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**Generic YANG Data Model for the Management of Operations,
Administration, and Maintenance (OAM) Protocols that use Connectionless
Communications**
[draft-ietf-lime-yang-connectionless-oam-17](#)

Abstract

This document presents a base YANG Data model for the management of Operations Administration, and Maintenance (OAM) protocols that use Connectionless Communications. The data model is defined using the YANG, as specified in [RFC7950](#) data modeling language. It provides a technology-independent abstraction of key OAM constructs for OAM protocols that use connectionless communication. The base model presented here can be extended to include technology-specific details.

There are two key benefits of this approach: First, it leads to uniformity between OAM protocols. And second, it support both nested OAM workflows (i.e., performing OAM functions at different or same levels through a unified interface) as well as interactive OAM workflows (i.e., performing OAM functions at same levels through a unified interface).

Status of This Memo

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1. Introduction

Operations, Administration, and Maintenance (OAM) are important networking functions that allow operators to:

1. Monitor network communications (i.e., Reachability Verification, Continuity Check)
2. Troubleshoot failures (i.e., Fault verification and Localization)
3. Monitor service-level agreements and performance (i.e., Performance Management)

An overview of OAM tools is presented at [\[RFC7276\]](#).

Ping and Traceroute (see [\[RFC792\]](#) and [\[RFC4443\]](#)) are respectively well-known fault verification and isolation tools for IP network. Over the years, different technologies have developed similar toolsets for equivalent purposes.

The different sets of OAM tools may support both connection-oriented technologies or connectionless technologies. In connection-oriented technologies, a connection is established prior to the transmission of data. After the connection is established, no additional control information such as signaling or operations and maintenance information is required to transmit the actual user data. In connectionless technologies, data is typically sent between communicating end points without prior arrangement, but control information is required to identify the destination (e.g., [\[G.800\]](#) and [\[RFC7276\]](#)). The YANG Data model for OAM protocols using connection-oriented communications is specified in [\[I-D.ietf-lime-yang-connection-oriented-oam-model\]](#).

This document defines a base YANG Data model for OAM protocols that use connectionless communications. The data model is defined using the YANG [\[RFC7950\]](#) data modeling language. This generic YANG model for connectionless OAM includes only configuration and state data. It can be used in conjunction with data retrieval method model described in [\[I-D.ietf-lime-yang-connectionless-oam-methods\]](#), which focuses on the data retrieval procedures such as RPC, or it can be used independently of this data retrieval method model.

2. Conventions used in this document

The following terms are defined in [\[RFC6241\]](#) and are used in this specification:

- o client

- o configuration data
- o server
- o state data

The following terms are defined in [[RFC7950](#)] and are used in this specification:

- o augment
- o data model
- o data node

The terminology for describing YANG data models is found in [[RFC7950](#)].

2.1. Abbreviations

bfd - Bidirectional Forwarding Detection [[RFC5880](#)].

rpc - Remote Procedure Call [[RFC1831](#)].

DSCP - Differentiated Services Code Point.

VRF - Virtual Routing and Forwarding [[RFC 4382](#)].

OWAMP - One-Way Active Measurement Protocol [[RFC 4656](#)].

TWAMP - Two-Way Active Measurement Protocol [[RFC 5357](#)].

AS - Autonomous System.

LSP - Label Switched Path.

TE - Traffic Engineering.

MPLS - Multiprotocol Label Switching.

NI - Network Instance.

PTP - Precision Time Protocol [[IEEE.1588](#)].

NTP - Network Time Protocol [[RFC5905](#)].

2.2. Terminology

MAC - Media Access Control.

MAC address - Address for the data-link layer interface.

TP - Test Point. The TP is a functional entity that is defined at a node in the network and can initiate and/or react to OAM diagnostic tests. This document focuses on the data-plane functionality of TPs.

RPC Operation - A specific Remote Procedure Call.

CC - Continuity Checks [[RFC7276](#)] are used to verify that a destination is reachable and therefore also referred to as reachability verification.

3. Overview of the Connectionless OAM Model

The YANG data model for OAM protocols that use Connectionless Communications has been split into two modules:

- o The `ietf-lime-common-types.yang` module provides common definitions such as Time-related data types and Timestamp-related data types.
- o The `ietf-connectionless-oam.yang` module defines technology-independent abstraction of key OAM constructs for OAM protocols that use connectionless communication.

The `ietf-connectionless-oam` module augments the `"/networks/network/node"` path defined in the `ietf-network` module [[I-D.ietf-i2rs-yang-network-topo](#)] with `'test-point-locations'` grouping defined in [Section 3.5](#). The network node in `"/networks/network/node"` path are used to describe the network hierarchies and the inventory of nodes contained in a network.

Under the `'test-point-locations'` grouping, each test point location is chosen based on `'tp-location-type'` leaf which when chosen, leads to a container that includes a list of `'test-point-locations'`.

Each `'test-point-locations'` list includes a `'test-point-location-info'` grouping. The `'test-point-location-info'` grouping includes:

- o `'tp-technology'` grouping,
- o `'tp-tools'` grouping, and
- o `'connectionless-oam-tps'` grouping.

The groupings of 'tp-address' and 'tp-address-ni' are kept out of 'test-point-location-info' grouping to make it addressing agnostic and allow varied composition. Depending upon the choice of the 'tp-location-type' (determined by the 'tp-address-ni'), the containers differ in its composition of 'test-point-locations' while the 'test-point-location-info', is a common aspect of every 'test-point-locations'.

The 'tp-address-ni' grouping is used to describe the corresponding network instance. The 'tp-technology' grouping indicate OAM technology details. The 'connectionless-oam-tps' grouping is used to describe the relationship of one test point with other test points. The 'tp-tools' grouping describe the OAM tools supported.

In addition, at the top of the model, there is an 'cc-oper-data' container for session statistics. A grouping is also defined for common session statistics and these are only applicable for proactive (see [Section 3.2](#)) OAM sessions.

[3.1.](#) TP Address

With connectionless OAM protocols, the TP address can be one of the following types:

- o MAC address [[RFC6136](#)] at the data-link layer for TPs
- o IPv4 or IPv6 address at IP layer for TPs
- o TP-attribute identifying a TP associated with an application layer function
- o Router-id to represent the device or node, which is commonly used to identify nodes in routing and other control plane protocols [[I-D.ietf-rtgwg-routing-types](#)].

To define a forwarding treatment of a test packet, the 'tp-address' grouping needs to be associated with additional parameters, e.g., DSCP for IP or Traffic Classic [[RFC5462](#)] for MPLS. In the generic connectionless OAM YANG model, these parameters are not explicitly configured. The model user can add corresponding parameters according to their requirements.

[3.2.](#) Tools

The different OAM tools may be used in one of two basic types of activation: proactive and on-demand. Proactive OAM refers to OAM actions which are carried out continuously to permit proactive reporting of faults. The proactive OAM method requires persistent

configuration. On-demand OAM refers to OAM actions which are initiated via manual intervention for a limited time to carry out specific diagnostics. The on-demand OAM method requires only transient configuration (e.g., [RFC7276] and [G.8013]). In connectionless OAM, the 'session-type' grouping is defined to indicate which kind of activation will be used by the current session.

In connectionless OAM, the tools attribute is used to describe a toolset for fault detection and isolation. And it can serve as a constraint condition when the base model be extended to a specific OAM technology. For example, to fulfill the ICMP PING configuration, the "../coam:continuity-check" leaf should be set to "true", and then the lime base model should be augmented with ICMP PING specific details.

3.3. OAM neighboring test points

Given that typical network communication stacks have a multi-layer architecture, the set of associated OAM protocols has also a multi-layer structure; each communication layer in the stack may have its own OAM protocol [RFC7276] that may also be linked to a specific administrative domain. Management of these OAM protocols will necessitate associated test points in the nodes accessible by appropriate management domains. Accordingly, a given network interface may actually present several test points.

Each OAM test point may have an associated list of neighboring test points in other layers up and down the protocol stack for the same interface and are therefore related to the current test point. This allows users to easily navigate between related neighboring layers to efficiently troubleshoot a defect. In this model, the 'position' leaf defines the relative position of the neighboring test point corresponding to the current test point, and is provided to allow correlation of faults at different locations. If there is one neighboring test point placed before the current test point, the 'position' leaf is set to -1. If there is one neighboring test point placed after the current test point, the 'position' leaf is set to 1. If there is no neighboring test point placed before or after the current test point, the 'position' leaf is set to 0.


```
list oam-neighboring-tps {
  key "index";
  leaf index {
    type uint16 {
      range "0..65535";
    }
    description
      "Index of a list of neighboring test points
       in adjacent layers up and down the stack for
       the same interface that are related to the
       current test point.";
  }
  leaf position {
    type int8 {
      range "-1..1";
    }
    description
      "The relative position
       of neighboring test point
       corresponding to the current
       test point";
  }
  description
    "List of related neighboring test points in adjacent
     layers up and down the stack for the same interface
     that are related to the current test point.";
}
```

3.4. Test Point Locations Information

This is a generic grouping for Test Point Locations Information (i.e., test-point-location-info grouping). It Provide details of Test Point Location using 'tp-technology','tp-tools' grouping, 'oam-neighboring-tps' grouping, all of which are defined above.

3.5. Test Point Locations

This is a generic grouping for Test Point Locations. 'tp-location-type' leaf is used to define locations types, for example 'ipv4-location-type', 'ipv6-location-type', etc. Container is defined under each location type containing list keyed to test point address, Test Point Location Information defined in section above, and network instance name (e.g., VRF instance name) if required.

