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A YANG Data Model for Layer 3 Topologies
draft-ietf-i2rs-yang-l3-topology-13.txt

Abstract

This document defines a YANG data model for layer 3 network topologies.

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 May 19, 2018.

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1. Introduction

This document introduces a YANG [RFC7950] [RFC6991] data model for Layer 3 network topologies, specifically Layer 3 Unicast. The model allows an application to have a holistic view of the topology of a Layer 3 network, all contained in a single conceptual YANG datastore. The data model builds on top of, and augments, the data model for network topologies defined in [I-D.draft-ietf-i2rs-yang-network-topo].

This document also shows how the model can be further refined to cover different Layer 3 Unicast topology types. For this purpose, example model is introduced that covers OSPF [RFC2328]. This example is intended purely for illustrative purpose; we expect that full-blown OSPF model will be more comprehensive and refined than the example shown here.

There are multiple applications for a topology data model. A number of use cases have been defined in section 6 of [I-D.draft-ietf-i2rs-usecase-reqs-summary]. For example, nodes within the network can use the data model to capture their understanding of the overall network topology and expose it to a network controller. A network controller can then use the instantiated topology data to compare and reconcile its own view of the network topology with that of the network elements that it controls. Alternatively, nodes within the network could propagate this understanding to compare and reconcile this understanding either amongst themselves or with help of a controller. Beyond the network element itself, a network controller might even use the data model to represent its view of the topology that it controls and expose it to applications north of itself.

The data model for Layer 3 Unicast topologies defined in this document is specified in a YANG module "ietf-l3-unicast-topology". To do so, it augments general network topology model defined in [I-D.draft-ietf-i2rs-yang-network-topo] with information specific to Layer 3 Unicast. This way, the general topology model is extended to be able to meet the needs of Layer 3 Unicast topologies.

Information that is kept in the Traffic Engineering Database (TED) will be specified in a separate model [I-D.draft-ietf-teas-yang-te-topo] and outside the scope of this specification.

2. Key Words

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.

3. Definitions and Acronyms

As this document defines a YANG data model, in this document many terms are used that have been defined in conjunction with YANG [RFC7950] and NETCONF [RFC6241]. Some terms, such as datastore and data tree, are repeated here for clarity and to put them in context.

Datastore: A conceptual place to store and access information. A datastore might be implemented, for example, using files, a database, flash memory locations, or combinations thereof. A datastore maps to an instantiated YANG data tree. (Definition adopted from [I-D.draft-ietf-netmod-revised-datastores])

Data subtree: An instantiated data node and the data nodes that are hierarchically contained within it.

IGP: Interior Gateway Protocol

IS-IS: Intermediate System to Intermediate System protocol

LSP: Label Switched Path

NETCONF: Network Configuration Protocol

NMDA: Network Management Datastore Architecture

OSPF: Open Shortest Path First, a link state routing protocol

URI: Uniform Resource Identifier

SRLG: Shared Risk Link Group

TED: Traffic Engineering Database

YANG: A data definition language for NETCONF

4. Model Structure

The Layer 3 Unicast topology model is defined by YANG module "l3-unicast-topology". The relationship of this module with other YANG modules is roughly depicted in the figure below.

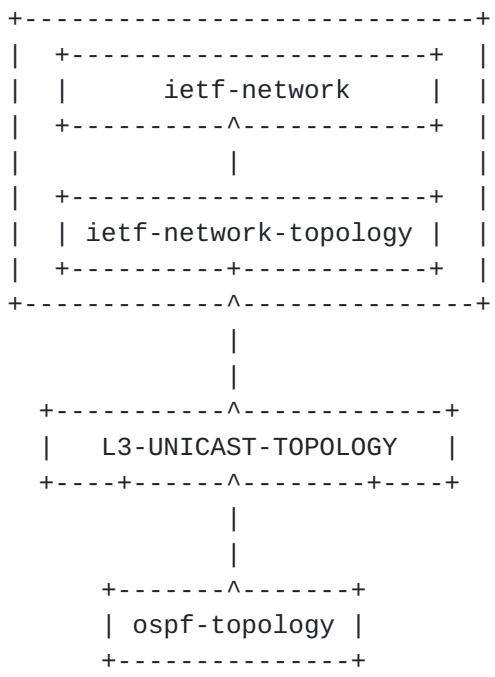

Figure 1: Overall model structure

YANG modules "ietf-network" and "ietf-network-topology" collectively define the basic network topology model. YANG module "ietf-l3-unicast-topology" augments those models with additional definitions needed to represent Layer 3 Unicast topologies. This module in turn can be augmented by YANG modules with additional definitions for specific types of Layer 3 Unicast topologies, such as OSPF and for IS-IS topologies.

The YANG modules ietf-network and ietf-network are designed to be used in conjunction with implementations that support the Network Management Datastore Architecture (NMDA) defined in [I-D.draft-ietf-netmod-revised-datastores]. Accordingly, the same is true for the YANG modules that augment it. In order to allow implementations to use the model even in cases when NMDA is not supported, companion YANG modules (that SHOULD NOT be supported by implementations that support NMDA) are defined in an Appendix, see Appendix A.

