mismatch the behavior is analogous to Section 5.3.

5.5. Label Advertisements for MPLS encapsulated BIER sub-domains

Each router MAY advertise within the BIER MPLS Encapsulation sub-sub-TLV (Section 6.2) of a BIER Info sub-TLV (Section 6.1, denoted as TLV<MT,SD>) for <MT,SD> for every supported bitstring length a valid starting label value and a non-zero range length. It MUST advertise at least one valid label value and a non-zero range length for the required bitstring lengths per [I-D.draft-wijnands-bier-architecture-02] in case it has computed

itself as being on the BFT rooted at any of the BFRs with valid BFR-ids (except itself if it does NOT have a valid BFR-id) participating in <MT,SD>.

A router MAY decide to not advertise the BIER Info sub-TLV (Section 6.1) for <MT,SD> if it does not want to participate in the sub-domain due to resource constraints, label space optimization, administrative configuration or any other reasons.

5.5.1. Special Consideration

A router MUST advertise for each bitstring length it supports in <MT,SD> a label range size that guarantees to cover the maximum BFR-id injected into <MT,SD> (which implies a certain maximum set id per bitstring length as described in [I-D.draft-wijnands-bier-architecture-02]). Any router that violates this condition MUST be excluded from BIER BFTs for <MT,SD>.

5.6. BFR-id Advertisements

Each BFER MAY advertise with its TLV<MT,SD> the BFR-id that it has administratively chosen.

If a router discovers that two BFRs it can reach advertise the same value for BFR-id for <MT,SD>, it MUST report a misconfiguration and disregard those routers for all BIER calculations and procedures for <MT,SD> to align with [I-D.draft-wijnands-bier-architecture-02]. It is worth observing that based on this procedure routers with colliding BFR-id assignments in <MT,SD> MAY still act as BFIRs in <MT,SD> but will be never able to receive traffic from other BFRs in <MT,SD>.

5.7. Flooding

BIER domain information SHOULD change and force flooding infrequently. Especially, the router SHOULD make every possible attempt to bundle all the changes necessary to sub-domains and ranges advertised with those into least possible updates.

5.8. Version

This RFC specifies Version 0 of the BIER extension encodings. Packet encoding supports introduction of future, higher versions with e.g. new sub-sub-TLVs or redefining reserved bits that can maintain the compatiblity to Version 0 or choose to indicate that the compatibility cannot be maintained anymore (changes that cannot work with the provided encoding would necessitate obviously introduction of completely new sub-TLV for BIER).

This kind of 'versioning' allows to introduce e.g. backwards-compatible automatic assignment of unique BFR-ids within sub-domains or addition of optional sub-sub-TLVs that can be ignored by version 0 BIER routers without the danger of incompatiblity.

This is a quite common technique in software development today to maintain and extend backwards compatible APIs.

6. Packet Formats

All ISIS BIER information is carried within the TLVs 235, 237 [RFC5120] and TLVs 135,236 [RFC5305], [RFC5308].

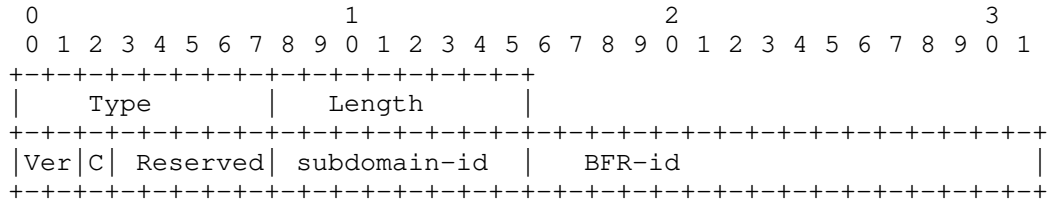
6.1. BIER Info sub-TLV

This sub-TLV carries the information for the BIER sub-domains that the router participates in as BFR. It can repeat multiple times for different sub-domain <MT,SD> combinations.

The sub-TLV carries a single <MT,SD> combination followed by optional sub-sub-TLVs specified within its context such as e.g. BIER MPLS Encapsulation per Section 6.2.

On violation of any of the following conditions, the receiving router SHOULD signal a misconfiguration condition. Further results are unspecified unless described in the according section of this RFC:

- The subdomain-id MUST be included only within a single topology.



