

Network Working Group  
Internet-Draft  
Intended status: Standards Track  
Expires: August 27, 2017

D. Kumar  
Cisco  
M. Wang  
Q. Wu  
Huawei  
R. Rahman  
S. Raghavan  
Cisco  
February 23, 2017

Generic YANG Data Model for Connectionless Operations, Administration,  
and Maintenance(OAM) protocols  
draft-ietf-lime-yang-connectionless-oam-04

#### 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).

#### Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <http://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on August 27, 2017.

#### Copyright Notice

Copyright (c) 2017 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<http://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

## Table of Contents

1.	Introduction	2
2.	Conventions used in this document	3
2.1.	Terminology	4
2.2.	Tree Diagrams	4
3.	Overview of the Connectionless OAM Model	5
3.1.	TP Address	5
3.2.	Tools	6
3.3.	OAM-layers	6
3.4.	Test Point Locations Information	7
3.5.	Test Point Locations	7
3.6.	Path Discovery Data	7
3.7.	Continuity Check Data	8
3.8.	OAM data hierarchy	8
4.	OAM YANG Module	17
5.	Connectionless model applicability	47
5.1.	BFD Extension	47
5.1.1.	Augment Method	47
5.1.2.	Schema Mount	50
5.2.	LSP ping extension	52
5.2.1.	Technology type extension	52
5.2.2.	Test point attributes extension	53
6.	Security Considerations	53
7.	IANA Considerations	55
8.	Acknowledgements	55
9.	References	55
9.1.	Normative References	55
9.2.	Informative References	57
	Authors' Addresses	58

## 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-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 key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

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, as used within the NETCONF protocol

CC - Continuity Check [RFC7276] , Continuity Checks are used to verify that a destination is reachable and therefore also referred to as reachability verification

## 2.2. Tree Diagrams

A simplified graphical representation of the data model is used in this document. The meaning of the symbols in these diagrams is as follows:

Each node is printed as:

```
<status> <flags> <name> <opts> <type>
```

<status> is one of:  
+ for current

<flags> is one of:

```
rw for configuration data  
ro for non-configuration data  
-x for rpcs  
-n for notifications
```

<name> is the name of the node

If the node is augmented into the tree from another module, its name is printed as <prefix>:<name>.

<opts> is one of:

- ? for an optional leaf or choice
- ! for a presence container
- \* for a leaf-list or list
- [<keys>] for a list's keys

<type> is the name of the type for leafs and leaf-lists

### 3. Overview of the Connectionless OAM Model

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 applicable for proactive OAM sessions. Multiple 'test-point-locations' keyed using technology specific keys (eg., IPv4 address for IPv4 locations) are possible by augmented 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' is chosen based on 'location-type' which when chosen, leads to a container that includes a list of 'test-point-locations' keyed by technology specific keys. Each test point location includes a 'test-point-location-info'. The 'test-point-location-info' includes 'tp-technology', 'tp-tools', and 'connectionless-oam-layers'. The groupings of 'tp-address' and 'tp-address-vrf' are kept out of 'test-point-location-info' to make it addressing agnostic and allow varied composition. Depending upon the choice of the 'location-type' (determined by the 'tp-address-vrf'), 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 vrf is used to describe the corresponding network instance. The 'tp-technology' indicate OAM technology details. The 'tp-tools' describe the OAM tools supported. The 'connectionless-oam-layers' is used to describe the relationship of one test point with other test points. The level in 'oam-layers' indicate whether related OAM test point is in client layer(lower layer described in section 3.3), server layer (upper layer described in section 3.3) or the same layer as the current test point under Test point Locations. The model is augmented to "/nd:networks/nd:network/nd:node" using 'test-point-locations' defined below.

#### 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' needs to be associated with additional parameters, e.g. DSCP for IP or TC 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 on-demand OAM refers to OAM actions which are initiated via manual intervention for a limited time to carry out diagnostics [RFC7276] [G.8013]. In connectionless OAM, 'session-type' 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" should be set to "true", and then the lime base model should be augmented with ICMP PING specific details.

### 3.3. OAM-layers

As typical networks have a multi-layer architecture, the set of OAM protocols similarly take a multi-layer structure; each layer may have its own OAM protocol [RFC7276] and is corresponding to specific network portion or path and has associated test points. OAM-layers is referred to a list of upper layer, lower layer that are related to current test point. This allows users to easily navigate up and down to efficiently troubleshoot a "loss of continuity defect" at different layer. In this model, we have kept level default as 0, when all test points are located at the same layer. 'Level' defines the relative technology level in a sequence of network portions, and is provided to allow correlation of faults in related OAM domains. For example, there is a network in which data traffic between two customer edges is transported over three consecutive network portions, the current test point is located in the second network portion. If there is a defect in the first network portion is

located at the upstream of the second network portion, the level of the first network portion is set to "-1". If the third network portion is located at the downstream of the second network portion and the level is set to "1". In another case, if the first network portion and the third network portion is in the same level of the second network portion, the level is set to "0". The snippet below depicts an example of OAM layers.

```
list oam-layers {
  key "index";
  leaf index {
    type uint16 {
      range "0..65535";
    }
  }
  leaf level {
    type int32 {
      range "-1..1";
    }
    description
      "Level";
  }
  ordered-by user;
  description
    "List of related oam layers.";
}
```

#### 3.4. Test Point Locations Information

This is a generic grouping for Test Point Locations Information. It Provide details of Test Point Location using Tools, 'OAM-Layers' grouping defined above.

#### 3.5. Test Point Locations

This is a generic grouping for Test Point Locations. Choice statement 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 routing instance VRF 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 RPCs. Path discovery data output from methods, includes 'src-test-point', 'dst-test-point', 'sequence-number', 'hop-cnt', 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' which includes information like 'timestamps', 'ingress-interface', 'egress-interface' 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 RPCs. Continuity check data output from methods, includes 'src-test-point', 'dst-test-point', 'sequence-number', 'hop-cnt' 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-oper-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-value?         identityref
    +--rw (location-type)?
      +--:(ipv4-location-type)
        +--rw test-point-ipv4-location-list
          +--rw test-point-locations* [ipv4-location]
            +--rw ipv4-location          inet:ipv4-address
            +--rw vrf?                   routing-instance-ref

```



```

+--rw (technology)?
|   +---:(technology-null)
|   |   +--rw tech-null?          empty
|   +---:(technology-string)
|   |   +--rw ipv4-icmp?          string
+--rw tp-tools
|   +--rw connectivity-verification?  boolean
|   +--rw continuity-check?          boolean
|   +--rw path-discovery?            boolean
+--rw root?
+--rw oam-layers* [index]
|   +--rw index                      uint16
|   +--rw level?                      int32
|   +--rw (tp-location)?
|   |   +---:(mac-address)
|   |   |   +--rw mac-address-location? yang:mac-address
|   |   +---:(ipv4-address)
|   |   |   +--rw ipv4-location?        inet:ipv4-address
|   |   +---:(ipv6-location)
|   |   |   +--rw ipv6-address          inet:ipv6-address
|   |   +---:(tunnel-location)
|   |   |   +--rw tunnel-location?      uint32
|   |   +---:(ip-prefix-location)
|   |   |   +--rw ip-prefix-location?   inet:ip-prefix
|   |   +---:(route-dist-location)
|   |   |   +--rw route-dist-location?  uint32
|   |   +---:(group-ip-address-location)
|   |   |   +--rw group-ip-address-location? IP-Multicast
|   |   |   |   -Group-Address
|   |   +---:(as-number-location)
|   |   |   +--rw as-number-location     inet:as-number
|   |   +---:(lsp-id-location)
|   |   |   +--rw lsp-id-location?      string
|   |   +---:(system-id-location)
|   |   |   +--rw system-id-location?    router-id
+---:(ipv6-location-type)
+--rw test-point-ipv6-location-list
|   +--rw test-point-locations* [ipv6-location]
|   |   +--rw ipv6-location            inet:ipv6-address
|   |   +--rw vrf?                     routing-instance-ref
|   +--rw (technology)?
|   |   +---:(technology-null)
|   |   |   +--rw tech-null?          empty
|   |   +---:(technology-string)
|   |   |   +--rw ipv4-icmp?          string
+--rw tp-tools
|   +--rw connectivity-verification?  boolean
|   +--rw continuity-check?          boolean

```

```

|   +--rw path-discovery?           boolean
+--rw root?
+--rw oam-layers* [index]
  +--rw index                       uint16
  +--rw level?                      int32
  +--rw (tp-location)?
    +--:(mac-address)
      | +--rw mac-address-location? yang:mac-address
    +--:(ipv4-address)
      | +--rw ipv4-location?       inet:ipv4-address
    +--:(ipv6-location)
      | +--rw ipv6-address?       inet:ipv6-address
    +--:(tunnel-location)
      | +--rw tunnel-location?    uint32
    +--:(ip-prefix-location)
      | +--rw ip-prefix-location? inet:ip-prefix
    +--:(route-dist-location)
      | +--rw route-dist-location? uint32
    +--:(group-ip-address-location)
      | +--rw group-ip-address-location? IP-Multicast
                                           -Group-Address
    +--:(as-number-location)
      | +--rw as-number-location?  inet:as-number
    +--:(lsp-id-location)
      | +--rw lsp-id-location?     string
    +--:(system-id-location)
      +--rw system-id-location?    router-id
+--:(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
      | +--:(technology-string)
      | | +--rw ipv4-icmp?         string
    +--rw tp-tools
      | +--rw connectivity-verification? boolean
      | +--rw continuity-check?     boolean
      | +--rw path-discovery?       boolean
    +--rw root?
    +--rw oam-layers* [index]
      +--rw index                   uint16
      +--rw level?                  int32
      +--rw (tp-location)?
        +--:(mac-address)
          | +--rw mac-address-location? yang:mac-address
        +--:(ipv4-address)

```

```

|         |  +--rw ipv4-location?          inet:ipv4-address
|         +---:(ipv6-location)
|         |  +--rw ipv6-address?        inet:ipv6-address
|         +---:(tunnel-location)
|         |  +--rw tunnel-location?     uint32
|         +---:(ip-prefix-location)
|         |  +--rw ip-prefix-location   inet:ip-prefix
|         +---:(route-dist-location)
|         |  +--rw route-dist-location? uint32
|         +---:(group-ip-address-location)
|         |  +--rw group-ip-address-location? IP-Multicast
|         |                                     -Group-Address
|         +---:(as-number-location)
|         |  +--rw as-number-location?   inet:as-number
|         +---:(lsp-id-location)
|         |  +--rw lsp-id-location?     string
|         +---:(system-id-location)
|         |  +--rw system-id-location?   router-id
+---:(tunnel-location-type)
+--rw test-point-tunnel-location-list
+--rw test-point-locations* [tunnel-location]
+--rw tunnel-location      uint32
+--rw vrf?                 routing-instance-ref
+--rw (technology)?
|  +---:(technology-null)
|  |  +--rw tech-null?      empty
|  +---:(technology-string)
|  |  +--rw ipv4-icmp?     string
+--rw tp-tools
|  +--rw connectivity-verification? boolean
|  +--rw continuity-check?         boolean
|  +--rw path-discovery?           boolean
+--rw root?
+--rw oam-layers* [index]
+--rw index          uint16
+--rw level?        int32
+--rw (tp-location)?
+---:(mac-address)
|  +--rw mac-address-location? yang:mac-address
+---:(ipv4-address)
|  +--rw ipv4-location?       inet:ipv4-address
+---:(ipv6-location)
|  +--rw ipv6-address?       inet:ipv6-address
+---:(tunnel-location)
|  +--rw tunnel-location?    uint32
+---:(ip-prefix-location)
|  +--rw ip-prefix-location   inet:ip-prefix
+---:(route-dist-location)

```

```

|         | +--rw route-dist-location?  uint32
|         +---:(group-ip-address-location)
|         | +--rw group-ip-address-location?  IP-Multicast
|         |                                     -Group-Address
|         +---:(as-number-location)
|         | +--rw as-number-location?        inet:as-number
|         +---:(lsp-id-location)
|         | +--rw lsp-id-location?          string
|         +---:(system-id-location)
|         | +--rw system-id-location?       router-id
+---:(ip-prefix-location-type)
+--rw test-point-ip-prefix-location-list
+--rw test-point-locations* [ip-prefix-location]
+--rw ip-prefix-location    inet:ip-prefix
+--rw vrf?                  routing-instance-ref
+--rw (technology)?
| +---:(technology-null)
| | +--rw tech-null?        empty
| +---:(technology-string)
| | +--rw ipv4-icmp?        string
+--rw tp-tools
| +--rw connectivity-verification?  boolean
| +--rw continuity-check?           boolean
| +--rw path-discovery?             boolean
+--rw root?
+--rw oam-layers* [index]
+--rw index                uint16
+--rw level?               int32
+--rw (tp-location)?
+---:(mac-address)
| +--rw mac-address-location?  yang:mac-address
+---:(ipv4-address)
| +--rw ipv4-location          inet:ipv4-address
+---:(ipv6-location)
| +--rw ipv6-address?         inet:ipv6-address
+---:(tunnel-location)
| +--rw tunnel-location?      uint32
+---:(ip-prefix-location)
| +--rw ip-prefix-location?    inet:ip-prefix
+---:(route-dist-location)
| +--rw route-dist-location?   uint32
+---:(group-ip-address-location)
| +--rw group-ip-address-location?  IP-Multicast
|                                     -Group-Address
+---:(as-number-location)
| +--rw as-number-location?     inet:as-number
+---:(lsp-id-location)
| +--rw lsp-id-location?        string

```

```

|           +---:(system-id-location)
|             +---rw system-id-location?           router-id
+---:(route-distinguisher-location-type)
|   +---rw test-point-route-dist-location-list
|     +---rw test-point-locations* [route-dist-location]
|       +---rw route-dist-location      uint32
|       +---rw vrf?                      routing-instance-ref
|       +---rw (technology)?
|         +---:(technology-null)
|         | +---rw tech-null?             empty
|         +---:(technology-string)
|         | +---rw ipv4-icmp?            string
+---rw tp-tools
|   +---rw connectivity-verification?    boolean
|   +---rw continuity-check?             boolean
|   +---rw path-discovery?               boolean
+---rw root?
+---rw oam-layers* [index]
|   +---rw index                          uint16
|   +---rw level?                          int32
|   +---rw (tp-location)?
|     +---:(mac-address)
|     | +---rw mac-address-location?    yang:mac-address
|     +---:(ipv4-address)
|     | +---rw ipv4-location             inet:ipv4-address
|     +---:(ipv6-location)
|     | +---rw ipv6-address              inet:ipv6-address
|     +---:(tunnel-location)
|     | +---rw tunnel-location?         uint32
|     +---:(ip-prefix-location)
|     | +---rw ip-prefix-location?      inet:ip-prefix
|     +---:(route-dist-location)
|     | +---rw route-dist-location?     uint32
|     +---:(group-ip-address-location)
|     | +---rw group-ip-address-location? IP-Multicast
|     |                                     -Group-Address
|     +---:(as-number-location)
|     | +---rw as-number-location?      inet:as-number
|     +---:(lsp-id-location)
|     | +---rw lsp-id-location?         string
|     +---:(system-id-location)
|     | +---rw system-id-location?      router-id
+---:(group-ip-address-location-type)
|   +---rw test-point-group-ip-address-location-list
|     +---rw test-point-locations* [group-ip-address-location]
|     | +---rw group-ip-address-location IP-Multicast
|     |                                     -Group-Address
|     +---rw vrf?                        routing-instance-ref

```

```

+--rw (technology)?
|   +---:(technology-null)
|   |   +--rw tech-null?           empty
|   +---:(technology-string)
|   |   +--rw ipv4-icmp?           string
+--rw tp-tools
|   +--rw connectivity-verification? boolean
|   +--rw continuity-check?        boolean
|   +--rw path-discovery?          boolean
+--rw root?
+--rw oam-layers* [index]
|   +--rw index                     uint16
|   +--rw level?                    int32
|   +--rw (tp-location)?
|   |   +---:(mac-address)
|   |   |   +--rw mac-address-location? yang:mac-address
|   |   +---:(ipv4-address)
|   |   |   +--rw ipv4-location?        inet:ipv4-address
|   |   +---:(ipv6-location)
|   |   |   +--rw ipv6-address?        inet:ipv6-address
|   |   +---:(tunnel-location)
|   |   |   +--rw tunnel-location?      uint32
|   |   +---:(ip-prefix-location)
|   |   |   +--rw ip-prefix-location?   inet:ip-prefix
|   |   +---:(route-dist-location)
|   |   |   +--rw route-dist-location?  uint32
|   |   +---:(group-ip-address-location)
|   |   |   +--rw group-ip-address-location? IP-Multicast
|   |   |   |   -Group-Address
|   |   +---:(as-number-location)
|   |   |   +--rw as-number-location?   inet:as-number
|   |   +---:(lsp-id-location)
|   |   |   +--rw lsp-id-location?      string
|   |   +---:(system-id-location)
|   |   |   +--rw system-id-location?   router-id
+---:(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 vrf?                     routing-instance-ref
|   +--rw (technology)?
|   |   +---:(technology-null)
|   |   |   +--rw tech-null?           empty
|   |   +---:(technology-string)
|   |   |   +--rw ipv4-icmp?           string
+--rw tp-tools
|   +--rw connectivity-verification? boolean
|   +--rw continuity-check?           boolean

```