5. Layer 3 Unicast Topology Model Overview

The Layer 3 Unicast topology model is defined by YANG module "ietf-l3-unicast-topology". Its structure is depicted in the following diagram. The notation syntax follows [I-D.draft-ietf-netmod-yang-tree-diagrams]. For purposes of brevity, notifications are not depicted.

```
module: ietf-l3-unicast-topology
  augment /nw:networks/nw:network/nw:network-types:
    +--rw l3-unicast-topology!
  augment /nw:networks/nw:network:
    +--rw l3-topology-attributes
       +--rw name?   string
       +--rw flag*   l3-flag-type
  augment /nw:networks/nw:network/nw:node:
    +--rw l3-node-attributes
       +--rw name?        inet:domain-name
       +--rw flag*        node-flag-type
       +--rw router-id*   inet:ip-address
       +--rw prefix* [prefix]
          +--rw prefix    inet:ip-prefix
          +--rw metric?   uint32
          +--rw flag*     prefix-flag-type
  augment /nw:networks/nw:network/nt:link:
    +--rw l3-link-attributes
       +--rw name?      string
       +--rw flag*      link-flag-type
       +--rw metric1?   uint64
       +--rw metric2?   uint64
  augment /nw:networks/nw:network/nw:node/nt:termination-point:
    +--rw l3-termination-point-attributes
       +--rw (termination-point-type)?
          +--:(ip)
          |  +--rw ip-address*       inet:ip-address
          +--:(unnumbered)
          |  +--rw unnumbered-id?    uint32
          +--:(interface-name)
             +--rw interface-name?   string
```

The module augments the original ietf-network and ietf-network-topology modules as follows:

- A new network topology type is introduced, l3-unicast-topology. The corresponding container augments the network-types of the ietf-network module.

- Additional topology attributes are introduced, defined in a grouping, which augments the "network" list of the network module. The attributes include a name for the topology, as well as a set of flags (represented through a leaf-list). Each type of flag is represented by a separate identity. This allows to introduce additional flags in augmenting modules using additional identities without needing to revise this module.

- Additional data objects for nodes are introduced by augmenting the "node" list of the network module. New objects include again a set of flags, as well as a list of prefixes. Each prefix in turn includes an ip prefix, a metric, and a prefix-specific set of flags.

- Links (in the ietf-network-topology module) are augmented with a set of parameters as well, allowing to associate a link with a link name, another set of flags, and a link metric.

- Termination points (in the ietf-network-topology module as well) are augmented with a choice of IP address, identifier, or name.

In addition, the module defines a set of notifications to alert clients of any events concerning links, nodes, prefixes, and termination points. Each notification includes an indication of the type of event, the topology from which it originated, and the affected node, or link, or prefix, or termination point. In addition, as a convenience to applications, additional data of the affected node, or link, or termination point (respectively) is included. While this makes notifications larger in volume than they would need to be, it avoids the need for subsequent retrieval of context information, which also might have changed in the meantime.