Type: as indicated in IANA section.

Length: 1 octet.

Version: Version of the BIER TLV advertised, must be 0 on transmission by router implementing this RFC. Behavior on reception depends on the 'C' bit. 2 bits

C-BIT: Compatibility bit indicating that the TLV can be interpreted by routers implementing lower than the advertised version. Router implementing this version of the RFC MUST set it to 1. On reception, IF the version of the protocol is higher than 0 AND the bit is set (i.e. its value is 1), the TLV MUST be processed normally, IF the bit is clear (i.e. its value is 0), the TLV MUST be ignored for further processing completely independent of the advertised version. When processing this sub-TLV with compatibility bit set, all sub-sub-TLV of unknown type MUST and CAN be safely ignored. 1 bit

Reserved: reserved, must be 0 on transmission, ignored on reception. May be used in future versions. 5 bits

subdomain-id: Unique value identifying the BIER sub-domain. 1 octet

BFR-id: A 2 octet field encoding the BFR-id, as documented in [I-D.draft-wijnands-bier-architecture-02]. If set to the invalid BFR-id advertising router is not owning a BFR-id in the sub-domain.

6.2. BIER MPLS Encapsulation sub-sub-TLV

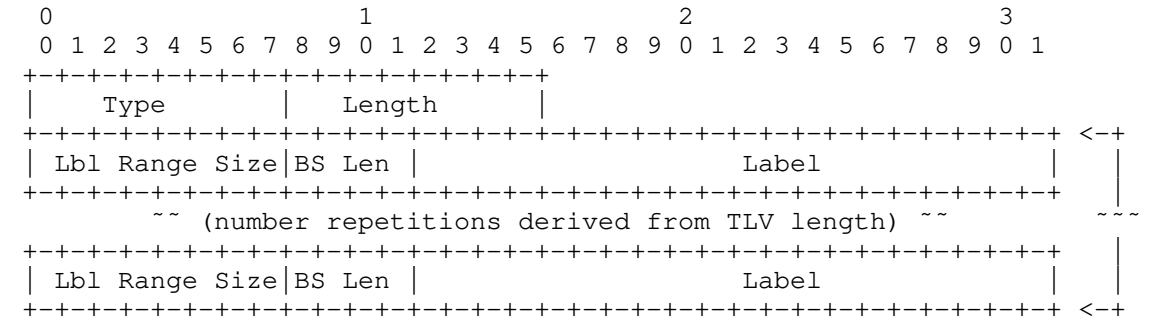
This sub-sub-TLV carries the information for the BIER MPLS encapsulation and the necessary label ranges per bitstring length for a certain <MT,SD> and is carried within the BIER Info sub-TLV (Section 6.1) that the router participates in as BFR.

On violation of any of the following conditions, the receiving router SHOULD signal a misconfiguration condition. Further results are unspecified:

- The sub-sub-TLV MUST be included once AND ONLY once within the sub-TLV.
- Label ranges within the sub-sub-TLV MUST NOT overlap. A receiving BFR MAY additionally check whether any of the ranges in all the sub-sub-TLVs advertised by another BFR overlap and apply the same treatement on violations.
- Bitstring lengths within the sub-sub-TLV MUST NOT repeat.
- The sub-sub-TLV MUST include the required bitstring lengths per [I-D.draft-wijnands-bier-architecture-02].

- All label range sizes MUST be greater than 0.

- All labels MUST represent valid label values.



Type: value of 0 indicating MPLS encapsulation.

Length: 1 octet.

Local BitString Length (BS Len): Bitstring length for the label range that this router is advertising per [I-D.draft-wijnands-mpls-bier-encapsulation-02]. 4 bits.

Label Range Size: Number of labels in the range used on encapsulation for this BIER sub-domain for this bitstring length, 1 octet. This MUST never be advertised as 0 (zero) and otherwise, this sub-sub-TLV must be treated as if not present for BFT calculations and a misconfiguration SHOULD be reported by the receiving router.

Label: First label of the range used on encapsulation for this BIER sub-domain for this bitstring length, 20 bits. The label is used for example by [I-D.draft-wijnands-mpls-bier-encapsulation-02] to forward traffic to sets of BFERs.