3.6. Path Discovery Data

This is a generic grouping for the path discovery data model that can be retrieved by any data retrieval methods including RPC operations. Path discovery data output from methods, includes 'src-test-point' container, 'dst-test-point' container, 'sequence-number' leaf, 'hop-cnt' leaf, session statistics of various kinds, path verification and path trace related information. Path discovery includes data to be retrieved on a 'per-hop' basis via a list of 'path-trace-info-list' items which includes information such as 'timestamp' grouping, 'ingress-intf-name', 'egress-intf-name' and 'app-meta-data'. The path discovery data model is made generic enough to allow different methods of data retrieval. None of the fields are made mandatory for that reason. Note that a set of retrieval methods are defined in [[I-D.ietf-lime-yang-connectionless-oam-methods](#)].

3.7. Continuity Check Data

This is a generic grouping for the continuity check data model that can be retrieved by any data retrieval methods including RPC operations. Continuity check data output from methods, includes 'src-test-point' container, 'dst-test-point' container, 'sequence-number' leaf, 'hop-cnt' leaf and session statistics of various kinds. The continuity check data model is made generic enough to allow different methods of data retrieval. None of the fields are made mandatory for that reason. Noted that a set of retrieval methods are defined in [[I-D.ietf-lime-yang-connectionless-oam-methods](#)].

3.8. OAM data hierarchy

The complete data hierarchy related to the OAM YANG model is presented below.

```
module: ietf-connectionless-oam
  +--ro cc-session-statistics-data {continuity-check}?
    +--ro cc-session-statistics* [type]
      +--ro type identityref
      +--ro cc-ipv4-sessions-statistics
        | +--ro cc-session-statistics
        |   +--ro session-count? uint32
        |   +--ro session-up-count? uint32
        |   +--ro session-down-count? uint32
        |   +--ro session-admin-down-count? uint32
      +--ro cc-ipv6-sessions-statistics
        +--ro cc-session-statistics
          +--ro session-count? uint32
          +--ro session-up-count? uint32
          +--ro session-down-count? uint32
```



```

        +--ro session-admin-down-count?  uint32
augment /nd:networks/nd:network/nd:node:
  +--rw tp-location-type?                identityref
  +--rw ipv4-location-type
  |   +--rw test-point-ipv4-location-list
  |   |   +--rw test-point-locations* [ipv4-location ni]
  |   |   |   +--rw ipv4-location          inet:ipv4-address
  |   |   |   +--rw ni                    routing-instance-ref
  |   |   |   +--rw (technology)?
  |   |   |   |   +--:(technology-null)
  |   |   |   |   |   +--rw tech-null?          empty
  |   |   |   +--rw tp-tools
  |   |   |   |   +--rw continuity-check      boolean
  |   |   |   |   +--rw path-discovery       boolean
  |   |   |   +--rw root?                    <anydata>
  |   |   +--rw oam-neighboring-tps* [index]
  |   |   |   +--rw index                    uint16
  |   |   |   +--rw position?               int8
  |   |   |   +--rw (tp-location)?
  |   |   |   |   +--:(mac-address)
  |   |   |   |   |   +--rw mac-address-location?  yang:mac-address
  |   |   |   |   +--:(ipv4-address)
  |   |   |   |   |   +--rw ipv4-address-location? inet:ipv4-address
  |   |   |   |   +--:(ipv6-address)
  |   |   |   |   |   +--rw ipv6-address-location? inet:ipv6-address
  |   |   |   |   +--:(as-number)
  |   |   |   |   |   +--rw as-number-location?   inet:as-number
  |   |   |   |   +--:(router-id)
  |   |   |   |   |   +--rw router-id-location?   rt:router-id
  |   +--rw ipv6-location-type
  |   |   +--rw test-point-ipv6-location-list
  |   |   |   +--rw test-point-locations* [ipv6-location ni]
  |   |   |   |   +--rw ipv6-location          inet:ipv6-address
  |   |   |   |   +--rw ni                    routing-instance-ref
  |   |   |   |   +--rw (technology)?
  |   |   |   |   |   +--:(technology-null)
  |   |   |   |   |   |   +--rw tech-null?          empty
  |   |   |   |   +--rw tp-tools
  |   |   |   |   |   +--rw continuity-check      boolean
  |   |   |   |   |   +--rw path-discovery       boolean
  |   |   |   |   +--rw root?                    <anydata>
  |   |   |   +--rw oam-neighboring-tps* [index]
  |   |   |   |   +--rw index                    uint16
  |   |   |   |   +--rw position?               int8
  |   |   |   |   +--rw (tp-location)?
  |   |   |   |   |   +--:(mac-address)
  |   |   |   |   |   |   +--rw mac-address-location?  yang:mac-address
  |   |   |   |   |   +--:(ipv4-address)

```



```

|         | +--rw ipv4-address-location?  inet:ipv4-address
|         +--:(ipv6-address)
|         | +--rw ipv6-address-location?  inet:ipv6-address
|         +--:(as-number)
|         | +--rw as-number-location?      inet:as-number
|         +--:(router-id)
|         +--rw router-id-location?        rt:router-id
+--rw mac-location-type
|   +--rw test-point-mac-address-location-list
|     +--rw test-point-locations* [mac-address-location]
|       +--rw mac-address-location      yang:mac-address
|       +--rw (technology)?
|         | +--:(technology-null)
|         |   +--rw tech-null?          empty
|       +--rw tp-tools
|         | +--rw continuity-check      boolean
|         | +--rw path-discovery        boolean
|       +--rw root?                     <anydata>
|       +--rw oam-neighboring-tps* [index]
|         +--rw index                   uint16
|         +--rw position?               int8
|         +--rw (tp-location)?
|           +--:(mac-address)
|             | +--rw mac-address-location?  yang:mac-address
|             +--:(ipv4-address)
|               | +--rw ipv4-address-location?  inet:ipv4-address
|               +--:(ipv6-address)
|                 | +--rw ipv6-address-location?  inet:ipv6-address
|                 +--:(as-number)
|                   | +--rw as-number-location?  inet:as-number
|                   +--:(router-id)
|                     +--rw router-id-location?  rt:router-id
+--rw group-as-number-location-type
|   +--rw test-point-as-number-location-list
|     +--rw test-point-locations* [as-number-location]
|       +--rw as-number-location      inet:as-number
|       +--rw ni?                     routing-instance-ref
|       +--rw (technology)?
|         | +--:(technology-null)
|         |   +--rw tech-null?          empty
|       +--rw tp-tools
|         | +--rw continuity-check      boolean
|         | +--rw path-discovery        boolean
|       +--rw root?                     <anydata>
|       +--rw oam-neighboring-tps* [index]
|         +--rw index                   uint16
|         +--rw position?               int8
|         +--rw (tp-location)?

```



```

|           +--:(mac-address)
|           |   +--rw mac-address-location?      yang:mac-address
|           +--:(ipv4-address)
|           |   +--rw ipv4-address-location?     inet:ipv4-address
|           +--:(ipv6-address)
|           |   +--rw ipv6-address-location?     inet:ipv6-address
|           +--:(as-number)
|           |   +--rw as-number-location?        inet:as-number
|           +--:(router-id)
|           |   +--rw router-id-location?        rt:router-id
+--rw group-router-id-location-type
  +--rw test-point-system-info-location-list
    +--rw test-point-locations* [router-id-location]
      +--rw router-id-location      rt:router-id
      +--rw ni?                    routing-instance-ref
      +--rw (technology)?
      |   +--:(technology-null)
      |   |   +--rw tech-null?      empty
      +--rw tp-tools
      |   +--rw continuity-check    boolean
      |   +--rw path-discovery      boolean
      +--rw root?                  <anydata>
      +--rw oam-neighboring-tps* [index]
        +--rw index                uint16
        +--rw position?            int8
        +--rw (tp-location)?
        |   +--:(mac-address)
        |   |   +--rw mac-address-location?      yang:mac-address
        |   +--:(ipv4-address)
        |   |   +--rw ipv4-address-location?     inet:ipv4-address
        |   +--:(ipv6-address)
        |   |   +--rw ipv6-address-location?     inet:ipv6-address
        |   +--:(as-number)
        |   |   +--rw as-number-location?        inet:as-number
        |   +--:(router-id)
        |   |   +--rw router-id-location?        rt:router-id

```

4. LIME Time Types YANG Module

This module imports definitions from [\[RFC7223\]](#), [\[RFC6991\]](#), [\[I-D.ietf-i2rs-yang-network-topo\]](#), [\[I-D.ietf-rtgwg-routing-types\]](#), [\[I-D.ietf-rtgwg-ni-model\]](#) and the LIME Time Types Module.

```
<CODE BEGINS> file "ietf-lime-time-types@2017-09-06.yang"
```

```

module ietf-lime-time-types {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-lime-time-types";

