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YANG Data Model for SR and SR TE Topologies on MPLS Data Plane
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Abstract

This document defines a YANG data model for Segment Routing (SR) topology and Segment Routing (SR) traffic engineering (TE) topology, using MPLS data plane.

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Table of Contents

1. Introduction 2
1.1. Terminology 3
1.2. Tree Diagrams 3
1.3. Prefixes in Data Node Names 3
2. Modeling Considerations 4
2.1. Segment Routing (SR) MPLS Topology 4
2.2. Segment Routing (SR) MPLS TE Topology 4
2.3. Relations to ietf-segment-routing 7
2.4. Topology Type Modeling 7
2.5. Topology Attributes 7
2.6. Node Attributes 7
2.7. Link Attributes 9
3. Model Structure 10
4. YANG Module 11
5. IANA Considerations 20
6. Security Considerations 21
7. References 23
7.1. Normative References 23
7.2. Informative References 25
Appendix A. Companion YANG Model for Non-NMDA Compliant Implementations 26
A.1. SR MPLS Topology State Module 26
Appendix B. Data Tree Example 29
B.1. SR MPLS Topology with TE Not Enabled 30
B.2. SR MPLS Topology with TE Enabled 37
Appendix C. Contributors 52
Authors' Addresses 52

1. Introduction

This document defines a YANG [RFC7950] data model for describing the presentations of Segment Routing (SR) topology and Segment Routing (SR) traffic engineering (TE) topology. The version of the model limits the transport type to an MPLS dataplane.

1.1. Terminology

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.

The following terms are defined in [RFC7950] and are not redefined here:

- o augment
- o data model
- o data node

1.2. Tree Diagrams

Tree diagrams used in this document follow the notation defined in [RFC8340].

1.3. Prefixes in Data Node Names

In this document, names of data nodes, actions, and other data model objects are often used without a prefix, as long as it is clear from the context in which YANG module each name is defined. Otherwise, names are prefixed using the standard prefix associated with the corresponding YANG module, as shown in Table 1.

Prefix	YANG module	Reference
nw	ietf-network	[RFC8345]
nt	ietf-network-topology	[RFC8345]
l3t	ietf-l3-unicast-topology	[RFC8346]
sr-cmn	ietf-segment-routing-common	[RFC9020]
tet	ietf-te-topology	[RFC8795]
tet-pkt	ietf-te-topology-packet	[I-D.ietf-teas-yang-l3-te-topo]

Table 1: Prefixes and Corresponding YANG Modules

2. Modeling Considerations

2.1. Segment Routing (SR) MPLS Topology

The Layer 3 network topology model is discussed in [RFC8346]. The Segment Routing (SR) MPLS topology model proposed in this document augments and uses the ietf-l3-unicast-topology module defined in [RFC8346]. SR MPLS related attributes are covered in the ietf-sr-mpls-topology module.

```
+-----------------------------+
|   Layer 3 Network Topology   |
|   ietf-l3-unicast-topology   |
+---------------^--------------+
                |
                |
                |
                |
   +------------^-----------+
   |    SR MPLS Topology    |
   | ietf-sr-mpls-topology  |
   +------------------------+
```

Figure 1: SR MPLS Topology Augmentation

2.2. Segment Routing (SR) MPLS TE Topology

A Segment Routing (SR) MPLS TE topology is an instance of SR MPLS topology with TE enabled. In order to instantiate an SR MPLS TE topology, the ietf-sr-mpls-topology module defined in this document can be used together with the ietf-te-topology module defined in [RFC8795] and the ietf-te-topology-packet module defined in [I-D.ietf-teas-yang-l3-te-topo]. All these modules directly or indirectly augment the ietf-network-topology module defind in [RFC8345], as shown in Figure 2.

```
                        +---------------------------+
                        |    Network Topology       |
                        |  ietf-network-topology    |
                        +-^-----------------------^-+
                         /                         \
                        /                           \
                       /                             \
                      /                               \
          +-------------^-------------+   +-------------^-------------+
          | Layer 3 Unicast Topology  |   |        TE Topology        |
          | ietf-l3-unicast-topology  |   |      ietf-te-topology     |
          +-------------^-------------+   +-------------^-------------+
                        |                               |
                        |                               |
                        |                               |
                        |                               |
          +-------------^-------------+   +-------------^-------------+
          |     SR MPLS Topology      |   |     TE Packet Topology    |
          |   ietf-sr-mpls-topology   |   |  ietf-te-topology-packet  |
          +---------------------------+   +---------------------------+
```

Figure 2: SR TE Topology Instance Inheritance Relations

Figure 3 shows the data structure of an SR TE topology instance. Because of the augmentation relationships shown in Figure 2, a data instance of an SR MPLS TE topology contains the capabilities from all these modules, so that the data includes the attributes from ietf-network-topology, ietf-l3-unicast-topology, ietf-sr-mpls-topology, ietf-te-topology, and ietf-te-topology-packet.

```
+-------------------------------------------------------+
| ietf-network-topology:                                |
|   network-id (key)                                    |
|   network-types: {                                    |
|     l3-unicast-topology: {                            |
|       sr-mpls{}                                       |
|     }                                                 |
|     te-topology: {                                    |
|       packet{}                                        |
|     }                                                 |
|   }                                                   |
|   <other network topology attributes>                 |
+-----------------------------+-------------------------+
| ietf-l3-unicast-topology:   | ietf-te-topology:       |
|   <L3 unicast attributes>   |   <TE attributes>       |
+-----------------------------+-------------------------+
| ietf-sr-mpls-topology:      | ietf-te-topology-packet: |
|   <SR MPLS attributes>      |   <TE packet attributes> |
+-----------------------------+-------------------------+
```

Figure 3: SR TE topology instance data structure

Each type of topology is indicated by a YANG presence container which augments "network-types" as defined in [RFC8345].2 For the five types of topologies above, the data representations are:

Base network topology [RFC8345]:

/nw:networks/nw:network/nw:network-types

Layer 3 Unicast Topology [RFC8346]:

/nw:networks/nw:network/nw:network-types/l3t:l3-unicast-topology

SR MPLS Topology (defined in this document):

/nw:networks/nw:network/nw:network-types/l3t:l3-unicast-topology/srmt:sr-mpls

TE Topology [RFC8795]:

/nw:networks/nw:network/nw:network-types/tet:te-topology

TE Packet Topology [I-D.ietf-teas-yang-l3-te-topo]:

/nw:networks/nw:network/nw:network-types/tet:te-topology/tet-pkt:packet

2.3. Relations to ietf-segment-routing

[RFC9020] defines ietf-segment-routing that is a model intended to be used on network elements to configure or operate segment routing; ietf-sr-mpls-topology defined in this document is intended to be used on a controller for the network-wide operations such as path computation.

SR MPLS topology model shares many modeling constructs defined in ietf-segment-routing. The module ietf-sr-mpls-topology uses the types and groupings defined in ietf-segment-routing.

2.4. Topology Type Modeling

A new topology type is defined in this document, to indicate a topology that is a Segment Routing (SR) topology on an MPLS dataplane.

```
augment /nw:networks/nw:network/nw:network-types
          /l3t:l3-unicast-topology:
  +--rw sr-mpls!
```

Section 4.4.8 of RFC 8345 describes how network types are represented using nested presence container. In this document, the presence container sr-mpls is used for such a purpose.

2.5. Topology Attributes

The Segment Routing attributes with topology-wide impacts are modeled by augmenting the container "l3-topology-attributes" in the L3 topology model [RFC8346]. SRGB (Segment Routing Global Block) is covered in this augmentation. A SR domain is mapped to a topology in this model.

```
augment /nw:networks/nw:network/l3t:l3-topology-attributes:
  +--rw sr-mpls
     +--rw srgb* [lower-bound upper-bound]
        +--rw lower-bound    uint32
        +--rw upper-bound    uint32
```

2.6. Node Attributes

The Segment Routing attributes within the node scope are modeled by augmenting the sub tree /nw:networks/nw:network/nw:node/ in the L3 topology model [RFC8346].

