

Internet Engineering Task Force (IETF)
Request for Comments: 8346
Category: Standards Track
ISSN: 2070-1721

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March 2018

A YANG Data Model for Layer 3 Topologies

Abstract

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

Status of This Memo

This is an Internet Standards Track document.

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Table of Contents

1. Introduction	3
2. Key Words	3
3. Definitions and Acronyms	4
4. Model Structure	5
5. Layer 3 Unicast Topology Model Overview	6
6. Layer 3 Unicast Topology YANG Module	7
7. Interactions with Other YANG Modules	15
8. IANA Considerations	15
9. Security Considerations	16
10. References	17
10.1. Normative References	17
10.2. Informative References	19
Appendix A. Companion YANG Data Model for Implementations Not Compliant with NMDA	20
Appendix B. Extending the Model	24
B.1. Example OSPF Topology	24
B.1.1. Model Overview	24
B.1.2. OSPF Topology YANG Module	26
Appendix C. An Example	29
Acknowledgments	34
Contributors	34
Authors' Addresses	35

1. Introduction

This document introduces a YANG [RFC7950] [RFC6991] data model for Layer 3 (L3) 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 [RFC8345].

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

There are multiple applications for a topology data model. A number of use cases have been defined in Section 6 of [USECASE-REQS]. 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 the YANG module "ietf-l3-unicast-topology". This YANG module augments the general network topology model defined in [RFC8345] with information specific to Layer 3 Unicast. In 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 [YANG-TE] and is 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

This document defines a YANG data model and thus uses many terms defined in YANG [RFC7950] and NETCONF [RFC6241]. Some terms, such as "datastore" and "data tree", are repeated here for clarity and 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 [RFC8342]).

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

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

TED: Traffic Engineering Database

YANG: YANG is a data modeling language used to model configuration data, state data, Remote Procedure Calls, and notifications for network management protocols [RFC7950].

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.

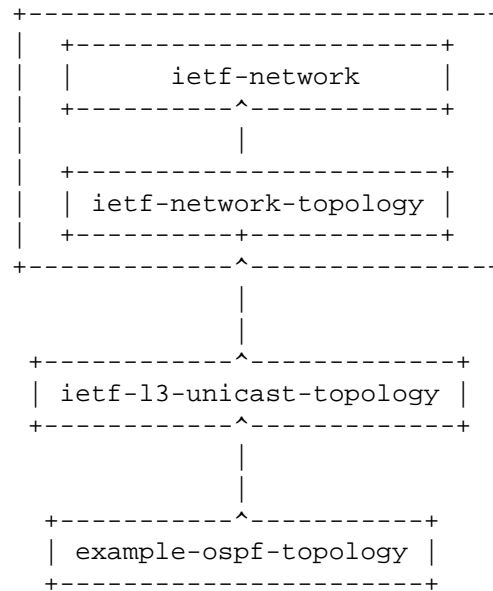


Figure 1: Overall Model Structure

YANG modules "ietf-network" and "ietf-network-topology" collectively define the basic network topology model [RFC8345]. 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 IS-IS topologies.

The YANG modules "ietf-network" and "ietf-network-topology" are designed to be used in conjunction with implementations that support the Network Management Datastore Architecture (NMDA) defined in [RFC8342]. 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 [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 [RFC8340]. 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* rt-types:router-id
      +--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:

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

- o Additional topology attributes are introduced, defined in a grouping that augments the "network" list of the network module. The attributes include a name for the topology and a set of flags (represented by a leaf-list). Each type of flag is represented by a separate identity. This allows additional flags to be introduced in augmenting modules using additional identities without needing to revise this module.
- o Additional data objects for nodes are introduced by augmenting the "node" list of the network module. New objects include a set of flags and a list of prefixes. Each prefix includes an IP prefix, a metric, and a prefix-specific set of flags.
- o Links (in the "ietf-network-topology" module) are augmented with a set of parameters that allow a link to be associated with a link name, another set of flags, and a link metric.
- o Termination points (in the "ietf-network-topology" module) 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, link, prefix, or termination point. Also, as a convenience to applications, additional data of the affected node, link, prefix, or termination point is included. While this makes notifications larger in volume than they need to be, it avoids the need for subsequent retrieval of context information that might have changed in the meantime.

6. Layer 3 Unicast Topology YANG Module

This YANG module makes reference to the following documents: [RFC2863] and [RFC8343].

```
<CODE BEGINS> file "ietf-l3-unicast-topology@2018-02-26.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";
}
import ietf-routing-types {
  prefix "rt-types";
}
organization
  "IETF I2RS (Interface to the Routing System) Working Group";
contact
  "WG Web:      <https://datatracker.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.tech>
  Editor:      Xufeng Liu
                <mailto:xufeng.liu.ietf@gmail.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.

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  authors of the code. All rights reserved.

  Redistribution and use in source and binary forms, with or
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  Relating to IETF Documents
  (https://trustee.ietf.org/license-info).

  This version of this YANG module is part of
  RFC 8346; see the RFC itself for full legal notices.";
revision "2018-02-26" {
  description
    "Initial revision.";
  reference
    "RFC 8346: A YANG Data Model for Layer 3 Topologies";
}

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