```

|   +--rw path-discovery?           boolean
+--rw root?
+--rw oam-layers* [index]
  +--rw index                       uint16
  +--rw level?                      int32
  +--rw (tp-location)?
    +--:(mac-address)
      |   +--rw mac-address-location? yang:mac-address
    +--:(ipv4-address)
      |   +--rw ipv4-location?       inet:ipv4-address
    +--:(ipv6-location)
      |   +--rw ipv6-address?       inet:ipv6-address
    +--:(tunnel-location)
      |   +--rw tunnel-location     uint32
    +--:(ip-prefix-location)
      |   +--rw ip-prefix-location? inet:ip-prefix
    +--:(route-dist-location)
      |   +--rw route-dist-location? uint32
    +--:(group-ip-address-location)
      |   +--rw group-ip-address-location? IP-Multicast
      |                                       -Group-Address
    +--:(as-number-location)
      |   +--rw as-number-location?  inet:as-number
    +--:(lsp-id-location)
      |   +--rw lsp-id-location?     string
    +--:(system-id-location)
      |   +--rw system-id-location?  router-id
+--:(group-lsp-id-location-type)
  +--rw test-point-lsp-id-location-list
    +--rw test-point-locations* [lsp-id-location]
      +--rw lsp-id-location         string
      +--rw vrf?                   routing-instance-ref
      +--rw (technology)?
        |   +--:(technology-null)
        |   |   +--rw tech-null?     empty
        |   +--:(technology-string)
        |   |   +--rw ipv4-icmp?     string
      +--rw tp-tools
        |   +--rw connectivity-verification? boolean
        |   +--rw continuity-check?     boolean
        |   +--rw path-discovery?      boolean
      +--rw root?
    +--rw oam-layers* [index]
      +--rw index                   uint16
      +--rw level?                  int32
      +--rw (tp-location)?
        +--:(mac-address)
          |   +--rw mac-address-location? yang:mac-address

```

```

|         +---:(ipv4-address)
|         |   +--rw ipv4-location           inet:ipv4-address
+---:(ipv6-location)
|         |   +--rw ipv6-address?         inet:ipv6-address
+---:(tunnel-location)
|         |   +--rw tunnel-location?      uint32
+---:(ip-prefix-location)
|         |   +--rw ip-prefix-location?   inet:ip-prefix
+---:(route-dist-location)
|         |   +--rw route-dist-location?  uint32
+---:(group-ip-address-location)
|         |   +--rw group-ip-address-location?  IP-Multicast
|                                         -Group-Address
+---:(as-number-location)
|         |   +--rw as-number-location?    inet:as-number
+---:(lsp-id-location)
|         |   +--rw lsp-id-location?       string
+---:(system-id-location)
|         |   +--rw system-id-location?    router-id
+---:(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 vrf?                    routing-instance-ref
+--rw (technology)?
|   +---:(technology-null)
|   |   +--rw tech-null?          empty
|   +---:(technology-string)
|   |   +--rw ipv4-icmp?          string
+--rw tp-tools
|   +--rw connectivity-verification?  boolean
|   +--rw continuity-check?           boolean
|   +--rw path-discovery?             boolean
+--rw root?
+--rw oam-layers* [index]
+--rw index                       uint16
+--rw level?                       int32
+--rw (tp-location)?
+---:(mac-address)
|   +--rw mac-address-location?  yang:mac-address
+---:(ipv4-address)
|   +--rw ipv4-location?         inet:ipv4-address
+---:(ipv6-location)
|   +--rw ipv6-address?         inet:ipv6-address
+---:(tunnel-location)
|   +--rw tunnel-location?      uint32
+---:(ip-prefix-location)
|   +--rw ip-prefix-location     inet:ip-prefix

```



```

+--:(route-dist-location)
|  +--rw route-dist-location?          uint32
+--:(group-ip-address-location)
|  +--rw group-ip-address-location?    IP-Multicast
                                         -Group-Address
+--:(as-number-location)
|  +--rw as-number-location?           inet:as-number
+--:(lsp-id-location)
|  +--rw lsp-id-location?              string
+--:(system-id-location)
   +--rw system-id-location?           router-id

```

data hierarchy of OAM

#### 4. OAM YANG Module

```
<CODE BEGINS> file "ietf-connectionless-oam.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";
  }

  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.
Functional level abstraction is independent with
YANG modeling. 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 2017-02-08 {
  description
    "Initial revision. - 10 version";
  reference "";
}
/* features */
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 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 model for
path discovery command.";
}

/* Identities */
/* typedefs */

  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 leaves that reference a routing instance
    configuration.";
}

typedef IPv4-Multicast-Group-Address {
  type string {
    pattern '(2((2[4-9])|(3[0-9]))\.)'
    +'([0-9]|[1-9][0-9]|1[0-9][0-9]|'
    +'2[0-4][0-9]|25[0-5])\.){2}'
    +'([0-9]|[1-9][0-9]|1[0-9][0-9]'
    +'|2[0-4][0-9]|25[0-5])';
  }
  description
    "The IPv4-Multicast-Group-Address type
    represents an IPv4 multicast address
    in dotted-quad notation.";
  reference "RFC4607";
} // typedef IPv4-Multicast-Group-Address
typedef IPv6-Multicast-Group-Address {
  type string {
    pattern
      '((FF|ff)[0-9a-fA-F]{2}):([0-9a-fA-F]'
      +'{0,4}):{0,5}((([0-9a-fA-F]{0,4}):)?'
      +'(:|[0-9a-fA-F]{0,4}))|(((25[0-5]|2[0-4]'
      +'[0-9]|01)?[0-9]?[0-9])\.){3}(25[0-5]|'
      +'2[0-4][0-9]|01)?[0-9]?[0-9]))';
    pattern
      '(([^:]+:){6}([[:^:]]+:[[:^:]]+)|'
      +'(.*\.\.*))|([[:^:]]+:[[:^:]]+)'
      +'?::([[:^:]]+:[[:^:]]+)?';
  }
  description
    "The IPv6-Multicast-Group-Address
    type represents an IPv6 address in full,
    mixed, shortened, and shortened-mixed

```

```
        notation.";
        reference "RFC4291 2.7.
        ietf-inet-types:ipv6-address";
    }
    typedef IP-Multicast-Group-Address {
        type union {
            type IPv4-Multicast-Group-Address;
            type IPv6-Multicast-Group-Address;
        }
        description
            "The IP-Multicast-Group-Address type
            represents an IP multicast address and
            is IP version neutral. The format of the
            textual representations implies the IP version.";
    }

    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.";
    }

    typedef opaque-tlv-type {
        type identityref {
            base opaque-tlv-type-id;
        }
        description
            "Opaque TLV type definition.";
    }

    identity time-resolution{
        description
            "Time interval resolution";
    }

    identity hours {
        base time-resolution;
        description
```

```
    "Hours";
  }

  identity minutes {
    base time-resolution;
    description
      "Minutes";
  }

  identity seconds {
    base time-resolution;
    description
      "Seconds";
  }

  identity milliseconds {
    base time-resolution;
    description
      "Milliseconds";
  }

  identity microseconds {
    base time-resolution;
    description
      "Microseconds";
  }

  identity nanoseconds {
    base time-resolution;
    description
      "Nanoseconds";
  }

  identity opaque-tlv-type-id {
    description
      "Base identity for opaque tlv types.";
  }

  identity default-tlv-type-id {
    base opaque-tlv-type-id;
    description
      "Default or unknown TLV type id.";
  }

  /* groupings */
  grouping cc-session-statistics {
    description "Grouping for session statistics.";
    container cc-session-statistics {
```

```
description "cc session counters";
leaf session-count {
    type uint32;
    description
        "Number of cc sessions.";
}
leaf session-up-count {
    type uint32;
    description
        "Number of sessions which are up.";
}
leaf session-down-count {
    type uint32;
    description
        "Number of sessions which are down.";
}
leaf session-admin-down-count {
    type uint32;
    description
        "Number of sessions which are admin-down.";
}
}
}

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;
            description
                "Total number of received OAM packet count.";
        }
        leaf tx-packet-count {
            type uint32;
            description
                "Total number of transmitted OAM packet count.";
        }
        leaf rx-bad-packet {
            type uint32;
            description
                "Total number of received bad OAM packet.";
        }
        leaf tx-packet-failed {
            type uint32;
            description
                "Total number of send OAM packet failed.";
        }
    }
}
```

```
    }
  }
}

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;
      description
        "Total down count.";
    }
    leaf admin-down-count {
      type uint32;
      description
        "Total down count.";
    }
  }
  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;
      description
        "Total received packet drops count.";
    }
  }
}
```

```
    leaf packet-reorder-count {
        type uint32;
        description
            "Total received packet reordered count.";
    }
    leaf packets-out-of-seq-count {
        type uint32;
        description
            "Total received out of sequence count.";
    }
    leaf packets-dup-count {
        type uint32;
        description
            "Total received packet duplicates count.";
    }
}

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;
            }
            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;
        }
        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.";
      }
      leaf failed-count {
        type uint32;
      }
    }
  }
}
```

```
        description
            "Total number of OAM packets that
            went through an unintended path.";
    }
}

grouping session-type {
    description
        "This object indicates the current session
        definition.";
    leaf session-type-enum {
        type enumeration {
            enum proactive {
                description
                    "The current session is proactive";
            }
            enum on-demand {
                description
                    "The current session is on-demand.";
            }
        }
        default "on-demand";
        description
            "Session type enum";
    }
}

grouping opaque-info-tlv {
    description
        "Opaque information as a TLV.";
    leaf type {
        type opaque-tlv-type;
        description "TLV type.";
    }
    leaf length {
        type uint16;
        description "TLV length.";
    }
    leaf value {
        type yang:hex-string;
        description "TLV value.";
    }
}

grouping opaque-tlvs {
    description
        "Opaque TLVs.";
    container opaque-tlvs {
```

```
    description
      "Opaque TLVs container.";
    list opaque-tlvs-list {
      description
        "Opaque TLVs list.";
      uses opaque-info-tlv;
    }
  }
}
identity tp-address-type {
  description
    "Test point address type";
}

identity mac-address-type {
  base tp-address-type;
  description
    "MAC address type";
}

identity ipv4-address-type {
  base tp-address-type;
  description
    "IPv4 address type";
}

identity ipv6-address-type {
  base tp-address-type;
  description
    "IPv6 address type";
}

identity tp-attribute-type {
  base tp-address-type;
  description
    "Test point attribute type";
}

identity system-id-address-type {
  base tp-address-type;
  description
    "System id address type";
}

identity lsp-id-address-type {
  base tp-address-type;
  description
```

```
    "LSP ID address type";
  }

  identity as-number-address-type {
    base tp-address-type;
    description
      "AS number address type";
  }

  identity group-ip-address-type {
    base tp-address-type;
    description
      "Group IP address type";
  }

  identity route-distinguisher-address-type {
    base tp-address-type;
    description
      "Route Distinguisher address type";
  }

  identity ip-prefix-address-type {
    base tp-address-type;
    description
      "IP prefix address type";
  }

  identity tunnel-address-type {
    base tp-address-type;
    description
      "Tunnel address type";
  }

  grouping tp-address {
    leaf tp-location-type-value {
      type identityref {
        base tp-address-type;
      }
      description "Test point address type.";
    }
  }

  choice tp-address {
    case mac-address {
      when "'tp-location-type-value' = 'mac-address-type'" {
        description "MAC address type";
      }
      leaf mac-address {

```

```
        type yang:mac-address;
        description
          "MAC Address";
      }
      description
        "MAC Address based MP Addressing.";
    }
    case ipv4-address {
      when "'tp-location-type-value' = 'ipv4-address-type'" {
        description "IPv4 address type";
      }
      leaf ipv4-address {
        type inet:ipv4-address;
        description
          "IPv4 Address";
      }
      description
        "IP Address based MP Addressing.";
    }
    case ipv6-address {
      when "'tp-location-type-value' = 'ipv6-address-type'" {
        description "IPv6 address type";
      }
      leaf ipv6-address {
        type inet:ipv6-address;
        description
          "IPv6 Address";
      }
      description
        "ipv6 Address based MP Addressing.";
    }

    case tp-attribute {
      when "'tp-location-type-value' = '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.";
    }
  }
  case vpls {
    leaf route-distinguisher {
      type uint32;
      description
        "Route Distinguisher(8 octets).";
    }
    leaf sender-ve-id{
      type uint32;
      description
        "Sender's VE ID.";
    }
    leaf receiver-ve-id{
      type uint32;
      description
        "Receiver's VE ID.";
    }
  }
}
```

```

    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 IP-Multicast-Group-Address;
            description
              "Group ip address.";
          }
        }
        case vpn{
          leaf as-number{
            type inet:as-number;
            description
              "AS number.";
          }
        }
        case global-id{
          leaf lsp-id{
            type string;
            description
              "LSP id.";
          }
        }
      }
    }
  }
}

case system-info {
  when "'tp-location-type-value' = 'system-id-address-type'" {
    description "System id address type";
  }
  leaf system-id {
    type router-id;
    description
      "System ID assigned to this node.";
  }
}
description
  "TP Addressing.";

```

```
    }
    description
    "TP Address";
  }

  grouping tp-address-vrf {
    description
    "Test point address with VRF.";
    leaf vrf {
      type routing-instance-ref;
      description
      "The vrf is used to describe the
      corresponding network instance";
    }
  }

  uses tp-address;
}

grouping connectionless-oam-layers {
  list oam-layers {
    key "index";
    leaf index {
      type uint16 {
        range "0..65535";
      }
      description
      "Index";
    }
    leaf level {
      type int32 {
        range "-1..1";
      }
      default 0;
      description
      "Level 0 indicates default level,
      -1 means server and +1 means client 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-location {
      type inet:ipv4-address;
      description
        "Ipv4 Address";
    }
    description
      "IP Address based MP Addressing.";
  }
  case ipv6-location {
    leaf ipv6-address {
      type inet:ipv6-address;
      description
        "IPv6 Address";
    }
    description
      "IPv6 Address based MP Addressing.";
  }
}

case tunnel-location{
  leaf tunnel-location{
    type uint32;
    description
      "VPN Prefix";
  }
  description
    "Tunnel location";
}

case ip-prefix-location{
  leaf ip-prefix-location{
    type inet:ip-prefix;
    description
      "IP prefix location";
  }
  description
    "IP prefix location";
}

case route-dist-location{
  leaf route-dist-location{
    type uint32;
    description
      "Route Distinguisher (8 octets)";
  }
  description
    "Route distinguisher location";
}
```

```
    }  
    case group-ip-address-location{  
      leaf group-ip-address-location{  
        type IP-Multicast-Group-Address;  
        description  
          "Group IP address location";  
      }  
      description  
        "Group IP address";  
    }  
    case as-number-location{  
      leaf as-number-location{  
        type inet:as-number;  
        description  
          "AS number location";  
      }  
      description  
        "AS number";  
    }  
    case lsp-id-location{  
      leaf lsp-id-location{  
        type string;  
        description  
          "LSP id";  
      }  
      description  
        "LSP ID";  
    }  
    case system-id-location{  
      leaf system-id-location{  
        type router-id;  
        description  
          "System id location";  
      }  
      description  
        "System ID";  
    }  
    description  
      "TP location.";  
  }  
  ordered-by user;  
  description
```

```

    "List of related oam layers.
      0 means they are in same level, especially
      interworking scenarios of stitching multiple
      technology at same layer. -1 means server layer,
      for eg:- in case of Overlay and Underlay,
      Underlay is server layer for Overlay Test Point.
      +1 means client layer, for eg:- in case of
      Service OAM and Transport OAM, Service OAM is client
      layer to Transport OAM.";
  }
  description
    "Connectionless related OAM 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 null";
  case technology-string {
    description
      "OAM technology string";
    leaf ipv4-icmp {
      type string;
      description
        "Name to identify oam technology";
    }
  }
}

description
  "OAM Technology";
}

grouping tp-tools {
  description
    "Test Point OAM Toolset.";
  container tp-tools{
    leaf connectivity-verification{

```

```
    type boolean;
    description
      "A flag indicating whether or not the
      connectivity-verification 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 5085: Pseudowire Virtual Circuit Connectivity Verification

      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 4379: LSP-PING.";
  }
  leaf continuity-check{
    type boolean;
    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;
    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-value {
      type identityref {
        base tp-address-type;
      }
      description "Test point location type.";
    }
  }
  choice location-type {
    case ipv4-location-type {
      when "'tp-location-type-value' = '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";
          leaf ipv4-location {
            type inet:ipv4-address;
            description
              "IPv4 Address.";
          }
          leaf vrf {
            type routing-instance-ref;
            description
              "The vrf is used to describe the
              corresponding network instance";
          }
        }
      }
    }
  }
}
```

```
        uses test-point-location-info;

        ordered-by user;
        description
            "List of test point locations.";
    }
    description
        "Serves as top-level container
         for test point location list.";
}
}
case ipv6-location-type {
    when "'tp-location-type-value' = '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";
            leaf ipv6-location {
                type inet:ipv6-address;
                description
                    "IPv6 Address.";
            }
            leaf vrf {
                type routing-instance-ref;
                description
                    "The vrf is used to describe the
                     corresponding network instance";
            }
            uses test-point-location-info;
            ordered-by user;
            description
                "List of test point locations.";
        }
        description
            "Serves as top-level container
             for test point location list.";
    }
}
case mac-location-type {
    when "'tp-location-type-value' = '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;
    ordered-by user;
    description
      "List of test point locations.";
  }
  description
    "Serves as top-level container
     for test point location list.";
}
}
case tunnel-location-type {
  when "'tp-location-type-value' ="
    + "'tunnel-address-type'" {
    description
      "When test point location type
       is equal to tunnel type.";
  }
  container test-point-tunnel-location-list {
    list test-point-locations {
      key "tunnel-location";
      leaf tunnel-location {
        type uint32;
        description
          "VPN Prefix";
      }
    }
    leaf vrf {
      type routing-instance-ref;
      description
        "The vrf is used to describe the
         corresponding network instance";
    }
    uses test-point-location-info;
    ordered-by user;
    description
      "List of test point locations.";
  }
  description
    "Serves as top-level container
     for test point location list.";
}
}
case ip-prefix-location-type {
```