The SR attributes that have node-scope impact are modeled by augmenting the container "l3-node-attributes" in the L3 topology

model, including the SR capabilities, SRGB (Segment Routing Global Block), and SRLB (Segment Routing Local Block) specified on this mode. This model also provides the information about how these SR attributes are learned:

The presence container sr-mpls is used to indicate that SR MPLS is enabled on this node when the container is present.

```
augment /nw:networks/nw:network/nw:node/l3t:l3-node-attributes:
  +--rw sr-mpls!
     +--rw srgb* [lower-bound upper-bound]
     |  +--rw lower-bound    uint32
     |  +--rw upper-bound    uint32
     +--rw srlb* [lower-bound upper-bound]
     |  +--rw lower-bound    uint32
     |  +--rw upper-bound    uint32
     +--rw msds {msd}?
     |  +--rw node-msd* [msd-type]
     |     +--rw msd-type     identityref
     |     +--rw msd-value?   uint8
     +--ro information-source?            enumeration
     +--ro information-source-instance?   string
     +--ro information-source-state
        +--ro credibility-preference?   uint16
```

The SR attributes that are related to a IGP-Prefix segment are modeled by augmenting the list entry "prefix" in the L3 topology model:

```
augment /nw:networks/nw:network/nw:node/l3t:l3-node-attributes
          /l3t:prefix:
  +--rw sr-mpls!
     +--rw sids
        +--rw sid* [algorithm]
           +--rw value-type?          enumeration
           +--rw start-sid            uint32
           +--rw range?               uint32
           +--rw algorithm            identityref
           +--rw last-hop-behavior?   enumeration
           |       {sid-last-hop-behavior}?
           +--rw is-local?            boolean
           +--rw is-node?             boolean
           +--ro is-readvertisment?   boolean
```

2.7. Link Attributes

A link in the topology model connects the termination point on the source node to the termination point on the destination node. When such a link is instantiated, the bindings between the nodes and the corresponding Adj-SIDs are formed, and the resulting FIB entries are installed.

A link in the topology model is mapped to an SR Adjacency Segment, formed by a pair of interfaces on two respective adjacent nodes. The SR Adjacency Segment attributes are modeled by augmenting the link attributes of the L3 topology model [RFC8346]. The modeling structure is as follows:

```
augment /nw:networks/nw:network/nt:link/l3t:l3-link-attributes:
  +--rw sr-mpls!
     +--rw msds {msd}?
     |  +--rw link-msd* [msd-type]
     |     +--rw msd-type     identityref
     |     +--rw msd-value?   uint8
     +--rw sids
     |  +--rw sid* [value-type sid]
     |     +--rw value-type                    enumeration
     |     +--rw sid                           uint32
     |     +--rw address-family?               enumeration
     |     +--rw is-eligible-for-protection?   boolean
     |     +--rw is-local?                     boolean
     |     +--rw is-part-of-set?               boolean
     |     +--rw is-persistent?                boolean
     |     +--rw is-on-lan?                    boolean
     |     +--rw weight?                       uint8
     +--ro information-source?            enumeration
     +--ro information-source-instance?   string
     +--ro information-source-state
        +--ro credibility-preference?   uint16
```

IGPs [RFC8665] [RFC8666] [RFC8667] and BGP-LS [RFC7752] [I-D.ietf-idr-bgp-ls-segment-routing-ext] can be supported by the model, the leaf "information-source" is used to indicate where the information is from.

The bundling capability of the Adjacency Segemnt is achieved by re-using the existing modeling construct (i.e. "bundle-stack-level") under /nw:networks/nw:network/nt:link/tet:te [RFC8795]

The presence container sr-mpls is used to indicate that SR SMPL is enabled on this link when the container is present.

3. Model Structure

The model tree structure of the Segment Routing (SR) topology module is as shown below:

```
module: ietf-sr-mpls-topology
  augment /nw:networks/nw:network/nw:network-types
            /l3t:l3-unicast-topology:
    +--rw sr-mpls!
  augment /nw:networks/nw:network/l3t:l3-topology-attributes:
    +--rw sr-mpls
       +--rw srgb* [lower-bound upper-bound]
          +--rw lower-bound    uint32
          +--rw upper-bound    uint32
  augment /nw:networks/nw:network/nw:node/l3t:l3-node-attributes:
    +--rw sr-mpls!
       +--rw srgb* [lower-bound upper-bound]
       |  +--rw lower-bound    uint32
       |  +--rw upper-bound    uint32
       +--rw srlb* [lower-bound upper-bound]
       |  +--rw lower-bound    uint32
       |  +--rw upper-bound    uint32
       +--rw msds {msd}?
       |  +--rw node-msd* [msd-type]
       |     +--rw msd-type     identityref
       |     +--rw msd-value?   uint8
       +--ro information-source?            enumeration
       +--ro information-source-instance?   string
       +--ro information-source-state
          +--ro credibility-preference?   uint16
  augment /nw:networks/nw:network/nw:node/l3t:l3-node-attributes
            /l3t:prefix:
    +--rw sr-mpls!
       +--rw sids
          +--rw sid* [algorithm]
             +--rw value-type?          enumeration
             +--rw start-sid            uint32
             +--rw range?               uint32
             +--rw algorithm            identityref
             +--rw last-hop-behavior?   enumeration
             |       {sid-last-hop-behavior}?
             +--rw is-local?            boolean
             +--rw is-node?             boolean
             +--ro is-readvertisment?   boolean
  augment /nw:networks/nw:network/nt:link/l3t:l3-link-attributes:
    +--rw sr-mpls!
       +--rw msds {msd}?
```

```
          |  +--rw link-msd* [msd-type]
          |     +--rw msd-type     identityref
          |     +--rw msd-value?   uint8
          +--rw sids
          |  +--rw sid* [value-type sid]
          |     +--rw value-type                    enumeration
          |     +--rw sid                           uint32
          |     +--rw address-family?               enumeration
          |     +--rw is-eligible-for-protection?   boolean
          |     +--rw is-local?                     boolean
          |     +--rw is-part-of-set?               boolean
          |     +--rw is-persistent?                boolean
          |     +--rw is-on-lan?                    boolean
          |     +--rw weight?                       uint8
          +--ro information-source?            enumeration
          +--ro information-source-instance?   string
          +--ro information-source-state
             +--ro credibility-preference?   uint16
```