```



```
prefix "lime";

organization
  "IETF Layer Independent OAM Management (LIME)
  Working Group";

contact
  "WG Web:   <https://datatracker.ietf.org/wg/lime>
  WG List:  <mailto:imap@ietf.org>

  Editor:   Qin Wu
            <bill.wu@huawei.com>";

description
  "This module provides time related definitions used by the data
  models written for Layer Independent OAM Management (LIME).
  This module defines identities but no schema tree elements.";

revision "2017-09-06" {
  description
    "Initial version";
  reference
    "RFC xxxx: A YANG Data Model for OAM Protocols that use Connectionless
    Communications";
}

/** Collection of common types related to time */
/** Time unit identity */
identity time-unit-type {
  description
    "Time unit type";
}
identity hours {
  base time-unit-type;
  description
    "Time unit in Hours";
}
identity minutes {
  base time-unit-type;
  description
    "Time unit in Minutes";
}
identity seconds {
  base time-unit-type;
  description
    "Time unit in Seconds";
}
identity milliseconds {
```



```
    base time-unit-type;
    description
        "Time unit in Milliseconds";
}
identity microseconds {
    base time-unit-type;
    description
        "Time unit in Microseconds";
}
identity nanoseconds {
    base time-unit-type;
    description
        "Time unit in Nanoseconds";
}
/**/ Timestamp format Identity ***/
identity timestamp-type {
    description
        "Base identity for Timestamp Type.";
}
identity truncated-ptp {
    base timestamp-type;
    description
        "Identity for 64bit short format PTP timestamp.";
}
identity truncated-ntp {
    base timestamp-type;
    description
        "Identity for 32bit short format NTP timestamp.";
}
identity ntp64 {
    base timestamp-type;
    description
        "Identity for 64bit NTP timestamp.";
}
identity icmp {
    base timestamp-type;
    description
        "Identity for 32bit ICMP timestamp.";
}
}

<CODE ENDS>
```

