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D. Kumar
Cisco
M. Wang
Q. Wu
Huawei
R. Rahman
S. Raghavan
Cisco
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**Generic YANG Data Model for Connectionless Operations, Administration,
and Maintenance(OAM) protocols
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Abstract

This document presents a base YANG Data model for connectionless Operations Administration, and Maintenance(OAM) protocols. It provides a technology-independent abstraction of key OAM constructs for connectionless protocols. The base model presented here can be extended to include technology specific details. This is leading to uniformity between OAM protocols and support both nested OAM workflows (i.e., performing OAM functions at different or same levels through a unified interface) and interacting OAM workflows (i.e., performing OAM functions at same levels through a unified interface).

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1. Introduction

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

1. Monitor networks connections (Reachability Verification, Continuity Check).
2. Troubleshoot failures (Fault verification and localization).
3. Monitor Performance

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

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

The different OAM tools may support connection-oriented technologies or connectionless technologies. In connection-oriented technologies, a connection is established prior to the transmission of data. In connectionless technologies, data is typically sent between end points without prior arrangement [[RFC7276](#)]. Note that the Connection-Oriented OAM YANG DATA model is defined in [[I-D.ietf-lime-yang-connection-oriented-oam-model](#)].

In this document, we presents a base YANG Data model for connectionless OAM protocols. The generic YANG model for connectionless OAM only includes configuration data and state data. It can be used in conjunction with data retrieval method model [[I-D.ietf-lime-yang-connectionless-oam-methods](#)], which focuses on data retrieval procedures like RPC. However it also can be used independently of data retrieval method model.

2. Conventions used in this document

The following terms are defined in [[RFC6241](#)] and are not redefined here:

- o client
- o configuration data
- o server
- o state data

The following terms are defined in [[RFC6020](#)] and are not redefined here:

- o augment
- o data model
- o data node

The terminology for describing YANG data models is found in [[RFC6020](#)].

2.1. Terminology

TP - Test Point

MAC - Media Access Control

bfd - Bidirectional Forwarding Detection

RPC - A Remote Procedure Call

RPC operation - A specific Remote Procedure Call.

CC - Continuity Check [[RFC7276](#)] , Continuity Checks 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 model is augmented to "/nd:networks/nd:network/nd:node" [[I-D.ietf-i2rs-yang-network-topo](#)] using 'test-point-locations' defined in [Section 3.5](#). The tool attribute 'tp-tools' grouping defined in this model is corresponding to technology-independent retrieval procedures (RPC operations) defined in [[I-D.ietf-lime-yang-connectionless-oam-methods](#)] and supports one of two basic types of activation: proactive and on-demand (determined by 'session-type' grouping defined in this model, see [section 3.2](#)).

At the top of the model, there is an 'cc-oper-data' container for session statistics. Grouping is also defined for common session statistics and these are only applicable for proactive OAM sessions.

Multiple 'test-point-locations' keyed using technology specific keys (eg., IPv4 address for IPv4 locations) are augmented into network nodes which are defined in [[I-D.ietf-i2rs-yang-network-topo](#)] to describe the network hierarchies and the inventory of nodes contained in a network. Each test point location under 'test-point-locations

'grouping is chosen based on 'tp-location-type' leaf which when chosen, leads to a container that includes a list of 'test-point-locations' keyed by technology specific keys(e.g., 'ipv4-location'leaf). Each test point location under 'test-point-locations' grouping includes a 'test-point-location-info' grouping. The 'test-point-location-info' grouping includes 'tp-technology' grouping, 'tp-tools' grouping, and 'connectionless-oam-layers' 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-location'. The 'tp-address-ni' grouping is used to describe the corresponding network instance. The 'tp-technology' grouping indicate OAM technology details. The 'tp-tools' grouping describe the OAM tools supported. The 'connectionless-oam-layers' grouping is used to describe the relationship of one test point with other test points. The 'technology-level' in 'oam-neighboring-layers' indicate relative technology level of neighboring test point corresponding to the current test point.