```
        when "'tp-location-type-value' = "
            + "'ip-prefix-address-type'" {
description
    "When test point location
        type is equal to ip prefix.";
    }
container test-point-ip-prefix-location-list {
    list test-point-locations {
        key "ip-prefix-location";
        leaf ip-prefix-location {
            type inet:ip-prefix;
            description
                "IP Prefix";
        }
        leaf vrf {
            type routing-instance-ref;
            description
                "The vrf is used to describe the
                    corresponding network instance";
        }
        uses test-point-location-info;
        ordered-by user;
        description
            "List of test point locations.";
    }
    description
        "Serves as top-level container
            for test point location list.";
}
}
case route-distinguisher-location-type {
    when "'tp-location-type-value' = "
        + "'route-distinguisher-address-type'" {
        description
            "When test point
                location type is equal to
                route distinguisher.";
    }
}
container test-point-route-dist-location-list {
    list test-point-locations {
        key "route-dist-location";
        leaf route-dist-location {
            type uint32;
            description
                "Route Distinguisher(8 octets).";
        }
        leaf vrf {
```



```
        type routing-instance-ref;
        description
            "The vrf is used to describe the
            corresponding network instance";
    }
    uses test-point-location-info;
    ordered-by user;
    description
        "List of test point locations.";
    }
    description
        "Serves as top-level container
        for test point location list.";
    }
}
case group-ip-address-location-type {
    when "'tp-location-type-value' = "
        + "'group-ip-address-type'" {
        description
            "When test point location type is equal to
            group ip address.";
    }
    container test-point-group-ip-address-location-list {
        list test-point-locations {
            key "group-ip-address-location";
            leaf group-ip-address-location {
                type IP-Multicast-Group-Address;
                description
                    "Group IP address.";
            }
            leaf vrf {
                type routing-instance-ref;
                description
                    "The vrf is used to describe the
                    corresponding network instance";
            }
            uses test-point-location-info;
            ordered-by user;
            description
                "List of test point locations.";
        }
        description
            "Serves as top-level container for
            test point location list.";
    }
}
case group-as-number-location-type {
```

```
when "'tp-location-type-value' = "
    + "'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.";
    }
    leaf vrf {
      type routing-instance-ref;
      description
        "The vrf is used to describe the
        corresponding network instance";
    }
    uses test-point-location-info;
    ordered-by user;
    description
      "List of test point locations.";
  }
  description
    "Serves as top-level container
    for test point location list.";
}
}
case group-lsp-id-location-type {
  when "'tp-location-type-value' = "
    + "'lsp-id-address-type'" {
    description
      "When test point location
      type is equal to lspid.";
  }
  container test-point-lsp-id-location-list {
    list test-point-locations {
      key "lsp-id-location";
      leaf lsp-id-location {
        type string;
        description
          "LSP Id.";
      }
    }
    leaf vrf {
      type routing-instance-ref;
      description

```

```

        "The vrf is used to describe the
        corresponding network instance";
    }
    uses test-point-location-info;
    ordered-by user;
    description
        "List of test point locations.";
    }
    description
        "Serves as top-level container for
        test point location list.";
    }
}
case group-system-id-location-type {
    when "'tp-location-type-value' = "
        + "'system-id-address-type'" {
        description
            "When test point location 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 vrf {
                type routing-instance-ref;
                description
                    "The vrf is used to describe the
                    corresponding network instance";
            }
            uses test-point-location-info;
            ordered-by user;
            description
                "List of test point locations.";
        }
        description
            "Serves as top-level container for
            test point location list.";
    }
}
description
    "Choice of address types.";
}
}

```

```
augment "/nd:networks/nd:network/nd:node"{
  description
    "Augment test points of connectionless oam.";
  uses test-point-locations;
}

grouping path-discovery-data {
  description
    "Path discovery related data output from nodes.";
  container src-test-point {
    description "Source test point.";
    uses tp-address-vrf;
  }
  container dest-test-point {
    description "Destination test point.";
    uses tp-address-vrf;
  }
  leaf sequence-number {
    type uint64;
    description "Sequence number in data packets.";
  }
  leaf hop-cnt {
    type uint8;
    description "Hop count.";
  }

  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 list has typically a single element for per-hop
      cases like path-discovery RPC 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-vrf;

leaf timestamp-sec {
  type uint64;
  description
    "Absolute timestamp in
    seconds as per IEEE1588v2.";
}
leaf timestamp-nanosec {
  type uint32;
  description
    "Fractional part in
    nanoseconds as per IEEE1588v2.";
}

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 egress interface
    queue of the interface.";
}
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.";
    }
    uses opaque-tlvs;
  }
}

grouping continuity-check-data {
  description
    "Continuity check data output from nodes.";
  container src-test-point {
    description "Source test point.";
    uses tp-address-vrf;

    leaf egress-intf-name {
      type if:interface-ref;
      description
        "Egress interface name";
    }
  }
  container dest-test-point {
    description
      "Destination test point.";
    uses tp-address-vrf;

    leaf ingress-intf-name {
      type if:interface-ref;
      description
        "Ingress interface name";
    }
  }
  leaf sequence-number {
    type uint64;
    description "Sequence number.";
  }
  leaf hop-cnt {
    type uint8;
    description "Hop count.";
  }

  uses session-packet-statistics;
}
```

```
    uses session-error-statistics;
    uses session-delay-statistics;
    uses session-jitter-statistics;
  }

  container cc-oper-data {
    if-feature continuity-check;
    config "false";
    description "CC operational information.";
    container cc-ipv4-sessions-statistics {
      description "CC ipv4 sessions";
      uses cc-session-statsitics;
    }
    container cc-ipv6-sessions-statistics {
      description "CC ipv6 sessions";
      uses cc-session-statsitics;
    }
  }
}
```

<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"
+"/coam:technology-string"
{
  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> 1.1.1.1</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

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.draft-zheng-mpls-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. 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"
+ "/coam:technology-string"
{
  leaf lsp-ping {
    type string;
  }
}

```

### 5.2.2. 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.draft-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. Security Considerations

The YANG module defined in this memo is designed to be accessed via the NETCONF protocol [RFC6241]. The lowest NETCONF layer is the secure transport layer and the mandatory-to-implement secure transport is SSH [RFC6242]. The NETCONF access control model [RFC6536] provides the means to restrict access for particular NETCONF users to a pre-configured subset of all available NETCONF protocol operations and content.

There are a number of data nodes defined in the YANG module which 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:tunnel-  
location-type/coam:test-point-tunnel-address-location-list/coam:test-  
point-locations/
```

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

```
/nd:networks/nd:network/nd:node/coam:location-type/coam:route-  
distinguisher-location-type/coam:test-point-route-dist-location-list/  
coam:test-point-locations/
```

```
/nd:networks/nd:network/nd:node/coam:location-type/coam:group-ip-  
address-location-type/coam:test-point-group-ip-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-lsp-id-  
location-type/coam:test-point-lsp-id-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.

## 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

The authors of this document would like to thank Greg Mirsky and others for their sustainable review and comments, proposals to improve and stabilize document.

## 9. References

### 9.1. Normative References

[I-D.draft-zheng-mpls-lsp-ping-yang-cfg]  
Zheng, L., Aldrin, S., Zheng, G., Mirsky, G., and R.  
Rahman, "Yang Data Model for LSP-PING", I-D draft-zheng-  
mpls-lsp-ping-yang-cfg, March 2016.

- [I-D.ietf-bfd-yang]  
Zheng, L., Rahman, R., Networks, J., Jethanandani, M., and G. Mirsky, "Yang Data Model for Bidirectional Forwarding Detection (BFD)", draft-ietf-bfd-yang-04 (work in progress), January 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-11 (work in progress), February 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-00 (work in progress), October 2016.
- [I-D.ietf-lime-yang-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-oam-model-08 (work in progress), December 2016.
- [I-D.ietf-netmod-schema-mount]  
Bjorklund, M. and L. Lhotka, "YANG Schema Mount", draft-ietf-netmod-schema-mount-03 (work in progress), October 2016.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<http://www.rfc-editor.org/info/rfc2119>>.
- [RFC3688] Mealling, M., "The IETF XML Registry", BCP 81, RFC 3688, DOI 10.17487/RFC3688, January 2004, <<http://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", RFC 4443, DOI 10.17487/RFC4443, March 2006, <<http://www.rfc-editor.org/info/rfc4443>>.



- [RFC6020] Bjorklund, M., Ed., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC 6020, DOI 10.17487/RFC6020, October 2010, <<http://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, <<http://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, <<http://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, <<http://www.rfc-editor.org/info/rfc6536>>.
- [RFC792] Postel, J., "Internet Control Message Protocol", RFC 792, September 1981.

## 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-spring-sr-yang]  
Litkowski, S., Qu, Y., Sarkar, P., and J. Tantsura, "YANG Data Model for Segment Routing", draft-ietf-spring-sr-yang-05 (work in progress), October 2016.
- [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, <<http://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, <<http://www.rfc-editor.org/info/rfc7276>>.

## Authors' Addresses

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

Email: [dekumar@cisco.com](mailto:dekumar@cisco.com)

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

Email: [wangzitao@huawei.com](mailto:wangzitao@huawei.com)

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

Email: [bill.wu@huawei.com](mailto:bill.wu@huawei.com)

Reshad Rahman  
CISCO Systems  
2000 Innovation Drive  
KANATA, ONTARIO K2K 3E8  
CANADA

Email: [rrahman@cisco.com](mailto: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](mailto:srihari@cisco.com)

Network Working Group  
Internet-Draft  
Intended status: Standards Track  
Expires: March 24, 2018

D. Kumar  
Cisco  
M. Wang  
Q. Wu  
Huawei  
R. Rahman  
S. Raghavan  
Cisco  
September 20, 2017

Generic YANG Data Model for Connectionless Operations, Administration,  
and Maintenance(OAM) protocols  
draft-ietf-lime-yang-connectionless-oam-11

#### 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).

#### Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <https://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on March 24, 2018.

## Copyright Notice

Copyright (c) 2017 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<https://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

## Table of Contents

1. Introduction . . . . .	3
2. Conventions used in this document . . . . .	3
2.1. Terminology . . . . .	4
3. Overview of the Connectionless OAM Model . . . . .	4
3.1. TP Address . . . . .	5
3.2. Tools . . . . .	5
3.3. OAM neighboring layers . . . . .	6
3.4. Test Point Locations Information . . . . .	7
3.5. Test Point Locations . . . . .	7
3.6. Path Discovery Data . . . . .	8
3.7. Continuity Check Data . . . . .	8
3.8. OAM data hierarchy . . . . .	8
4. OAM YANG Module . . . . .	11
5. Connectionless model applicability . . . . .	35
5.1. BFD Extension . . . . .	36
5.1.1. Augment Method . . . . .	36
5.1.2. Schema Mount . . . . .	38
5.2. LSP ping extension . . . . .	40
5.2.1. Augment Method . . . . .	40
5.2.2. Schema Mount . . . . .	41
6. Security Considerations . . . . .	43
7. IANA Considerations . . . . .	45
8. Acknowledgements . . . . .	45
9. References . . . . .	45
9.1. Normative References . . . . .	45
9.2. Informative References . . . . .	46
Authors' Addresses . . . . .	48

## 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 Class 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-neighbor-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-neighbor-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 leaves 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-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, '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

```



```
        "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;

```

```
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-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, '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.";

```

```
    }
    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
```



```

        "as number location type container.";
    }
    container group-system-id-location-type {
        when "derived-from-or-self(../tp-location-type, 'coam:system-id-ad
dress-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 {

```

```
    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-mpls-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-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.";
    .....
  }
}

```

#### 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-mpls-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

The authors of this document would like to thank Greg Mirsky and others for their sustainable review and comments, proposals to improve and stabilize document.

## 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-16 (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-07 (work in progress), September 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](mailto:dekumar@cisco.com)

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

Email: [wangzitao@huawei.com](mailto:wangzitao@huawei.com)

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

Email: [bill.wu@huawei.com](mailto:bill.wu@huawei.com)

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

Email: [rrahman@cisco.com](mailto: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

Network Working Group  
Internet-Draft  
Intended status: Standards Track  
Expires: August 27, 2017

D. Kumar  
Cisco  
M. Wang  
Q. Wu  
Huawei  
R. Rahman  
S. Raghavan  
Cisco  
February 23, 2017

Retrieval Methods YANG Data Model for Connectionless Operations,  
Administration, and Maintenance(OAM) protocols  
draft-ietf-lime-yang-connectionless-oam-methods-01

Abstract

This document presents a retrieval method YANG Data model for connectionless OAM protocols. It provides a technology-independent RPC commands for connectionless OAM protocols. The retrieval methods 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 levels through a unified interface) and interactive OAM workflows ( i.e., performing OAM functions at same levels through a unified interface).

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <http://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on August 27, 2017.

Copyright Notice

Copyright (c) 2017 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<http://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

1. Introduction . . . . .	2
2. Conventions used in this document . . . . .	3
2.1. Terminology . . . . .	3
2.2. Tree Diagrams . . . . .	4
3. Overview of the Connectionless OAM retrieval methods Model . . . . .	4
3.1. RPC definitions . . . . .	5
3.2. OAM Retrieval Methods Hierarchy . . . . .	8
4. OAM Retrieval Methods YANG Module . . . . .	19
5. Security Considerations . . . . .	34
6. IANA Considerations . . . . .	34
7. References . . . . .	34
7.1. Normative References . . . . .	35
7.2. Informative References . . . . .	36
Authors' Addresses . . . . .	36

1. Introduction

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

1. Monitor reachability of destinations (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] and BFD [RFC5880] are well-known fault verification and isolation tools, respectively, for IP

networks. Over the years, different technologies have developed similar tools for similar purposes.

In this document, we present a retrieval method YANG Data model for connectionless OAM protocols. This module provides technology-independent RPC commands for connectionless OAM protocols. It is separated from the generic YANG model for connectionless OAM [I-D.ietf-lime-yang-connectionless-oam] and can avoid mixing the models for the retrieved-data from the retrieval procedures. It is expected that retrieval procedures would evolve faster than the data model [I-D.ietf-lime-yang-connectionless-oam] and will allow new procedures to be defined for retrieval of the same data defined by the base data model.

## 2. Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

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

RPC - A Remote Procedure Call, as used within the NETCONF protocol

## 2.2. Tree Diagrams

A simplified graphical representation of the data model is used in this document. The meaning of the symbols in these diagrams is as follows:

Each node is printed as:

```
<status> <flags> <name> <opts> <type>
```

<status> is one of:  
+ for current

<flags> is one of:

- rw for configuration data
- ro for non-configuration data
- x for rpcs
- n for notifications

<name> is the name of the node

If the node is augmented into the tree from another module, its name is printed as <prefix>:<name>.

<opts> is one of:

- ? for an optional leaf or choice
- ! for a presence container
- \* for a leaf-list or list
- [<keys>] for a list's keys

<type> is the name of the type for leafs and leaf-lists

## 3. Overview of the Connectionless OAM retrieval methods Model

In this document, we present a retrieval method YANG Data model for connectionless OAM protocols. This module provides technology-independent retrieval procedures (RPC commands) for connectionless OAM protocols. It provides a flexible way to retrieve the retrieved-data which defined by the "ietf-connectionless-oam.yang" [I-D.ietf-lime-yang-connectionless-oam].

### 3.1. RPC definitions

The RPC model facilitates issuing commands to a NETCONF server (in this case to the device that need to execute the OAM command) and obtaining a response.

Under 'connectionless-oam-methods' module, we summarize the common OAM functions and define the generic RPC commands: 'continuity-check' and 'path-discovery'. In practice, these commands are supported by corresponding technology-specific OAM tools [RFC7276]. For example, for the IP OAM model, the continuity-check RPC corresponds to the IP Ping [RFC792] [RFC4443], while the path-discovery RPC command corresponds to IP Traceroute [RFC792] [RFC4443].

Note that the RPC command presented in this document is the base building block, which is used to derive a model for a technology-specific OAM (i.e., ICMP ping [RFC792] [RFC4443], LSP ping [RFC4379]), the base building block should be extended with corresponding technology specific parameters. To facilitate this and for future enhancements to data retrieval methods, the RPCs are captured under a separate module.

The generic 'path-discovery-data' and 'continuity-check-data' are used as data outputs from the different RPCs described in the document. Similar methods including other RPCs can retrieve the data using the same data model.

The persistent method RPCs are commands to trigger persistent continuity check or path discovery OAM while specifying the options for data-export from the device. Internet Protocol Flow Information Export (IPFIX) [RFC7011] or yang-push [I-D.ietf-netconf-yang-push]. are currently outlined here as data export options and more can be added in future. It should be noted that the persistent methods are used to trigger create, modify and delete the persistent state associated with the data export options. The data export specific configurations are beyond the scope of this document.