5. Connectionless OAM YANG Module

```
<CODE BEGINS> file "ietf-connectionless-oam@2017-09-06.yang"

module ietf-connectionless-oam {
```



```
yang-version 1.1;
namespace "urn:ietf:params:xml:ns:yang:ietf-connectionless-oam";
prefix cl-oam;
import ietf-yang-schema-mount {
  prefix yangmnt;
}
import ietf-network {
  prefix nd;
}
import ietf-yang-types {
  prefix yang;
}
import ietf-interfaces {
  prefix if;
}
import ietf-inet-types {
  prefix inet;
}
import ietf-network-instance {
  prefix ni;
}
import ietf-routing-types {
  prefix rt;
}
import ietf-lime-time-types {
  prefix lime;
}
organization
  "IETF LIME Working Group";
contact
  "Deepak Kumar dekumar@cisco.com
  Qin Wu bill.wu@huawei.com
  S Raghavan srihari@cisco.com
  Zitao Wang wangzitao@huawei.com
  R Rahman rrahman@cisco.com";
description
  "This YANG module defines the generic configuration,
  data model, and statistics for OAM protocols using
  connectionless communications, described in a
  protocol independent manner. It is assumed that each
  protocol maps corresponding abstracts to its native
  format. Each protocol may extend the YANG model defined
  here to include protocol specific extensions.";
revision 2017-09-06 {
  description
    "Base model for Connectionless
    Operations, Administration,
    and Maintenance (OAM)";
```



```
    reference
      "RFC XXXX: Connectionless
      Operations, Administration, and
      Maintenance (OAM) YANG Data Model";
  }
  feature connectionless {
    description
      "This feature indicates that OAM solution is connectionless.";
  }
  feature continuity-check {
    description
      "This feature indicates that the server supports
      executing continuity check OAM command and
      returning a response. Servers that do not advertise
      this feature will not support executing
      continuity check command or RPC operation model for
      continuity check command.";
  }
  feature path-discovery {
    description
      "This feature indicates that the server supports
      executing path discovery OAM command and
      returning a response. Servers that do not advertise
      this feature will not support executing
      path discovery command or RPC operation model for
      path discovery command.";
  }
  feature ptp-long-format {
    description
      "This feature indicates that timestamp is PTP long format.";
  }
  feature ntp-short-format {
    description
      "This feature indicates that timestamp is NTP short format.";
  }
  feature icmp-timestamp {
    description
      "This feature indicates that timestamp is ICMP timestamp.";
  }
  identity traffic-type {
    description
      "This is base identity of traffic type
      which include IPv4 and IPv6, etc.";
  }
  identity ipv4 {
    base traffic-type;
    description
      "identity for IPv4 traffic type.";
```



```
}
  identity ipv6 {
    base traffic-type;
    description
      "identity for IPv4 traffic type.";
  }
  identity address-attribute-types {
    description
      "This is base identity of address
      attribute types which are Generic
      IPv4/IPv6 Prefix, BGP Labeled
      IPv4/IPv6 Prefix, Tunnel ID,
      PW ID, VPLS VE ID, etc. (see RFC8029
      for details.)";
  }
  typedef address-attribute-type {
    type identityref {
      base address-attribute-types;
    }
    description
      "Target address attribute type.";
  }
  typedef percentage {
    type decimal64 {
      fraction-digits 5;
      range "0..100";
    }
    description "Percentage";
  }
  typedef routing-instance-ref {
    type leafref {
      path "/ni:network-instances/ni:network-instance/ni:name";
    }
    description
      "This type is used for leafs that reference a routing instance
      configuration.";
  }
  grouping cc-session-statistics {
    description
      "Grouping for session statistics.";
    container cc-session-statistics {
      description
        "cc session counters";
      leaf session-count {
        type uint32;
        default "0";
        description
          "Number of Continuity Check sessions.
```



```
        A value of zero indicates that no session
        count is sent.";
    }
    leaf session-up-count {
        type uint32;
        default "0";
        description
            "Number of sessions which are up.
            A value of zero indicates that no up
            session count is sent.";
    }
    leaf session-down-count {
        type uint32;
        default "0";
        description
            "Number of sessions which are down.
            A value of zero indicates that no down
            session count is sent.";
    }
    leaf session-admin-down-count {
        type uint32;
        default "0";
        description
            "Number of sessions which are admin-down.
            A value of zero indicates that no admin
            down session count is sent.";
    }
}

grouping session-packet-statistics {
    description
        "Grouping for per session packet statistics";
    container session-packet-statistics {
        description
            "Per session packet statistics.";

        leaf rx-packet-count {
            type uint32{
                range "0..4294967295";
            }
            default "0";
            description
                "Total number of received OAM packet count.
                The value of count will be set to zero (0)
                on creation and will thereafter increase
                monotonically until it reaches a maximum value
                of 2^32-1 (4294967295 decimal), when it wraps
                around and starts increasing again from zero.";
```



```
}
leaf tx-packet-count {
  type uint32{
    range "0..4294967295";
  }
  default "0";
  description
    "Total number of transmitted OAM packet count.
    The value of count will be set to zero (0)
    on creation and will thereafter increase
    monotonically until it reaches a maximum value
    of 2^32-1 (4294967295 decimal), when it wraps
    around and starts increasing again from zero.";
}
leaf rx-bad-packet {
  type uint32 {
    range "0..4294967295";
  }
  default "0";
  description
    "Total number of received bad OAM packet.
    The value of count will be set to zero (0)
    on creation and will thereafter increase
    monotonically until it reaches a maximum value
    of 2^32-1 (4294967295 decimal), when it wraps
    around and starts increasing again from zero.";
}
leaf tx-packet-failed {
  type uint32 {
    range "0..4294967295";
  }
  default "0";
  description
    "Total number of failed sending OAM packet.
    The value of count will be set to zero (0)
    on creation and will thereafter increase
    monotonically until it reaches a maximum value
    of 2^32-1 (4294967295 decimal), when it wraps
    around and starts increasing again from zero.";
}
}
}
grouping cc-per-session-statistics {
  description
    "Grouping for per session statistics";
  container cc-per-session-statistics {
    description
      "per session statistics.";
  }
}
```



```
    leaf create-time {
      type yang:date-and-time;
      description
        "Time and date when session is created.";
    }
    leaf last-down-time {
      type yang:date-and-time;
      description
        "Time and date last time session is down.";
    }
    leaf last-up-time {
      type yang:date-and-time;
      description
        "Time and date last time session is up.";
    }
    leaf down-count {
      type uint32 {
        range "0..4294967295";
      }
      default "0";
      description
        "Total Continuity Check sessions down count.
        The value of count will be set to zero (0)
        on creation and will thereafter increase
        monotonically until it reaches a maximum value
        of 2^32-1 (4294967295 decimal), when it wraps
        around and starts increasing again from zero.";
    }
    leaf admin-down-count {
      type uint32 {
        range "0..4294967295";
      }
      default "0";
      description
        "Total Continuity Check sessions admin down count.
        The value of count will be set to zero (0)
        on creation and will thereafter increase
        monotonically until it reaches a maximum value
        of 2^32-1 (4294967295 decimal), when it wraps
        around and starts increasing again from zero.";
    }
    uses session-packet-statistics;
  }
}
grouping session-error-statistics {
  description
    "Grouping for per session error statistics";
  container session-error-statistics {
```



```
description
  "Per session error statistics.";
leaf packet-loss-count {
  type uint32 {
    range "0..4294967295";
  }
  default "0";
  description
    "Total received packet drops count.
    The value of count will be set to zero (0)
    on creation and will thereafter increase
    monotonically until it reaches a maximum value
    of 2^32-1 (4294967295 decimal), when it wraps
    around and starts increasing again from zero.";
}
leaf loss-ratio{
  type percentage;
  description
    "Loss ratio of the packets. Express as percentage
    of packets lost with respect to packets sent.";
}
leaf packet-reorder-count {
  type uint32 {
    range "0..4294967295";
  }
  default "0";
  description
    "Total received packet reordered count.
    The value of count will be set to zero (0)
    on creation and will thereafter increase
    monotonically until it reaches a maximum value
    of 2^32-1 (4294967295 decimal), when it wraps
    around and starts increasing again from zero.";
}
leaf packets-out-of-seq-count {
  type uint32 {
    range "0..4294967295";
  }
  description
    "Total received out of sequence count.
    The value of count will be set to zero (0)
    on creation and will thereafter increase
    monotonically until it reaches a maximum value
    of 2^32-1 (4294967295 decimal), when it wraps
    around and starts increasing again from zero..";
}
leaf packets-dup-count {
  type uint32 {
```



```
    range "0..4294967295";
  }
  description
    "Total received packet duplicates count.
    The value of count will be set to zero (0)
    on creation and will thereafter increase
    monotonically until it reaches a maximum value
    of 2^32-1 (4294967295 decimal), when it wraps
    around and starts increasing again from zero.";
}
}
}
grouping session-delay-statistics {
  description
    "Grouping for per session delay statistics";
  container session-delay-statistics {
    description
      "Session delay summarised information. By default,
      one way measurement protocol (e.g., OWAMP) is used
      to measure delay. When two way measurement protocol
      (e.g., TWAMP) is used instead, it can be indicated
      using and protocol-id defined in RPC operation of
      draft-ietf-lime-yang-connectionless-oam-methods, i.e.,
      set protocol-id as OWAMP. Note that only one measurement
      protocol for delay is specified for interoperability reason.";
    leaf time-unit-value {
      type identityref {
        base lime:time-unit-type;
      }
      default lime:milliseconds;
      description
        "Time units among choice of s, ms, ns, etc.";
    }
    leaf min-delay-value {
      type uint32;
      description
        "Minimum delay value observed.";
    }
    leaf max-delay-value {
      type uint32;
      description
        "Maximum delay value observed.";
    }
    leaf average-delay-value {
      type uint32;
      description
        "Average delay value observed.";
    }
  }
}
```



```
    }
  }
  grouping session-jitter-statistics {
    description
      "Grouping for per session jitter statistics";
    container session-jitter-statistics {
      description
        "Session jitter summarised information. By default,
        jitter is measured using IP Packet Delay Variation
        (IPDV) as defined in RFC3393. When the other measurement
        method is used instead (e.g., Packet Delay Variation used
        in Y.1540, it can be indicated using protocol-id-meta-data
        defined in RPC operation of
        draft-ietf-lime-yang-connectionless-oam-methods. Note that
        only one measurement method for jitter is specified
        for interoperability reason.";
      leaf unit-value {
        type identityref {
          base lime:time-unit-type;
        }
        default lime:milliseconds;
        description
          "Time units among choice of s, ms, ns, etc.";
      }
      leaf min-jitter-value {
        type uint32;
        description
          "Minimum jitter value observed.";
      }
      leaf max-jitter-value {
        type uint32;
        description
          "Maximum jitter value observed.";
      }
      leaf average-jitter-value {
        type uint32;
        description
          "Average jitter value observed.";
      }
    }
  }
  grouping session-path-verification-statistics {
    description
      "Grouping for per session path verification statistics";
    container session-path-verification-statistics {
      description
        "OAM per session path verification statistics.";
      leaf verified-count {
```



```
    type uint32 {
      range "0..4294967295";
    }
    description
      "Total number of OAM packets that
      went through a path as intended.
      The value of count will be set to zero (0)
      on creation and will thereafter increase
      monotonically until it reaches a maximum value
      of 2^32-1 (4294967295 decimal), when it wraps
      around and starts increasing again from zero.";
  }
  leaf failed-count {
    type uint32 {
      range "0..4294967295";
    }
    description
      "Total number of OAM packets that
      went through an unintended path.
      The value of count will be set to zero (0)
      on creation and will thereafter increase
      monotonically until it reaches a maximum value
      of 2^32-1 (4294967295 decimal), when it wraps
      around and starts increasing again from zero.";
  }
}

grouping session-type {
  description
    "This object indicates which kind
    of activation will be used by the current
    session.";
  leaf session-type {
    type enumeration {
      enum "proactive" {
        description
          "The current session is proactive session.";
      }
      enum "on-demand" {
        description
          "The current session is on-demand session.";
      }
    }
  }
  default "on-demand";
  description
    "Indicate which kind of activation will be used
    by the current session";
}
```



```
}
identity tp-address-technology-type {
  description
    "Test point address type";
}
identity mac-address-type {
  base tp-address-technology-type;
  description
    "MAC address type";
}
identity ipv4-address-type {
  base tp-address-technology-type;
  description
    "IPv4 address type";
}
identity ipv6-address-type {
  base tp-address-technology-type;
  description
    "IPv6 address type";
}
identity tp-attribute-type {
  base tp-address-technology-type;
  description
    "Test point attribute type";
}
identity router-id-address-type {
  base tp-address-technology-type;
  description
    "System id address type";
}
identity as-number-address-type {
  base tp-address-technology-type;
  description
    "AS number address type";
}
identity route-distinguisher-address-type {
  base tp-address-technology-type;
  description
    "Route Distinguisher address type";
}
grouping tp-address {
  leaf tp-location-type {
    type identityref {
      base tp-address-technology-type;
    }
    mandatory true;
    description
```



```
    "Test point address type.";
}
container mac-address {
  when "derived-from-or-self(..tp-location-type,"+
    "'cl-oam:mac-address-type')\" {
    description
      "MAC address type";
  }
  leaf mac-address {
    type yang:mac-address;
    mandatory true;
    description
      "MAC Address";
  }
  description
    "MAC Address based TP Addressing.";
}
container ipv4-address {
  when "derived-from-or-self(..tp-location-type,"+
    "'cl-oam:ipv4-address-type')\" {
    description
      "IPv4 address type";
  }
  leaf ipv4-address {
    type inet:ipv4-address;
    mandatory true;

    description
      "IPv4 Address";
  }
  description
    "IP Address based TP Addressing.";
}
container ipv6-address {
  when "derived-from-or-self(..tp-location-type,"+
    "'cl-oam:ipv6-address-type')\" {
    description
      "IPv6 address type";
  }
  leaf ipv6-address {

    type inet:ipv6-address;
    mandatory true;
    description
      "IPv6 Address";
  }
  description
    "ipv6 Address based TP Addressing.";
```



```
}
container tp-attribute {
  when "derived-from-or-self(../tp-location-type, "+
    "'cl-oam:tp-attribute-type')" {
    description
      "Test point attribute type";
  }
  leaf tp-attribute-type {
    type address-attribute-type;
    description
      "Test point type.";
  }
  choice tp-attribute-value {
    description
      "Test point value.";
    case ip-prefix {
      leaf ip-prefix {
        type inet:ip-prefix;
        description
          "Generic IPv4/IPv6 prefix. See Section 3.2.13 and
            Section 3.2.14 of RFC8029.";
        reference
          "RFC 8029 :Detecting Multi-Protocol Label
            Switched (MPLS) Data Plane Failures";
      }
    }
    case bgp {
      leaf bgp {
        type inet:ip-prefix;
        description
          "BGP Labeled IPv4/IPv6 Prefix. See section
            3.2.11 and section 3.2.12 of RFC8029 for details. ";
        reference
          "RFC 8029 :Detecting Multi-Protocol Label
            Switched (MPLS) Data Plane Failures";
      }
    }
    case tunnel {
      leaf tunnel-interface {
        type uint32;
        description
          "Basic IPv4/IPv6 Tunnel ID. See section 3.2.3
            and Section 3.2.4 of RFC8029 for details.";
        reference
          "RFC 8029 :Detecting Multi-Protocol Label
            Switched (MPLS) Data Plane Failures.";
      }
    }
  }
}
```



```
case pw {
  leaf remote-pe-address {
    type inet:ip-address;
    description
      "Remote PE address. See section 3.2.8
of RFC8029 for details.";
    reference
      "RFC 8029 :Detecting Multi-Protocol Label
      Switched (MPLS) Data Plane Failures";
  }
  leaf pw-id {
    type uint32;
    description
      "Pseudowire ID is a non-zero 32-bit ID. See section
3.2.8 and Section 3.2.9 for details.";
    reference
      "RFC 8029 :Detecting Multi-Protocol Label
      Switched (MPLS) Data Plane Failures";
  }
}
case vpls {
  leaf route-distinguisher {
    type rt:route-distinguisher;
    description
      "Route Distinguisher is an 8 octets identifier
      used to distinguish information about various
      L2VPN advertised by a node.";
    reference
      "RFC 8029 :Detecting Multi-Protocol Label
      Switched (MPLS) Data Plane Failures";
  }
  leaf sender-ve-id {
    type uint16;
    description
      "Sender's VE ID. The VE ID (VPLS Edge Identifier)
      is a 2-octet identifier.";
    reference
      "RFC 8029 :Detecting Multi-Protocol Label
      Switched (MPLS) Data Plane Failures";
  }
  leaf receiver-ve-id {
    type uint16;
    description
      "Receiver's VE ID. The VE ID (VPLS Edge Identifier)
      is a 2-octet identifier.";
    reference
      "RFC 8029 :Detecting Multi-Protocol Label
      Switched (MPLS) Data Plane Failures";
  }
}
```



```
    }
  }
  case mpls-mlbp {
    choice root-address {
      description
        "Root address choice.";
      case ip-address {
        leaf source-address {
          type inet:ip-address;
          description
            "IP address.";
        }
        leaf group-ip-address {
          type inet:ip-address;
          description
            "Group ip address.";
        }
      }
    }
  }
  case vpn {
    leaf as-number {
      type inet:as-number;
      description
        "The AS number represents autonomous system
        numbers which identify an Autonomous System.";
    }
  }
  case global-id {
    leaf lsp-id {
      type string;
      description
        "LSP ID is an identifier of a LSP
        within a MPLS network.";
      reference
        "RFC 8029 :Detecting Multi-Protocol Label
        Switched (MPLS) Data Plane Failures";
    }
  }
}
}
}
description
  "Test Point Attribute Container";
}
container system-info {
  when "derived-from-or-self(../tp-location-type,"+
  "'cl-oam:router-id-address-type')\" {
    description
      "System id address type";
```



```
    }
    leaf router-id {
      type rt:router-id;
      description
        "Router ID assigned to this node.";
    }
    description
      "Router ID container.";
  }
  description
    "TP Address";
}
grouping tp-address-ni {
  description
    "Test point address with VRF.";
  leaf ni {
    type routing-instance-ref;
    description
      "The ni is used to describe virtual resource partitioning
      that may be present on a network device. Example of common
      industry terms for virtual resource partitioning is VRF
      instance.";
  }
  uses tp-address;
}
grouping connectionless-oam-tps {
  list oam-neighboring-tps {
    key "index";
    leaf index {
      type uint16{
        range "0..65535";
      }
      description
        "List of related neighboring test points in adjacent
        layers up and down the stack for the same interface
        that are related to the current test point";
    }
  }
  leaf position {
    type int8 {
      range "-1..1";
    }
    default "0";
    description
      "The relative position
      of neighboring test point
      corresponding to the current
      test point. Level 0 indicates no neighboring
      test points placed before or after the current
```



```
        test point in the same layer.-1 means there is
        a neighboring test point placed before the current
        test point in the same layer and +1 means there is
        a neighboring test point placed after the current
        test point in same layer.";
    }
    choice tp-location {
        case mac-address {
            leaf mac-address-location {
                type yang:mac-address;
                description
                    "MAC Address";
            }
            description
                "MAC Address based TP Addressing.";
        }
        case ipv4-address {
            leaf ipv4-address-location {
                type inet:ipv4-address;
                description
                    "Ipv4 Address";
            }
            description
                "IP Address based TP Addressing.";
        }
        case ipv6-address {
            leaf ipv6-address-location {
                type inet:ipv6-address;
                description
                    "IPv6 Address";
            }
            description
                "IPv6 Address based TP Addressing.";
        }
        case as-number {
            leaf as-number-location {
                type inet:as-number;
                description
                    "AS number location";
            }
            description
                "AS number for point to multipoint OAM";
        }
        case router-id {
            leaf router-id-location {
                type rt:router-id;
                description
                    "System id location";
            }
        }
    }
}
```



```
    }

    description
      "System ID";
  }
  description
    "TP location.";
}
description
  "List of neighboring test points in the same layer that are related to
current test
point. If the neighboring test-point is placed after the current test
point, the
position is specified as +1. If neighboring test-point
is placed before the current test point, the position is specified
as -1, if no neighboring test points placed before or after the
current
test point in the same layer, the position is specified as 0.";
}
description
  "Connectionless OAM related neighboring test points list.";
}
grouping tp-technology {
  choice technology {
    default "technology-null";
    case technology-null {
      description
        "This is a placeholder when no technology is needed.";
      leaf tech-null {
        type empty;
        description
          "There is no technology to be defined.";
      }
    }
  }
  description
    "Technology choice.";
}
description
  "OAM Technology";
}
grouping tp-tools {
  description
    "Test Point OAM Toolset.";
  container tp-tools {
    leaf continuity-check {
      type boolean;
      mandatory true;
      description
```