3.1. TP Address

In connectionless OAM, the TP address is defined with the following type:

- o MAC address [[RFC6136](#)]
- o IPv4 or IPv6 address
- o TP-attribute
- o System-id to represent the device or node. [[I-D.ietf-spring-sr-yang](#)]

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 EXP (renamed to Traffic Classic in [RFC5462](#)) for MPLS. In generic connectionless OAM YANG model, these parameters are not explicit 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. The proactive OAM refers to OAM actions which are carried out continuously to permit proactive

reporting of fault. The proactive OAM method requires persistent configuration. The on-demand OAM refers to OAM actions which are initiated via manual intervention for a limited time to carry out diagnostics. The on-demand OAM method requires only transient configuration. [RFC7276] [G.8013]. In connectionless OAM, '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 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 layers

As typical networks have a multi-layer architecture, the set of OAM protocols similarly take a multi-layer structure; each layer may has its own OAM protocol [RFC7276] and is corresponding to specific administrative domain and has associated test points. OAM-neighboring-layers is referred to a list of neighboring test points in the upstream layer and/or downstream layer and the same layer that are related to current test point. This allows users to easily navigate between related neighboring layer to efficiently troubleshoot a defect. In this model, we have kept technology-level default as 0, when a list of neighboring test points under 'oam-neighboring-layers' list are located at the same layer as the current test point. 'Technology-Level'leaf defines the relative technology level of neighboring test point corresponding to the current test point in multi-layer and multi-technology networks , and is provided to allow correlation of faults at different administrative and technology layers . If there is one neighboring test point at higher layer of the current test point, 'Technology-level'leaf is set to 1. If there is one neighboring test point at lower layer of the current test point, 'Technology-level'leaf is set to -1.


```
list oam-neighboring-layers {
  key "index";
  leaf index {
    type uint8 {
      range "0..128";
    }
    description
      "Index of a list of neighboring test points
      in the upstream layer and/or downstream layer
      and/or same layer ";
  }
  leaf technology-level {
    type int8 {
      range "-1..1";
    }
    description
      "The relative technology level
      of neighboring test point
      corresponding to the current
      test point";
  }
  description
    "List of related neighboring test points at upstream layer
    and or downstream layer or at the same layer.";
}
```

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-tool'grouping, 'OAM-neighboring Layers' grouping 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 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' list which includes information like '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. Noted that the retrieval methods are defined in [\[I-D.ietf-lime-yang-connectionless-oam-methods\]](#).