6. Layer 3 Unicast Topology YANG Module

```
<CODE BEGINS> file "ietf-l3-unicast-topology@2017-11-15.yang"
module ietf-l3-unicast-topology {
  yang-version 1.1;
  namespace
    "urn:ietf:params:xml:ns:yang:ietf-l3-unicast-topology";
  prefix "l3t";
  import ietf-network {
    prefix "nw";
  }
  import ietf-network-topology {
    prefix "nt";
  }
  import ietf-inet-types {
    prefix "inet";
  }
  organization
    "IETF I2RS (Interface to the Routing System) Working Group";
  contact
    "WG Web:    <http://tools.ietf.org/wg/i2rs/>
     WG List:   <mailto:i2rs@ietf.org>
     Editor:    Alexander Clemm
                <mailto:ludwig@clemm.org>
```

```
        Editor:    Jan Medved
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        Editor:    Robert Varga
                   <mailto:robert.varga@pantheon.sk>
        Editor:    Xufeng Liu
                   <mailto:xliu@kuatrotech.com>
        Editor:    Nitin Bahadur
                   <mailto:nitin_bahadur@yahoo.com>
        Editor:    Hariharan Ananthakrishnan
                   <mailto:hari@packetdesign.com>";
    description
      "This module defines a model for Layer 3 Unicast
       topologies.
       Copyright (c) 2017 IETF Trust and the persons identified as
       authors of the code.  All rights reserved.
       Redistribution and use in source and binary forms, with or
       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
       draft-ietf-i2rs-yang-l3-topology-13;
       see the RFC itself for full legal notices.
       NOTE TO RFC EDITOR: Please replace above reference to
       draft-ietf-i2rs-yang-l3-topology-13 with RFC
       number when published (i.e. RFC xxxx).";
    revision "2017-11-15" {
      description
        "Initial revision.
         NOTE TO RFC EDITOR: Please replace the following reference
         to draft-ietf-i2rs-yang-l3-topology-13 with
         RFC number when published (i.e. RFC xxxx).";
      reference
        "draft-ietf-i2rs-yang-l3-topology-13";
    }

    identity flag-identity {
      description "Base type for flags";
    }

    typedef l3-event-type {
      type enumeration {
        enum "add" {
          description
            "An Layer 3 node or link or prefix or termination-point has
            been added";
        }
```

```
        enum "remove" {
          description
            "An Layer 3 node or link or prefix or termination-point has
            been removed";
        }
        enum "update" {
          description
            "An Layer 3 node or link or prefix or termination-point has
            been updated";
        }
      }
      description "Layer 3 Event type for notifications";
    }

    typedef prefix-flag-type {
      type identityref {
        base "flag-identity";
      }
      description "Prefix flag attributes";
    }

    typedef node-flag-type {
      type identityref {
        base "flag-identity";
      }
      description "Node flag attributes";
    }

    typedef link-flag-type {
      type identityref {
        base "flag-identity";
      }
      description "Link flag attributes";
    }

    typedef l3-flag-type {
      type identityref {
        base "flag-identity";
      }
      description "L3 flag attributes";
    }

    grouping l3-prefix-attributes {
      description
        "L3 prefix attributes";
      leaf prefix {
        type inet:ip-prefix;
        description
```

```
          "IP prefix value";
      }
      leaf metric {
        type uint32;
        description
          "Prefix metric";
      }
      leaf-list flag {
        type prefix-flag-type;
        description
          "Prefix flags";
      }
    }
    grouping l3-unicast-topology-type {
      description "Identify the topology type to be L3 unicast.";
      container l3-unicast-topology {
        presence "indicates L3 Unicast Topology";
        description
          "The presence of the container node indicates L3 Unicast
          Topology";
      }
    }
    grouping l3-topology-attributes {
      description "Topology scope attributes";
      container l3-topology-attributes {
        description "Containing topology attributes";
        leaf name {
          type string;
          description
            "Name of the topology";
        }
        leaf-list flag {
          type l3-flag-type;
          description
            "Topology flags";
        }
      }
    }
    grouping l3-node-attributes {
      description "L3 node scope attributes";
      container l3-node-attributes {
        description
          "Containing node attributes";
        leaf name {
          type inet:domain-name;
          description
            "Node name";
        }
```

```
        leaf-list flag {
          type node-flag-type;
          description
            "Node flags";
        }
        leaf-list router-id {
          type inet:ip-address;
          description
            "Router-id for the node";
        }
        list prefix {
          key "prefix";
          description
            "A list of prefixes along with their attributes";
          uses l3-prefix-attributes;
        }
      }
    }
    grouping l3-link-attributes {
      description
        "L3 link scope attributes";
      container l3-link-attributes {
        description
          "Containing link attributes";
        leaf name {
          type string;
          description
            "Link Name";
        }
        leaf-list flag {
          type link-flag-type;
          description
            "Link flags";
        }
        leaf metric1 {
          type uint64;
          description
              "Link Metric 1";
        }
        leaf metric2 {
          type uint64;
          description
              "Link Metric 2";
        }
      }
    }
    grouping l3-termination-point-attributes {
      description "L3 termination point scope attributes";
```

```
      container l3-termination-point-attributes {
        description
          "Containing termination point attributes";
        choice termination-point-type {
          description
            "Indicates the termination point type";
          case ip {
            leaf-list ip-address {
              type inet:ip-address;
              description
                "IPv4 or IPv6 address.";
            }
          }
          case unnumbered {
            leaf unnumbered-id {
              type uint32;
              description
                "Unnumbered interface identifier.
                 The identifier will correspond to the ifIndex value
                 of the interface, i.e. the ifIndex value of the
                 ifEntry that represents the interface in
                 implementations where the Interfaces Group MIB
                 (RFC 2863) is supported.";
              reference
                "RFC 2863: The Interfaces Group MIB";
            }
          }
          case interface-name {
            leaf interface-name {
              type string;
              description
                "A name of the interface.  The name can (but does not
                 have to) correspond to an interface reference of a
                 containing node's interface, i.e. the path name of a
                 corresponding interface data node on the containing
                 node reminiscent of data type if-ref defined in
                 RFC 7223. It should be noted that data type if-ref of
                 RFC 7223 cannot be used directly, as this data type
                 is used to reference an interface in a datastore of
                 a single node in the network, not to uniquely
                 reference interfaces across a network.";
            }
          }
        }
      }
    }
    augment "/nw:networks/nw:network/nw:network-types" {
      description
```

```
        "Introduce new network type for L3 unicast topology";
      uses l3-unicast-topology-type;
    }
    augment "/nw:networks/nw:network" {
      when "nw:network-types/l3-unicast-topology" {
        description
          "Augmentation parameters apply only for networks with
          L3 unicast topology";
      }
      description
          "L3 unicast for the network as a whole";
      uses l3-topology-attributes;
    }
    augment "/nw:networks/nw:network/nw:node" {
      when "../nw:network-types/l3-unicast-topology" {
        description
          "Augmentation parameters apply only for networks with
          L3 unicast topology";
      }
      description
          "L3 unicast node level attributes ";
      uses l3-node-attributes;
    }
    augment "/nw:networks/nw:network/nt:link" {
      when "../nw:network-types/l3-unicast-topology" {
        description
          "Augmentation parameters apply only for networks with
          L3 unicast topology";
      }
      description
        "Augment topology link attributes";
      uses l3-link-attributes;
    }
    augment "/nw:networks/nw:network/nw:node/"
           +"nt:termination-point" {
      when "../../nw:network-types/l3-unicast-topology" {
        description
          "Augmentation parameters apply only for networks with
          L3 unicast topology";
      }
      description "Augment topology termination point configuration";
      uses l3-termination-point-attributes;
    }
    notification l3-node-event {
      description
        "Notification event for L3 node";
      leaf l3-event-type {
        type l3-event-type;
```

```
        description
          "Event type";
      }
      uses nw:node-ref;
      uses l3-unicast-topology-type;
      uses l3-node-attributes;
    }
    notification l3-link-event {
      description
        "Notification event for L3 link";
      leaf l3-event-type {
        type l3-event-type;
        description
          "Event type";
      }
      uses nt:link-ref;
      uses l3-unicast-topology-type;
      uses l3-link-attributes;
    }
    notification l3-prefix-event {
      description
        "Notification event for L3 prefix";
      leaf l3-event-type {
        type l3-event-type;
        description
          "Event type";
      }
      uses nw:node-ref;
      uses l3-unicast-topology-type;
      container prefix {
        description
          "Containing L3 prefix attributes";
        uses l3-prefix-attributes;
      }
    }
    notification termination-point-event {
      description
        "Notification event for L3 termination point";
      leaf l3-event-type {
        type l3-event-type;
        description
          "Event type";
      }
      uses nt:tp-ref;
      uses l3-unicast-topology-type;
      uses l3-termination-point-attributes;
    }
  }
```