"A flag indicating whether or not the
continuity check function is supported.";
reference

```
    "RFC 792: INTERNET CONTROL MESSAGE PROTOCOL.
    RFC 4443: Internet Control Message Protocol (ICMPv6)
    for the Internet Protocol Version 6 (IPv6) Specification.
    RFC 5880: Bidirectional Forwarding Detection.
    RFC 5881: BFD for IPv4 and IPv6.
    RFC 5883: BFD for Multihop Paths.

    RFC 5884: BFD for MPLS Label Switched Paths.
    RFC 5885: BFD for PW VCCV.
    RFC 6450: Multicast Ping Protocol.
    RFC 8029: Detecting Multiprotocol Label Switched
    (MPLS) Data-Plane Failures.";
  }
  leaf path-discovery {
    type boolean;
    mandatory true;
    description
      "A flag indicating whether or not the
      path discovery function is supported.";
    reference
      "RFC 792: INTERNET CONTROL MESSAGE PROTOCOL.
      RFC 4443: Internet Control Message Protocol (ICMPv6)
      for the Internet Protocol Version 6 (IPv6) Specification.
      RFC 4884: Extended ICMP to Support Multi-part Message.
      RFC 5837: Extending ICMP for Interface.
      and Next-Hop Identification.
      RFC 8029: Detecting Multiprotocol Label Switched (MPLS)
      Data-Plane Failures.";
  }
  description
    "Container for test point OAM tools set.";
}
}
grouping test-point-location-info {
  uses tp-technology;
  uses tp-tools;
  anydata root {
    yangmnt:mount-point "root";
    description
      "Root for models supported per
      test point";
  }
  uses connectionless-oam-tps;
  description
    "Test point Location";
}
grouping test-point-locations {
  description
```



```
    "Group of test point locations.";
    leaf tp-location-type {
      type identityref {
        base tp-address-technology-type;
      }
      description
        "Test point location type.";
    }
  container ipv4-location-type {
    when "derived-from-or-self(..../tp-location-type,"+
      "'cl-oam:ipv4-address-type')\" {
      description
        "When test point location type is equal to ipv4 address.";
    }
    container test-point-ipv4-location-list {
      list test-point-locations {
        key "ipv4-location ni";
        leaf ipv4-location {
          type inet:ipv4-address;
          description
            "IPv4 Address.";
        }
        leaf ni {
          type routing-instance-ref;
          description
            "The ni is used to describe the
              corresponding network instance";
        }
        uses test-point-location-info;
        description
          "List of test point locations.";
      }
      description
        "Serves as top-level container
          for test point location list.";
    }
    description
      "ipv4 location type container.";
  }
  container ipv6-location-type {
    when "derived-from-or-self(..../tp-location-type,"+
      "'cl-oam:ipv6-address-type')\" {
      description
        "When test point location is equal to ipv6 address";
    }
    container test-point-ipv6-location-list {
      list test-point-locations {
        key "ipv6-location ni";
```



```
    leaf ipv6-location {
      type inet:ipv6-address;
      description
        "IPv6 Address.";
    }
    leaf ni {
      type routing-instance-ref;
      description
        "The ni is used to describe the
        corresponding network instance";
    }
    uses test-point-location-info;
    description
      "List of test point locations.";
  }
  description
    "Serves as top-level container
    for test point location list.";
}
description
  "ipv6 location type container.";
}
container mac-location-type {
  when "derived-from-or-self(../tp-location-type,"+
    "'cl-oam:mac-address-type')\" {
    description
      "when test point location type is equal to mac address.";
  }
}
container test-point-mac-address-location-list {
  list test-point-locations {
    key "mac-address-location";
    leaf mac-address-location {
      type yang:mac-address;
      description
        "MAC Address";
    }
  }
  uses test-point-location-info;
  description
    "List of test point locations.";
}
description
  "Serves as top-level container
  for test point location list.";
}
description
  "mac address location type container.";
}
container group-as-number-location-type {
```



```
when "derived-from-or-self(..tp-location-type,"+
"'cl-oam:as-number-address-type')" {
  description
    "when test point location type is equal to as-number.";
}
container test-point-as-number-location-list {
  list test-point-locations {
    key "as-number-location";
    leaf as-number-location {
      type inet:as-number;
      description
        "AS number for point to multi point OAM.";
    }
    leaf ni {
      type routing-instance-ref;
      description
        "The ni is used to describe the
        corresponding network instance";
    }
    uses test-point-location-info;
    description
      "List of test point locations.";
  }
  description
    "Serves as top-level container
    for test point location list.";
}
description
  "as number location type container.";
}
container group-router-id-location-type {
when "derived-from-or-self(..tp-location-type,"+
"'cl-oam:router-id-address-type')" {
  description
    "when test point location type is equal to system-info.";
  }
  container test-point-system-info-location-list {
    list test-point-locations {
      key "router-id-location";
      leaf router-id-location {
        type rt:router-id;
        description
          "System Id.";
      }
    }
    leaf ni {
      type routing-instance-ref;
      description
        "The ni is used to describe the
```



```
        corresponding network instance";
    }
    uses test-point-location-info;
    description
        "List of test point locations.";
    }
    description
        "Serves as top-level container for
        test point location list.";
    }
    description
        "system ID location type container.";
    }
}
augment "/nd:networks/nd:network/nd:node" {
    description
        "augments the /networks/network/node path defined in the
        ietf-network module (I-D.ietf-i2rs-yang-network-topo) with
        test-point-locations grouping.";
    uses test-point-locations;
}
grouping timestamp {
    description
        "Grouping for timestamp.";
    leaf timestamp-type {
        type identityref {
            base lime:timestamp-type;
        }
        description
            "Type of Timestamp, such as Truncated PTP, NTP.";
    }
}
container timestamp-64bit {
    when "derived-from-or-self(..timestamp-type, 'cl-oam:truncated-ntp')"+
    "or derived-from-or-self(..timestamp-type, 'cl-oam:ntp64')";
    description
        "Only applies when Truncated PTP or 64bit NTP Timestamp.";
    }
    leaf timestamp-sec {
        type uint32;
        description
            "Absolute timestamp in seconds as per IEEE1588v2
            or seconds part in 64-bit NTP timestamp.";
    }
    leaf timestamp-nanosec {
        type uint32;
        description
            "Fractional part in nanoseconds as per IEEE1588v2
            or Fractional part in 64-bit NTP timestamp.";
```



```
    }
    description
    "Container for 64bit timestamp. See section 4.2.1 of
    draft-ietf-ntp-packet-timestamps for NTP 64-bit Timestamp
    Format and section 4.3 of draft-ietf-ntp-packet-timestamps
    for The PTP Truncated Timestamp Format.";
  }
  container timestamp-80bit {
    when "derived-from-or-self(..../timestamp-type, 'cl-oam:ptp80')"{
      description
      "Only applies when 80bit PTP Timestamp.";
    }
    if-feature ptp-long-format;
    leaf timestamp-sec {
      type uint64 {
        range "0..281474976710655";
      }
      description
      "48bit Timestamp in seconds as per IEEE1588v2.";
    }
    leaf timestamp-nanosec {
      type uint32;
      description
      "Fractional part in nanoseconds as per IEEE1588v2.";
    }
    description
    "Container for 80bit timestamp.";
  }
  container ntp-timestamp-32bit {
    when "derived-from-or-self(..../timestamp-type, 'cl-oam:truncated-ntp')"{
      description
      "Only applies when 32 bit NTP Short format Timestamp.";
    }
    if-feature ntp-short-format;
    leaf timestamp-sec {
      type uint16;
      description
      "Timestamp in seconds as per short format NTP.";
    }
    leaf timestamp-nanosec {
      type uint16;
      description
      "Truncated Fractional part in 16-bit NTP timestamp.";
    }
    description
    "Container for 32bit timestamp. See section 4.2.2 of
    draft-ietf-ntp-packet-timestamps for NTP 32-bit Timestamp
    Format.";
```



```
    }
  container icmp-timestamp-32bit {
    when "derived-from-or-self(..../timestamp-type, 'cl-oam:icmp-ntp')"{
      description
        "Only applies when Truncated NTP or 64bit NTP Timestamp.";
    }
    if-feature icmp-timestamp;
      leaf timestamp-millisec {
        type uint32;

        description
          "timestamp in milliseconds for ICMP timestamp.";
      }
      description
        "Container for 32bit timestamp. See RFC792 for ICMP
        timestamp format.";
    }
  }
  grouping path-discovery-data {
    description
      "Path discovery related data output from nodes.";
    container src-test-point {
      description
        "Source test point.";
      uses tp-address-ni;
    }
    container dest-test-point {
      description
        "Destination test point.";
      uses tp-address-ni;
    }
    leaf sequence-number {
      type uint64;
      default "0";
      description
        "Sequence number in data packets. A value of
        zero indicates that no sequence number is sent.";
    }
    leaf hop-cnt {
      type uint8;
      default "0";
      description
        "Hop count. A value of zero indicates
        that no hop count is sent";
    }
    uses session-packet-statistics;
    uses session-error-statistics;
    uses session-delay-statistics;
```



```
uses session-jitter-statistics;
container path-verification {
  description
    "Optional path verification related information.";
  leaf flow-info {
    type string;
    description
      "Informations that refers to the flow.";
  }
  uses session-path-verification-statistics;
}
container path-trace-info {
  description
    "Optional path trace per-hop test point information.
    The path trace information list has typically a single
    element for per-hop cases such as path-discovery RPC operation
    but allows a list of hop related information for other types of
    data retrieval methods.";
  list path-trace-info-list {
    key "index";
    description
      "Path trace information list.";
    leaf index {
      type uint32;
      description
        "Trace information index.";
    }
    uses tp-address-ni;
    uses timestamp;
    leaf ingress-intf-name {
      type if:interface-ref;
      description
        "Ingress interface name";
    }
    leaf egress-intf-name {
      type if:interface-ref;
      description
        "Egress interface name";
    }
    leaf queue-depth {
      type uint32;
      description
        "Length of the queue of the interface from where
        the packet is forwarded out. The queue depth could
        be the current number of memory buffers used by the
        queue and a packet can consume one or more memory buffers
        thus constituting device-level information.";
    }
  }
}
```



```
    leaf transit-delay {
      type uint32;
      description
        "Time in nano seconds
        packet spent transiting a node.";
    }
    leaf app-meta-data {
      type uint64;
      description
        "Application specific
        data added by node.";
    }
  }
}
}
grouping continuity-check-data {
  description
    "Continuity check data output from nodes.";
  container src-test-point {
    description
      "Source test point.";
    uses tp-address-ni;
    leaf egress-intf-name {
      type if:interface-ref;
      description
        "Egress interface name.";
    }
  }
  container dest-test-point {
    description
      "Destination test point.";
    uses tp-address-ni;
    leaf ingress-intf-name {
      type if:interface-ref;
      description
        "Ingress interface name.";
    }
  }
}
leaf sequence-number {
  type uint64;
  default "0";
  description
    "Sequence number in data packets. A value of
    zero indicates that no sequence number is sent.";
}
leaf hop-cnt {
  type uint8;
```



```
    default "0";
    description
      "Hop count. A value of zero indicates
       that no hop count is sent";
  }
  uses session-packet-statistics;
  uses session-error-statistics;
  uses session-delay-statistics;
  uses session-jitter-statistics;
}
container cc-session-statistics-data {
  if-feature "continuity-check";
  config false;
  list cc-session-statistics {
    key type;
    leaf type {
      type identityref {
        base traffic-type;
      }
      description
        "Type of traffic.";
    }
    container cc-ipv4-sessions-statistics {
      when "../type = 'ipv4'" {
        description
          "Only applies when traffic type is Ipv4.";
      }
    }
    description
      "CC ipv4 sessions";
    uses cc-session-statistics;
  }
  container cc-ipv6-sessions-statistics {
    when "../type = 'ipv6'" {
      description
        "Only applies when traffic type is Ipv6.";
    }
  }
  description
    "CC ipv6 sessions";
  uses cc-session-statistics;
}
  description
    "List of CC session statistics data.";
}
description
  "CC operational information.";
}
```