4. YANG Module

This module references [RFC7752], [RFC8345], [RFC8346], [RFC8476], [RFC8491], [RFC8665], [RFC8666], [RFC8667], [RFC8814], [RFC9020], and [I-D.ietf-idr-bgp-ls-segment-routing-ext].

```
<CODE BEGINS> file "ietf-sr-mpls-topology@2021-10-23.yang"
module ietf-sr-mpls-topology {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-sr-mpls-topology";
  prefix "srmt";

  import ietf-network {
    prefix "nw";
    reference "RFC 8345: A YANG Data Model for Network Topologies";
  }
  import ietf-network-topology {
    prefix "nt";
    reference "RFC 8345: A YANG Data Model for Network Topologies";
  }
  import ietf-l3-unicast-topology {
    prefix "l3t";
    reference "RFC 8346: A YANG Data Model for Layer 3 Topologies";
  }
  import ietf-segment-routing-common {
    prefix "sr-cmn";
    reference "RFC 9020: YANG Data Model for Segment Routing";
```

```
     }

     organization
       "IETF Traffic Engineering Architecture and Signaling (TEAS)
        Working Group";

     contact
       "WG Web:   <http://tools.ietf.org/wg/teas/>
        WG List:  <mailto:teas@ietf.org>

        Editor:   Xufeng Liu
                  <mailto:xufeng.liu.ietf@gmail.com>

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        Editor:   Himanshu Shah
                  <mailto:hshah@ciena.com>

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

     description
       "YANG data model for representing and manipulating Segment
        Routing Topologies on MPLS Data Plane.

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        Relating to IETF Documents
        (http://trustee.ietf.org/license-info).

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

     revision 2021-10-23 {
       description "Initial revision";
       reference
```

```
        "RFC XXXX: YANG Data Model for SR and SR TE Topologies on MPLS
         Data Plane";
    }

    identity msd-base-type {
      description
        "Base identity for MSD Type";
    }

    identity base-mpls-msd {
      base msd-base-type;
      description
        "Base MPLS Imposition MSD.";
      reference
        "RFC 8491: Signaling Maximum SID Depth (MSD) Using IS-IS";
    }

    identity erld-msd {
      base msd-base-type;
      description
        "ERLD-MSD is defined to advertise the ERLD.";
      reference
        "RFC 8662: Entropy Label for Source Packet Routing in
         Networking (SPRING) Tunnels";
    }

    feature msd {
      description
        "Support of signaling MSD (Maximum SID Depth) in IGP.";
      reference
        "RFC 8476: Signaling Maximum SID Depth (MSD) Using OSPF.
         RFC 8491: Signaling Maximum SID Depth (MSD) Using IS-IS.
         RFC 8814: Signaling Maximum SID Depth (MSD) Using the Border
         Gateway Protocol - Link State.";
    }

    grouping sr-mpls-topology-type {
      description
        "Identifies the SR-MPLS topology type. This type of network
         topologies use Segment Routing (SR) technology over the MPLS
         data plane";
      container sr-mpls {
        presence "Indicates SR-MPLS topology";
        description
          "Its presence identifies the SR MPLS topology type.";
      }
    }
```

```
     augment "/nw:networks/nw:network/nw:network-types/"
       + "l3t:l3-unicast-topology" {
       description
         "Defines the SR MPLS topology type.";
       uses sr-mpls-topology-type;
     }

     augment "/nw:networks/nw:network/l3t:l3-topology-attributes" {
       when "../nw:network-types/l3t:l3-unicast-topology/srmt:sr-mpls" {
         description "Augment only for SR MPLS topology.";
       }
       description "Augment topology configuration";
       uses sr-mpls-topology-attributes;
     }

     augment "/nw:networks/nw:network/nw:node/l3t:l3-node-attributes" {
       when "../../nw:network-types/l3t:l3-unicast-topology/"
         + "srmt:sr-mpls" {
         description "Augment only for SR MPLS topology.";
       }
       description "Augment node configuration.";
       uses sr-node-attributes;
     }

     augment "/nw:networks/nw:network/nw:node/l3t:l3-node-attributes"
       + "/l3t:prefix" {
       when "../../../nw:network-types/l3t:l3-unicast-topology/"
         + "srmt:sr-mpls" {
         description "Augment only for SR MPLS topology.";
       }
       description "Augment node prefix.";
       uses sr-node-prefix-attributes;
     }

     augment "/nw:networks/nw:network/nt:link/l3t:l3-link-attributes" {
       when "../../nw:network-types/l3t:l3-unicast-topology/"
         + "srmt:sr-mpls" {
         description "Augment only for SR MPLS topology.";
       }
       description "Augment link configuration";
       uses sr-link-attributes;
     }

     grouping sr-mpls-topology-attributes {
       description "SR MPLS topology scope attributes.";
       container sr-mpls {
         description
           "Containing SR attributes.";
```

```
        uses sr-cmn:srgb;
      } // sr
    } // sr-mpls-topology-attributes

    grouping information-source-attributes {
      description
        "The attributes identifying source that has provided the
         related information, and the source credibility.";
      leaf information-source {
        type enumeration {
          enum "unknown" {
            description "The source is unknown.";
          }
          enum "locally-configured" {
            description "Configured entity.";
          }
          enum "ospfv2" {
            description "OSPFv2.";
            reference
              "RFC 8665: OSPF Extensions for Segment Routing.";
          }
          enum "ospfv3" {
            description "OSPFv3.";
            reference
              "RFC 8666: OSPFv3 Extensions for Segment Routing.";
          }
          enum "isis" {
            description "ISIS.";
            reference
              "RFC 8667: IS-IS Extensions for Segment Routing.";
          }
          enum "bgp-ls" {
            description "BGP-LS.";
            reference
              "RFC 7752: North-Bound Distribution of Link-State and
               Traffic Engineering (TE) Information Using BGP.
               I-D.ietf-idr-bgp-ls-segment-routing-ext:
               BGP Link-State extensions for Segment Routing.";
          }
          enum "system-processed" {
            description "System processed entity.";
          }
          enum "other" {
            description "Other source.";
          }
        }
        config false;
        description
```

```
          "Indicates the type of the information source.";
      }
      leaf information-source-instance {
        type string;
        config false;
        description
          "The name indicating the instance of the information
           source.";
      }
      container information-source-state {
        config false;
        description
          "The container contains state attributes related to
           the information source.";
        leaf credibility-preference {
          type uint16;
          description
            "The preference value to calculate the traffic
             engineering database credibility value used for
             tie-break selection between different
             information-source values.
             Higher value is more preferable.";
        }
      }
    } // information-source-attributes

    grouping sr-node-attributes {
      description "SR node scope attributes.";
      container sr-mpls {
        presence "Presence indicates SR is enabled.";
        description
          "Containing SR attributes.";
        uses sr-cmn:srgb;
        uses sr-cmn:srlb;
        container msds {
          if-feature "msd";
          description
            "MSDs on the node.";
          list node-msd {
            key "msd-type";
            leaf msd-type {
              type identityref {
                base msd-base-type;
              }
              description
                "MSD Type.";
            }
            leaf msd-value {
```

```
               type uint8;
               description
                 "MSD value, in the range of 0-255. Node MSD is the
                  lowest MSD supported by the node.";
             }
             description
               "List of node MSDs. A node may have a list of MSD values,
                with at most one value for each msd-type.";
             reference
               "RFC 8491: Signaling Maximum SID Depth (MSD) Using
                IS-IS";
           }
         }
         // Operational state data
         uses information-source-attributes;
       } // sr
     } // sr-node-attributes

     grouping sr-node-prefix-attributes {
       description "Containing SR attributes for a prefix.";
       container sr-mpls {
         presence "Presence indicates SR is enabled.";
         description
           "Containing SR attributes for a prefix.";
         container sids {
           description
             "Containing Prefix SIDs assigned to this prefix.";
           list sid {
             key "algorithm";
             description
               "A list of SIDs with their properties.";
             uses sr-cmn:prefix-sid-attributes;
             uses sr-cmn:last-hop-behavior;
             leaf is-local {
               type boolean;
               default false;
               description
                 "'true' if the SID is local.";
             }
             leaf is-node {
               type boolean;
               default false;
               description
                 "'true' if the Prefix-SID refers to the router
                  identified by the prefix.  Typically, the leaf
                  'is-node' (N-Flag) is set on Prefix-SIDs attached to a
                  router loopback address.";
             }
```

```
            leaf is-readvertisment {
              type boolean;
              config false;
              description
                "'true' if the prefix to which this Prefix-SID is
                  attached, has been propagated by the router from
                  another topology by redistribution.";
              reference
                "RFC 8667: IS-IS Extensions for Segment Routing.
                 Sec 2.1.";
            }
          }
        }
      } // sr
    } // sr-node-prefix-attributes

    grouping sr-link-attributes {
      description "SR link scope attributes";
      container sr-mpls {
        presence "Presence indicates SR is enabled.";
        description
          "Containing SR attributes.";

        container msds {
          if-feature "msd";
          description
            "MSDs on the link.";
          list link-msd {
            key "msd-type";
            leaf msd-type {
              type identityref {
                base msd-base-type;
              }
              description
                "MSD Type.";
            }
            leaf msd-value {
              type uint8;
              description
                "MSD value, in the range of 0-255.";
            }
            description
              "List of link MSDs. A link may have a list of MSD values,
               with at most one value for each msd-type.";
            reference
              "RFC 8491: Signaling Maximum SID Depth (MSD) Using
               IS-IS";
          }
```

```
        }
        container sids {
          description
            "Containing Adjacency SIDs assigned to this link.";
          list sid {
            key "value-type sid";
            description
              "A list of SIDs with their properties.";
            uses sr-cmn:sid-value-type;
            leaf sid {
              type uint32;
              mandatory true;
              description
                "Adjacency SID, which can be either IGP-Adjacency SID
                 or BGP PeerAdj SID, depending on the context.";
            }
            leaf address-family {
              type enumeration {
                enum "ipv4" {
                  description
                    "The Adj-SID refers to an adjacency with outgoing
                     IPv4 encapsulation.";
                }
                enum "ipv6" {
                  description
                    "The Adj-SID refers to an adjacency with outgoing
                     IPv6 encapsulation.";
                }
              }
              default "ipv4";
              description
                "This leaf defines the F-Flag (Address-Family flag) of
                 the SID.";
            }
            leaf is-eligible-for-protection {
              type boolean;
              default false;
              description
                "'true' if the SID is is eligible for protection.";
              reference
                "RFC 8402: Segment Routing Architecture. Sec. 3.4.";
            }
            leaf is-local {
              type boolean;
              default false;
              description
                "'true' if the SID is local.";
            }
```

```
            leaf is-part-of-set {
              type boolean;
              default false;
              description
                "'true' if the SID is part of a set.";
            }
            leaf is-persistent {
              type boolean;
              default true;
              description
                "'true' if the SID is persistently allocated.";
            }
            leaf is-on-lan {
              type boolean;
              default false;
              description
                "'true' if on a lan.";
            }
            leaf weight {
              type uint8;
              description
                "The value represents the weight of the SID for the
                 purpose of load balancing.  The use of the weight
                 is defined in RFC 8402.";
              reference
                "RFC 8402: Segment Routing Architecture. Sec. 3.4.";
            }
          }
        }
        uses information-source-attributes;
      } // sr
    } // sr-tp-attributes
  }
  <CODE ENDS>
```