<CODE ENDS>

7. Interactions with Other YANG Modules

As described in section Section 4, the model builds on top of, and augments, the YANG modules defined in [I-D.draft-ietf-i2rs-yang-network-topo]. Specifically, module ietf-l3-unicast-topology augments modules "ietf-network" and "ietf-network-topology". In addition, the model makes use of data types that have been defined in [RFC6991].

The moodel defines a protocol independent YANG data model with layer 3 topology information. It is separate from and not linked with data models that are used to configure routing protocols or routing information. This includes e.g. model "ietf-routing" [RFC8022] and model "ietf-fb-rib" [I-D.draft-acee-rtgwg-yang-rib-extend].

The model obeys the requirements for the ephemeral state found in the document [RFC8242]. For ephemeral topology data that is server provided, the process tasked with maintaining topology information will load information from the routing process (such as OSPF) into the data model without relying on a configuration datastore.

8. IANA Considerations

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

URI: urn:ietf:params:xml:ns:yang:ietf-l3-unicast-topology
Registrant Contact: The IESG.
XML: N/A; the requested URI is an XML namespace.

URI: urn:ietf:params:xml:ns:yang:ietf-l3-unicast-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-l3-unicast-topology
Namespace: urn:ietf:params:xml:ns:yang:ietf-l3-unicast-topology
Prefix: l3t
Reference: draft-ietf-i2rs-yang-l3-topology-13.txt (RFC form)

Name: ietf-l3-unicast-topology-state
Namespace: urn:ietf:params:xml:ns:yang:ietf-l3-unicast-topology-state
Prefix: l3t-s
Reference: draft-ietf-i2rs-yang-l3-topology-13.txt (RFC form)

9. Security Considerations

The YANG module defined in this document 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 [RFC5246].

The NETCONF access control model [RFC6536] 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.

In general, Layer 3 Unicast topologies are system-controlled and provide ephemeral topology information. In an NMDA-complient server, they are only part of <operational> which provides read-only access to clients, they are less vulnerable. That said, the YANG module does in principle allow information to be configurable.

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 in the ietf-network module:

l3-topology-attributes: A malicious client could attempt to sabotage the configuration of any of the ctonained attributes, i.e. the name or the flag data nodes.

l3-node-attributes: A malicious client could attempt to sabotage the configuration of important node attributes, such as the router-id or node prefix.

l3-link-attributes: A malicious client could attempt to sabotage the configuration of important link attributes, such as name, flag, and metrics of the link respectively corresponding data nodes.

l3-termination-point-attributes: A malicious client could attempt to sabotage the configuration information of a termination point, such as its ip-address and interface name, respectively the corresponding data nodes.