<CODE ENDS>

6. Connectionless model applicability

The "ietf-connectionless-oam" model defined in this document provides a technology-independent abstraction of key OAM constructs for OAM protocols that use connectionless communication. This model can be further extended to include technology-specific details, e.g., adding new data nodes with technology specific functions and parameters into proper anchor points of the base model, so as to develop a technology-specific connectionless OAM model.

This section demonstrates the usability of the connectionless YANG OAM data model to various connectionless OAM technologies, e.g., BFD, LSP ping. Note that, in this section, several snippets of technology-specific model extensions are presented for illustrative purposes. The complete model extensions should be worked on in respective protocol working groups.

6.1. BFD Extension

[RFC 7276](#) defines BFD as a connection-oriented protocol. It is used to monitor a connectionless protocol in the case of basic BFD for IP.

6.1.1. Augment Method

The following sections shows how the "ietf-connectionless-oam" model can be extended to cover BFD technology. For this purpose, a set of extension are introduced such as technology-type extension and test-point attributes extension.

Note that a dedicated BFD YANG data model [[I-D.ietf-bfd-yang](#)] is also standardized. Augmentation of the "ietf-connectionless-oam" model with BFD specific details provides an alternative approach that provides a unified view of management information across various OAM protocols. The BFD specific details can be the grouping defined in the BFD model avoiding duplication of effort.

6.1.1.1. Technology type extension

No BFD technology type has been defined in the "ietf-connectionless-oam" model. Therefore a technology type extension is required in the model Extension.

The snippet below depicts an example of adding the "bfd" type as an augment to the ietf-connectionless-oam" model:


```
augment "/nd:networks/nd:network/nd:node/"
+"coam:location-type/coam:ipv4-location-type"
+"/coam:test-point-ipv4-location-list/"
+"coam:test-point-locations/coam:technology"
{
    leaf bfd{
        type string;
    }
}
```

6.1.1.2. Test point attributes extension

To support BFD, the "ietf-connectionless-oam" model can be extended by adding specific parameters into the "test-point-locations" list and/or adding a new location type such as "BFD over MPLS TE" under "location-type".

6.1.1.2.1. Define and insert new nodes into corresponding test-point-location

In the "ietf-connectionless-oam" model, multiple "test-point-location" lists are defined under the "location-type" choice node. Therefore, to derive a model for some BFD technologies (such as ip single-hop, ip multi-hops, etc), data nodes for BFD specific details need to be added into corresponding "test-point-locations" list. In this section, some groupings which are defined in [[I-D.ietf-bfd-yang](#)] are reused as follows:

The snippet below shows how the "ietf-connectionless-oam" model can be extended to support "BFD IP Single-Hop":


```
augment "/nd:networks/nd:network/nd:node/"
+"coam:location-type/coam:ipv4-location-type"
+"/coam:test-point-ipv4-location-list/"
  +"coam:test-point-locations"
{
  container session-cfg {
    description "BFD IP single-hop session configuration";
    list sessions {
      key "interface dest-addr";
      description "List of IP single-hop sessions";
      leaf interface {
        type if:interface-ref;
        description
          "Interface on which the BFD session is running.";
      }
      leaf dest-addr {
        type inet:ip-address;
        description "IP address of the peer";
      }
      uses bfd:bfd-grouping-common-cfg-parms;
      uses bfd:bfd-grouping-echo-cfg-parms;
    }
  }
}
```

Similar augmentations can be defined to support other BFD technologies such as BFD IP Multi-Hop, BFD over MPLS, etc.

6.1.1.2.2. Add new location-type cases

In the "ietf-connectionless-oam" model, If there is no appropriate "location type" case that can be extended, a new "location-type" case can be defined and inserted into the "location-type" choice node.