5. IANA Considerations

RFC Ed.: In this section, replace all occurrences of 'XXXX' with the actual RFC number (and remove this note).

This document registers the following namespace URIs in the IETF XML registry [RFC3688]:

```
--------------------------------------------------------------------
URI: urn:ietf:params:xml:ns:yang:ietf-sr-mpls-topology
Registrant Contact: The IESG.
XML: N/A, the requested URI is an XML namespace.
--------------------------------------------------------------------

--------------------------------------------------------------------
URI: urn:ietf:params:xml:ns:yang:ietf-sr-mpls-topology-state
Registrant Contact: The IESG.
XML: N/A, the requested URI is an XML namespace.
--------------------------------------------------------------------
```

This document registers the following YANG modules in the YANG Module Names registry [RFC6020]:

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

--------------------------------------------------------------------
name:         ietf-sr-mpls-topology-state
namespace:    urn:ietf:params:xml:ns:yang:ietf-sr-mpls-topology-state
prefix:       srmt-s
reference:    RFC XXXX
--------------------------------------------------------------------
```

6. Security Considerations

The YANG module specified in this document defines 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 Network Configuration Access Control Model (NACM) [RFC8341] provides the means to restrict access for particular NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

There are a number of data nodes defined in this 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. These are the subtrees and data nodes and their sensitivity/vulnerability:

/nw:networks/nw:network/nw:network-types/l3t:l3-unicast-topology/sr-mpls
This subtree specifies the SR MPLS topology type. Modifying the configurations can make SR MPLS topology type invalid and cause interruption to all SR networks.

/nw:networks/nw:network/l3t:l3-topology-attributes/sr
This subtree specifies the topology-wide configurations, including the SRGB (Segment Routing Global Block). Modifying the configurations here can cause traffic disabled or rerouted in this topology and the connected topologies.

/nw:networks/nw:network/nw:node/l3t:l3-node-attributes
This subtree specifies the SR configurations for nodes. Modifying the configurations in this subtree can add, remove, or modify SR nodes, causing traffic disabled or rerouted in the specified nodes and the related TE topologies.

/nw:networks/nw:network/nt:link/l3t:l3-link-attributes/sr
This subtree specifies the configurations for SR Adjacency Segments. Modifying the configurations in this subtree can add, remove, or modify SR Adjacency Segments causing traffic disabled or rerouted on the specified SR adjacencies, the related nodes, and the related SR MPLS topologies.

Some of the readable data nodes in this 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. These are the subtrees and data nodes and their sensitivity/vulnerability:

/nw:networks/nw:network/nw:network-types/l3t:l3-unicast-topology/sr-mpls
Unauthorized access to this subtree can disclose the SR MPLS topology type.

/nw:networks/nw:network/l3t:l3-topology-attributes/sr
Unauthorized access to this subtree can disclose the topology-wide configurations, including the SRGB (Segment Routing Global Block).

/nw:networks/nw:network/nw:node/l3t:l3-node-attributes
Unauthorized access to this subtree can disclose the operational state information of the SR nodes.

/nw:networks/nw:network/nt:link/l3t:l3-link-attributes/sr
Unauthorized access to this subtree can disclose the operational state information of SR Adjacency Segments.

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Appendix A. Companion YANG Model for Non-NMDA Compliant Implementations

The YANG module ietf-sr-mpls-topology defined in this document is designed to be used in conjunction with implementations that support the Network Management Datastore Architecture (NMDA) defined in [RFC8342]. In order to allow implementations to use the model even in cases when NMDA is not supported, the following companion module, ietf-sr-mpls-topology-state, is defined as state model, which mirrors the module ietf-sr-mpls-topology defined earlier in this document. However, all data nodes in the companion module are non-configurable, to represent the applied configuration or the derived operational states.

The companion module, ietf-sr-mpls-topology-state, is redundant and SHOULD NOT be supported by implementations that support NMDA.

As the structure of the companion module mirrors that of the coorespinding NMDA model, the YANG tree of the companion module is not depicted separately.

A.1. SR MPLS Topology State Module

This module references [RFC8345] and [RFC8346].

```
<CODE BEGINS> file "ietf-sr-mpls-topology-state@2021-10-23.yang"
module ietf-sr-mpls-topology-state {
  yang-version 1.1;
  namespace
    "urn:ietf:params:xml:ns:yang:ietf-sr-mpls-topology-state";
  prefix "srmt-s";

  import ietf-sr-mpls-topology {
    prefix "srmt";
  }
  import ietf-network-state {
    prefix "nw-s";
    reference "RFC 8345: A YANG Data Model for Network Topologies";
  }
  import ietf-network-topology-state {
    prefix "nt-s";
    reference "RFC 8345: A YANG Data Model for Network Topologies";
  }
  import ietf-l3-unicast-topology-state {
    prefix "l3t-s";
    reference "RFC 8346: A YANG Data Model for Layer 3 Topologies";
  }
  import ietf-segment-routing-common {
```

```
      prefix "sr-cmn";
      reference "RFC 9020: YANG Data Model for Segment Routing";
    }

    organization
      "IETF Traffic Engineering Architecture and Signaling (TEAS)
       Working Group";

    contact
      "WG Web:   <http://tools.ietf.org/wg/teas/>
       WG List:  <mailto:teas@ietf.org>

       Editor:   Xufeng Liu
                 <mailto:xufeng.liu.ietf@gmail.com>

       Editor:   Igor Bryskin
                 <mailto:Igor.Bryskin@huawei.com>

       Editor:   Vishnu Pavan Beeram
                 <mailto:vbeeram@juniper.net>

       Editor:   Tarek Saad
                 <mailto:tsaad@cisco.com>

       Editor:   Himanshu Shah
                 <mailto:hshah@ciena.com>

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

    description
      "YANG data model for representing operational state information
       of Segment Routing Topologies on MPLS data plane, when NMDA is
       not supported.