```
rpc continuity-check {
  if-feature coam:continuity-check;
  description
    "Generates continuity-check as per RFC7276.";
  input {
    container destination-tp {
      uses coam:tp-address;
      description
        "destination test point.";
    }
  }
  uses coam:session-type;
```



```
leaf source-interface {
  type if:interface-ref;
  description
    "source interface.";
}
leaf outbound-interface {
  type if:interface-ref;

  description
    "outbound interface.";
}
leaf count {
  type uint32;
  default "5";
  description
    "Specifies the number of packets that will be sent.";
}
leaf vrf {
  type coam:routing-instance-ref;
  description
    "vrf instance.";
}
leaf ttl {
  type uint8;
  default "255";
  description
    "Time to live (TTL).";
}
leaf packet-size {
  type uint32 {
    range "64..10000";
  }
  default "64";
  description
    "Size of ping echo request packets, in octets";
}
}
output {
  list error-code-list {
    key "response-index";
    leaf response-index {
      type uint32;
      description
        "response index.";
    }
  }
  leaf status-code {
    type int32;
    description

```

```
        "error code is ";
    }
    leaf status-sub-code {
        type uint8;
        description
            "sub code.";
    }
    description
        "error code list.";
}
uses coam:continuity-check-data;
}
}

rpc path-discovery {
    description
        "Generates path discovery as per RFC7276.";
    input {
        container destination-tp {
            uses coam:tp-address;
            description
                "destination test point.";
        }
        uses coam:session-type;
        leaf source-interface {
            type if:interface-ref;
            description
                "source interface.";
        }
        leaf outbound-interface {
            type if:interface-ref;
            description
                "outbound interface.";
        }
        leaf vrf {
            type coam:routing-instance-ref;
            description
                "vrf";
        }
        leaf max-ttl {
            type uint8;
            default "255";
            description
                "max ttl.";
        }
    }
    output {
```

```

list response-list {
  key "response-index";
  description
    "path discovery response list.";
  leaf response-index {
    type uint32;
    description
      "response index.";
  }
  leaf status-code {
    type int32;
    description
      "error code is ";
  }
  leaf status-sub-code {
    type uint8;

    description
      "sub code is ";
  }
}

uses coam:path-discovery-data;
}

```

Snippet of data hierarchy related to RPC calls

### 3.2. OAM Retrieval Methods Hierarchy

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

module: ietf-connectionless-oam-methods

```

rpcs:
  +---x continuity-check {coam:continuity-check}?
  | +---w input
  | | +---w destination-tp
  | | | +---w tp-location-type-value?  identityref
  | | | +---w (tp-address)?
  | | | | +---:(mac-address)
  | | | | | +---w mac-address?          yang:mac-address
  | | | | +---:(ipv4-address)
  | | | | | +---w ipv4-address?        inet:ipv4-address
  | | | | +---:(ipv6-address)
  | | | | | +---w ipv6-address?        inet:ipv6-address
  | | | | +---:(tp-attribute)

```

```

| | | | +---w tp-attribute-type?          fec-type
| | | | +---w (tp-attribute-value)?
| | | | | +--:(ip-prefix)
| | | | | | +---w ip-prefix?          inet:ip-prefix
| | | | | +--:(bgp)
| | | | | | +---w bgp                inet:ip-prefix
| | | | | +--:(tunnel)
| | | | | | +---w tunnel-interface?   uint32
| | | | | +--:(pw)
| | | | | | +---w remote-pe-address?  inet:ip-address
| | | | | | +---w pw-id?              uint32
| | | | | +--:(vpls)
| | | | | | +---w route-distinguisher? uint32
| | | | | | +---w sender-ve-id?       uint32
| | | | | | +---w receiver-ve-id?     uint32
| | | | | +--:(mpls-mldp)
| | | | | | +---w (root-address)?
| | | | | | | +--:(ip-address)
| | | | | | | | +---w source-address?  inet:ip-address
| | | | | | | | +---w group-ip-address? IP-Multicast
| | | | | -Group-Address
| | | | | | +--:(vpn)
| | | | | | | +---w as-number          inet:as-number
| | | | | | +--:(global-id)
| | | | | | | +---w lsp-id?            string
| | | | | +--:(system-info)
| | | | | | +---w system-id?           router-id
| | | | | +---w session-type-enum?     enumeration
| | | | | +---w source-interface?      if:interface-ref
| | | | | +---w outbound-interface?    if:interface-ref
| | | | | +---w count?                 uint32
| | | | | +---w vrf?                   coam:routing-instance-ref
| | | | | +---w ttl?                   uint8
| | | | | +---w packet-size?           uint32
| | | | | +--ro output
| | | | | | +--ro error-code-list* [response-index]
| | | | | | | +--ro response-index    uint32
| | | | | | | +--ro status-code?      int32
| | | | | | | +--ro status-sub-code?   uint8
| | | | | | +--ro src-test-point
| | | | | | | +--ro vrf?               routing-instance-ref
| | | | | | | +--ro tp-location-type-value? identityref
| | | | | | | +--ro (tp-address)?
| | | | | | | | +--:(mac-address)
| | | | | | | | | +--ro mac-address?   yang:mac-address
| | | | | | | | +--:(ipv4-address)
| | | | | | | | | +--ro ipv4-address?   inet:ipv4-address
| | | | | | | | +--:(ipv6-address)

```

```

| | | | | +--ro ipv6-address?                inet:ipv6-address
| | | | | +---:(tp-attribute)
| | | | | +--ro tp-attribute-type?         fec-type
| | | | | +--ro (tp-attribute-value)?
| | | | |   +---:(ip-prefix)
| | | | |     | +--ro ip-prefix?          inet:ip-prefix
| | | | |     +---:(bgp)
| | | | |     | +--ro bgp?                inet:ip-prefix
| | | | |     +---:(tunnel)
| | | | |     | +--ro tunnel-interface?   uint32
| | | | |     +---:(pw)
| | | | |     | +--ro remote-pe-address?  inet:ip-address
| | | | |     | +--ro pw-id?             uint32
| | | | |     +---:(vpls)
| | | | |     | +--ro route-distinguisher? uint32
| | | | |     | +--ro sender-ve-id?      uint32
| | | | |     | +--ro receiver-ve-id?    uint32
| | | | |     +---:(mpls-mldp)
| | | | |       +--ro (root-address)?
| | | | |         +---:(ip-address)
| | | | |           | +--ro source-address? inet:ip-address
| | | | |           | +--ro group-ip-address? IP-Multicast
| | | | |
| | | | | -Group-Address
| | | | |   +---:(vpn)
| | | | |     | +--ro as-number?          inet:as-number
| | | | |     +---:(global-id)
| | | | |       +--ro lsp-id?            string
| | | | |   +---:(system-info)
| | | | |     +--ro system-id?           router-id
| | | | |   +--ro egress-intf-name?     if:interface-ref
| | | | | +--ro dest-test-point
| | | | |   +--ro vrf?                    routing-instance-ref
| | | | |   +--ro tp-location-type-value? identityref
| | | | | +--ro (tp-address)?
| | | | |   +---:(mac-address)
| | | | |     | +--ro mac-address?        yang:mac-address
| | | | |     +---:(ipv4-address)
| | | | |       | +--ro ipv4-address?     inet:ipv4-address
| | | | |     +---:(ipv6-address)
| | | | |       | +--ro ipv6-address?    inet:ipv6-address
| | | | |     +---:(tp-attribute)
| | | | |       +--ro tp-attribute-type?  fec-type
| | | | |       +--ro (tp-attribute-value)?
| | | | |         +---:(ip-prefix)
| | | | |           | +--ro ip-prefix     inet:ip-prefix
| | | | |           +---:(bgp)
| | | | |             | +--ro bgp?       inet:ip-prefix
| | | | |           +---:(tunnel)

```



```

+---:(mac-address)
| +---w mac-address?          yang:mac-address
+---:(ipv4-address)
| +---w ipv4-address?        inet:ipv4-address
+---:(ipv6-address)
| +---w ipv6-address?        inet:ipv6-address
+---:(tp-attribute)
| +---w tp-attribute-type?    fec-type
| +---w (tp-attribute-value)?
|   +---:(ip-prefix)
|   | +---w ip-prefix?        inet:ip-prefix
|   +---:(bgp)
|   | +---w bgp?              inet:ip-prefix
|   +---:(tunnel)
|   | +---w tunnel-interface? uint32
|   +---:(pw)
|   | +---w remote-pe-address? inet:ip-address
|   | +---w pw-id?            uint32
|   +---:(vpls)
|   | +---w route-distinguisher? uint32
|   | +---w sender-ve-id?        uint32
|   | +---w receiver-ve-id?     uint32
|   +---:(mpls-mldp)
|   | +---w (root-address)?
|   |   +---:(ip-address)
|   |   | +---w source-address?  inet:ip-address
|   |   | +---w group-ip-address? IP-Multicast-
+---:(system-info)
|   +---w system-id?          router-id
+---w session-type-enum?      enumeration
+---w source-interface?       if:interface-ref
+---w outbound-interface?     if:interface-ref
+---w vrf?                     coam:routing-instance-ref
+---w ttl?                     uint8
+---w data-export-method?      export-method
+---w (cc-trigger)?
|   +---:(periodic)
|   | +---w period?            yang:timeticks
|   | +---w start-time?        yang:date-and-time
|   +---:(on-change)
|   | +---w all-data-on-start?  boolean
|   | +---w excluded-change*    change-type
+---ro output

```

```

|         +--ro error-code-list* [response-index]
|         |   +--ro response-index      uint32
|         |   +--ro status-code?        int32
|         |   +--ro status-sub-code?    uint8
|         +--ro cc-persistent-id?      string
+----x cc-persistent-modify {coam:continuity-check}?
|   +---w input
|   |   +---w cc-persistent-id?        string
|   |   +---w data-export-method?     export-method
|   |   +---w (cc-trigger)?
|   |   |   +---:(periodic)
|   |   |   |   +---w period?          yang:timeticks
|   |   |   |   +---w start-time?     yang:date-and-time
|   |   |   +---:(on-change)
|   |   |   |   +---w all-data-on-start?  boolean
|   |   |   |   +---w excluded-change*  change-type
|   +--ro output
|   |   +--ro error-code-list* [response-index]
|   |   |   +--ro response-index      uint32
|   |   |   +--ro status-code?        int32
|   |   |   +--ro status-sub-code?    uint8
|   |   +--ro cc-persistent-id?      string
+----x cc-persistent-delete {coam:continuity-check}?
|   +---w input
|   |   +---w cc-persistent-id?      string
|   +--ro output
|   |   +--ro error-code-list* [response-index]
|   |   |   +--ro response-index      uint32
|   |   |   +--ro status-code?        int32
|   |   |   +--ro status-sub-code?    uint8
+----x path-discovery
|   +---w input
|   |   +---w destination-tp
|   |   |   +---w tp-location-type-value?  identityref
|   |   |   +---w (tp-address)?
|   |   |   |   +---:(mac-address)
|   |   |   |   |   +---w mac-address?    yang:mac-address
|   |   |   |   +---:(ipv4-address)
|   |   |   |   |   +---w ipv4-address?   inet:ipv4-address
|   |   |   |   +---:(ipv6-address)
|   |   |   |   |   +---w ipv6-address?   inet:ipv6-address
|   |   |   +---:(tp-attribute)
|   |   |   |   +---w tp-attribute-type?   fec-type
|   |   |   |   +---w (tp-attribute-value)?
|   |   |   |   |   +---:(ip-prefix)
|   |   |   |   |   |   +---w ip-prefix?   inet:ip-prefix
|   |   |   |   |   +---:(bgp)
|   |   |   |   |   |   +---w bgp         inet:ip-prefix

```



```

+--:(tunnel)
| +---w tunnel-interface?   uint32
+--:(pw)
| +---w remote-pe-address?  inet:ip-address
| +---w pw-id?              uint32
+--:(vpls)
| +---w route-distinguisher? uint32
| +---w sender-ve-id?       uint32
| +---w receiver-ve-id?    uint32
+--:(mpls-mldp)
+---w (root-address)?
+--:(ip-address)
| +---w source-address?    inet:ip-address
| +---w group-ip-address?  IP-Multicast
-Group-Address
+--:(vpn)
| +---w as-number?         inet:as-number
+--:(global-id)
+---w lsp-id?              string
+--:(system-info)
+---w system-id?           router-id
+---w session-type-enum?   enumeration
+---w source-interface?   if:interface-ref
+---w outbound-interface? if:interface-ref
+---w vrf?                 coam:routing-instance-ref
+---w max-ttl?             uint8
+--ro output
+--ro response-list* [response-index]
| +--ro response-index     uint32
| +--ro status-code?       int32
| +--ro status-sub-code?   uint8
+--ro src-test-point
+--ro vrf?                 routing-instance-ref
+--ro tp-location-type-value? identityref
+--ro (tp-address)?
+--:(mac-address)
| +--ro mac-address?       yang:mac-address
+--:(ipv4-address)
| +--ro ipv4-address?     inet:ipv4-address
+--:(ipv6-address)
| +--ro ipv6-address?     inet:ipv6-address
+--:(tp-attribute)
| +--ro tp-attribute-type? fec-type
| +--ro (tp-attribute-value)?
| +--:(ip-prefix)
| | +--ro ip-prefix?      inet:ip-prefix
+--:(bgp)
| +--ro bgp?              inet:ip-prefix

```

```

+---:(tunnel)
| +--ro tunnel-interface?      uint32
+---:(pw)
| +--ro remote-pe-address?    inet:ip-address
| +--ro pw-id?                uint32
+---:(vpls)
| +--ro route-distinguisher?  uint32
| +--ro sender-ve-id?         uint32
| +--ro receiver-ve-id?       uint32
+---:(mpls-mldp)
+--ro (root-address)?
  +---:(ip-address)
  | +--ro source-address?     inet:ip-address
  | +--ro group-ip-address?   IP-Multicast
-Group-Address
  +---:(vpn)
  | +--ro as-number?          inet:as-number
  +---:(global-id)
  | +--ro lsp-id?             string
+---:(system-info)
  +--ro system-id?            router-id
+--ro dest-test-point
  +--ro vrf?                  routing-instance-ref
  +--ro tp-location-type-value? identityref
  +--ro (tp-address)?
  +---:(mac-address)
  | +--ro mac-address?        yang:mac-address
  +---:(ipv4-address)
  | +--ro ipv4-address?       inet:ipv4-address
  +---:(ipv6-address)
  | +--ro ipv6-address?       inet:ipv6-address
  +---:(tp-attribute)
  | +--ro tp-attribute-type?   fec-type
  | +--ro (tp-attribute-value)?
  | +---:(ip-prefix)
  | | +--ro ip-prefix         inet:ip-prefix
  | +---:(bgp)
  | | +--ro bgp?              inet:ip-prefix
  | +---:(tunnel)
  | | +--ro tunnel-interface?  uint32
  | +---:(pw)
  | | +--ro remote-pe-address? inet:ip-address
  | | +--ro pw-id?            uint32
  | +---:(vpls)
  | | +--ro route-distinguisher? uint32
  | | +--ro sender-ve-id?       uint32
  | | +--ro receiver-ve-id?     uint32
  +---:(mpls-mldp)

```

```

|
|
|           +--ro (root-address)?
|             +---:(ip-address)
|               | +--ro source-address? inet:ip-address
|               | +--ro group-ip-address? IP-Multicast
-Group-Address
|             +---:(vpn)
|               | +--ro as-number?          inet:as-number
|             +---:(global-id)
|               | +--ro lsp-id?              string
|             +---:(system-info)
|               +--ro system-id?              router-id
+--ro sequence-number?          uint64
+--ro hop-cnt?                  uint8
+--ro session-packet-statistics
|   +--ro rx-packet-count?      uint32
|   +--ro tx-packet-count?      uint32
|   +--ro rx-bad-packet?        uint32
|   +--ro tx-packet-failed?     uint32
+--ro session-error-statistics
|   +--ro packet-drops-count?   uint32
|   +--ro packet-reorder-count? uint32
|   +--ro packets-out-of-seq-count? uint32
|   +--ro packets-dup-count?    uint32
+--ro session-delay-statistics
|   +--ro time-resolution-value? identityref
|   +--ro min-delay-value?      uint32
|   +--ro max-delay-value?      uint32
|   +--ro average-delay-value?  uint32
+--ro session-jitter-statistics
|   +--ro time-resolution-value? identityref
|   +--ro min-jitter-value?     uint32
|   +--ro max-jitter-value?     uint32
|   +--ro average-jitter-value? uint32
+--ro path-verification
|   +--ro flow-info?            string
|   +--ro session-path-verification-statistics
|     +--ro verified-count?     uint32
|     +--ro failed-count?       uint32
+--ro path-trace-info
|   +--ro path-trace-info-list* [index]
|     +--ro index                uint32
|     +--ro vrf?                  routing-instance-ref
|     +--ro tp-location-type-value? identityref
|     +--ro (tp-address)?
|       | +---:(mac-address)
|       | | +--ro mac-address?     yang:mac-address
|       | | +---:(ipv4-address)
|       | | | +--ro ipv4-address?  inet:ipv4-address

```

```

| | | | | +---:(ipv6-address)
| | | | | | +---ro ipv6-address?          inet:ipv6-address
+---:(tp-attribute)
| | | | | +---ro tp-attribute-type?      fec-type
| | | | | +---ro (tp-attribute-value)?
| | | | | | +---:(ip-prefix)
| | | | | | | +---ro ip-prefix?          inet:ip-prefix
+---:(bgp)
| | | | | | +---ro bgp?                  inet:ip-prefix
+---:(tunnel)
| | | | | | +---ro tunnel-interface?     uint32
+---:(pw)
| | | | | | +---ro remote-pe-address?   inet:ip-address
| | | | | | +---ro pw-id?                uint32
+---:(vpls)
| | | | | | +---ro route-distinguisher?  uint32
| | | | | | +---ro sender-ve-id?         uint32
| | | | | | +---ro receiver-ve-id?      uint32
+---:(mpls-mldp)
| | | | | | +---ro (root-address)?
| | | | | | | +---:(ip-address)
| | | | | | | | +---ro source-address?   inet:ip-address
| | | | | | | | +---ro group-ip-address? IP-Multicast
-Group-Address
| | | | | | +---:(vpn)
| | | | | | | +---ro as-number?          inet:as-number
+---:(global-id)
| | | | | | | +---ro lsp-id?              string
+---:(system-info)
| | | | | | +---ro system-id?            router-id
+---ro timestamp-sec?          yang:timestamp
+---ro timestamp-nanosec?     yang:timestamp
+---ro ingress-intf-name?     if:interface-ref
+---ro egress-intf-name?     if:interface-ref
+---ro queue-depth?          uint32
+---ro transit-delay?        uint32
+---ro app-meta-data?        uint64
+---ro opaque-tlvs
| | | | | | +---ro opaque-tlvs-list*
| | | | | | | +---ro type?              opaque-tlv-type
| | | | | | | +---ro length?           uint16
| | | | | | | +---ro value?           yang:hex-string
+---x pd-persistent-create
| | | | | +---w input
| | | | | | +---w destination-tp
| | | | | | | +---w tp-location-type-value? identityref
| | | | | | | +---w (tp-address)?
| | | | | | | | +---:(mac-address)

```