Therefore, the model user can flexibly add "location-type" to support other type of test point which are not defined in the "ietf-connectionless-oam" model. In this section, a new "location-type" case is added and some groupings that are defined in [\[I-D.ietf-bfd-yang\]](#) are reused as follows:

The snippet below shows how the "ietf-connectionless-oam" model can be extended to support "BFD over MPLS-TE":


```
augment "/nd:networks/nd:network/nd:node/coam:location-type"{
  case te-location{
    list test-point-location-list{
      key "tunnel-name";
      leaf tunnel-name{
        type leafref{
          path "/te:te/te:tunnels/te:tunnel/te:name";
        }
      }
    }
  }
  description
    "point to a te instance.";
  }
  uses bfd:bfd-grouping-common-cfg-parms;
  uses bfd-mpls:bfd-encap-cfg;
}
}
```

Similar augmentations can be defined to support other BFD technologies such as BFD over LAG, etc.

6.1.2. Schema Mount

An alternative method is using the schema mount mechanism [I-D.ietf-netmod-schema-mount] in the "ietf-connectionless-oam" model. Within the "test-point-locations" list, a "root" attribute is defined to provide a mount point for models mounted per "test-point-locations". Therefore, the "ietf-connectionless-oam" model can provide a place in the node hierarchy where other OAM YANG data models can be attached, without any special extension in the "ietf-connectionless-oam" YANG data models [[I-D.ietf-netmod-schema-mount](#)]. Note that the limitation of the Schema Mount method is it is not allowed to specify certain modules that are required to be mounted under a mount point.

The snippet below depicts the definition of the "root" attribute.

```
anydata root {
  yangmnt:mount-point root;
  description
    "Root for models supported per
     test point";
}
```

The following section shows how the "ietf-connectionless-oam" model can use schema mount to support BFD technology.

6.1.2.1. BFD Modules be populated in schema-mount

To support BFD technology, "ietf-bfd-ip-sh" and "ietf-bfd-ip-mh" YANG modules might be populated in the "schema-mounts" container:

```
<schema-mounts
  xmlns="urn:ietf:params:xml:ns:yang:ietf-yang-schema-mount">
  <mount-point>
    <module> ietf-connectionless-oam </module>
    <name>root</name>
    <use-schema>
      <name>root</name>
    </use-schema>
  </mount-point>
  <schema>
    <name>root</name>
    <module>
      <name>ietf-bfd-ip-sh </name>
      <revision>2016-07-04</revision>
      <namespace>
        urn:ietf:params:xml:ns:yang:ietf-bfd-ip-sh
      </namespace>
      <conformance-type>implement</conformance-type>
    </module>
    <module>
      <name>ietf-bfd-ip-mh </name>
      <revision> 2016-07-04</revision>
      <namespace>
        urn:ietf:params:xml:ns:yang:ietf-bfd-ip-mh
      </namespace>
      <conformance-type>implement</conformance-type>
    </module>
  </schema>
</schema-mounts>
```

and the "ietf-connectionless-oam" module might have:


```
<ietf-connectionless-oam
uri="urn:ietf:params:xml:ns:yang:ietf-connectionless-oam">
  .....
  <test-point-locations>
    <ipv4-location>192.0.2.1</ipv4-location>
    .....
  <root>
    <ietf-bfd-ip-sh uri="urn:ietf:params:xml:ns:yang:ietf-bfd-ip-sh">
      <ip-sh>
        foo
        .....
      </ip-sh>
    </ietf-bfd-ip-sh>
    <ietf-bfd-ip-mh uri="urn:ietf:params:xml:ns:yang:ietf-bfd-ip-mh">
      <ip-mh>
        foo
        .....
      </ip-mh>
    </ietf-bfd-ip-mh>
  </root>
</test-point-locations>
</ietf-connectionless-oam>
```

6.2. LSP Ping extension

6.2.1. Augment Method

The following sections shows how the "ietf-connectionless-oam" model can be extended to support LSP ping technology. For this purpose, a set of extensions are introduced such as the "technology-type" extension and the test-point "attributes" extension.

Note that an LSP Ping YANG data model is being specified [[I-D.zheng-mp1s-lsp-ping-yang-cfg](#)]. As with BFD, users can choose to use the "ietf-connectionless-oam" as basis and augment the "ietf-connectionless-oam" model with LSP Ping specific details in the model extension to provide a unified view across different technologies. The LSP Ping specific details can be the grouping defined in the LSP ping model to avoid duplication of effort.

6.2.1.1. Technology type extension

No LSP Ping technology type has been defined in the "ietf-connectionless-oam" model. Therefore a technology type extension is required in the model extension.

The snippet below depicts an example of augmenting the "ietf-connectionless-oam" with "lsp-ping" type:


```
augment "/nd:networks/nd:network/nd:node/"
+"coam:location-type/coam:ipv4-location-type"
+"/coam:test-point-ipv4-location-list/"
    +"coam:test-point-locations/coam:technology"
{
    leaf lsp-ping{
        type string;
    }
}
```

6.2.1.2. Test point attributes extension

To support LSP Ping, the "ietf-connectionless-oam" model can be extended and add LSP Ping specific parameters can be defined and under "test-point-locations" list.

Users can reuse the attributes or groupings which are defined in [\[I-D.zheng-mpls-lsp-ping-yang-cfg\]](#) as follows:

The snippet below depicts an example of augmenting the "test-point-locations" list with lsp ping attributes:

```
augment "/nd:networks/nd:network/nd:node/"
+"coam:location-type/coam:ipv4-location-type"
+"/coam:test-point-ipv4-location-list/"
    +"coam:test-point-locations"
{
    list lsp-ping {
        key "lsp-ping-name";
        leaf lsp-ping-name {
            type string {
                length "1..31";
            }
            mandatory "true";
            description "LSP Ping test name.";
            .....
        }
    }
}
```

6.2.2. Schema Mount

An alternative method is using schema mount mechanism [\[I-D.ietf-netmod-schema-mount\]](#) in the "ietf-connectionless-oam". Within the "test-point-locations" list, a "root" attribute is defined to provide a mounted point for models mounted per "test-point-locations". Therefore, the "ietf-connectionless-oam" model can provide a place in the node hierarchy where other OAM YANG data models can be attached, without any special extension in the "ietf-connectionless-oam" YANG data models [\[I-D.ietf-netmod-schema-mount\]](#).

Note that the limitation of the Schema Mount method is it is not allowed to specify certain modules that are required to be mounted under a mount point.

The snippet below depicts the definition of "root" attribute.

```
anydata root {
  yangmnt:mount-point root;
  description
    "Root for models supported per
     test point";
}
```

The following section shows how the "ietf-connectionless-oam" model can use schema mount to support LSP-PING technology.

6.2.2.1. LSP-PING Modules be populated in schema-mount

To support LSP-PING technology, "ietf-lspping" YANG module [[I-D.zheng-mpis-lsp-ping-yang-cfg](#)] might be populated in the "schema-mounts" container:

```
<schema-mounts
  xmlns="urn:ietf:params:xml:ns:yang:ietf-yang-schema-mount">
  <mount-point>
    <module> ietf-connectionless-oam </module>
    <name>root</name>
    <use-schema>
      <name>root</name>
    </use-schema>
  </mount-point>
  <schema>
    <name>root</name>
    <module>
      <name>ietf-lspping </name>
      <revision>2016-03-18</revision>
      <namespace>
        urn:ietf:params:xml:ns:yang: ietf-lspping
      </namespace>
      <conformance-type>implement</conformance-type>
    </module>
  </schema>
</schema-mounts>
```

and the "ietf-connectionless-oam" module might have:


```
<ietf-connectionless-oam
uri="urn:ietf:params:xml:ns:yang:ietf-connectionless-oam">
  .....
  <test-point-locations>
    <ipv4-location> 192.0.2.1</ipv4-location>
    .....
  <root>
    <ietf-lspping uri="urn:ietf:params:xml:ns:yang:ietf-lspping">
      <lsp-pings>
        foo
        .....
      </lsp-pings>
    </ietf-lspping>
  </root>
</test-point-locations>
</ietf-connectionless-oam>
```

7. 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.

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.

The vulnerable "config true" subtrees and data nodes are the following:

```
/nd:networks/nd:network/nd:node/cl-oam:location-type/cl-oam:ipv4-
location-type/cl-oam:test-point-ipv4-location-list/cl-oam:test-
point-locations/
```

```
/nd:networks/nd:network/nd:node/cl-oam:location-type/cl-oam:ipv6-
location-type/cl-oam:test-point-ipv6-location-list/cl-oam:test-
point-locations/
```



```
/nd:networks/nd:network/nd:node/cl-oam:location-type/cl-oam:mac-  
location-type/cl-oam:test-point-mac-address-location-list/cl-  
oam:test-point-locations/
```

```
/nd:networks/nd:network/nd:node/cl-oam:location-type/cl-oam:group-  
as-number-location-type/cl-oam:test-point-as-number-location-list/  
cl-oam:test-point-locations/
```

```
/nd:networks/nd:network/nd:node/cl-oam:location-type/cl-oam:group-  
router-id-location-type/cl-oam:test-point-system-info-location-  
list/cl-oam:test-point-locations/
```

Unauthorized access to any of these lists can adversely affect OAM management system handling of end-to-end OAM and coordination of OAM within underlying network layers. This may lead to inconsistent configuration, reporting, and presentation for the OAM mechanisms used to manage the network.