       Copyright (c) 2021 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
       (http://trustee.ietf.org/license-info).

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

```
     revision 2021-10-23 {
       description "Initial revision";
       reference
         "RFC XXXX: YANG Data Model for SR and SR TE Topologies on MPLS
          Data Plane";
     }

     augment "/nw-s:networks/nw-s:network/nw-s:network-types/"
       + "l3t-s:l3-unicast-topology" {
       description
         "Defines the SR MPLS topology type.";
       uses srmt:sr-mpls-topology-type;
     }

     augment "/nw-s:networks/nw-s:network/"
       + "l3t-s:l3-topology-attributes" {
       when "../nw-s:network-types/l3t-s:l3-unicast-topology/"
         + "srmt-s:sr-mpls" {
         description "Augment only for SR MPLS topology.";
       }
       description "Augment topology configuration";
       uses srmt:sr-mpls-topology-attributes;
     }

     augment "/nw-s:networks/nw-s:network/nw-s:node/"
       + "l3t-s:l3-node-attributes" {
       when "../../nw-s:network-types/l3t-s:l3-unicast-topology/"
         + "srmt-s:sr-mpls" {
         description "Augment only for SR MPLS topology.";
       }
       description "Augment node configuration.";
       uses srmt:sr-node-attributes;
     }

     augment "/nw-s:networks/nw-s:network/nw-s:node/"
       + "l3t-s:l3-node-attributes/l3t-s:prefix" {
       when "../../../nw-s:network-types/l3t-s:l3-unicast-topology/"
         + "srmt-s:sr-mpls" {
         description "Augment only for SR MPLS topology.";
       }
       description "Augment node prefix.";
       uses srmt:sr-node-prefix-attributes;
     }

     augment "/nw-s:networks/nw-s:network/nt-s:link/"
       + "l3t-s:l3-link-attributes" {
       when "../../nw-s:network-types/l3t-s:l3-unicast-topology/"
         + "srmt-s:sr-mpls" {
```

```
        description "Augment only for SR MPLS topology.";
      }
      description "Augment link configuration";
      uses srmt:sr-link-attributes;
    }

    grouping sr-mpls-topology-attributes {
      description "SR MPLS topology scope attributes.";
      container sr-mpls {
        description
          "Containing SR attributes.";
        uses sr-cmn:srgb;
      } // sr
    } // sr-mpls-topology-attributes
  }
  <CODE ENDS>
```

Appendix B. Data Tree Example

This section contains an example of an instance data tree in the JSON encoding [RFC7951]. The example instantiates "ietf-sr-mpls-topology" for the topology that is depicted in the following diagram.

```
                router-id: 203.0.113.1           router-id: 203.0.113.2
                    +------------+                   +------------+
                    |     D1     |                   |     D2     |
                   /-\          /-\                 /-\          /-\
                   | | 1-0-1    | |---------------->| | 2-1-1    | |
                   | |    1-2-1 | |<----------------| |    2-0-1 | |
                   \-/  1-3-1   \-/                 \-/  2-3-1   \-/
                    |   /----\   |                   |   /----\   |
                    +---|    |---+                   +---|    |---+
                        \----/                           \----/
                         A  |                             A  |
                         |  |                             |  |
                         |  |   router-id: 203.0.113.3    |  |
                         |  |       +------------+        |  |
                         |  |       |     D3     |        |  |
                         |  |      /-\          /-\       |  |
                         |  +----->| | 3-1-1    | |-------+  |
                         +---------| |    3-2-1 | |<---------+
                                   \-/          \-/
                                    |            |
                                    +------------+
```

Figure 4: Example SR MPLS Topology

The corresponding instance data tree is depicted below. Note that some lines have been wrapped to adhere to the 72-character line limitation of RFCs.