10. Contributors

The model presented in this document was contributed to by more people than can be listed on the author list. Additional contributors include:

- Vishnu Pavan Beeram, Juniper
- Igor Bryskin, Huawei
- Ken Gray, Cisco
- Aihua Guo, Huawei
- Tom Nadeau, Brocade
- Tony Tkacik
- Aleksandr Zhdankin, Cisco

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Appendix A. Companion YANG model for non-NMDA compliant implementations

The YANG module ietf-l3-unicast-topology defined in this document augments two modules, ietf-network and ietf-network-topology, that are designed to be used in conjunction with implementations that support the Network Management Datastore Architecture (NMDA) defined in [I-D.draft-ietf-netmod-revised-datastores]. In order to allow implementations to use the model even in cases when NMDA is not supported, a set of companion modules have been defined that represent a state model of networks and network topologies, ietf-network-state and ietf-network-topology-state, respectively.

In order to be able to use the model for layer 3 topologies defined in this in this document in conjunction with non-NMDA compliant implementations, a corresponding companion module needs to be introduced as well. This companion module, ietf-l3-unicast-topology-state, mirrors ietf-l3-unicast-topology. However, the module augments ietf-network-state and ietf-network-topology-state (instead of ietf-network and ietf-network-topology) and all of its data nodes are non-configurable.

Similar considerations apply for any modules that augment ietf-l3-unicast-topology, such as the example modules defined in see Appendix B, example-ietf-ospf-topology. For non-NMDA compliant implementations, companion modules will need to be introduced that represent state information and are non-configurable, augmenting ietf-l3-unicast-topology-state instead of ietf-l3-unicast-topology. Because they served as examples only, companion modules for those examples are not given.

Like ietf-network-state and ietf-network-topology-state, ietf-l3-unicast-topology SHOULD NOT be supported by implementations that support NMDA. It is for this reason that the module is defined in the Appendix.

The definition of the module follows below. As the structure of the module mirrors that of its underlying module, the YANG tree is not depicted separately.

```
<CODE BEGINS> file "ietf-l3-unicast-topology-state@2017-11-15.yang"
module ietf-l3-unicast-topology-state {
  yang-version 1.1;
  namespace
    "urn:ietf:params:xml:ns:yang:ietf-l3-unicast-topology-state";
  prefix "l3t-s";
  import ietf-network-state {
    prefix "nw-s";
  }
```

```
    import ietf-network-topology-state {
      prefix "nt-s";
    }
    import ietf-l3-unicast-topology {
      prefix "l3t";
    }
    organization
      "IETF I2RS (Interface to the Routing System) Working Group";
    contact
      "WG Web:    <http://tools.ietf.org/wg/i2rs/>
       WG List:   <mailto:i2rs@ietf.org>
       Editor:    Alexander Clemm
                  <mailto:ludwig@clemm.org>
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       Editor:    Xufeng Liu
                  <mailto:xliu@kuatrotech.com>
       Editor:    Nitin Bahadur
                  <mailto:nitin_bahadur@yahoo.com>
       Editor:    Hariharan Ananthakrishnan
                  <mailto:hari@packetdesign.com>";
    description
      "This module defines a model for Layer 3 Unicast topology
       state, representing topology that is either learned, or topology
       that results from applying topology that has been configured per
       the ietf-l3-unicast-topology model, mirroring the corresponding
       data nodes in this model.

       The model mirrors ietf-l3-unicast-topology, but contains only
       read-only state data.  The model is not needed when the
       underlying implementation infrastructure supports the Network
       Management Datastore Architecture (NMDA).

       Copyright (c) 2017 IETF Trust and the persons identified as
       authors of the code.  All rights reserved.
       Redistribution and use in source and binary forms, with or
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       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
       draft-ietf-i2rs-yang-l3-topology-13;
       see the RFC itself for full legal notices.
       NOTE TO RFC EDITOR: Please replace above reference to
       draft-ietf-i2rs-yang-l3-topology-13 with RFC
```

```
        number when published (i.e. RFC xxxx).";
    revision "2017-11-15" {
      description
        "Initial revision.
         NOTE TO RFC EDITOR: Please replace the following reference
         to draft-ietf-i2rs-yang-l3-topology-13 with
         RFC number when published (i.e. RFC xxxx).";
      reference
        "draft-ietf-i2rs-yang-l3-topology-13";
    }
    augment "/nw-s:networks/nw-s:network/nw-s:network-types" {
      description
        "Introduce new network type for L3 unicast topology";
      uses l3t:l3-unicast-topology-type;
    }
    augment "/nw-s:networks/nw-s:network" {
      when "nw-s:network-types/l3-unicast-topology" {
        description
          "Augmentation parameters apply only for networks with
          L3 unicast topology";
      }
      description
          "L3 unicast for the network as a whole";
      uses l3t:l3-topology-attributes;
    }
    augment "/nw-s:networks/nw-s:network/nw-s:node" {
      when "../nw-s:network-types/l3-unicast-topology" {
        description
          "Augmentation parameters apply only for networks with
          L3 unicast topology";
      }
      description
          "L3 unicast node level attributes ";
      uses l3t:l3-node-attributes;
    }
    augment "/nw-s:networks/nw-s:network/nt-s:link" {
      when "../nw-s:network-types/l3-unicast-topology" {
        description
          "Augmentation parameters apply only for networks with
          L3 unicast topology";
      }
      description
        "Augment topology link attributes";
      uses l3t:l3-link-attributes;
    }
    augment "/nw-s:networks/nw-s:network/nw-s:node/"
          +"nt-s:termination-point" {
      when "../../nw-s:network-types/l3-unicast-topology" {
```

```
        description
          "Augmentation parameters apply only for networks with
          L3 unicast topology";
      }
      description "Augment topology termination point configuration";
      uses l3t:l3-termination-point-attributes;
    }
    notification l3-node-event {
      description
        "Notification event for L3 node";
      leaf l3-event-type {
        type l3t:l3-event-type;
        description
          "Event type";
      }
      uses nw-s:node-ref;
      uses l3t:l3-unicast-topology-type;
      uses l3t:l3-node-attributes;
    }
    notification l3-link-event {
      description
        "Notification event for L3 link";
      leaf l3-event-type {
        type l3t:l3-event-type;
        description
          "Event type";
      }
      uses nt-s:link-ref;
      uses l3t:l3-unicast-topology-type;
      uses l3t:l3-link-attributes;
    }
    notification l3-prefix-event {
      description
        "Notification event for L3 prefix";
      leaf l3-event-type {
        type l3t:l3-event-type;
        description
          "Event type";
      }
      uses nw-s:node-ref;
      uses l3t:l3-unicast-topology-type;
      container prefix {
        description
          "Containing L3 prefix attributes";
        uses l3t:l3-prefix-attributes;
      }
    }
    notification termination-point-event {
```

```
      description
        "Notification event for L3 termination point";
      leaf l3-event-type {
        type l3t:l3-event-type;
        description
          "Event type";
      }
      uses nt-s:tp-ref;
      uses l3t:l3-unicast-topology-type;
      uses l3t:l3-termination-point-attributes;
    }
  }

  <CODE ENDS>
```