```

| | | | +---w mac-address?                yang:mac-address
| | | | +---:(ipv4-address)
| | | | | +---w ipv4-address?            inet:ipv4-address
| | | | +---:(ipv6-address)
| | | | | +---w ipv6-address?            inet:ipv6-address
| | | | +---:(tp-attribute)
| | | | | +---w tp-attribute-type?        fec-type
| | | | | +---w (tp-attribute-value)?
| | | | | | +---:(ip-prefix)
| | | | | | | +---w ip-prefix?          inet:ip-prefix
| | | | | | +---:(bgp)
| | | | | | | +---w bgp?                inet:ip-prefix
| | | | | | +---:(tunnel)
| | | | | | | +---w tunnel-interface?    uint32
| | | | | | +---:(pw)
| | | | | | | +---w remote-pe-address?   inet:ip-address
| | | | | | | +---w pw-id?              uint32
| | | | | | +---:(vpls)
| | | | | | | +---w route-distinguisher? uint32
| | | | | | | +---w sender-ve-id?       uint32
| | | | | | | +---w receiver-ve-id?     uint32
| | | | | | +---:(mpls-mldp)
| | | | | | | +---w (root-address)?
| | | | | | | | +---:(ip-address)
| | | | | | | | | +---w source-address  inet:ip-address
| | | | | | | | | +---w group-ip-address? IP-Multicast
| | | | -Group-Address
| | | | | +---:(vpn)
| | | | | | +---w as-number?            inet:as-number
| | | | | +---:(global-id)
| | | | | | +---w lsp-id?              string
| | | | +---:(system-info)
| | | | | +---w system-id?              router-id
| | | | +---w session-type-enum?        enumeration
| | | | +---w source-interface?         if:interface-ref
| | | | +---w outbound-interface?      if:interface-ref
| | | | +---w vrf?                      coam:routing-instance-ref
| | | | +---w max-ttl?                  uint8
| | | | +---w data-export-method?       export-method
| | | | +---w (pd-trigger)?
| | | | | +---:(periodic)
| | | | | | +---w period?                yang:timeticks
| | | | | | +---w start-time?           yang:date-and-time
| | | | | +---:(on-change)
| | | | | | +---w all-data-on-start?     boolean
| | | | | | +---w excluded-change*      change-type
| | | | +---ro output
| | | | | +---ro response-list* [response-index]

```

```

|         +--ro response-index      uint32
|         +--ro status-code?        int32
|         +--ro status-sub-code?    uint8
|         +--ro pd-persistent-id?   string
+---x pd-persistent-modify
|   +---w input
|   |   +---w pd-persistent-id?      string
|   |   +---w data-export-method?   export-method
|   |   +---w (pd-trigger)?
|   |   |   +--:(periodic)
|   |   |   |   +---w period?        yang:timeticks
|   |   |   |   +---w start-time?    yang:date-and-time
|   |   |   +--:(on-change)
|   |   |   |   +---w all-data-on-start?  boolean
|   |   |   |   +---w excluded-change*  change-type
|   +--ro output
|   |   +--ro response-list* [response-index]
|   |   +--ro response-index      uint32
|   |   +--ro status-code?        int32
|   |   +--ro status-sub-code?    uint8
|   |   +--ro pd-persistent-id?   string
+---x pd-persistent-delete
|   +---w input
|   |   +---w pd-persistent-id?    string
+--ro output
|   +--ro response-list* [response-index]
|   +--ro response-index      uint32
|   +--ro status-code?        int32
|   +--ro status-sub-code?    uint8

```

#### data hierarchy of OAM Retrieval Methods

#### 4. OAM Retrieval Methods YANG Module

```
<CODE BEGINS> file "ietf-connectionless-oam-methods.yang"
```

```

module ietf-connectionless-oam-methods {
namespace "urn:ietf:params:xml:ns:yang:ietf-connectionless-oam-methods";
prefix coam-methods;

import ietf-interfaces {
prefix if;
}
import ietf-connectionless-oam {
prefix coam;
}
import ietf-yang-types {

```

```
    prefix yang;
  }

  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 RPCs for ,
     connectionless OAM to be used within IETF
     in a protocol Independent manner.
     Functional level abstraction is indendent with
     YANG modeling. 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 2017-02-15 {
    description
      "02 version";
    reference
      "draft-ietf-lime-yang-connectionless-oam-methods";
  }

  rpc continuity-check {
    if-feature coam:continuity-check;
    description
      "Generates continuity-check as per RFC7276.";
    input {
      container destination-tp {
        uses coam:tp-address;
        description
          "Destination test point.";
      }
      uses coam:session-type;
      leaf source-interface {
        type if:interface-ref;
        description
          "Source interface.";
      }
      leaf outbound-interface {
        type if:interface-ref;

        description
          "Outbound interface.";
      }
    }
  }
}
```

```
    }
    leaf count {
      type uint32;
      default "5";
      description
        "Specifies the number of
         packets that will be sent.";
    }
    leaf vrf {
      type coam:routing-instance-ref;
      description
        "VRF instance.";
    }

    leaf ttl {
      type uint8;
      default "255";
      description
        "Time to live (TTL).";
    }
    leaf packet-size {
      type uint32 {
        range "64..10000";
      }
      default "64";
      description
        "Size of ping echo request
         packets, in octets";
    }
  }
}
output {
  list error-code-list {
    key "response-index";
    leaf response-index {
      type uint32;
      description
        "Response index.";
    }
    leaf status-code {
      type int32;
      description
        "Error code is ";
    }
    leaf status-sub-code {
      type uint8;
      description
        "Sub code.";
    }
  }
}
```



```
        description
            "Error code list.";
    }

    uses coam:continuity-check-data;
}

identity export-method {
    description
        "Base identity to represent a conceptual export-method.";
}

identity ipfix-export {
    base export-method;
    description
        "IPFIX based export. Configuration provided separately.";
}

identity yang-push-export {
    base export-method;
    description
        "Yang-push from draft-ietf-netconf-yang-push";
}

typedef export-method {
    type identityref {
        base export-method;
    }
    description
        "Export method type.";
}

typedef change-type {
    type enumeration {
        enum "create" {
            description
                "Change due to a create.";
        }
        enum "delete" {
            description
                "Change due to a delete.";
        }
        enum "modify" {
            description
                "Change due to an update.";
        }
    }
}
```

```
    description
      "Different types of changes that may occur.";
  }

  rpc cc-persistent-create {
    if-feature coam:continuity-check;
    description
      "Generates persistent continuity-check.";
    input {
      container destination-tp {
        uses coam:tp-address;
        description
          "Destination test point.";
      }

      uses coam:session-type;

      leaf source-interface {
        type if:interface-ref;
        description
          "Source interface.";
      }

      leaf outbound-interface {
        type if:interface-ref;
        description
          "Outbound interface.";
      }

      leaf vrf {
        type coam:routing-instance-ref;
        description
          "VRF instance.";
      }

      leaf ttl {
        type uint8;
        default "255";
        description
          "Time to live (TTL).";
      }

      leaf data-export-method {
        type export-method;
        description
          "Type of export.";
      }
    }
  }
}
```

```
choice cc-trigger {
  description
    "Defines necessary conditions for
     periodic or on-change trigger.>";
  case periodic {
    description "Periodic reports.>";
    leaf period {
      type yang:timeticks;
      description "Time interval between reports.>";
    }
    leaf start-time {
      type yang:date-and-time;
      description
        "Timestamp from which reports are started.>";
    }
  }
  case on-change {
    description
      "On-change trigger and not periodic.>";
    leaf all-data-on-start {
      type boolean;
      description
        "Full update needed on start or not.>";
    }
    leaf-list excluded-change {
      type change-type;
      description
        "Restrict which changes trigger an update.>";
    }
  }
}
}
output {
  list error-code-list {
    key "response-index";
    leaf response-index {
      type uint32;
      description
        "Response index.>";
    }
  }
  leaf status-code {
    type int32;
    description
      "Error code.>";
  }
  leaf status-sub-code {
```

```
        type uint8;
        description
            "Sub code.";
    }

    description
        "Error code list.";
}
leaf cc-persistent-id {
    type string;
    description
        "Id to act as a cookie.";
}
}
}

rpc cc-persistent-modify {
    if-feature coam:continuity-check;
    description
        "Modifies persistent continuity-check
         as per RFC7276.";
    input {
        leaf cc-persistent-id {
            type string;
            description
                "Cookie Id to be used for modifications.";
        }

        leaf data-export-method {
            type export-method;
            description
                "Type of export to use.";
        }
    }

    choice cc-trigger {
        description
            "Defines necessary conditions for
             periodic or on-change trigger.";
        case periodic {
            description "Periodic reports.";
            leaf period {
                type yang:timeticks;
                description
                    "Time interval between reports.";
            }
        }
        leaf start-time {
            type yang:date-and-time;
            description

```

```
        "Timestamp from which reports are started.";
    }
}
case on-change {
    description
        "On-change trigger and not periodic.";
    leaf all-data-on-start {
        type boolean;
        description
            "Full update needed on start or not.";
    }
    leaf-list excluded-change {
        type change-type;
        description
            "Restrict which changes trigger an update.";
    }
}
}
}
output {
    list error-code-list {
        key "response-index";
        leaf response-index {
            type uint32;
            description
                "Response index.";
        }
    }
    leaf status-code {
        type int32;
        description
            "Error code";
    }
    leaf status-sub-code {
        type uint8;
        description
            "Sub code.";
    }
    description
        "Error code list.";
}
leaf cc-persistent-id {
    type string;
    description
        "Id to represent a cookie.";
```

```
    }
  }
}

rpc cc-persistent-delete {
  if-feature coam:continuity-check;
  description
    "Deletes persistent continuity-check as per RFC7276.";
  input {
    leaf cc-persistent-id {
      type string;
      description
        "Cookie Id to be used in deletion.";
    }
  }
  output {
    list error-code-list {
      key "response-index";
      leaf response-index {
        type uint32;
        description
          "Response index.";
      }

      leaf status-code {
        type int32;
        description
          "Error code.";
      }

      leaf status-sub-code {
        type uint8;
        description
          "Sub code.";
      }

      description
        "Error code list.";
    }
  }
}

rpc path-discovery {
  description
    "Generates path discovery as per RFC7276.";
  input {
    container destination-tp {
      uses coam:tp-address;
    }
  }
}
```

```
    description
      "Destination test point.";
  }
  uses coam:session-type;
  leaf source-interface {
    type if:interface-ref;
    description
      "Source interface.";
  }

  leaf outbound-interface {
    type if:interface-ref;
    description
      "Outbound interface.";
  }

  leaf vrf {
    type coam:routing-instance-ref;
    description
      "VRF";
  }

  leaf max-ttl {
    type uint8;
    default "255";
    description
      "Max ttl.";
  }
}
output {
  list response-list {
    key "response-index";
    description
      "Path discovery response list.";
    leaf response-index {
      type uint32;
      description
        "Response index.";
    }

    leaf status-code {
      type int32;
      description
        "Error code is ";
    }

    leaf status-sub-code {
```

```
        type uint8;
        description
            "Sub code is ";
    }
}

uses coam:path-discovery-data;

}

}

rpc pd-persistent-create {
    description
        "Generates persistent path discovery.";
    input {
        container destination-tp {
            uses coam:tp-address;
            description
                "Destination test point.";
        }

        uses coam:session-type;

        leaf source-interface {
            type if:interface-ref;
            description
                "Source interface.";
        }

        leaf outbound-interface {
            type if:interface-ref;
            description
                "Outbound interface.";
        }

        leaf vrf {
            type coam:routing-instance-ref;
            description
                "VRF";
        }

        leaf max-ttl {
            type uint8;
            default "255";
            description
                "Max ttl.";
        }
    }
}
```



```
leaf data-export-method {
  type export-method;
  description
    "Type of export.";
}

choice pd-trigger {
  description
    "Defines necessary conditions
     for periodic or on-change
     trigger.";
  case periodic {
    description
      "Periodic reports.";
    leaf period {
      type yang:timeticks;
      description
        "Time interval between reports.";
    }
    leaf start-time {
      type yang:date-and-time;
      description
        "Timestamp from which reports are started.";
    }
  }
  case on-change {
    description
      "On-change trigger and not periodic.";
    leaf all-data-on-start {
      type boolean;
      description
        "Full update needed on start or not.";
    }
    leaf-list excluded-change {
      type change-type;
      description
        "Restrict which changes trigger an update.";
    }
  }
}

output {
  list response-list {
    key "response-index";
    description
      "Path discovery response list.";
    leaf response-index {
      type uint32;
    }
  }
}
```

```
        description
        "Response index. ";
    }

    leaf status-code {
        type int32;
        description
        "Error code is ";
    }

    leaf status-sub-code {
        type uint8;
        description
        "Sub code is ";
    }

    leaf pd-persistent-id {
        type string;
        description
            "Id to act as a cookie. ";
    }
}
}
}

rpc pd-persistent-modify {
    description
    "Modifies persistent path discovery. ";
    input {
        leaf pd-persistent-id {
            type string;
            description "Cookie Id to be used for modifications. ";
        }

        leaf data-export-method {
            type export-method;
            description "Type of export. ";
        }

        choice pd-trigger {
            description
            "Defines necessary conditions for periodic or on-change
            trigger. ";
            case periodic {
                description "Periodic reports. ";
                leaf period {
                    type yang:timeticks;
                    description

```

```
        "Time interval between reports.";
    }
    leaf start-time {
        type yang:date-and-time;
        description
            "Timestamp from which reports are started.";
    }
}
case on-change {
    description
        "On-change trigger and not periodic.";
    leaf all-data-on-start {
        type boolean;
        description
            "Full update needed on start or not.";
    }
    leaf-list excluded-change {
        type change-type;
        description
            "Restrict which changes trigger an update.";
    }
}
}
}
output {
    list response-list {
        key "response-index";
        description
            "path discovery response list.";
        leaf response-index {
            type uint32;
            description
                "response index.";
        }

        leaf status-code {
            type int32;
            description
                "error code is ";
        }

        leaf status-sub-code {
            type uint8;
            description
                "sub code is ";
        }

        leaf pd-persistent-id {
```

```
        type string;
        description "Id to act as a cookie.";
    }
}
}

rpc pd-persistent-delete {
    description
        "Deletes persistent path discovery.";
    input {
        leaf pd-persistent-id {
            type string;
            description "Cookie Id to be used in deletion.";
        }
    }

    output {
        list response-list {
            key "response-index";
            description
                "path discovery response list.";
            leaf response-index {
                type uint32;
                description
                    "response index.";
            }

            leaf status-code {
                type int32;
                description
                    "error code is ";
            }