B.1. SR MPLS Topology with TE Not Enabled

```
{
  "ietf-network:networks": {
    "network": [
      {
        "network-types": {
          "ietf-l3-unicast-topology:l3-unicast-topology": {
            "ietf-sr-mpls-topology:sr-mpls": {}
          }
        },
        "network-id": "sr-mpls-topo-example",
        "ietf-l3-unicast-topology:l3-topology-attributes": {
          "ietf-sr-mpls-topology:sr-mpls": {
            "srgb": [
              {
                "lower-bound": 16000,
                "upper-bound": 23999
              }
```

```
              ]
            }
          },
          "node": [
            {
              "node-id": "D1",
              "ietf-network-topology:termination-point": [
                {
                  "tp-id": "1-0-1",
   "ietf-l3-unicast-topology:l3-termination-point-attributes": {
                    "unnumbered-id": 101
                  }
                },
                {
                  "tp-id": "1-2-1",
   "ietf-l3-unicast-topology:l3-termination-point-attributes": {
                    "unnumbered-id": 121
                  }
                },
                {
                  "tp-id": "1-3-1",
   "ietf-l3-unicast-topology:l3-termination-point-attributes": {
                    "unnumbered-id": 131
                  }
                }
              ],
              "ietf-l3-unicast-topology:l3-node-attributes": {
                "router-id": ["203.0.113.1"],
                "prefix": [
                  {
                    "prefix": "203.0.113.1/32",
                    "ietf-sr-mpls-topology:sr-mpls": {
                      "sids": {
                        "sid": [
                          {
   "algorithm": "prefix-sid-algorithm-shortest-path",
                            "start-sid": 101,
                            "range": 1,
                            "is-local": false,
                            "is-node": true
                          }
                        ]
                      }
                    }
                  }
                ],
                "ietf-sr-mpls-topology:sr-mpls": {
                  "srgb": [
```

```
                    {
                      "lower-bound": 16000,
                      "upper-bound": 23999
                    }
                  ],
                  "srlb": [
                    {
                      "lower-bound": 15000,
                      "upper-bound": 15999
                    }
                  ]
                }
              }
            },
            {
              "node-id": "D2",
              "ietf-network-topology:termination-point": [
                {
                  "tp-id": "2-0-1",
   "ietf-l3-unicast-topology:l3-termination-point-attributes": {
                    "unnumbered-id": 201
                  }
                },
                {
                  "tp-id": "2-1-1",
   "ietf-l3-unicast-topology:l3-termination-point-attributes": {
                    "unnumbered-id": 211
                  }
                },
                {
                  "tp-id": "2-3-1",
   "ietf-l3-unicast-topology:l3-termination-point-attributes": {
                    "unnumbered-id": 231
                  }
                }
              ],
              "ietf-l3-unicast-topology:l3-node-attributes": {
                "router-id": ["203.0.113.2"],
                "prefix": [
                  {
                    "prefix": "203.0.113.2/32",
                    "ietf-sr-mpls-topology:sr-mpls": {
                      "sids": {
                        "sid": [
                          {
   "algorithm": "prefix-sid-algorithm-shortest-path",
                            "start-sid": 102,
                            "range": 1,
```

```
                            "is-local": false,
                            "is-node": true
                          }
                        ]
                      }
                    }
                  }
                ],
                "ietf-sr-mpls-topology:sr-mpls": {
                  "srgb": [
                    {
                      "lower-bound": 16000,
                      "upper-bound": 23999
                    }
                  ],
                  "srlb": [
                    {
                      "lower-bound": 15000,
                      "upper-bound": 15999
                    }
                  ]
                }
              }
            },
            {
              "node-id": "D3",
              "ietf-network-topology:termination-point": [
                {
                  "tp-id": "3-1-1",
   "ietf-l3-unicast-topology:l3-termination-point-attributes": {
                    "unnumbered-id": 311
                  }
                },
                {
                  "tp-id": "3-2-1",
   "ietf-l3-unicast-topology:l3-termination-point-attributes": {
                    "unnumbered-id": 321
                  }
                }
              ],
              "ietf-l3-unicast-topology:l3-node-attributes": {
                "router-id": ["203.0.113.3"],
                "prefix": [
                  {
                    "prefix": "203.0.113.3/32",
                    "ietf-sr-mpls-topology:sr-mpls": {
                      "sids": {
                        "sid": [
```

```
                            {
   "algorithm": "prefix-sid-algorithm-shortest-path",
                              "start-sid": 103,
                              "range": 1,
                              "is-local": false,
                              "is-node": true
                            }
                          ]
                        }
                      }
                    }
                  ],
                  "ietf-sr-mpls-topology:sr-mpls": {
                    "srgb": [
                      {
                        "lower-bound": 16000,
                        "upper-bound": 23999
                      }
                    ],
                    "srlb": [
                      {
                        "lower-bound": 15000,
                        "upper-bound": 15999
                      }
                    ]
                  }
                }
              }
            ],
            "ietf-network-topology:link": [
              {
                "link-id": "D1,1-2-1,D2,2-1-1",
                "source": {
                  "source-node": "D1",
                  "source-tp": "1-2-1"
                },
                "destination": {
                  "dest-node": "D2",
                  "dest-tp": "2-1-1"
                },
                "ietf-l3-unicast-topology:l3-link-attributes": {
                  "metric1": "100",
                  "ietf-sr-mpls-topology:sr-mpls": {
                    "sids": {
                      "sid": [
                        {
                          "value-type": "index",
                          "sid": 121,
```

```
                "is-local": true
              }
            ]
          }
        }
      }
    },
    {
      "link-id": "D2,2-1-1,D1,1-2-1",
      "source": {
        "source-node": "D2",
        "source-tp": "2-1-1"
      },
      "destination": {
        "dest-node": "D1",
        "dest-tp": "1-2-1"
      },
      "ietf-l3-unicast-topology:l3-link-attributes": {
        "metric1": "100",
        "ietf-sr-mpls-topology:sr-mpls": {
          "sids": {
            "sid": [
              {
                "value-type": "index",
                "sid": 211,
                "is-local": true
              }
            ]
          }
        }
      }
    },
    {
      "link-id": "D1,1-3-1,D3,3-1-1",
      "source": {
        "source-node": "D1",
        "source-tp": "1-3-1"
      },
      "destination": {
        "dest-node": "D3",
        "dest-tp": "3-1-1"
      },
      "ietf-l3-unicast-topology:l3-link-attributes": {
        "metric1": "100",
        "ietf-sr-mpls-topology:sr-mpls": {
          "sids": {
            "sid": [
              {
```

```
                        "value-type": "index",
                        "sid": 131,
                        "is-local": true
                      }
                    ]
                  }
                }
              }
            },
            {
              "link-id": "D3,3-1-1,D1,1-3-1",
              "source": {
                "source-node": "D3",
                "source-tp": "3-1-1"
              },
              "destination": {
                "dest-node": "D1",
                "dest-tp": "1-3-1"
              },
              "ietf-l3-unicast-topology:l3-link-attributes": {
                "metric1": "100",
                "ietf-sr-mpls-topology:sr-mpls": {
                  "sids": {
                    "sid": [
                      {
                        "value-type": "index",
                        "sid": 311,
                        "is-local": true
                      }
                    ]
                  }
                }
              }
            },
            {
              "link-id": "D2,2-3-1,D3,3-2-1",
              "source": {
                "source-node": "D2",
                "source-tp": "2-3-1"
              },
              "destination": {
                "dest-node": "D3",
                "dest-tp": "3-2-1"
              },
              "ietf-l3-unicast-topology:l3-link-attributes": {
                "metric1": "100",
                "ietf-sr-mpls-topology:sr-mpls": {
                  "sids": {
```

```
                    "sid": [
                      {
                        "value-type": "index",
                        "sid": 231,
                        "is-local": true
                      }
                    ]
                  }
                }
              }
            },
            {
              "link-id": "D3,3-2-1,D2,2-3-1",
              "source": {
                "source-node": "D3",
                "source-tp": "3-2-1"
              },
              "destination": {
                "dest-node": "D2",
                "dest-tp": "2-3-1"
              },
              "ietf-l3-unicast-topology:l3-link-attributes": {
                "metric1": "100",
                "ietf-sr-mpls-topology:sr-mpls": {
                  "sids": {
                    "sid": [
                      {
                        "value-type": "index",
                        "sid": 321,
                        "is-local": true
                      }
                    ]
                  }
                }
              }
            }
          ]
        }
      ]
    }
  }
```


B.2. SR MPLS Topology with TE Enabled

In this section, the example below shows an instance data of a overlay topology as shown in Figure 4. Some attributes are from the underlay topology shown in Figure 5.

```
                 ............................   ....................
                 .            D1             .   .        D2        .
                 .                           .   .                  .
                 .        SID:17012          .   .                  .
                 .     Base64:MTcwMTI=       .   .                  .
                 .  +---+    +---+    +---+  .   .  +---+    +---+  .
               -----|S11|----|S12|----|S15|---------|S23|----|S25|-----
                 .  +---+\   +---+   /+---+  .   .  +---+   /+---+  .
                 .        \         /        .   .         /   |    .
                 .         \       /         .   .        /    |    .
                 .          \+---+/          .   .  +---+/   +---+  .
                 .           |S14|           .   .  |S24|----|S28|  .
                 .           +---+           .   .  +---+    +---+  .
                 ...............|...............   .....|..............
                                |                      |
                   SID:17051 +---+    +---+ SID:17052 |
                   Base64:   |S51|----|S52| Base64:   |
                   MTcwNTE=  +---+   /+---+ MTcwNTI=  |
                               |    /                 /
                               |   /      .........../
                               |  /       .   D3    /
                               | /        .        /.
                   SID:17053 +---+        .  +---+/ .
                   Base64:   |S53|-----------|S31|  .
                   MTcwNTM=  +---+        .  +---+  .
                                          ...........
```