3.7. Continuity Check Data

This is a generic grouping for 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 the 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-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 location-type
  +--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?
  |         +--rw oam-neighboring-layers* [index]
  |           +--rw index                  uint8
  |           +--rw technology-level?     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
  |             +--:(system-id)
  |               +--rw system-id-location?  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?
  |         +--rw oam-neighboring-layers* [index]
  |           +--rw index                  uint8
  |           +--rw technology-level?     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
|         +--:(system-id)
|         +--rw system-id-location?      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?
|     +--rw oam-neighboring-layers* [index]
|       +--rw index                    uint8
|       +--rw technology-level?       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
|         +--:(system-id)
|         +--rw system-id-location?    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?
|     +--rw oam-neighboring-layers* [index]
|       +--rw index                    uint8
|       +--rw technology-level?       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
|           +--:(system-id)
|           +--rw system-id-location?     router-id
+--rw group-system-id-location-type
  +--rw test-point-system-info-location-list
    +--rw test-point-locations* [system-id-location]
      +--rw system-id-location         inet:uri
      +--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?
      +--rw oam-neighboring-layers* [index]
        +--rw index                   uint8
        +--rw technology-level?       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
          +--:(system-id)
          +--rw system-id-location?     router-id

```

4. 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 coam;
  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;
}
organization
  "IETF LIME Working Group";
contact
  "Deepak Kumar dekkumar@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, statistics for connectionless OAM to be
  used within IETF 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 connection-less {
  description
    "This feature indicates that OAM solution is connection less.";
}
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.";
}
typedef router-id {
  type yang:dotted-quad;
  description
    "A 32-bit number in the dotted quad format assigned to each
    router. This number uniquely identifies the router within an
    Autonomous System.";
}
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.";
}
identity address-attribute-types {
  description
    "This is base identity of address
    attribute types which are ip-prefix,
    bgp, tunnel, pwe3, vpls, etc.";
}
typedef address-attribute-type {
  type identityref {
    base address-attribute-types;
  }
  description
    "Target address attribute type.";
}
identity time-resolution {
  description
    "Time interval resolution";
```



```
}
identity hours {
  base time-resolution;
  description
    "Time resolution in Hours";
}
identity minutes {
  base time-resolution;
  description
    "Time resolution in Minutes";
}
identity seconds {
  base time-resolution;
  description
    "Time resolution in Seconds";
}
identity milliseconds {
  base time-resolution;
  description
    "Time resolution in Milliseconds";
}
identity microseconds {
  base time-resolution;
  description
    "Time resolution in Microseconds";
}
identity nanoseconds {
  base time-resolution;
  description
    "Time resolution in Nanoseconds";
}
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;
      default "0";
      description
        "Total number of received OAM packet count.
        A value of zero indicates that no received
        OAM packet count number is sent.";
    }
    leaf tx-packet-count {
      type uint32;
      default "0";
      description
        "Total number of transmitted OAM packet count.
        A value of zero indicates that no transmitted
        OAM packet count number is sent.";
    }
  }
  leaf rx-bad-packet {
    type uint32;
    default "0";
  }
}
```



```
    description
      "Total number of received bad OAM packet.
      A value of zero indicates that no received bad
      OAM packet count number is sent.";
  }
  leaf tx-packet-failed {
    type uint32;
    default "0";
    description
      "Total number of failed sending OAM packet.
      A value of zero indicates that no failed
      sending OAM packet count number is sent.";
  }
}
}
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;
      default "0";
      description
        "Total Continuity Check sessions down count.
        A value of zero indicates that no
        down count per session is sent.";
    }
    leaf admin-down-count {
      type uint32;
      default "0";
      description
```



```
        "Total Continuity Check sessions admin down count.
        A value of zero indicates that no
        admin down count per session is sent.";
    }
    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-drops-count {
            type uint32;
            default "0";
            description
                "Total received packet drops count.
                A value of zero indicates that no
                packet drops count is sent.";
        }
        leaf packet-reorder-count {
            type uint32;
            default "0";
            description
                "Total received packet reordered count.
                A value of zero indicates that no packet
                reorder count is sent.";
        }
        leaf packets-out-of-seq-count {
            type uint32;
            description
                "Total received out of sequence count.
                A value of zero indicates that no packet
                out of sequence count is sent.";
        }
        leaf packets-dup-count {
            type uint32;
            description
                "Total received packet duplicates count.
                A value of zero indicates that no packet
                duplicates count is sent.";
        }
    }
}
}
grouping session-delay-statistics {
    description
        "Grouping for per session delay statistics";
```



```
container session-delay-statistics {
  description
    "Session delay summarised information.";
  leaf time-resolution-value {
    type identityref {
      base time-resolution;
    }
    default "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.";
    leaf time-resolution-value {
      type identityref {
        base time-resolution;
      }
      default "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;
            description
                "Total number of OAM packets that
                 went through a path as intended.
                 A value of zero indicates that no
                 verified count is sent.";
        }
        leaf failed-count {
            type uint32;
            description
                "Total number of OAM packets that
                 went through an unintended path.
                 A value of zero indicates that no
                 failed count is sent.";
        }
    }
}
}
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 system-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-types {
    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, 'coam:mac-address-
type')" {
      description
        "MAC address type";
    }
    leaf mac-address {
      type yang:mac-address;
      mandatory true;
      description
        "MAC Address";
    }
    description
      "MAC Address based MP Addressing.";
  }
  container ipv4-address {
    when "derived-from-or-self(..../tp-location-type, 'coam:ipv4-address-
type')" {
      description
        "IPv4 address type";
    }
    leaf ipv4-address {
      type inet:ipv4-address;
      mandatory true;
      description
        "IPv4 Address";
    }
    description
      "IP Address based MP Addressing.";
  }
  container ipv6-address {
    when "derived-from-or-self(..../tp-location-type, 'coam:ipv6-address-
type')" {
      description
        "IPv6 address type";
    }
    leaf ipv6-address {
      type inet:ipv6-address;
      mandatory true;
    }
  }
}
```



```
description
  "IPv6 Address";
}
```

```
    description
      "ipv6 Address based MP Addressing.";
  }
  container tp-attribute {
    when "derived-from-or-self(..//tp-location-type, 'coam: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
            "IP prefix.";
        }
      }
      case bgp {
        leaf bgp {
          type inet:ip-prefix;
          description
            "BGP Labeled Prefix ";
        }
      }
      case tunnel {
        leaf tunnel-interface {
          type uint32;
          description
            "VPN Prefix ";
        }
      }
      case pw {
        leaf remote-pe-address {
          type inet:ip-address;
          description
            "Remote pe address.";
        }
        leaf pw-id {
          type uint32;
          description
            "Pseudowire ID is a non-zero 32-bit ID.";
        }
      }
    }
  }
}
```