```
}

typedef l3-event-type {
  type enumeration {
    enum "add" {
      description
        "A Layer 3 node, link, prefix, or termination point has
        been added";
    }
    enum "remove" {
      description
        "A Layer 3 node, link, prefix, or termination point has
        been removed";
    }
    enum "update" {
      description
        "A Layer 3 node, link, 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 "Identifies 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 "Contains 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
    "Contains 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 rt-types:router-id;
    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
      "Contains 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
      "Contains 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
            "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 interface-ref defined
            in RFC 8343. It should be noted that data type
            interface-ref of RFC 8343 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.";
    reference
        "RFC 8343: A YANG Data Model for Interface Management";
    }
}
}
}
}
augment "/nw:networks/nw:network/nw:network-types" {
    description
        "Introduces new network type for L3 Unicast topology";
    uses l3-unicast-topology-type;
}
augment "/nw:networks/nw:network" {
    when "nw:network-types/l3t: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/l3t: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/l3t:l3-unicast-topology" {
        description
            "Augmentation parameters apply only for networks with
            L3 Unicast topology";
    }
    description
        "Augments topology link attributes";
    uses l3-link-attributes;
}
augment "/nw:networks/nw:network/nw:node/"
    + "nt:termination-point" {
    when "../../../nw:network-types/l3t:l3-unicast-topology" {

```

```
    description
      "Augmentation parameters apply only for networks with
      L3 Unicast topology";
  }
  description "Augments 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
      "Contains 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 4](#), the model defined in this document builds on top of, and augments, the YANG modules defined in [\[RFC8345\]](#). Specifically, the "ietf-l3-unicast-topology" module augments the "ietf-network" and "ietf-network-topology" modules. In addition, the model makes use of data types defined in [\[RFC6991\]](#).

The model defined in this document is 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, e.g., "ietf-routing" [\[RFC8022\]](#) and "ietf-rib-extension" [\[YANG-RIB\]](#). That said, the model does import a type definition from model "ietf-routing-types" [\[RFC8294\]](#).

The model complies with the requirements for the ephemeral state found in [\[RFC8242\]](#). 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: RFC 8346

Name: ietf-l3-unicast-topology-state

Namespace: urn:ietf:params:xml:ns:yang:ietf-l3-unicast-topology-state

Prefix: l3t-s

Reference: RFC 8346

9. Security Considerations

The YANG modules specified in this document define a schema for data that is designed to be accessed via network management protocols such as NETCONF [RFC6241] or RESTCONF [RFC8040]. The lowest NETCONF layer is the secure transport layer, and the mandatory-to-implement secure transport is Secure Shell (SSH) [RFC6242]. The lowest RESTCONF layer is HTTPS, and the mandatory-to-implement secure transport is TLS [RFC5246].

The NETCONF access control model [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.

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

There are a number of data nodes defined in these YANG modules 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-l3-unicast-topology" module:

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

- o l3-node-attributes: A malicious client could attempt to sabotage the configuration of important node attributes, such as the router-id or node prefix.
- o 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.
- o l3-termination-point-attributes: A malicious client could attempt to sabotage the configuration information of a termination point, such as the termination point's IP address and interface name.

10. References

10.1. Normative References

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Appendix A. Companion YANG Data Model for Implementations Not Compliant with NMDA

The YANG module "ietf-l3-unicast-topology" defined in this document augments two modules defined in [RFC8345]: "ietf-network" and "ietf-network-topology". These two modules were 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 in cases when NMDA is not supported, [RFC8345] defines two companion modules, "ietf-network-state" and "ietf-network-topology-state", that represent state models of networks and network topologies, respectively.

In order to be able to use the model for Layer 3 topologies defined in this document in conjunction with implementations not compliant with NMDA, 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 to any module that augments "ietf-l3-unicast-topology", such as the example module defined in Appendix B (i.e., example-ospf-topology). For implementations that are not compliant with NMDA, companion modules that represent state information and that are non-configurable will need to be introduced. These modules augment "ietf-l3-unicast-topology-state" instead of "ietf-l3-unicast-topology". Companion modules for the example module defined in Appendix B are not provided (since it is just an example).

Like "ietf-network-state" and "ietf-network-topology-state", "ietf-l3-unicast-topology-state" SHOULD NOT be supported by implementations that support NMDA. The module is therefore defined in an 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@2018-02-26.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:      <https://datatracker.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.tech>
  Editor:      Xufeng Liu
                <mailto:xufeng.liu.ietf@gmail.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 either is learned or
  results from applying topology that has been configured per
  the 'ietf-l3-unicast-topology' model, mirroring the
  corresponding data nodes in this model.

  This 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).

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  authors of the code. All rights reserved.

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  set forth in Section 4.c of the IETF Trust's Legal Provisions
  Relating to IETF Documents
  (https://trustee.ietf.org/license-info).