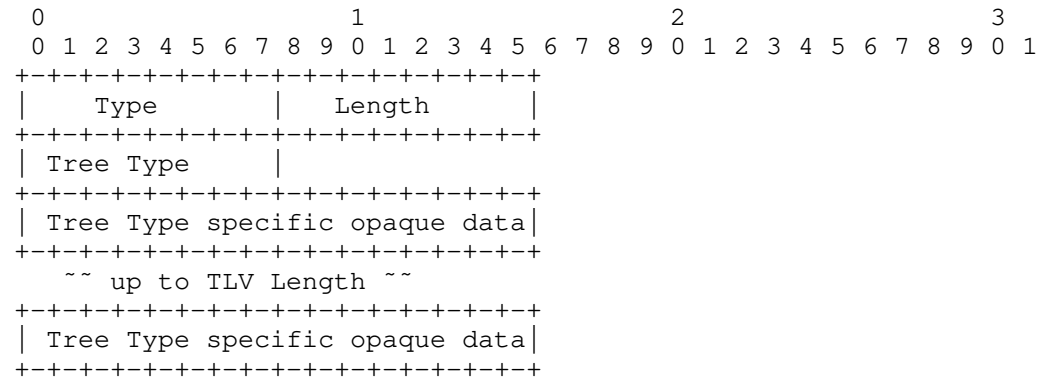
6.3. Optional BIER sub-domain Tree Type sub-sub-TLV

This sub-sub-TLV carries the information of the BIER tree type for a certain <MT,SD>. It is carried within the BIER Info sub-TLV (Section 6.1) that the router participates in as BFR. This sub-sub-TLV is optional and its absence indicates the same as its presence

with Tree Type value 0 (SPF). BIER implementation following this version of the RFC SHOULD NOT advertise this TLV.

On violation of any of the following conditions, the receiving router implementing this RFC SHOULD signal a misconfiguration condition. Further results are unspecified unless described further:

- The sub-sub-TLV MUST be included once AND ONLY once.
- The advertised BIER TLV version is 0 and the value of Tree Type MUST be 0 (SPF).



Type: value of 1 indicating BIER Tree Type.

Length: 1 octet.

Tree Type: The only supported value today is 0 and indicates that BIER uses normal SPF computed reachability to construct BIFT. BIER implementation following this RFC MUST ignore the node for purposes of the sub-domain <MT,SD> if this field has any value except 0.

Tree type specific opaque data: Opaque data up to the length of the TLV carrying tree type specific parameters. For Tree Type 0 (SPF) no such data is included and therefore TLV Length is 1.

7. Security Considerations

Implementations must assure that malformed TLV and Sub-TLV permutations do not result in errors which cause hard protocol failures.

8. Acknowledgements

The RFC is aligned with the [I-D.draft-psenak-ospf-bier-extension-01] draft as far as the protocol mechanisms overlap.

Many thanks for comments from (in no particular order) Hannes Gredler, Ijsbrand Wijnands and Peter Psenak.

9. Normative References

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Advertising Tunnelling Capability in IS-IS
draft-xu-isis-encapsulation-cap-07

Abstract

Some networks use tunnels for a variety of reasons. A large variety of tunnel types are defined and the ingress needs to select a type of tunnel which is supported by the egress. This document defines how to advertise egress tunnel capabilities in IS-IS Router Capability TLV.

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

Some networks use tunnels for a variety of reasons, such as:

- Partial deployment of MPLS-SPRING as described in [I-D.xu-mpls-spring-islands-connection-over-ip], where IP tunnels are used between MPLS-SPRING-enabled routers so as to traverse non- MPLS routers.

- Partial deployment of MPLS-BIER as described in Section 6.9 of [I-D.ietf-bier-architecture], where IP tunnels are used between

MPLS-BIER-capable routers so as to traverse non MPLS-BIER [I-D.ietf-bier-mpls-encapsulation] routers.

- Partial deployment of IPv6 (resp. IPv4) in IPv4 (resp. IPv6) networks as described in [RFC5565], where IPvx tunnels are used between IPvx-enabled routers so as to traverse non-IPvx routers.

- Remote Loop Free Alternate repair tunnels as described in [RFC7490], where tunnels are used between the Point of Local Repair and the selected PQ node.