reference

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```
        "RFC 4379 :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 4379 :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 4379 :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 4379 :Detecting Multi-Protocol Label
      Switched (MPLS) Data Plane Failures";
  }
}
case mpls-mldp {
  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 4379 :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, 'coam:system-id-
address-type')" {
    description
      "System id address type";
  }
  leaf system-id {
    type rt:router-id;
    description
      "System ID assigned to this node.";
  }
  description
    "system ID container.";
}
description
  "TP Address";
}
grouping tp-address-ni {
  description
    "Test point address with VRF.";
  leaf ni {
```

type routing-instance-ref;

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```
    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-layers {
  list oam-neighboring-layers {
    key "index";
    leaf index {
      type uint8{
        range "0..128";}
      description
        "Index of a list of neighboring test points
        in the upstream layer and/or downstream layer
        and/or same layer";
    }
    leaf technology-level {
      type int8 {
        range "-1..1";
      }
      default "0";
      description
        "The relative technology level
        of neighboring test point
        corresponding to the current
        test point.Level 0 indicates default level,
        -1 means downstream layer related to current layer and +1
        means upstream layer related to current layer.
        In relationship 0 means same layer.";
    }
  }
  choice tp-location {
    case mac-address {
      leaf mac-address-location {
        type yang:mac-address;
        description
          "MAC Address";
      }
      description
        "MAC Address based MP Addressing.";
    }
    case ipv4-address {
      leaf ipv4-address-location {
        type inet:ipv4-address;
        description
          "Ipv4 Address";
      }
    }
  }
}
```



```
    }
    description
      "IP Address based MP Addressing.";
  }
  case ipv6-address {
    leaf ipv6-address-location {
      type inet:ipv6-address;
      description
        "IPv6 Address";
    }
    description
      "IPv6 Address based MP 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 system-id {
    leaf system-id-location {
      type router-id;
      description
        "System id location";
    }
    description
      "System ID";
  }
  description
    "TP location.";
}
description
  "List of neighboring test points in the upstream layer and/or
  downstream layer or same layer that are related to current test
  point. If neighboring test-point in the upstream layer exist, the
  technology-level is specified as +1. If neighboring test-point
  in the downstream layer exist, the technology-level is specified
  as -1, if neighboring test-points are located at the same layer
  as the current test-point, the technology-level is specified as
  0.";
}
description
  "Connectionless related OAM neighboring layer";
}
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 define";
    }
  }
  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.";
    }
  }
  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 4379: LSP-PING.";
  }
  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-layers;
  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, 'coam:ipv4-address-
type')" {
      description
        "When test point location type is equal to ipv4 address.";
    }
  }
  container test-point-ipv4-location-list {
    list test-points {
      key "ipv4-location ni";
      leaf ipv4-location {
        type inet:ipv4-address;
        description
          "IPv4 Address.";
      }
      leaf ni {
        type routing-instance-ref;
      }
    }
  }
}

```

description

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```
        "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, 'coam: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, 'coam:mac-address-
type')" {
```


description

"when test point location type is equal to mac address.";

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```
    }
    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, 'coam: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

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```
        "as number location type container.";
    }
    container group-system-id-location-type {
        when "derived-from-or-self(../tp-location-type, 'coam:system-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 "system-id-location";
                leaf system-id-location {
                    type inet:uri;
                    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
        "Augment test points of connectionless oam.";
    uses test-point-locations;
}
grouping uint64-timestamp {
    description
        "Grouping for 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 {
```

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```
        type uint32;
        description
            "Fractional part in nanoseconds as per IEEE1588v2
            or Fractional part in 64-bit NTP timestamp.";
    }
}
grouping timestamp {
    description
        "Grouping for timestamp.";
    leaf timestamp-type {
        type uint32;
        description
            "Truncated PTP = 0, NTP = 1";
    }
    uses uint64-timestamp;
}
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 like 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;
    description
        "CC operational information.";
    container cc-ipv4-sessions-statistics {
        description
            "CC ipv4 sessions";
        uses cc-session-statistics;
    }
    container cc-ipv6-sessions-statistics {
        description
            "CC ipv6 sessions";
        uses cc-session-statistics;
    }
}
}
```

<CODE ENDS>

5. Connectionless model applicability

"ietf-connectionless-oam" model defined in this document provides technology-independent abstraction of key OAM constructs for connectionless protocols. 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, we only present several snippets of technology-specific model extensions for illustrative purposes. The complete model extensions should be worked on in respective protocol working groups.

5.1. BFD Extension

5.1.1. 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 in BFD WG, there is a BFD YANG data model [[I-D.ietf-bfd-yang](#)] to be produced. Users can choose to use "ietf-connectionless-oam" as basis and augment the "ietf-connectionless-oam" model with bfd specific details. The bfd specific details can be the grouping defined in the BFD model.

5.1.1.1. 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 augmenting "bfd" type into the ietf-connectionless-oam":