            leaf status-sub-code {
                type uint8;
                description
                    "sub code is ";
            }
        }
    }
}
}
```

<CODE ENDS>

## 5. Security Considerations

The YANG modules defined in this memo are designed to be accessed via the NETCONF protocol [RFC6241]. The lowest NETCONF layer is the secure transport layer and the mandatory to implement secure transport is SSH [RFC6242]. The NETCONF access control model [RFC6536] provides the means to restrict access for particular NETCONF users to a pre-configured subset of all available NETCONF protocol operations and content. Some of the RPC operations in the "ietf-connectionless-oam-methods" YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control access to these operations.

These are the operations and their sensitivity/vulnerability:

- o continuity-check: Generates continuity check.
- o path-discovery: Generates path discovery.

## 6. 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-methods

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-methods

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

prefix: coam-methods

reference: RFC XXXX

## 7. References

## 7.1. Normative References

- [I-D.ietf-lime-yang-connectionless-oam]  
Kumar, D., Wang, Z., Wu, Q., Rahman, R., and S. Raghavan,  
"Generic YANG Data Model for Connectionless Operations,  
Administration, and Maintenance(OAM) protocols", draft-  
ietf-lime-yang-connectionless-oam-03 (work in progress),  
December 2016.
- [I-D.ietf-netconf-yang-push]  
Clemm, A., Voit, E., Prieto, A., Tripathy, A., Nilsen-  
Nygaard, E., Bierman, A., and B. Lengyel, "Subscribing to  
YANG datastore push updates", draft-ietf-netconf-yang-  
push-04 (work in progress), October 2016.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate  
Requirement Levels", BCP 14, RFC 2119,  
DOI 10.17487/RFC2119, March 1997,  
<<http://www.rfc-editor.org/info/rfc2119>>.
- [RFC3688] Mealling, M., "The IETF XML Registry", BCP 81, RFC 3688,  
DOI 10.17487/RFC3688, January 2004,  
<<http://www.rfc-editor.org/info/rfc3688>>.
- [RFC6020] Bjorklund, M., Ed., "YANG - A Data Modeling Language for  
the Network Configuration Protocol (NETCONF)", RFC 6020,  
DOI 10.17487/RFC6020, October 2010,  
<<http://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,  
<<http://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,  
<<http://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,  
<<http://www.rfc-editor.org/info/rfc6536>>.
- [RFC7011] Claise, B., Ed., Trammell, B., Ed., and P. Aitken,  
"Specification of the IP Flow Information Export (IPFIX)  
Protocol for the Exchange of Flow Information", STD 77,  
RFC 7011, DOI 10.17487/RFC7011, September 2013,  
<<http://www.rfc-editor.org/info/rfc7011>>.

- [RFC792] Postel, J., "Internet Control Message Protocol", RFC 792, September 1981.

## 7.2. Informative References

- [RFC4379] Kompella, K. and G. Swallow, "Detecting Multi-Protocol Label Switched (MPLS) Data Plane Failures", RFC 4379, DOI 10.17487/RFC4379, February 2006, <<http://www.rfc-editor.org/info/rfc4379>>.
- [RFC4443] Conta, A., Deering, S., and M. Gupta, Ed., "Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification", RFC 4443, DOI 10.17487/RFC4443, March 2006, <<http://www.rfc-editor.org/info/rfc4443>>.
- [RFC5880] Katz, D. and D. Ward, "Bidirectional Forwarding Detection (BFD)", RFC 5880, DOI 10.17487/RFC5880, June 2010, <<http://www.rfc-editor.org/info/rfc5880>>.
- [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, <<http://www.rfc-editor.org/info/rfc7276>>.

## Authors' Addresses

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

Email: [dekumar@cisco.com](mailto:dekumar@cisco.com)

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

Email: [wangzitao@huawei.com](mailto: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



Network Working Group  
Internet-Draft  
Intended status: Standards Track  
Expires: March 24, 2018

D. Kumar  
Cisco  
M. Wang  
Q. Wu  
Huawei  
R. Rahman  
S. Raghavan  
Cisco  
September 20, 2017

Retrieval Methods YANG Data Model for Connectionless Operations,  
Administration, and Maintenance(OAM) protocols  
draft-ietf-lime-yang-connectionless-oam-methods-08

Abstract

This document presents a retrieval method YANG Data model for connectionless OAM protocols. It provides technology-independent RPC operations for connectionless OAM protocols. The retrieval methods 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 levels through a unified interface) and interacting OAM workflows ( i.e., performing OAM functions at same levels through a unified interface).

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <https://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on March 24, 2018.

Copyright Notice

Copyright (c) 2017 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<https://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

1. Introduction . . . . .	2
2. Conventions used in this document . . . . .	3
2.1. Terminology . . . . .	3
2.2. Tree Diagrams . . . . .	4
3. Overview of the Connectionless OAM retrieval methods Model . . . . .	4
3.1. RPC operation definitions . . . . .	5
3.2. OAM Retrieval Methods Hierarchy . . . . .	7
4. OAM Retrieval Methods YANG Module . . . . .	14
5. Security Considerations . . . . .	19
6. IANA Considerations . . . . .	19
7. References . . . . .	20
7.1. Normative References . . . . .	20
7.2. Informative References . . . . .	21
Appendix A. Appdendix A.1 Extending Connectionless OAM Method Module Example . . . . .	21
Appendix B. Appendix A.2 Example of new retrieval procedures Model . . . . .	22
Authors' Addresses . . . . .	30

1. Introduction

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

1. Monitor reachability of destinations (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] and BFD [RFC5880] are well-known fault verification and isolation tools, respectively, for IP networks. Over the years, different technologies have developed similar tools for similar purposes.

In this document, we present an on-demand retrieval method YANG Data model for connectionless OAM protocols. This model provides technology-independent RPC operations for connectionless OAM protocols. It is separated from the generic YANG model for connectionless OAM [I-D.ietf-lime-yang-connectionless-oam] and can avoid mixing the models for the retrieved-data from the retrieval procedures. It is expected that retrieval procedures would evolve faster than the data model [I-D.ietf-lime-yang-connectionless-oam] and will allow new procedures to be defined for retrieval of the same data defined by the base data 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

RPC - A Remote Procedure Call

RPC operation - A specific Remote Procedure Call

## 2.2. Tree Diagrams

A simplified graphical representation of the data model is used in this document. The meaning of the symbols in these diagrams is as follows:

Each node is printed as:

```
<status> <flags> <name> <opts> <type>
```

<status> is one of:  
+ for current

<flags> is one of:

```
rw for configuration data
ro for non-configuration data
-x for rpcs
-n for notifications
```

<name> is the name of the node

If the node is augmented into the tree from another module, its name is printed as <prefix>:<name>.

<opts> is one of:

```
? for an optional leaf or choice
! for a presence container
* for a leaf-list or list
[<keys>] for a list's keys
```

<type> is the name of the type for leafs and leaf-lists

## 3. Overview of the Connectionless OAM retrieval methods Model

In this document, we present an on-demand retrieval method YANG Data model for connectionless OAM protocols. This model provides technology-independent retrieval procedures (RPC operations) for connectionless OAM protocols. It provides a flexible way to retrieve the data which defined by the "ietf-connectionless-oam.yang" [I-D.ietf-lime-yang-connectionless-oam].

### 3.1. RPC operation definitions

The RPC model facilitates issuing commands to a NETCONF server (in this case to the device that need to execute the OAM command) and obtaining a response.

Under 'connectionless-oam-methods' module, we summarize common OAM functions and define two generic RPC operations: 'continuity-check' and 'path-discovery'. In practice, these RPC operations are activated on-demand and supported by corresponding technology-specific OAM tools [RFC7276]. For example, for the IP OAM model, the continuity-check RPC corresponds to the IP Ping [RFC792] [RFC4443], while the path-discovery RPC operation corresponds to IP Traceroute [RFC792] [RFC4443].

Note that the RPC operation presented in this document is the base building block, which is used to derive a model for a technology-specific OAM (i.e., ICMP ping [RFC792] [RFC4443], LSP ping [RFC8029]), the base building block should be extended with corresponding technology specific parameters. To facilitate this for future enhancements to data retrieval methods, the RPCs are captured under a separate module.

The generic 'path-discovery-data' and 'continuity-check-data' groupings are used as data outputs from different RPCs described in this document. Similar methods including other RPCs can retrieve the data using the same data model.

```
rpc continuity-check {
  if-feature coam:continuity-check;
  description
    "Continuity-check RPC operation as per RFC7276.";
  input {
    uses rpc-input-parameters;
    ....
  }
  output {
    container error-code {
      leaf status-code {
        type identityref{
          base status-code;
        }
      }
      mandatory true;
      description
        "Error code for CC.";
    }
    leaf status-sub-code {
      type identityref{
```

```
        base status-sub-code;
    }
    mandatory true;
    description
        "Sub code for CC.";
    }
    description
        "Error code and Sub Code for CC.";
    }
    uses coam:continuity-check-data;
}
}

rpc path-discovery {
    description
        "path discovery RPC operation as per RFC7276.";
    input {
        uses rpc-input-parameters;
        .....
    }
    output {
        list response-list {
            key "response-index";
            description
                "Path discovery response list.";
            leaf response-index {
                type uint32;
                mandatory true;
                description
                    "Response index.";
            }

            leaf status-code {
                type identityref{
                    base status-code;
                }
                mandatory true;
                description
                    "Error code for Path Discovery. ";
            }
            leaf status-sub-code {
                type identityref{
                    base status-sub-code;
                }
                mandatory true;
                description
                    "Sub code for Path Discovery. ";
            }
        }
    }
}
```

```

    }
    uses coam:path-discovery-data;
  }
}

```

Snippet of data hierarchy related to RPC operations

### 3.2. OAM Retrieval Methods Hierarchy

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

```
module: ietf-connectionless-oam-methods
```

```
rpcs:
```

```

+---x continuity-check {coam:continuity-check}?
|
|   +---w input
|   |
|   |   +---w destination-tp
|   |   |
|   |   |   +---w tp-location-type      identityref
|   |   |   +---w tp-address
|   |   |   |   +---w mac-address
|   |   |   |   |   +---w mac-address      yang:mac-address
|   |   |   |   +---w ipv4-address
|   |   |   |   |   +---w ipv4-address      inet:ipv4-address
|   |   |   |   +---w ipv6-address
|   |   |   |   |   +---w ipv6-address      inet:ipv6-address
|   |   |   +---w tp-attribute
|   |   |   |   +---w tp-attribute-type?    address-attribute-type
|   |   |   |   +---w (tp-attribute-value)?
|   |   |   |   +---:(ip-prefix)
|   |   |   |   |   +---w ip-prefix?        inet:ip-prefix
|   |   |   |   +---:(bgp)
|   |   |   |   |   +---w bgp?              inet:ip-prefix
|   |   |   |   +---:(tunnel)
|   |   |   |   |   +---w tunnel-interface?  uint32
|   |   |   |   +---:(pw)
|   |   |   |   |   +---w remote-pe-address?  inet:ip-address
|   |   |   |   |   +---w pw-id?            uint32
|   |   |   |   +---:(vpls)
|   |   |   |   |   +---w route-distinguisher?  rt:route-distinguisher
|   |   |   |   |   +---w sender-ve-id?        uint16
|   |   |   |   |   +---w receiver-ve-id?      uint16
|   |   |   |   +---:(mpls-mldp)
|   |   |   |   |   +---w (root-address)?
|   |   |   |   |   |   +---:(ip-address)
|   |   |   |   |   |   |   +---w source-address?  inet:ip-address
|   |   |   |   |   |   |   +---w group-ip-address?  inet:ip-address
|   |   |   |   |   +---:(vpn)
|   |   |   |   |   |   +---w as-number?          inet:as-number

```







```

|   |   |--ro tx-packet-failed?   uint32
+--ro session-error-statistics
|   |   |--ro packet-drops-count?      uint32
|   |   |--ro packet-reorder-count?    uint32
|   |   |--ro packets-out-of-seq-count? uint32
|   |   |--ro packets-dup-count?       uint32
+--ro session-delay-statistics
|   |   |--ro time-resolution-value?    identityref
|   |   |--ro min-delay-value?          uint32
|   |   |--ro max-delay-value?          uint32
|   |   |--ro average-delay-value?      uint32
+--ro session-jitter-statistics
|   |   |--ro time-resolution-value?    identityref
|   |   |--ro min-jitter-value?         uint32
|   |   |--ro max-jitter-value?         uint32
|   |   |--ro average-jitter-value?     uint32
+---x path-discovery {coam:path-discovery}?
+---w input
|   |   +---w destination-tp
|   |   |   +---w tp-location-type      identityref
|   |   |   +---w tp-address
|   |   |   |   +---w mac-address
|   |   |   |   |   +---w mac-address      yang:mac-address
|   |   |   |   +---w ipv4-address
|   |   |   |   |   +---w ipv4-address      inet:ipv4-address
|   |   |   |   +---w ipv6-address
|   |   |   |   |   +---w ipv6-address      inet:ipv6-address
|   |   |   +---w tp-attribute
|   |   |   |   +---w tp-attribute-type?    address-attribute-type
|   |   |   |   +---w (tp-attribute-value)?
|   |   |   |   |   +---:(ip-prefix)
|   |   |   |   |   |   +---w ip-prefix?      inet:ip-prefix
|   |   |   |   |   +---:(bgp)
|   |   |   |   |   |   +---w bgp?            inet:ip-prefix
|   |   |   |   |   +---:(tunnel)
|   |   |   |   |   |   +---w tunnel-interface?  uint32
|   |   |   |   |   +---:(pw)
|   |   |   |   |   |   +---w remote-pe-address?  inet:ip-address
|   |   |   |   |   |   +---w pw-id?            uint32
|   |   |   |   |   +---:(vpls)
|   |   |   |   |   |   +---w route-distinguisher?  rt:route-distinguisher
|   |   |   |   |   |   +---w sender-ve-id?        uint16
|   |   |   |   |   |   +---w receiver-ve-id?      uint16
|   |   |   |   |   +---:(mpls-mldp)
|   |   |   |   |   |   +---w (root-address)?
|   |   |   |   |   |   |   +---:(ip-address)
|   |   |   |   |   |   |   |   +---w source-address?      inet:ip-address
|   |   |   |   |   |   |   |   +---w group-ip-address?    inet:ip-address

```



```

|         |         +---:(global-id)
|         |         +---ro lsp-id?           string
+---ro system-info
|         +---ro system-id?   rt:router-id
+---ro dest-test-point
|         +---ro ni?           routing-instance-ref
|         +---ro tp-location-type identityref
+---ro tp-address
|         +---ro mac-address
|         | +---ro mac-address   yang:mac-address
+---ro ipv4-address
|         +---ro ipv4-address   inet:ipv4-address
+---ro ipv6-address
|         +---ro ipv6-address   inet:ipv6-address
+---ro tp-attribute
|         +---ro tp-attribute-type? address-attribute-type
|         +---ro (tp-attribute-value)?
|         | +---:(ip-prefix)
|         | | +---ro ip-prefix?   inet:ip-prefix
|         | +---:(bgp)
|         | | +---ro bgp?         inet:ip-prefix
|         | +---:(tunnel)
|         | | +---ro tunnel-interface? uint32
|         | +---:(pw)
|         | | +---ro remote-pe-address? inet:ip-address
|         | | +---ro pw-id?         uint32
|         | +---:(vpls)
|         | | +---ro route-distinguisher? rt:route-distinguisher
|         | | +---ro sender-ve-id?       uint16
|         | | +---ro receiver-ve-id?    uint16
|         | +---:(mpls-mldp)
|         | | +---ro (root-address)?
|         | | | +---:(ip-address)
|         | | | | +---ro source-address?   inet:ip-address
|         | | | | +---ro group-ip-address?  inet:ip-address
|         | | | +---:(vpn)
|         | | | | +---ro as-number?       inet:as-number
|         | | | +---:(global-id)
|         | | | | +---ro lsp-id?         string
+---ro system-info
|         +---ro system-id?   rt:router-id
+---ro sequence-number?      uint64
+---ro hop-cnt?              uint8
+---ro session-packet-statistics
|         +---ro rx-packet-count?   uint32
|         +---ro tx-packet-count?   uint32
|         +---ro rx-bad-packet?     uint32
|         +---ro tx-packet-failed?  uint32

```

```

+--ro session-error-statistics
|   +--ro packet-drops-count?          uint32
|   +--ro packet-reorder-count?       uint32
|   +--ro packets-out-of-seq-count?   uint32
|   +--ro packets-dup-count?          uint32
+--ro session-delay-statistics
|   +--ro time-resolution-value?      identityref
|   +--ro min-delay-value?            uint32
|   +--ro max-delay-value?            uint32
|   +--ro average-delay-value?        uint32
+--ro session-jitter-statistics
|   +--ro time-resolution-value?      identityref
|   +--ro min-jitter-value?           uint32
|   +--ro max-jitter-value?           uint32
|   +--ro average-jitter-value?       uint32
+--ro path-verification
|   +--ro flow-info?                  string
|   +--ro session-path-verification-statistics
|       +--ro verified-count?         uint32
|       +--ro failed-count?          uint32
+--ro path-trace-info
|   +--ro path-trace-info-list* [index]
|       +--ro index                   uint32
|       +--ro ni?                     routing-instance-ref
|       +--ro tp-location-type        identityref
|       +--ro tp-address
|           +--ro mac-address
|               | +--ro mac-address    yang:mac-address
|           +--ro ipv4-address
|               | +--ro ipv4-address   inet:ipv4-address
|           +--ro ipv6-address
|               | +--ro ipv6-address   inet:ipv6-address
|       +--ro tp-attribute
|           +--ro tp-attribute-type?   address-attribute-type
|           +--ro (tp-attribute-value)?
|               +--:(ip-prefix)
|                   | +--ro ip-prefix?   inet:ip-prefix
|               +--:(bgp)
|                   | +--ro bgp?         inet:ip-prefix
|               +--:(tunnel)
|                   | +--ro tunnel-interface? uint32
|               +--:(pw)
|                   | +--ro remote-pe-address? inet:ip-address
|                   | +--ro pw-id?       uint32
|               +--:(vpls)
|                   | +--ro route-distinguisher? rt:route-distinguisher
|                   | +--ro sender-ve-id?  uint16
|                   | +--ro receiver-ve-id? uint16

```

```

|         +---:(mpls-mldp)
|         |   +---ro (root-address)?
|         |   |   +---:(ip-address)
|         |   |   |   +---ro source-address?           inet:ip-address
|         |   |   |   +---ro group-ip-address?        inet:ip-address
|         |   |   +---:(vpn)
|         |   |   |   +---ro as-number?                inet:as-number
|         |   |   +---:(global-id)
|         |   |   |   +---ro lsp-id?                   string
|         |   +---ro system-info
|         |   |   +---ro system-id?   rt:router-id
+---ro timestamp-type?           uint32
+---ro timestamp-sec?           uint32
+---ro timestamp-nanosec?       uint32
+---ro ingress-intf-name?       if:interface-ref
+---ro egress-intf-name?        if:interface-ref
+---ro queue-depth?             uint32
+---ro transit-delay?           uint32
+---ro app-meta-data?           uint64

```

data hierarchy of OAM Retrieval Methods

#### 4. OAM Retrieval Methods YANG Module

```

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

module ietf-connectionless-oam-methods {
namespace "urn:ietf:params:xml:ns:yang:ietf-connectionless-oam-methods";
prefix coam-methods;
import ietf-interfaces {
prefix if;
}
import ietf-connectionless-oam {
prefix coam;
}
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 RPC operations 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
    "08 version";
  reference "draft-ietf-lime-yang-connectionless-oam-methods";
}

identity status-code{
  description
    "Base status code";
}

identity invalid-cc{
  base status-code;
  description
    "Indicates that the Continuity check message is invalid";
}

identity invalid-pd {
  base status-code;
  description
    "Indicates that the path discovery message is invalid";
}

identity status-sub-code {
  description
    "Base status sub code";
}

grouping rpc-input-parameters {
  container destination-tp {
    uses coam:tp-address;
    description
      "Destination test point.";
  }
  leaf source-interface {
    type if:interface-ref;
    mandatory true;
    description
      "Source interface.";
  }
  leaf outbound-interface {
    type if:interface-ref;
    mandatory true;
    description
```