The ingress needs to select a type of tunnel which is supported by the egress. This document describes how to use IS-IS Router Capability TLV to advertise the egress tunnelling capabilities of nodes.

2. Terminology

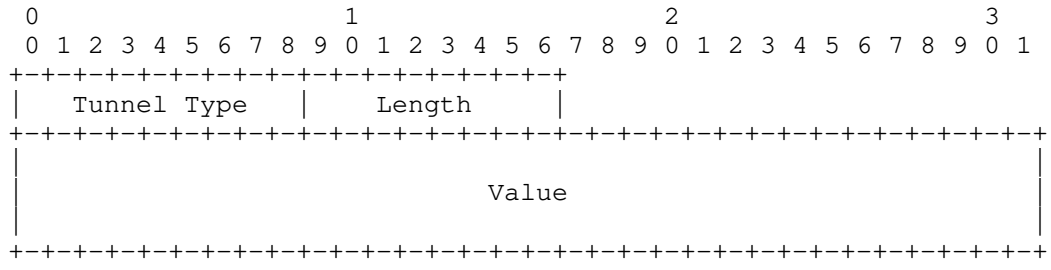
This memo makes use of the terms defined in [RFC4971].

3. Advertising Encapsulation Capability

Routers advertises their supported encapsulation type(s) by advertising a new sub-TLV of the IS-IS Router CAPABILITY TLV [RFC4971], referred to as Encapsulation Capability sub-TLV. This sub-TLV SHOULD NOT appear more than once within a given IS-IS Router CAPABILITY TLV. The scope of the advertisement depends on the application but it is recommended that it SHOULD be domain-wide. The Type code of the Encapsulation Capability sub-TLV is TBD1, the Length value is variable, and the Value field contains one or more Tunnel Encapsulation Type sub-TLVs. Each Encapsulation Type sub-TLVs indicates a particular encapsulation format that the advertising router supports.

4. Tunnel Encapsulation Type

The Tunnel Encapsulation Type sub-TLV is structured as follows:



Tunnel Type (1 octets): identifies the type of tunneling technology being signaled. This document defines the following types:

1. L2TPv3 over IP [RFC3931] : Type code=1;

2. GRE [RFC2784] : Type code=2;

3. Transmit tunnel endpoint [RFC5566] : Type code=3;

4. IPsec in Tunnel-mode [RFC5566] : Type code=4;

5. IP in IP tunnel with IPsec Transport Mode [RFC5566] : Type code=5;

6. MPLS-in-IP tunnel with IPsec Transport Mode [RFC5566] : Type code=6;

7. IP in IP [RFC2003] [RFC4213]: Type code=7;

8. VXLAN [RFC7348] : Type code=8;

9. NVGRE [RFC7637] : Type code=9;

10. MPLS [RFC3032] : Type code=10;

11. MPLS-in-GRE [RFC4023] : Type code=11;

12. VXLAN GPE [I-D.ietf-nvo3-vxlan-gpe] : Type code=12;

13. MPLS-in-UDP [RFC7510] : Type code=13;

14. MPLS-in-UDP-with-DTLS [RFC7510] : Type code=14;

15. MPLS-in-L2TPv3 [RFC4817] : Type code=15;

16. GTP: Type code=16;

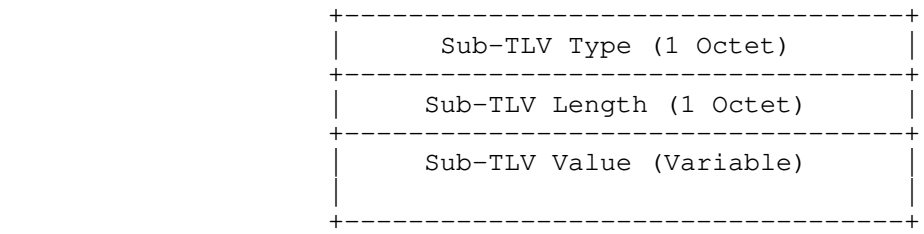
Unknown types are to be ignored and skipped upon receipt.

Length (1 octets): unsigned integer indicating the total number of octets of the value field.

Value (variable): zero or more Tunnel Encapsulation Attribute sub-TLVs as defined in Section 5.