Appendix B. Extending the Model

The model can be extended for specific Layer 3 Unicast types. Examples include OSPF and IS-IS topologies. In the following, one additional YANG module is introduced that define simple topology model for OSPF. This module is intended to serve as an example that illustrates how the general topology model can be refined across multiple levels. It does not constitute full-fledged OSPF topology model which may be more comprehensive and refined than the model that is described here.

B.1. Example OSPF Topology

B.1.1. Model Overview

The following model shows how the Layer 3 Unicast topology model can be extended to cover OSFP topologies. For this purpose, a set of augmentations are introduced in a separate YANG module, "example-ietf-ospf-topology", whose structure is depicted in the following diagram. As before, the notation syntax follows [I-D.draft-ietf-netmod-yang-tree-diagrams].

```
  module: example-ietf-ospf-topology
  augment /nw:networks/nw:network/nw:network-types/l3t:l3-unicast-topology:
    +--rw ospf!
  augment /nw:networks/nw:network/l3t:l3-topology-attributes:
    +--rw ospf-topology-attributes
       +--rw area-id?   area-id-type
  augment /nw:networks/nw:network/nw:node/l3t:l3-node-attributes:
    +--rw ospf-node-attributes
       +--rw (router-type)?
       |  +--:(abr)
       |  |  +--rw abr?              empty
       |  +--:(asbr)
       |  |  +--rw asbr?             empty
       |  +--:(internal)
       |  |  +--rw internal?         empty
       |  +--:(pseudonode)
       |     +--rw pseudonode?       empty
       +--rw dr-interface-id?   uint32
  augment /nw:networks/nw:network/nt:link/l3t:l3-link-attributes:
    +--rw ospf-link-attributes
  augment /l3t:l3-node-event:
    +---- ospf!
    +---- ospf-node-attributes
       +---- (router-type)?
       |  +--:(abr)
       |  |  +---- abr?              empty
       |  +--:(asbr)
       |  |  +---- asbr?             empty
       |  +--:(internal)
       |  |  +---- internal?         empty
       |  +--:(pseudonode)
       |     +---- pseudonode?       empty
       +---- dr-interface-id?   uint32
  augment /l3t:l3-link-event:
    +---- ospf!
    +---- ospf-link-attributes
```

The module augments "ietf-l3-unicast-topology" as follows:

- A new topology type for an OSPF topology is introduced.

- Additional topology attributes are defined in a new grouping which augments l3-topology-attributes of the ietf-l3-unicast-topology module. The attributes include an OSPF area-id identifying the OSPF area.

- Additional data objects for nodes are introduced by augmenting the l3-node-attributes of the l3-unicast-topology module. New objects include router-type and dr-interface-id for pseudonodes.

- Links are augmented with ospf link attributes.

In addition, the module extends notifications for events concerning Layer 3 nodes and links with OSPF attributes.