Figure 5: Example Underlay SR MPLS TE Toplogy


```
{
  "ietf-network:networks": {
    "network": [
      {
        "network-types": {
          "ietf-l3-unicast-topology:l3-unicast-topology": {
            "ietf-sr-mpls-topology:sr-mpls": {}
          },
          "ietf-te-topology:te-topology": {
            "ietf-te-topology-packet:packet": {}
          }
        },
        "network-id": "sr-mpls-te-topo-example",
        "ietf-l3-unicast-topology:l3-topology-attributes": {
          "ietf-sr-mpls-topology:sr-mpls": {
            "srgb": [
              {
                "lower-bound": 16000,
```

```
                  "upper-bound": 23999
                }
              ]
            }
          },
          "ietf-te-topology:te-topology-identifier": {
            "provider-id": 0,
            "client-id": 0,
            "topology-id": "sr-mpls-te-topo-example"
          },
          "ietf-te-topology:te": {
   "optimization-criterion": "ietf-te-types:of-minimize-cost-path"
          },
          "node": [
            {
              "node-id": "D1",
              "ietf-network-topology:termination-point": [
                {
                  "tp-id": "1-0-1",
   "ietf-l3-unicast-topology:l3-termination-point-attributes": {
                    "unnumbered-id": 101
                  },
                  "ietf-te-topology:te": {
                    "interface-switching-capability": [
                      {
                        "switching-capability": "switching-psc1",
                        "encoding": "lsp-encoding-packet",
                        "max-lsp-bandwidth": [
                          {
                            "priority": 7,
                            "te-bandwidth": {
                              "generic": "0x1p22"
                            }
                          }
                        ]
                      }
                    ]
                  }
                },
                {
                  "tp-id": "1-2-1",
   "ietf-l3-unicast-topology:l3-termination-point-attributes": {
                    "unnumbered-id": 121
                  },
                  "ietf-te-topology:te": {
                    "interface-switching-capability": [
                      {
                        "switching-capability": "switching-psc1",
```

```
                        "encoding": "lsp-encoding-packet",
                        "max-lsp-bandwidth": [
                          {
                            "priority": 7,
                            "te-bandwidth": {
                              "generic": "0x1p22"
                            }
                          }
                        ]
                      }
                    ]
                  }
                },
                {
                  "tp-id": "1-3-1",
   "ietf-l3-unicast-topology:l3-termination-point-attributes": {
                    "unnumbered-id": 131
                  },
                  "ietf-te-topology:te": {
                    "interface-switching-capability": [
                      {
                        "switching-capability": "switching-psc1",
                        "encoding": "lsp-encoding-packet",
                        "max-lsp-bandwidth": [
                          {
                            "priority": 7,
                            "te-bandwidth": {
                              "generic": "0x1p22"
                            }
                          }
                        ]
                      }
                    ]
                  }
                }
              ],
              "ietf-l3-unicast-topology:l3-node-attributes": {
                "router-id": ["203.0.113.1"],
                "prefix": [
                  {
                    "prefix": "203.0.113.1/32",
                    "ietf-sr-mpls-topology:sr-mpls": {
                      "sids": {
                        "sid": [
                          {
   "algorithm": "prefix-sid-algorithm-shortest-path",
                            "start-sid": 101,
                            "range": 1,
```

```
                            "is-local": false,
                            "is-node": true
                          }
                        ]
                      }
                    }
                  }
                ],
                "ietf-sr-mpls-topology:sr-mpls": {
                  "srgb": [
                    {
                      "lower-bound": 16000,
                      "upper-bound": 23999
                    }
                  ],
                  "srlb": [
                    {
                      "lower-bound": 15000,
                      "upper-bound": 15999
                    }
                  ]
                }
              },
              "ietf-te-topology:te-node-id": "203.0.113.1",
              "ietf-te-topology:te": {
                "te-node-attributes": {
                  "admin-status": "up",
                  "domain-id": 1001,
                  "is-abstract": [null],
                  "signaling-address": [
                    "203.0.113.1"
                  ],
                  "connectivity-matrices": {
                    "is-allowed": true,
                    "path-constraints": {
                      "te-bandwidth": {
                        "generic": "0x1p20"
                      },
                      "path-metric-bounds": {
                        "path-metric-bound": [
                          {
                            "metric-type": "path-metric-delay-average",
                            "upper-bound": 15000
                          }
                        ]
                      }
                    },
                    "ietf-te-topology-packet:throttle": {
```

```
                    "threshold-out": {
                      "two-way-delay": 18000
                    }
                  },
                  "connectivity-matrix": [
                    {
                      "id": 1,
                      "from": {
                        "tp-ref": "1-0-1"
                      },
                      "to": {
                        "tp-ref": "1-2-1"
                      },
                      "is-allowed": true,
                      "underlay": {
                        "enabled": true,
                        "primary-path": {
                          "network-ref": "underlay-example",
                          "path-element": [
                            {
                              "path-element-id": 1,
                              "label-hop": {
                                "te-label": {
                                  "generic": "MTcwMTI=",
                                  "direction": "forward"
                                }
                              }
                            }
                          ]
                        }
                      }
                    },
                    {
                      "id": 2,
                      "from": {
                        "tp-ref": "1-2-1"
                      },
                      "to": {
                        "tp-ref": "1-0-1"
                      },
                      "is-allowed": true,
                      "underlay": {
                        "enabled": true,
                        "primary-path": {
                          "network-ref": "underlay-example",
                          "path-element": [
                            {
                              "path-element-id": 1,
```

```
                                "label-hop": {
                                  "te-label": {
                                    "generic": "MTcwMTI=",
                                    "direction": "forward"
                                  }
                                }
                              }
                            ]
                          }
                        }
                      }
                    ]
                  }
                }
              }
            },
            {
              "node-id": "D2",
              "ietf-network-topology:termination-point": [
                {
                  "tp-id": "2-0-1",
   "ietf-l3-unicast-topology:l3-termination-point-attributes": {
                    "unnumbered-id": 201
                  },
                  "ietf-te-topology:te": {
                    "interface-switching-capability": [
                      {
                        "switching-capability": "switching-psc1",
                        "encoding": "lsp-encoding-packet",
                        "max-lsp-bandwidth": [
                          {
                            "priority": 7,
                            "te-bandwidth": {
                              "generic": "0x1p22"
                            }
                          }
                        ]
                      }
                    ]
                  }
                },
                {
                  "tp-id": "2-1-1",
   "ietf-l3-unicast-topology:l3-termination-point-attributes": {
                    "unnumbered-id": 211
                  },
                  "ietf-te-topology:te": {
                    "interface-switching-capability": [
```

```
                      {
                        "switching-capability": "switching-psc1",
                        "encoding": "lsp-encoding-packet",
                        "max-lsp-bandwidth": [
                          {
                            "priority": 7,
                            "te-bandwidth": {
                              "generic": "0x1p22"
                            }
                          }
                        ]
                      }
                    ]
                  }
                },
                {
                  "tp-id": "2-3-1",
   "ietf-l3-unicast-topology:l3-termination-point-attributes": {
                    "unnumbered-id": 231
                  }
                }
              ],
              "ietf-l3-unicast-topology:l3-node-attributes": {
                "router-id": ["203.0.113.2"],
                "prefix": [
                  {
                    "prefix": "203.0.113.2/32",
                    "ietf-sr-mpls-topology:sr-mpls": {
                      "sids": {
                        "sid": [
                          {
   "algorithm": "prefix-sid-algorithm-shortest-path",
                            "start-sid": 102,
                            "range": 1,
                            "is-local": false,
                            "is-node": true
                          }
                        ]
                      }
                    }
                  }
                ],
                "ietf-sr-mpls-topology:sr-mpls": {
                  "srgb": [
                    {
                      "lower-bound": 16000,
                      "upper-bound": 23999
                    }
```

```
                  ],
                  "srlb": [
                    {
                      "lower-bound": 15000,
                      "upper-bound": 15999