5. Tunnel Encapsulation Attribute

The Tunnel Encapsulation Attribute sub-TLV is structured as as follows:



Sub-TLV Type (1 octet): each sub-TLV type defines a certain property about the tunnel TLV that contains this sub-TLV. The following are the types defined in this document:

1. Encapsulation Parameters: sub-TLV type = 1; (See Section 5.1)

2. Encapsulated Protocol: sub-TLV type = 2; (See Section 5.2)

3. End Point: sub-TLV type = 3; (See Section 5.3)

4. Color: sub-TLV type = 4; (See Section 5.4)

Sub-TLV Length (1 octet): unsigned integer indicating the total number of octets of the sub-TLV value field.

Sub-TLV Value (variable): encodings of the value field depend on the sub-TLV type as enumerated above. The following sub-sections define the encoding in detail.

Any unknown sub-TLVs MUST be ignored and skipped. However, if the TLV is understood, the entire TLV MUST NOT be ignored just because it contains an unknown sub-TLV.

If a sub-TLV is erroneous, this specific Tunnel Encapsulation MUST be ignored and skipped. However, others Tunnel Encapsulations MUST be considered.

5.1. Tunnel Parameters sub-TLV

This sub-TLV has its format defined in [RFC5512] under the name Encapsulation sub-TLV.

5.2. Encapsulated Protocol sub-TLV

This sub-TLV has its format defined in [RFC5512] under the name Protocol Type.

5.3. End Point sub-TLV

The value field carries the Network Address to be used as tunnel destination address.

If length is 4, the Address Family (AFI) is IPv4.

If length is 16, the Address Family (AFI) is IPv6.

5.4. Color sub-TLV

The valued field is a 4 octets opaque unsigned integer.

The color value is user defined and configured locally on the routers. It may be used by the service providers to define policies.

6. IANA Considerations

6.1. IS-IS Router Capability

This document requests IANA to allocate a new code point from registry IS-IS Router CAPABILITY TLV.

Value	TLV Name	Reference
TBD1	Tunnel Capabilities	This document

6.2. IGP Tunnel Encapsulation Types Registry

This document requests IANA to create a new registry "IGP Tunnel Encapsulation Types" with the following registration procedure:

Registry Name: IGP Tunnel Encapsulation Type.

Value	Name	Reference
0	Reserved	This document
1	L2TPv3 over IP	This document
2	GRE	This document
3	Transmit tunnel endpoint	This document
4	IPsec in Tunnel-mode	This document
5	IP in IP tunnel with IPsec Transport Mode	This document
6	MPLS-in-IP tunnel with IPsec Transport Mode	This document
7	IP in IP	This document
8	VXLAN	This document
9	NVGRE	This document
10	MPLS	This document
11	MPLS-in-GRE	This document
12	VXLAN-GPE	This document
13	MPLS-in-UDP	This document
14	MPLS-in-UDP-with-DTLS	This document
15	MPLS-in-L2TPv3	This document
16	GTP	This document
17-250	Unassigned	
251-254	Experimental	This document
255	Reserved	This document

Assignments of Encapsulation Types are via Standards Action [RFC5226].

6.3. IGP Tunnel Encapsulation Attribute Types Registry

This document requests IANA to create a new registry "IGP Tunnel Encapsulation Attribute Types" with the following registration procedure:

Registry Name: IGP Tunnel Encapsulation Attribute Types.

Value	Name	Reference
0	Reserved	This document
1	Encapsulation parameters	This document
2	Protocol	This document
3	End Point	This document
4	Color	This document
5-250	Unassigned	
251-254	Experimental	This document
255	Reserved	This document

Assignments of Encapsulation Attribute Types are via Standards Action [RFC5226].

7. Security Considerations

Security considerations applicable to softwires can be found in the mesh framework [RFC5565]. In general, security issues of the tunnel protocols signaled through this IGP capability extension are inherited.

If a third party is able to modify any of the information that is used to form encapsulation headers, to choose a tunnel type, or to choose a particular tunnel for a particular payload type, user data packets may end up getting misrouted, misdelivered, and/or dropped.

Security considerations for the base IS-IS protocol are covered in [RFC1195].

8. Acknowledgements

This document is partially inspired by [RFC5512].

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