It should be noted that the model defined here represents topology and is intended as an example. It does not define how to configure OSPF routers or interfaces.

B.1.2. OSPF Topology YANG Module

The OSPF Topology YANG Module is specified below. As mentioned, the module is intended as an example for how the Layer 3 Unicast topology model can be extended to cover OSFP topologies, but it is not normative. Accordingly, the module is not delimited with CODE BEGINS and CODE ENDS tags.

```
file "example-ietf-ospf-topology@2017-11-15.yang"
module example-ietf-ospf-topology {
    yang-version 1.1;
    namespace "urn:ietf:params:xml:ns:yang:example-ietf-ospf-topology";
    prefix "ospft";
    import ietf-yang-types {
        prefix "yang";
    }
    import ietf-network {
        prefix "nw";
    }
    import ietf-network-topology {
        prefix "nt";
    }
    import ietf-l3-unicast-topology {
        prefix "l3t";
    }
    organization
        "IETF I2RS (Interface to the Routing System) Working Group";
    contact
       "WG Web:    <http://tools.ietf.org/wg/i2rs/>
        WG List:   <mailto:i2rs@ietf.org>
        Editor:    Alexander Clemm
                   <mailto:ludwig@clemm.org>
        Editor:    Jan Medved
                   <mailto:jmedved@cisco.com>
        Editor:    Robert Varga
```

```
                    <mailto:robert.varga@pantheon.sk>
        Editor:     Xufeng Liu
                    <mailto:xliu@kuatrotech.com>
        Editor:     Nitin Bahadur
                    <mailto:nitin_bahadur@yahoo.com>
        Editor:     Hariharan Ananthakrishnan
                    <mailto:hari@packetdesign.com>";
    description
       "This module defines a model for OSPF network topologies.
        Copyright (c) 2017 IETF Trust and the persons identified as
        authors of the code.  All rights reserved.
        Redistribution and use in source and binary forms, with or
        without modification, is permitted pursuant to, and subject
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        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
        draft-ietf-i2rs-yang-l3-topology-13;
        see the RFC itself for full legal notices.
        NOTE TO RFC EDITOR: Please replace above reference to
        draft-ietf-i2rs-yang-l3-topology-13 with RFC
        number when published (i.e. RFC xxxx).";
    revision "2017-11-15" {
        description
           "Initial revision.
            NOTE TO RFC EDITOR: Please replace the following reference
            to draft-ietf-i2rs-yang-l3-topology-13 with
            RFC number when published (i.e. RFC xxxx).";
        reference
            "draft-ietf-i2rs-yang-l3-topology-13";
    }
    typedef area-id-type {
        type yang:dotted-quad;
        description
            "Area ID type.";
    }
    grouping ospf-topology-type {
        description
            "Identifies the OSPF topology type.";
        container ospf {
            presence "indiates OSPF Topology";
            description
                "Its presence identifies the OSPF topology type.";
        }
    }
    augment "/nw:networks/nw:network/nw:network-types/"
    + "l3t:l3-unicast-topology" {
```

```
        description
            "Defines the OSPF topology type.";
        uses ospf-topology-type;
    }
    augment "/nw:networks/nw:network/l3t:l3-topology-attributes" {
        when "../nw:network-types/l3t:l3-unicast-topology/ospf" {
            description
                "Augment only for OSPF topology";
            }
        description
            "Augment topology configuration";
        container ospf-topology-attributes {
            description
                "Containing topology attributes";
            leaf area-id {
                type area-id-type;
                description
                    "OSPF area ID";
            }
        }
    }
    augment "/nw:networks/nw:network/nw:node/l3t:l3-node-attributes" {
        when "../../nw:network-types/l3t:l3-unicast-topology/ospf" {
            description
                "Augment only for OSPF topology";
        }
        description
            "Augment node configuration";
        uses ospf-node-attributes;
    }
    augment "/nw:networks/nw:network/nt:link/l3t:l3-link-attributes" {
        when "../../nw:network-types/l3t:l3-unicast-topology/ospf" {
            description
                "Augment only for OSPF topology";
        }
        description
            "Augment link configuration";
        uses ospf-link-attributes;
    }
    grouping ospf-node-attributes {
        description
            "OSPF node scope attributes";
        container ospf-node-attributes {
            description
                "Containing node attributes";
            choice router-type {
                description
                    "Indicates router type";
```

```
                case abr {
                    leaf abr {
                        type empty;
                        description
                            "The node is ABR";
                    }
                }
                case asbr {
                    leaf asbr {
                        type empty;
                        description
                            "The node is ASBR";
                    }
                }
                case internal {
                    leaf internal {
                        type empty;
                        description
                            "The node is internal";
                    }
                }
                case pseudonode {
                    leaf pseudonode {
                        type empty;
                        description
                            "The node is pseudonode";
                    }
                }
            }
            leaf dr-interface-id {
                when "../pseudonode" {
                    description
                        "Valid only for pseudonode";
                }
                type uint32;
                default "0";
                description
                    "For pseudonodes, DR interface-id";
            }
        }
    }
    grouping ospf-link-attributes {
        description
            "OSPF link scope attributes";
        container ospf-link-attributes {
            description
                "Containing OSPF link attributes";
        }
```

```
    } // ospf-link-attributes
    augment "/l3t:l3-node-event" {
        description
            "OSPF node event";
        uses ospf-topology-type;
        uses ospft:ospf-node-attributes;
    }
    augment "/l3t:l3-link-event" {
        description
            "OSPF link event";
        uses ospf-topology-type;
        uses ospft:ospf-link-attributes;
    }
}
```