```
        "Outbound interface.";
    }
    leaf vrf {
        type coam:routing-instance-ref;
        description
            "VRF instance.";
    }
    description
        "Grouping for RPC input parameters";
}
rpc continuity-check {
    if-feature "coam:continuity-check";
    description
        "Continuity-check RPC operation as per RFC7276.";
    input {
        uses rpc-input-parameters;
        uses coam:session-type {
            description "If session-type is specified, then session-type
                must be set to on-demand";
        }
        leaf count {
            type uint32;
            default "5";
            description
                "Specifies the number of
                packets that will be sent. By
                default, the packet number is
                set to 5.";
        }
        leaf ttl {
            type uint8;
            default "255";
            description
                "Time to live (TTL) used to limit lifetime
                of data packet transmitted in the network
                and prevent looping. The TTL value is decremented
                for every hop which the packet traverses. If the
                TTL is zero, the data packet will be discarded.";
        }
    }
    leaf packet-size {
        type uint32 {
            range "64..10000";
        }
        default "64";
        description
            "Packet size of continuity-check message, in octets.
            By default, the packet size is set to 64 octets.";
    }
}
```



```
    }
    output {
      container error-code {
        leaf status-code {
          type identityref{
            base status-code;
          }
        }
        mandatory true;
        description
          "Error code for continuity-check message. For example, Error code in
          ICMPv6 message includes
          1-Destination Unreachable
          2- Packet Too Big
          3- Time Exceeded
          4- Parameter Problem [RFC4443].";
      }
      leaf status-sub-code {
        type identityref{
          base status-sub-code;
        }
      }
      mandatory true;
      description
        "Sub code for continuity-check message. For example Sub code in
        ICMPv6 Parameter Problem Message includes:
        1-Erroneous header field encountered
        2-Unrecognized Next Header type encountered
        3-Unrecognized IPv6 option encountered.";
    }
    description
      "Error code and Sub Code for continuity-check message.";
  }
  uses coam:continuity-check-data;
}

rpc path-discovery {
  if-feature "coam:path-discovery";
  description
    "Path discovery RPC operation as per RFC7276.";
  input {
    uses rpc-input-parameters;
    uses coam:session-type {
      description "If session-type is specified, then session-type
      must be set to on-demand";
    }
  }
  leaf max-ttl {
    type uint8;
    default "255";
  }
}
```

```
    description
      "Maximum TTL indicates the maximum number of hops that
      a packet is permitted to travel before being discarded
      by a router. By default, the maximum TTL is set to 255."
    }
  }
}
output {
  list response-list {
    key "response-index";
    description
      "Path discovery response list.";
    leaf response-index {
      type uint32;
      mandatory true;
      description
        "Response index.";
    }
    leaf status-code {
      type identityref {
        base status-code;
      }
      mandatory true;
      description
        "Error code for Path Discovery message.
        For example, Error code in ICMPv6 message includes
        1-Destination Unreachable
        2- Packet Too Big
        3- Time Exceeded
        4- Parameter Problem [RFC4443]. ";
    }
    leaf status-sub-code {
      type identityref {
        base status-sub-code;
      }
      mandatory true;
      description
        "Sub code for Path Discovery message. For example Sub code in
        ICMPv6 Parameter Problem Message includes:
        1-Erroneous header field encountered
        2-Unrecognized Next Header type encountered
        3-Unrecognized IPv6 option encountered ";
    }
  }
}
uses coam:path-discovery-data;
}
}
```

<CODE ENDS>

## 5. 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.

Some of the RPC operations in this YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control access to these operations. These are the operations and their sensitivity/vulnerability:

- o continuity-check: Generates continuity check.
- o path-discovery: Generates path discovery.

which may lead to Denial-of-Service attack on both the local device and the network or unauthorized source access to some sensitive information.

## 6. 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-methods

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-methods

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

prefix: coam-methods

reference: RFC XXXX

## 7. References

### 7.1. Normative References

- [I-D.ietf-lime-yang-connectionless-oam]  
Kumar, D., Wang, Z., Wu, Q., Rahman, R., and S. Raghavan,  
"Generic YANG Data Model for Connectionless Operations,  
Administration, and Maintenance(OAM) protocols", draft-  
ietf-lime-yang-connectionless-oam-10 (work in progress),  
September 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>>.
- [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>>.
- [RFC7011] Claise, B., Ed., Trammell, B., Ed., and P. Aitken,  
"Specification of the IP Flow Information Export (IPFIX)  
Protocol for the Exchange of Flow Information", STD 77,  
RFC 7011, DOI 10.17487/RFC7011, September 2013,  
<<https://www.rfc-editor.org/info/rfc7011>>.

- [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>>.

## 7.2. Informative References

- [I-D.ietf-netconf-yang-push] Clemm, A., Voit, E., Prieto, A., Tripathy, A., Nilsen-Nygaard, E., Bierman, A., and B. Lengyel, "Subscribing to YANG datastore push updates", draft-ietf-netconf-yang-push-09 (work in progress), September 2017.
- [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>>.
- [RFC5880] Katz, D. and D. Ward, "Bidirectional Forwarding Detection (BFD)", RFC 5880, DOI 10.17487/RFC5880, June 2010, <<https://www.rfc-editor.org/info/rfc5880>>.
- [RFC6087] Bierman, A., "Guidelines for Authors and Reviewers of YANG Data Model Documents", RFC 6087, DOI 10.17487/RFC6087, January 2011, <<https://www.rfc-editor.org/info/rfc6087>>.
- [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>>.
- [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>>.

## Appendix A. Appdendix A.1 Extending Connectionless OAM Method Module Example

The following is an example of extensions possible to "ietf-connectionless-oam-methods" YANG model defined in this document.

The snippet below depicts an example of augmenting the "ietf-connectionless-oam-methods" YANG model with ICMP ping attributes:

```
augment "/coam-methods:continuity-check"
+ "/coam-methods:output" {
  container session-rtt-statistics {
    leaf min-rtt {
      type uint32;
    }
    description
    "This minimum ping round-trip-time(RTT) received.";
  }
  leaf max-rtt {
    type uint32;
  }
  description
  "This maximum ping round-trip-time(RTT) received.";
  }
  leaf avg-rtt {
    type uint32;
  }
  description
  "The current average ping round-trip-time(RTT)";
  }
  description
  "This container presents the ping round-trip-time statistics.";
  }
}
```

#### Appendix B. Appendix A.2 Example of new retrieval procedures Model

As discussed in introduction section of this document, the new retrieval procedures can be defined for retrieval of the same data defined by base YANG Data model for connectionless OAM protocols. This appendix demonstrates how the base connectionless OAM data model can be extended to support persistent data retrieval besides on demand retrieval procedures defined in section 3, i.e., first retrieve persistent-id based on destination test point location information and then retrieve export details based on persistent-id. Internet Protocol Flow Information Export (IPFIX) [RFC7011] or YANG-push [I-D.ietf-netconf-yang-push]. are currently outlined here as data export options and more can be added in future.

The YANG module "example-cl-oam-persistent-methods" shown below is intended as an illustration rather than a real definition of a RPC operation model for persistent data retrieval. For the sake of brevity, this module does not obey all the guidelines specified in [RFC6087].

```
module example-cl-oam-persistent-methods {
namespace "http://example.com/cl-oam-persistent-methods";
```

```
prefix pcoam-methods;
import ietf-interfaces {
  prefix if;
}
import ietf-connectionless-oam {
  prefix coam;
}
import ietf-yang-types {
  prefix yang;
}
identity export-method {
  description
    "Base identity to represent a conceptual export-method.";
}
identity ipfix-export {
  base export-method;
  description
    "IPFIX based export. Configuration provided separately.";
}
identity yang-push-export {
  base export-method;
  description
    "Yang-push from draft-ietf-netconf-yang-push";
}
identity status-code{
  description
    "Base status code";
}
identity invalid-cc{
  base status-code;
  description
    "Indicates that the Continuity check message is invalid";
}
identity invalid-pd {
  base status-code;
  description
    "Indicates that the path discovery message is invalid";
}
identity status-sub-code {
  description
    "Base status sub code";
}
typedef export-method {
  type identityref {
    base export-method;
  }
}
```

```
    }
    description
      "Export method type.";
  }
  typedef change-type {
    type enumeration {
      enum "create" {
        description
          "Change due to a create.";
      }
      enum "delete" {
        description
          "Change due to a delete.";
      }
      enum "modify" {
        description
          "Change due to an update.";
      }
    }
  }
  description
    "Different types of changes that may occur.";
}

rpc cc-get-persistent-id {
  if-feature "coam:continuity-check";
  description
    "Obtains continuity-check persistent identification given mapping
    parameters as input.";
  input {
    container destination-tp {
      uses coam:tp-address;
      description
        "Destination test point.";
    }
    uses coam:session-type;
    leaf source-interface {
      type if:interface-ref;
      description
        "Source interface.";
    }
    leaf outbound-interface {
      type if:interface-ref;
      description
        "Outbound interface.";
    }
    leaf vrf {
      type coam:routing-instance-ref;
      description

```



```
        "VRF instance.";
    }
}
output {
  container error-code {
    leaf status-code {
      type identityref{
        base status-code;
      }
      mandatory true;
      description
        "Error code.";
    }
    leaf status-sub-code {
      type identityref{
        base status-sub-code;
      }
      mandatory true;
      description
        "Sub code for CC.";
    }
  }
  description
    "Error code and Sub Code.";
}

leaf cc-persistent-id {
  type string;
  description
    "Id to act as a cookie.";
}
}

rpc cc-persistent-get-export-details {
  if-feature "coam:continuity-check";
  description
    "Given the persistent id, gets the configuration
    options, details related to the configured data
    export.";
  input {
    leaf cc-persistent-id {
      type string;
      description
        "Persistent Id for use as a key in search.";
    }
  }
  output {
    container error-code {
```

```
leaf status-code {
  type identityref{
    base status-code;
  }
  mandatory true;
  description
    "Error code.";
}
leaf status-sub-code {
  type identityref{
    base status-sub-code;
  }
  mandatory true;
  description
    "Sub code for CC.";
}
description
  "Error code and Sub Code.";
}

leaf data-export-method {
  type export-method;
  description
    "Type of export in use.";
}

choice cc-trigger {
  description
    "Necessary conditions for
    periodic or on-change trigger.";
  case periodic {
    description
      "Periodic reports.";
    leaf period {
      type yang:timeticks;
      description
        "Time interval between reports.";
    }
    leaf start-time {
      type yang:date-and-time;
      description
        "Timestamp from which reports were started.";
    }
  }
  case on-change {
    description
      "On-change trigger and not periodic.";
    leaf all-data-on-start {
```

```
        type boolean;
        description
            "Full update done on start or not.";
    }
    leaf-list excluded-change {
        type change-type;
        description
            "Changes that will not trigger an update.";
    }
}
}
}
}

rpc pd-get-persistent-id {
    if-feature "coam:path-discovery";
    description
        "Obtains persistent path discovery identification.";

    input {
        container destination-tp {
            uses coam:tp-address;
            description
                "Destination test point.";
        }
        uses coam:session-type;
        leaf source-interface {
            type if:interface-ref;
            description
                "Source interface.";
        }
        leaf outbound-interface {
            type if:interface-ref;
            description
                "Outbound interface.";
        }
        leaf vrf {
            type coam:routing-instance-ref;
            description
                "VRF";
        }
    }
    output {
        list response-list {
            key "response-index";
            description
                "Path discovery response list.";
            leaf response-index {
```

```
        type uint32;
        mandatory true;
        description
            "Response index.";
    }
    leaf status-code {
        type identityref {
            base status-code;
        }
        mandatory true;
        description
            "Error code for Persistent Path Discovery Information. ";
    }
    leaf status-sub-code {
        type identityref {
            base status-sub-code;
        }
        mandatory true;
        description
            "Sub code for Persistent Path Discovery Information. ";
    }
    leaf pd-persistent-id {
        type string;
        description
            "Id to act as a cookie.";
    }
}
}
}

rpc pd-persistent-get-export-details {
    if-feature "coam:path-discovery";
    description
        "Given the persistent id, gets the configuration
        options, details related to the configured data
        export.";
    input {
        leaf cc-persistent-id {
            type string;
            description
                "Persistent Id for use as a key in search.";
        }
    }

    output {
        list response-list {
            key "response-index";
            description

```

```
    "Path discovery response list.";
leaf response-index {
  type uint32;
  mandatory true;
  description
    "Response index.";
}
leaf status-code {
  type identityref{
    base status-code;
  }
  mandatory true;
  description
    "Error code for Persistent Path Discovery Creation. ";
}
leaf status-sub-code {
  type identityref{
    base status-sub-code;
  }
  mandatory true;
  description
    "Sub code for Persistent Path Discovery Creation. ";
}
leaf data-export-method {
  type export-method;
  description
    "Type of export.";
}
choice pd-trigger {
  description
    "Necessary conditions
    for periodic or on-change
    trigger.";
  case periodic {
    description
      "Periodic reports.";
    leaf period {
      type yang:timeticks;
      description
        "Time interval between reports.";
    }
    leaf start-time {
      type yang:date-and-time;
      description
        "Timestamp from which reports are started.";
    }
  }
  case on-change {
```