```
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;
  }
}
```

5.1.1.2. Test point attributes extension

To support bfd technology, the "ietf-connectionless-oam" model can be extended and add bfd specific parameters under "test-point-location" list and/or add new location type such as "bfd over MPLS-TE" under "location-type".

5.1.1.2.1. 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, we reuse some groupings which are defined in [\[I-D.ietf-bfd-yang\]](#) as following:

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.

[5.1.1.2.2.](#) 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, we add a new "location-type" case and reuse some groupings which are defined in [\[I-D.ietf-bfd-yang\]](#) 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.

5.1.2. Schema Mount

And another alternative method is using schema mount mechanism [[I-D.ietf-netmod-schema-mount](#)] in the "ietf-connectionless-oam". Within the "test-point-location" list, a "root" attribute is defined to provide a mounted point for models mounted per "test-point-location". 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 BFD technology.

5.1.2.1. 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>
```

5.2. LSP ping extension

5.2.1. 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 extension are introduced such as technology-type extension and test-point attributes extension.

Note that in MPLS WG, there is a LSP Ping YANG data model [[I-D.zheng-mppls-lsp-ping-yang-cfg](#)] to be produced. Users can choose to use "ietf-connectioless-oam" as basis and augment the "ietf-connectionless-oam" model with LSP Ping specific details in the model extension. The LSP Ping specific details can be the grouping defined in the LSP ping model.

5.2.1.1. 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;
  }
}
```

5.2.1.2. 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-location" list.

User can reuse the attributes or groupings which are defined in [[I-D.zheng-mpis-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.";
    .....
  }
}
```

5.2.2. Schema Mount

And another alternative method is using schema mount mechanism [[I-D.ietf-netmod-schema-mount](#)] in the "ietf-connectionless-oam". Within the "test-point-location" list, a "root" attribute is defined to provide a mounted point for models mounted per "test-point-location". 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.

5.2.2.1. 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>
```

6. 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/coam:location-type/coam:ipv4-
location-type/coam:test-point-ipv4-location-list/coam:test-point-
locations/
```

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



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

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

```
/nd:networks/nd:network/nd:node/coam:location-type/coam:group-  
system-id-location-type/coam:test-point-system-info-location-list/  
coam: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/coam:cc-ipv4-sessions-statistics/  
coam:cc-session-statistics/coam:session-count/
```

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

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

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

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

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

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

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


7. 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-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 [[RFC6020](#)].

name: ietf-connectionless-oam

namespace: urn:ietf:params:xml:ns:yang:ietf-connectionless-oam

prefix: coam

reference: RFC XXXX

8. Acknowledgements

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9. References

9.1. Normative References

- [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>>.

- [RFC6020] Bjorklund, M., Ed., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", [RFC 6020](#), DOI 10.17487/RFC6020, October 2010, <<https://www.rfc-editor.org/info/rfc6020>>.
- [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.
- [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>>.

9.2. Informative References

- [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-06](#) (work in progress), June 2017.

[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-15](#) (work in progress), September 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-06](#) (work in progress), August 2017.

[I-D.ietf-netmod-schema-mount]

Bjorklund, M. and L. Lhotka, "YANG Schema Mount", [draft-ietf-netmod-schema-mount-06](#) (work in progress), July 2017.

[I-D.ietf-spring-sr-yang]

Litkowski, S., Qu, Y., Sarkar, P., and J. Tantsura, "YANG Data Model for Segment Routing", [draft-ietf-spring-sr-yang-07](#) (work in progress), July 2017.

[I-D.zheng-mpls-lsp-ping-yang-cfg]

Zheng, L., Aldrin, S., Zheng, G., Mirsky, G., and R. Rahman, "Yang Data Model for LSP-PING", [draft-zheng-mpls-lsp-ping-yang-cfg-05](#) (work in progress), June 2017.

[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>>.

Authors' Addresses

Deepak Kumar
CISCO Systems
510 McCarthy Blvd
Milpitas, CA 95035
USA

Email: dekumar@cisco.com

Michael Wang
Huawei Technologies, Co., Ltd
101 Software Avenue, Yuhua District
Nanjing 210012
China

Email: wangzitao@huawei.com

Qin Wu
Huawei
101 Software Avenue, Yuhua District
Nanjing, Jiangsu 210012
China

Email: bill.wu@huawei.com

Reshad Rahman
Cisco Systems
2000 Innovation Drive
Kanata, Ontario K2K 3E8
Canada

Email: rrahman@cisco.com

Srihari Raghavan
Cisco Systems
Tril Infopark Sez, Ramanujan IT City
Neville Block, 2nd floor, Old Mahabalipuram Road
Chennai, Tamil Nadu 600113
India

Email: srihari@cisco.com