  This version of this YANG module is part of RFC 8346;
  see the RFC itself for full legal notices."
```

```
revision "2018-02-26" {
  description
    "Initial revision.";
  reference
    "RFC 8346: A YANG Data Model for Layer 3 Topologies";
}
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/l3t-s: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/l3t-s: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/l3t-s:l3-unicast-topology" {
    description
      "Augmentation parameters apply only for networks with
      L3 Unicast topology";
  }
  description
    "Augments 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/l3t-s:l3-unicast-topology" {
    description
      "Augmentation parameters apply only for networks with
      L3 Unicast topology";
  }
}
```

```
    description "Augments 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
            "Contains 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. This appendix introduces a YANG module that defines a 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 a 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, in this case, to cover OSPF topologies. For this purpose, a set of augmentations are introduced in a separate YANG module, "example-ospf-topology", whose structure is depicted in the following diagram. As before, the notation syntax follows [RFC8340]. Note that one of the lines has been wrapped to adhere to the 72-character line limitation of RFCs.


```

module: example-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:

- o A new topology type for an OSPF topology is introduced.
- o Additional topology attributes are defined in a new grouping that augments l3-topology-attributes of the "ietf-l3-unicast-topology" module. The attributes include an OSPF area-id identifying the OSPF area.

- o Additional data objects for nodes are introduced by augmenting the l3-node-attributes of the "ietf-l3-unicast-topology" module. New objects include router-type and dr-interface-id for pseudonodes.
- o 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 OSPF topologies, but it is not normative. Accordingly, the module is not delimited with <CODE BEGINS> and <CODE ENDS> tags.

```
file "example-ospf-topology@2017-12-16.yang"
module example-ospf-topology {
  yang-version 1.1;
  namespace "urn:example:example-ospf-topology";
  prefix "ex-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";
  }
  description
    "This module is intended as an example for how the
    Layer 3 Unicast topology model can be extended to cover
    OSPF topologies.";
  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 "indicates 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/" +
        "ex-ospft:ospf" {
        description
            "Augments only for OSPF topology";
    }
    description
        "Augments topology configuration";
    container ospf-topology-attributes {
        description
            "Contains 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/" +
        "ex-ospft:ospf" {
        description
            "Augments only for OSPF topology";
    }
    description
        "Augments 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/" +
        "ex-ospft:ospf" {
        description
            "Augments only for OSPF topology";
    }
}

```

```
    description
      "Augments link configuration";
    uses ospf-link-attributes;
  }
  grouping ospf-node-attributes {
    description
      "OSPF node scope attributes";
    container ospf-node-attributes {
      description
        "Contains 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
            "Contains OSPF link attributes";
    }
} // ospf-link-attributes
augment "/l3t:l3-node-event" {
    description
        "OSPF node event";
    uses ospf-topology-type;
    uses ospf-node-attributes;
}
augment "/l3t:l3-link-event" {
    description
        "OSPF link event";
    uses ospf-topology-type;
    uses 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.

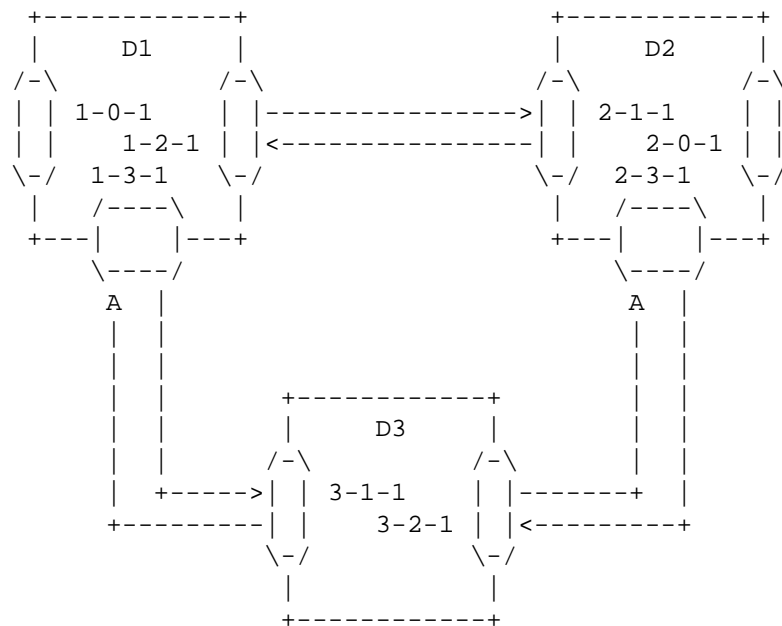


Figure 2: A Network Topology Example

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

```
{
  "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",
      "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"
      }
    },
    {
      "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"
      }
    }
  ]
}

```



```

    }
  },
  {
    "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"
    }
  },
  {
    "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"
    }
  },
  {
    "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"
    }
  },
  {
    "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"
      }
    }
  ]
}

```

Figure 3: Instance Data Tree

Acknowledgments

We wish to acknowledge the helpful contributions, comments, and suggestions that were received from Alia Atlas, Andy Bierman, Benoit Claise, Joel Halpern, Susan Hares, Ladislav Lhotka, Carl Moberg, Carlos Pignataro, Juergen Schoenwaelder, Michal Vasco, and Kent Watsen.

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