Appendix C. An Example

This section contains an example of an instance data tree in JSON encoding [RFC7951]. The example instantiates ietf-l3-unicast-topology for the topology that is depicted in the following diagram. There are three nodes, D1, D2, and D3. D1 has three termination points, 1-0-1, 1-2-1, and 1-3-1. D2 has three termination points as well, 2-1-1, 2-0-1, and 2-3-1. D3 has two termination points, 3-1-1 and 3-2-1. In addition there are six links, two between each pair of nodes with one going in each direction.

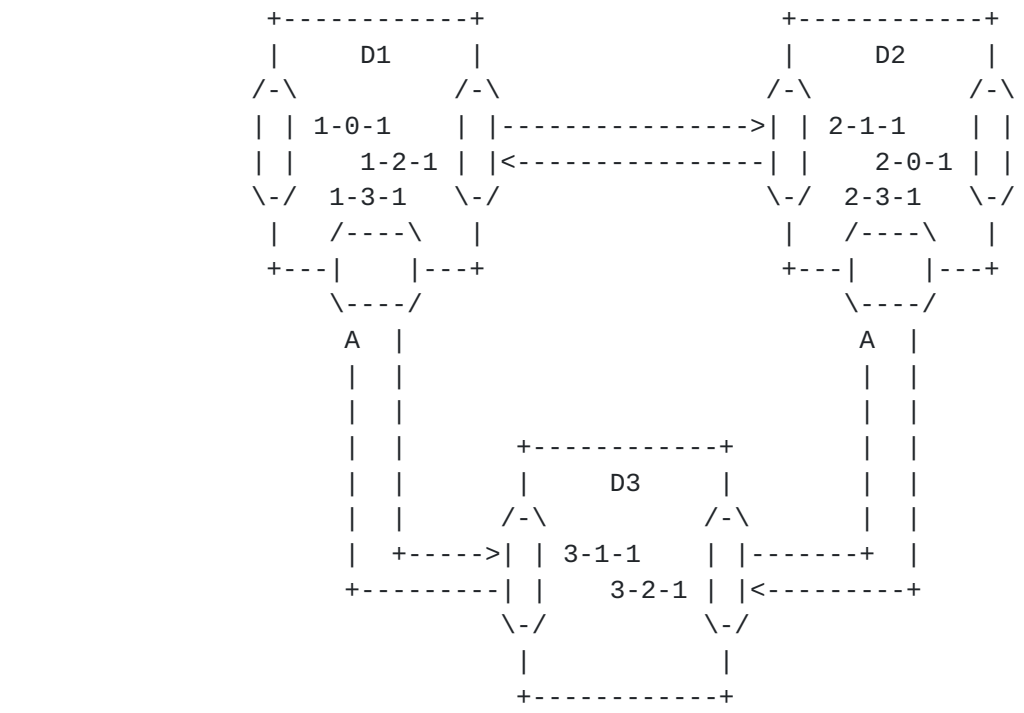

Figure 2: A network topology example

The corresponding instance data tree is depicted below:

```
{
  "ietf-network:networks": {
    "network": [
      {
        "network-types": {
          "ietf-l3-unicast-topology:l3-unicast-topology": {}
        },
        "network-id": "l3-topo-example",
        "node": [
          {
            "node-id": "D1",
            "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"]
        }
      },
      {
        "node-id": "D2",
        "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"]
        }
      },
      {
        "node-id": "D3",
        "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"]
          }
        }
      ],
      "ietf-network-topology:link": [
        {
          "link-id": "D1,1-2-1,D2,2-1-1",
          "destination": {
            "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"
          }
        },
        {
          "link-id": "D2,2-1-1,D1,1-2-1",
          "destination": {
            "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"
          }
        },
        {
          "link-id": "D1,1-3-1,D3,3-1-1",
          "destination": {
            "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"
          }
        },
        {
          "link-id": "D3,3-1-1,D1,1-3-1",
          "destination": {
            "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"
          }
        },
        {
          "link-id": "D2,2-3-1,D3,3-2-1",
          "destination": {
            "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"
          }
        },
        {
          "link-id": "D3,3-2-1,D2,2-3-1",
          "destination": {
            "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"
          }
```

```
          }
        ]
      }
    ]
  }
}
```

Figure 3: Instance data tree

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