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:

```
/coam:cc-session-statistics-data/cl-oam:cc-ipv4-sessions-  
statistics/cl-oam:cc-session-statistics/cl-oam:session-count/
```

```
/coam:cc-session-statistics-data/cl-oam:cc-ipv4-sessions-  
statistics/cl-oam:cc-session-statistics/cl-oam:session-up-count/
```

```
/coam:cc-session-statistics-data/cl-oam:cc-ipv4-sessions-  
statistics/cl-oam:cc-session-statistics/cl-oam: session-down-  
count/
```

```
/coam:cc-session-statistics-data/cl-oam:cc-ipv4-sessions-  
statistics/cl-oam:cc-session-statistics/cl-oam:session-admin-down-  
count/
```

```
/coam:cc-session-statistics-data/cl-oam:cc-ipv6-sessions-  
statistics/cl-oam:cc-session-statistics/cl-oam:session-count/
```

```
/coam:cc-session-statistics-data/cl-oam:cc-ipv6-sessions-  
statistics/cl-oam:cc-session-statistics/cl-oam:session-up-count//
```

```
/coam:cc-session-statistics-data/cl-oam:cc-ipv6-sessions-  
statistics/cl-oam:cc-session-statistics/cl-oam:session-down-count/
```



```
/coam:cc-session-statistics-data/cl-oam:cc-ipv6-sessions-
statistics/cl-oam:cc-session-statistics/cl-oam:session-admin-down-
count/
```

8. IANA Considerations

This document registers a URI in the IETF XML registry [[RFC3688](#)]. Following the format in [[RFC3688](#)], the following registration is requested to be made:

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

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

This document registers a YANG module in the YANG Module Names registry [[RFC7950](#)].

Name: ietf-lime-common-types
Namespace: urn:ietf:params:xml:ns:yang:ietf-lime-time-types
Prefix: lime
Reference: RFC XXXX

Name: ietf-connectionless-oam
Namespace: urn:ietf:params:xml:ns:yang:ietf-connectionless-oam
Prefix: cl-oam
Reference: RFC XXXX

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10. References

10.1. Normative References

[I-D.ietf-i2rs-yang-network-topo]
Clemm, A., Medved, J., Varga, R., Bahadur, N.,
Ananthakrishnan, H., and X. Liu, "A Data Model for Network
Topologies", [draft-ietf-i2rs-yang-network-topo-17](#) (work in
progress), October 2017.

[I-D.ietf-rtgwg-ni-model]

Berger, L., Hopps, C., Lindem, A., Bogdanovic, D., and X. Liu, "YANG Network Instances", [draft-ietf-rtgwg-ni-model-04](#) (work in progress), September 2017.

[I-D.ietf-rtgwg-routing-types]

Liu, X., Qu, Y., Lindem, A., Hopps, C., and L. Berger, "Routing Area Common YANG Data Types", [draft-ietf-rtgwg-routing-types-17](#) (work in progress), October 2017.

[RFC3688] Mealling, M., "The IETF XML Registry", [BCP 81](#), [RFC 3688](#), DOI 10.17487/RFC3688, January 2004, <<https://www.rfc-editor.org/info/rfc3688>>.

[RFC4443] Conta, A., Deering, S., and M. Gupta, Ed., "Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification", STD 89, [RFC 4443](#), DOI 10.17487/RFC4443, March 2006, <<https://www.rfc-editor.org/info/rfc4443>>.

[RFC5246] Dierks, T. and E. Rescorla, "The Transport Layer Security (TLS) Protocol Version 1.2", [RFC 5246](#), DOI 10.17487/RFC5246, August 2008, <<https://www.rfc-editor.org/info/rfc5246>>.

[RFC5905] Mills, D., Martin, J., Ed., Burbank, J., and W. Kasch, "Network Time Protocol Version 4: Protocol and Algorithms Specification", [RFC 5905](#), DOI 10.17487/RFC5905, June 2010, <<https://www.rfc-editor.org/info/rfc5905>>.

[RFC6021] Schoenwaelder, J., Ed., "Common YANG Data Types", [RFC 6021](#), DOI 10.17487/RFC6021, October 2010, <<https://www.rfc-editor.org/info/rfc6021>>.

[RFC6241] Enns, R., Ed., Bjorklund, M., Ed., Schoenwaelder, J., Ed., and A. Bierman, Ed., "Network Configuration Protocol (NETCONF)", [RFC 6241](#), DOI 10.17487/RFC6241, June 2011, <<https://www.rfc-editor.org/info/rfc6241>>.

[RFC6242] Wasserman, M., "Using the NETCONF Protocol over Secure Shell (SSH)", [RFC 6242](#), DOI 10.17487/RFC6242, June 2011, <<https://www.rfc-editor.org/info/rfc6242>>.

[RFC6536] Bierman, A. and M. Bjorklund, "Network Configuration Protocol (NETCONF) Access Control Model", [RFC 6536](#), DOI 10.17487/RFC6536, March 2012, <<https://www.rfc-editor.org/info/rfc6536>>.

- [RFC6991] Schoenwaelder, J., Ed., "Common YANG Data Types", [RFC 6991](#), DOI 10.17487/RFC6991, July 2013, <<https://www.rfc-editor.org/info/rfc6991>>.
- [RFC7223] Bjorklund, M., "A YANG Data Model for Interface Management", [RFC 7223](#), DOI 10.17487/RFC7223, May 2014, <<https://www.rfc-editor.org/info/rfc7223>>.
- [RFC792] Postel, J., "Internet Control Message Protocol", [RFC 792](#), September 1981.
- [RFC7950] Bjorklund, M., Ed., "The YANG 1.1 Data Modeling Language", [RFC 7950](#), DOI 10.17487/RFC7950, August 2016, <<https://www.rfc-editor.org/info/rfc7950>>.
- [RFC8029] Kompella, K., Swallow, G., Pignataro, C., Ed., Kumar, N., Aldrin, S., and M. Chen, "Detecting Multiprotocol Label Switched (MPLS) Data-Plane Failures", [RFC 8029](#), DOI 10.17487/RFC8029, March 2017, <<https://www.rfc-editor.org/info/rfc8029>>.
- [RFC8040] Bierman, A., Bjorklund, M., and K. Watsen, "RESTCONF Protocol", [RFC 8040](#), DOI 10.17487/RFC8040, January 2017, <<https://www.rfc-editor.org/info/rfc8040>>.

10.2. Informative References

- [G.800] "Unified functional architecture of transport networks", ITU-T Recommendation G.800, 2016.
- [G.8013] "OAM functions and mechanisms for Ethernet based networks", ITU-T Recommendation G.8013/Y.1731, 2013.
- [I-D.ietf-bfd-yang]
Rahman, R., Zheng, L., Jethanandani, M., Networks, J., and G. Mirsky, "YANG Data Model for Bidirectional Forwarding Detection (BFD)", [draft-ietf-bfd-yang-07](#) (work in progress), October 2017.
- [I-D.ietf-lime-yang-connection-oriented-oam-model]
Kumar, D., Wu, Q., and Z. Wang, "Generic YANG Data Model for Connection Oriented Operations, Administration, and Maintenance(OAM) protocols", [draft-ietf-lime-yang-connection-oriented-oam-model-00](#) (work in progress), June 2017.

- [I-D.ietf-lime-yang-connectionless-oam-methods]
Kumar, D., Wang, Z., Wu, Q., Rahman, R., and S. Raghavan,
"Retrieval Methods YANG Data Model for Connectionless
Operations, Administration, and Maintenance(OAM)
protocols", [draft-ietf-lime-yang-connectionless-oam-methods-12](#) (work in progress), October 2017.
- [I-D.ietf-netmod-schema-mount]
Bjorklund, M. and L. Lhotka, "YANG Schema Mount", [draft-ietf-netmod-schema-mount-08](#) (work in progress), October 2017.
- [I-D.ietf-ntp-packet-timestamps]
Mizrahi, T., Fabini, J., and A. Morton, "Guidelines for
Defining Packet Timestamps", [draft-ietf-ntp-packet-timestamps-00](#) (work in progress), October 2017.
- [I-D.zheng-mppls-lsp-ping-yang-cfg]
Zheng, L., Aldrin, S., Zheng, G., Mirsky, G., and R.
Rahman, "YANG Data Model for LSP-Ping", [draft-zheng-mppls-lsp-ping-yang-cfg-06](#) (work in progress), October 2017.
- [IEEE.1588]
"IEEE Standard for a Precision Clock Synchronization
Protocol for Networked Measurement and Control Systems",
IEEE IEEE Std 1588-2008, 2008.
- [RFC5462] Andersson, L. and R. Asati, "Multiprotocol Label Switching
(MPLS) Label Stack Entry: "EXP" Field Renamed to "Traffic
Class" Field", [RFC 5462](#), DOI 10.17487/RFC5462, February
2009, <<https://www.rfc-editor.org/info/rfc5462>>.
- [RFC6136] Sajassi, A., Ed. and D. Mohan, Ed., "Layer 2 Virtual
Private Network (L2VPN) Operations, Administration, and
Maintenance (OAM) Requirements and Framework", [RFC 6136](#),
DOI 10.17487/RFC6136, March 2011,
<<https://www.rfc-editor.org/info/rfc6136>>.
- [RFC7276] Mizrahi, T., Sprecher, N., Bellagamba, E., and Y.
Weingarten, "An Overview of Operations, Administration,
and Maintenance (OAM) Tools", [RFC 7276](#),
DOI 10.17487/RFC7276, June 2014,
<<https://www.rfc-editor.org/info/rfc7276>>.

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