                    }
                  ]
                }
              },
              "ietf-te-topology:te-node-id": "203.0.113.2",
              "ietf-te-topology:te": {
                "te-node-attributes": {
                  "admin-status": "up",
                  "domain-id": 1001,
                  "is-abstract": [null],
                  "signaling-address": [
                    "203.0.113.2"
                  ]
                }
              }
            },
            {
              "node-id": "D3",
              "ietf-network-topology:termination-point": [
                {
                  "tp-id": "3-1-1",
   "ietf-l3-unicast-topology:l3-termination-point-attributes": {
                    "unnumbered-id": 311
                  },
                  "ietf-te-topology:te": {
                    "interface-switching-capability": [
                      {
                        "switching-capability": "switching-psc1",
                        "encoding": "lsp-encoding-packet",
                        "max-lsp-bandwidth": [
                          {
                            "priority": 7,
                            "te-bandwidth": {
                              "generic": "0x1p22"
                            }
                          }
                        ]
                      }
                    ]
                  }
                },
                {
                  "tp-id": "3-2-1",
```

```
   "ietf-l3-unicast-topology:l3-termination-point-attributes": {
                      "unnumbered-id": 321
                    }
                  }
                ],
                "ietf-l3-unicast-topology:l3-node-attributes": {
                  "router-id": ["203.0.113.3"],
                  "prefix": [
                    {
                      "prefix": "203.0.113.3/32",
                      "ietf-sr-mpls-topology:sr-mpls": {
                        "sids": {
                          "sid": [
                            {
   "algorithm": "prefix-sid-algorithm-shortest-path",
                              "start-sid": 103,
                              "range": 1,
                              "is-local": false,
                              "is-node": true
                            }
                          ]
                        }
                      }
                    }
                  ],
                  "ietf-sr-mpls-topology:sr-mpls": {
                    "srgb": [
                      {
                        "lower-bound": 16000,
                        "upper-bound": 23999
                      }
                    ],
                    "srlb": [
                      {
                        "lower-bound": 15000,
                        "upper-bound": 15999
                      }
                    ]
                  }
                },
                "ietf-te-topology:te-node-id": "203.0.113.3",
                "ietf-te-topology:te": {
                  "te-node-attributes": {
                    "admin-status": "up",
                    "domain-id": 1001,
                    "signaling-address": [
                      "203.0.113.3"
                    ]
```

```
                }
              }
            }
          ],
          "ietf-network-topology:link": [
            {
              "link-id": "D1,1-2-1,D2,2-1-1",
              "source": {
                "source-node": "D1",
                "source-tp": "1-2-1"
              },
              "destination": {
                "dest-node": "D2",
                "dest-tp": "2-1-1"
              },
              "ietf-l3-unicast-topology:l3-link-attributes": {
                "metric1": "100",
                "ietf-sr-mpls-topology:sr-mpls": {
                  "sids": {
                    "sid": [
                      {
                        "value-type": "index",
                        "sid": 121,
                        "is-local": true
                      }
                    ]
                  }
                }
              },
              "ietf-te-topology:te": {
                "te-link-attributes": {
                  "interface-switching-capability": [
                    {
                      "switching-capability": "switching-psc1",
                      "encoding": "lsp-encoding-packet",
                      "ietf-te-topology-packet:packet-switch-capable":
                      {
                        "minimum-lsp-bandwidth": "0x1p20"
                      }
                    }
                  ]
                }
              }
            },
            {
              "link-id": "D2,2-1-1,D1,1-2-1",
              "source": {
                "source-node": "D2",
```

```
                "source-tp": "2-1-1"
              },
              "destination": {
                "dest-node": "D1",
                "dest-tp": "1-2-1"
              },
              "ietf-l3-unicast-topology:l3-link-attributes": {
                "metric1": "100",
                "ietf-sr-mpls-topology:sr-mpls": {
                  "sids": {
                    "sid": [
                      {
                        "value-type": "index",
                        "sid": 211,
                        "is-local": true
                      }
                    ]
                  }
                }
              },
              "ietf-te-topology:te": {
                "te-link-attributes": {
                  "interface-switching-capability": [
                    {
                      "switching-capability": "switching-psc1",
                      "encoding": "lsp-encoding-packet",
                      "ietf-te-topology-packet:packet-switch-capable":
                      {
                        "minimum-lsp-bandwidth": "0x1p20"
                      }
                    }
                  ]
                }
              }
            },
            {
              "link-id": "D1,1-3-1,D3,3-1-1",
              "source": {
                "source-node": "D1",
                "source-tp": "1-3-1"
              },
              "destination": {
                "dest-node": "D3",
                "dest-tp": "3-1-1"
              },
              "ietf-l3-unicast-topology:l3-link-attributes": {
                "metric1": "100",
                "ietf-sr-mpls-topology:sr-mpls": {
```

```
                "sids": {
                  "sid": [
                    {
                      "value-type": "index",
                      "sid": 131,
                      "is-local": true
                    }
                  ]
                }
              }
            },
            "ietf-te-topology:te": {
              "te-link-attributes": {
                "is-abstract": [null],
                "underlay": {
                  "enabled": true,
                  "primary-path": {
                    "network-ref": "underlay-example",
                    "path-element": [
                      {
                        "path-element-id": 1,
                        "label-hop": {
                          "te-label": {
                            "generic": "MTcwNTE=",
                            "direction": "forward"
                          }
                        }
                      },
                      {
                        "path-element-id": 2,
                        "label-hop": {
                          "te-label": {
                            "generic": "MTcwNTI=",
                            "direction": "forward"
                          }
                        }
                      },
                      {
                        "path-element-id": 3,
                        "label-hop": {
                          "te-label": {
                            "generic": "MTcwNTM=",
                            "direction": "forward"
                          }
                        }
                      }
                    ]
                  }
```

```
                },
                "interface-switching-capability": [
                  {
                    "switching-capability": "switching-psc1",
                    "encoding": "lsp-encoding-packet",
                    "ietf-te-topology-packet:packet-switch-capable":
                    {
                      "minimum-lsp-bandwidth": "0x1p20"
                    }
                  }
                ]
              }
            }
          },
          {
            "link-id": "D3,3-1-1,D1,1-3-1",
            "source": {
              "source-node": "D3",
              "source-tp": "3-1-1"
            },
            "destination": {
              "dest-node": "D1",
              "dest-tp": "1-3-1"
            },
            "ietf-l3-unicast-topology:l3-link-attributes": {
              "metric1": "100",
              "ietf-sr-mpls-topology:sr-mpls": {
                "sids": {
                  "sid": [
                    {
                      "value-type": "index",
                      "sid": 311,
                      "is-local": true
                    }
                  ]
                }
              }
            },
            "ietf-te-topology:te": {
              "te-link-attributes": {
                "is-abstract": [null],
                "interface-switching-capability": [
                  {
                    "switching-capability": "switching-psc1",
                    "encoding": "lsp-encoding-packet",
                    "ietf-te-topology-packet:packet-switch-capable":
                    {
                      "minimum-lsp-bandwidth": "0x1p20"
```

```
                }
              }
            ]
          }
        }
      },
      {
        "link-id": "D2,2-3-1,D3,3-2-1",
        "source": {
          "source-node": "D2",
          "source-tp": "2-3-1"
        },
        "destination": {
          "dest-node": "D3",
          "dest-tp": "3-2-1"
        },
        "ietf-l3-unicast-topology:l3-link-attributes": {
          "metric1": "100",
          "ietf-sr-mpls-topology:sr-mpls": {
            "sids": {
              "sid": [
                {
                  "value-type": "index",
                  "sid": 231,
                  "is-local": true
                }
              ]
            }
          }
        }
      },
      {
        "link-id": "D3,3-2-1,D2,2-3-1",
        "source": {
          "source-node": "D3",
          "source-tp": "3-2-1"
        },
        "destination": {
          "dest-node": "D2",
          "dest-tp": "2-3-1"
        },
        "ietf-l3-unicast-topology:l3-link-attributes": {
          "metric1": "100",
          "ietf-sr-mpls-topology:sr-mpls": {
            "sids": {
              "sid": [
                {
                  "value-type": "index",
```

```
                          "sid": 321,
                          "is-local": true
                        }
                      ]
                    }
                  }
                }
              }
            ]
          }
        ]
      }
    }
```

Appendix C. Contributors

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