```
description
  "On-change trigger and not periodic.";
leaf all-data-on-start {
  type boolean;
  description
    "Full update done on start or not.";
}
leaf-list excluded-change {
  type change-type;
  description
    "Changes that will not trigger an update.";
}
}
}
}
}
}
```

## Authors' Addresses

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

Email: [dekumar@cisco.com](mailto:dekumar@cisco.com)

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

Email: [wangzitao@huawei.com](mailto:wangzitao@huawei.com)

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

Email: [bill.wu@huawei.com](mailto: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

Network Working Group  
Internet-Draft  
Intended status: Standards Track  
Expires: September 7, 2017

D. Kumar  
Cisco  
Q. Wu  
M. Wang  
Huawei  
March 6, 2017

Generic YANG Data Model for Connection Oriented Operations,  
Administration, and Maintenance(OAM) protocols  
draft-ietf-lime-yang-oam-model-09

Abstract

This document presents a base YANG Data model for connection oriented OAM protocols. It provides a technology-independent abstraction of key OAM constructs for such protocols. The model presented here can be extended to include technology specific details. This guarantees uniformity in the management of OAM protocols and provides support for nested OAM workflows (i.e., performing OAM functions at different levels through a unified interface)

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <http://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on September 7, 2017.

Copyright Notice

Copyright (c) 2017 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<http://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents



carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

## Table of Contents

1. Introduction . . . . .	3
2. Conventions used in this document . . . . .	4
2.1. Terminology . . . . .	5
3. Architecture of Generic YANG Model for OAM . . . . .	6
4. Overview of the OAM Model . . . . .	7
4.1. Maintenance Domain (MD) configuration . . . . .	8
4.2. Maintenance Association (MA) configuration . . . . .	9
4.3. Maintenance Endpoint (MEP) configuration . . . . .	9
4.4. RPC definitions . . . . .	10
4.5. Notifications . . . . .	13
4.6. Monitor statistics . . . . .	13
4.7. OAM data hierarchy . . . . .	13
5. OAM YANG Module . . . . .	18
6. Base Mode . . . . .	41
6.1. MEP Address . . . . .	41
6.2. MEP ID for Base Mode . . . . .	41
6.3. Maintenance Association . . . . .	42
7. Connection-oriented OAM YANG model applicability . . . . .	42
7.1. Generic YANG Model extension for TRILL OAM . . . . .	43
7.1.1. MD Configuration Extension . . . . .	43
7.1.2. MA Configuration Extension . . . . .	43
7.1.3. MEP Configuration Extension . . . . .	44
7.1.4. RPC extension . . . . .	45
7.2. Generic YANG Model extension for MPLS-TP OAM . . . . .	45
7.2.1. MD Configuration Extension . . . . .	46
7.2.2. MA Configuration Extension . . . . .	47
7.2.3. MEP Configuration Extension . . . . .	47
8. Security Considerations . . . . .	48
9. IANA Considerations . . . . .	48
10. Acknowledgments . . . . .	49
11. References . . . . .	49
11.1. Normative References . . . . .	49
11.2. Informative References . . . . .	50
Appendix A. Contributors' Addresses . . . . .	51
Authors' Addresses . . . . .	52

## 1. Introduction

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

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

An overview of OAM tools is presented in [RFC7276]. Over the years, many technologies have developed similar tools for fault and performance management.

[IEEE802.1ag] Connectivity Fault Management is a well-established OAM standard that is widely adopted for Ethernet networks. ITU-T [G.8013], MEF Service OAM, MPLS-TP [RFC6371], TRILL [RFC7455] all define OAM mechanisms based on the manageability frame work of CFM [IEEE802.1ag].

Given the wide adoption of the underlying OAM concepts defined in CFM [IEEE802.1ag], it is a reasonable choice to develop the unified management framework for connection oriented OAM based on those concepts. In this document, we take the CFM [IEEE802.1ag] model and extend it to a technology independent framework and define the corresponding YANG model accordingly. The YANG model presented in this document is the base model for connection oriented OAM protocols and supports generic continuity check, connectivity verification and path discovery (traceroute). The generic YANG model for connection oriented OAM is designed to be extensible to other connection oriented technologies. Technology dependent nodes and remote process call (RPC) commands are defined in technology specific YANG models, which use and extend the base model defined here. As an example, VXLAN uses source UDP port number for flow entropy, while TRILL uses either MAC addresses, the VLAN tag or fine grain label, and/or IP addresses for flow entropy in the hashing for multipath selection. To capture this variation, corresponding YANG models would define the applicable structures as augmentation to the generic base model presented here. This accomplishes three goals: First it keeps each YANG model smaller and more manageable. Second, it allows independent development of corresponding YANG models. Third, implementations can limit support to only the applicable set of YANG models. (e.g. TRILL RBridge may only need to implement Generic model and the TRILL YANG model).

All implementations that follow the YANG framework presented in this document MUST implement the generic connection oriented YANG model presented here.

The YANG data model presented in this document is generated at the management layer. Encapsulations and state machines may differ according to each OAM protocol. A user who wishes to issues a Continuity Check command or a Loopback or initiate a performance monitoring session can do so in the same manner regardless of the underlying protocol or technology or specific vendor implementation.

As an example, consider a scenario where Loopback from device A to Device B fails. Between device A and B there are IEEE 802.1 bridges a, b and c. Let's assume a,b and c are using CFM [IEEE802.lag]. Upon detecting the Loopback failures, a user may decide to drill down to the lower level at different segments of the path and issue the corresponding fault verification (LBM) and fault isolation (LTM) tools, using the same API. This ability to drill down to a lower layer of the protocol stack at a specific segment within a path for fault localization and troubleshooting is referred to as "nested OAM workflow". It is a useful concept that leads to efficient network troubleshooting and maintenance workflows. The connection oriented OAM YANG model presented in this document facilitates that without needing changes to the underlying protocols.

## 2. Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119]. In this document, these words will appear with that interpretation only when in ALL CAPS. Lower case uses of these words are not to be interpreted as carrying [RFC2119] significance.

The following notations are used within the data tree and carry the meaning as below.

Each node is printed as:

<status> <flags> <name> <opts> <type>

<status> is one of:

+ for current

<flags> is one of:

rw for configuration data  
ro for non-configuration data  
-x for rpcs  
-n for notifications  
-w for writable

<name> is the name of the node

If the node is augmented into the tree from another module, its name is printed as <prefix>:<name>.

<opts> is one of:

? for an optional leaf or choice  
! for a presence container  
\* for a leaf-list or list  
[<keys>] for a list's keys  
(choice)/:(case) Parentheses enclose choice and case nodes,  
and case nodes are also marked with a colon (":")

<type> is the name of the type for leafs and leaf-lists

## 2.1. Terminology

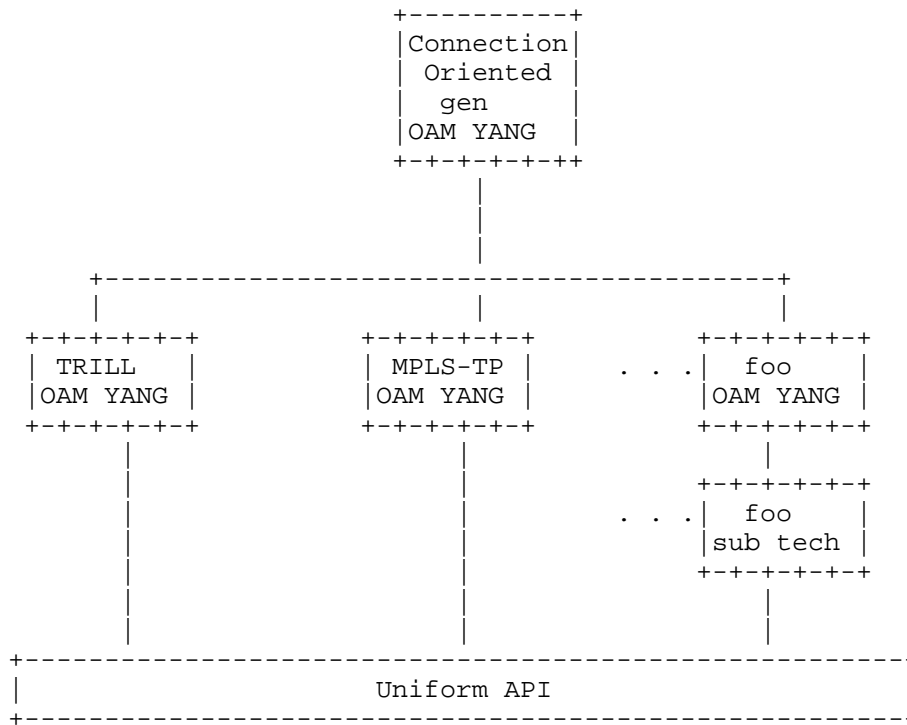
- CCM - Continuity Check Message [IEEE802.1ag].
- ECMP - Equal Cost Multipath.
- LBM - Loopback Message [IEEE802.1ag].
- MP - Maintenance Point [IEEE802.1ag].
- MEP - Maintenance End Point [RFC7174] (Maintenance association End Point [IEEE802.1ag], MEG End Points [RFC6371]).
- MIP - Maintenance Intermediate Point [RFC7174] (Maintenance domain Intermediate Point [IEEE802.1ag], MEG Intermediate Point [RFC6371]).
- MA - Maintenance Association [IEEE802.1ag] [RFC7174].

- MD - Maintenance Domain [IEEE802.lag]
- MEG - Maintenance Entity Group [RFC6371]
- MTV - Multi-destination Tree Verification Message.
- OAM - Operations, Administration, and Maintenance [RFC6291].
- TRILL - Transparent Interconnection of Lots of Links [RFC6325].
- CFM - Connectivity Fault Management [RFC7174] [IEEE802.lag].
- RPC - Remote Process Call.
- CC - Continuity Check [RFC7276]. Continuity Checks are used to verify that a destination is reachable and therefore also referred to as reachability verification.
- CV - Connectivity Verification [RFC7276]. Connectivity Verification are used to verify that a destination is connected. It are also referred to as path verification and used to verify not only that the two MPs are connected, but also that they are connected through the expected path, allowing detection of unexpected topology changes.

### 3. Architecture of Generic YANG Model for OAM

In this document we define a generic YANG model for connection oriented OAM protocols. The YANG model defined here is generic in a sense that other technologies can extend it for technology specific needs. The Generic YANG model acts as the root for other OAM YANG models. This allows users to traverse between different OAM protocols with ease through a uniform API set. This also enables a nested OAM workflow. Figure 1 depicts the relationship of different OAM YANG models to the Generic YANG Model for connection oriented OAM. The Generic YANG model for OAM provides a framework where technology- specific YANG models can inherit constructs from the base YANG models without needing to redefine them within the sub-technology.

Figure 1 depicts relationship of different YANG modules.



Relationship of OAM YANG model to generic (base) YANG model

4. Overview of the OAM Model

In this document we adopt the concepts of the CFM [IEEE802.1ag] model and structure it such that it can be adapted to different connection oriented OAM protocols.

At the top of the Model is the Maintenance Domain. Each Maintenance Domain is associated with a Maintenance Name and a Domain Level.

Under each Maintenance Domain there is one or more Maintenance Association (MA). In TRILL this can be per Fine-Grained Label or for VPLS this can be per VPLS instance [RFC6136].

Under each MA, there can be two or more MEPs (Maintenance End Points). MEPs are addressed by their respective technology specific address identifiers. The YANG model presented here provides flexibility to accommodate different addressing schemes.

In the vertical direction orthogonal to the Maintenance Domain, presented are the commands. Those, in YANG terms, are the RPC

commands. These RPC commands provide uniform APIs for continuity check, connectivity verification, path discovery(traceroute) and their equivalents as well as other OAM commands.

The OAM entities in the generic YANG model defined here will be either explicitly or implicitly configured using any of the OAM tools. The OAM tools used here are limited to OAM toolset specified in section 5.1 of [RFC7276]. In order to facilitate zero-touch experience, this document defines a default mode of OAM. The default mode of OAM is referred to as the Base Mode and specifies default values for each of model parameters, such as Maintenance Domain Level, Name of the Maintenance Association, Addresses of MEPs and so on. The default values of these depend on the technology. Base Mode for TRILL is defined in [RFC7455]. Base mode for other technologies and future extensions developed in IETF will be defined in their corresponding documents.

It is important to note that, no specific enhancements are needed in the YANG model to support Base Mode. Implementations that comply with this document, by default implement the data nodes of the applicable technology. Data nodes of the Base Mode are read-only nodes.

#### 4.1. Maintenance Domain (MD) configuration

The container "domains" is the top level container within the gen-oam module. Within the container "domains", separate list is maintained per MD. The MD list uses the key MD-name-string for indexing. MD-name-string is a leaf and derived from type string. Additional name formats as defined in [IEEE802.lag] or other standards can be included by association of the MD-name-format with an identity-ref. MD-name-format indicates the format of the augmented MD-names. MD-name is presented as choice/case construct. Thus, it is easily augmentable by derivative work.

```

module: ietf-conn-oam
+--rw domains
  +--rw domain* [technology MD-name-string]
    +--rw technology          identityref
    +--rw MD-name-string      MD-name-string
    +--rw MD-name-format?    identityref
    +--rw (MD-name)?
      | +--:(MD-name-null)
      |   +--rw MD-name-null?      empty
    +--rw md-level?          MD-level

```

Snippet of data hierarchy related to OAM domains

#### 4.2. Maintenance Association (MA) configuration

Within a given Maintenance Domain there can be one or more Maintenance Associations (MA). MAs are represented as a list and indexed by the MA-name-string. Similar to MD-name defined previously, additional name formats can be added by augmenting the name-format identity-ref and adding applicable case statements to MA-name.

```
module: ietf-conn-oam
  +--rw domains
    +--rw domain* [technology MD-name-string]
      .
      .
    +--rw MAs
      +--rw MA* [MA-name-string]
        +--rw MA-name-string          MA-name-string
        +--rw MA-name-format?         identityref
        +--rw (MA-name)?
          | +--:(MA-name-null)
          | +--rw MA-name-null?       empty
```

Snippet of data hierarchy related to Maintenance Associations (MA)

#### 4.3. Maintenance Endpoint (MEP) configuration

Within a given Maintenance Association (MA), there can be one or more Maintenance End Points (MEP). MEPs are represented as a list within the data hierarchy and indexed by the key MEP-name.



```

module: ietf-conn-oam
  +--rw domains
    +--rw domain* [technology MD-name-string]
      +--rw technology          identityref
      .
      .
    +--rw MAs
      +--rw MA* [MA-name-string]
        +--rw MA-name-string    MA-name-string
        .
        .
      +--rw MEP* [mep-name]
        +--rw mep-name          MEP-name
        +--rw (MEP-ID)?
          +--:(MEP-ID-int)
            +--rw MEP-ID-int?    int32
        +--rw MEP-ID-format?    identityref
        +--rw (mep-address)?
          +--:(mac-address)
            | +--rw mac-address?  yang:mac-address
            +--:(ipv4-address)
            | +--rw ipv4-address? inet:ipv4-address
            +--:(ipv6-address)
            | +--rw ipv6-address? inet:ipv6-address
          .
          .
        .
        .

```

Snippet of data hierarchy related to Maintenance Endpoint (MEP)

#### 4.4. RPC definitions

The RPC model facilitates issuing commands to a NETCONF server (in this case to the device that need to execute the OAM command) and obtain a response. RPC model defined here abstracts OAM specific commands in a technology independent manner.

There are several RPC commands defined for the purpose of OAM. In this section we present a snippet of the continuity check command for illustration purposes. Please refer to Section 4.5 for the complete data hierarchy and Section 5 for the YANG model.

```

module: ietf-conn-oam
  +--rw domains
    +--rw domain* [technology MD-name-string]
      +--rw technology          identityref
      .
      .

```

```

rpcs:
  +---x continuity-check {continuity-check}?
  | +---w input
  | | +---w technology?          identityref
  | | +---w MD-name-string  -> /domains/domain/MD-name-string
  | | +---w MA-name-string  -> /domains/domain/MAs/MA/MA-name-string
  | | +---w cos-id?         uint8
  | | +---w (ttl)?
  | | | +---:(ip-ttl)
  | | | | +---w ip-ttl?          uint8
  | | | +---:(mpls-ttl)
  | | | | +---w mpls-ttl?       uint8
  | | +---w sub-type?       identityref
  | | +---w source-mep?     -> /domains/domain/MAs/MA/MEP/mep-name
  | | +---w destination-mep
  | | | +---w (mep-address)?
  | | | | +---:(mac-address)
  | | | | | +---w mac-address?   yang:mac-address
  | | | | +---:(ipv4-address)
  | | | | | +---w ipv4-address?  inet:ipv4-address
  | | | | +---:(ipv6-address)
  | | | | | +---w ipv6-address?  inet:ipv6-address
  | | +---w (MEP-ID)?
  | | | +---:(MEP-ID-int)
  | | | | +---w MEP-ID-int?     int32
  | | | +---w MEP-ID-format?   identityref
  | | +---w count?            uint32
  | | +---w cc-transmit-interval? Interval
  | | +---w packet-size?     uint32
  | +--ro output
  | | +--ro (monitor-stats)?
  | | | +---:(monitor-null)
  | | | +--ro monitor-null?   empty
  +---x continuity-verification {connectivity-verification}?
  | +---w input
  | | +---w MD-name-string  ->/domains/domain/MD-name-string
  | | +---w MA-name-string  ->/domains/domain/MAs/MA/MA-name-string
  | | +---w cos-id?         uint8
  | | +---w (ttl)?
  | | | +---:(ip-ttl)
  | | | | +---w ip-ttl?          uint8
  | | | +---:(mpls-ttl)
  | | | | +---w mpls-ttl?       uint8
  | | +---w sub-type?       identityref
  | | +---w source-mep?     -> /domains/domain/MAs/MA/MEP/mep-name
  | | +---w destination-mep
  | | | +---w (mep-address)?
  | | | | +---:(mac-address)

```

```

| | | | +---w mac-address? yang:mac-address
| | | | +---:(ipv4-address)
| | | | | +---w ipv4-address? inet:ipv4-address
| | | | | +---:(ipv6-address)
| | | | | +---w ipv6-address? inet:ipv6-address
| | | | +---w (MEP-ID)?
| | | | | +---:(MEP-ID-int)
| | | | | +---w MEP-ID-int? int32
| | | | +---w MEP-ID-format? identityref
+---w count? uint32
+---w interval? Interval
+---w packet-size? uint32
+--ro output
+--ro (monitor-stats)?
+--:(monitor-null)
+--ro monitor-null? empty
+---x traceroute {traceroute}?
+---w input
+---w MD-name-string -> /domains/domain/MD-name-string
+---w MA-name-string -> /domains/domain/MAs/MA/MA-name-string
+---w cos-id? uint8
+---w (ttl)?
| +---:(ip-ttl)
| | +---w ip-ttl? uint8
| | +---:(mpls-ttl)
| | +---w mpls-ttl? uint8
+---w command-sub-type? identityref
+---w source-mep? -> /domains/domain/MAs/MA/MEP/mep-name
+---w destination-mep
| +---w (mep-address)?
| | +---:(mac-address)
| | | +---w mac-address? yang:mac-address
| | | +---:(ipv4-address)
| | | | +---w ipv4-address? inet:ipv4-address
| | | | +---:(ipv6-address)
| | | | +---w ipv6-address? inet:ipv6-address
| | +---w (MEP-ID)?
| | | +---:(MEP-ID-int)
| | | +---w MEP-ID-int? int32
| | +---w MEP-ID-format? identityref
+---w count? uint32
+---w interval? Interval
+--ro output
+--ro response* [response-index]
+--ro response-index uint8
+--ro (ttl)?
| +---:(ip-ttl)
| | +--ro ip-ttl? uint8

```

```

|   +---:(mpls-ttl)
|       +---ro mpls-ttl?           uint8
+---ro destination-mep
|   +---ro (mep-address)?
|       +---:(mac-address)
|           |   +---ro mac-address?   yang:mac-address
|           +---:(ipv4-address)
|           |   +---ro ipv4-address?  inet:ipv4-address
|           +---:(ipv6-address)
|           |   +---ro ipv6-address?  inet:ipv6-address
+---ro (MEP-ID)?
|   +---:(MEP-ID-int)
|       +---ro MEP-ID-int?         int32
+---ro MEP-ID-format?  identityref
+---ro mip {mip}?
|   +---ro interface?           if:interface-ref
|   +---ro (mip-address)?
|       +---:(mac-address)
|           |   +---ro mac-address?   yang:mac-address
|           +---:(ipv4-address)
|           |   +---ro ipv4-address?  inet:ipv4-address
|           +---:(ipv6-address)
|           |   +---ro ipv6-address?  inet:ipv6-address
+---ro (monitor-stats)?
|   +---:(monitor-null)
|       +---ro monitor-null?       empty

```

Snippet of data hierarchy related to RPC call continuity-check

#### 4.5. Notifications

Notification is sent on defect condition and defect clears with Maintenance Domain Name, MA Name, defect-type (The currently active defects), generating-mepid, and defect-message to indicate more details.

#### 4.6. Monitor statistics

Grouping for monitoring statistics is to be used by Yang modules which Augment Yang to provide statistics due to pro-active OAM like CCM Messages. For example CCM Transmit, CCM Receive, CCM Errors, etc.

#### 4.7. OAM data hierarchy

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

```

module: ietf-conn-oam
  +--rw domains
    +--rw domain* [technology MD-name-string]
      +--rw technology          identityref
      +--rw MD-name-string      MD-name-string
      +--rw MD-name-format?    identityref
      +--rw (MD-name)?
      | +--:(MD-name-null)
      |   +--rw MD-name-null?    empty
      +--rw md-level?          MD-level
    +--rw MAs
      +--rw MA* [MA-name-string]
        +--rw MA-name-string    MA-name-string
        +--rw MA-name-format?  identityref
        +--rw (MA-name)?
        | +--:(MA-name-null)
        |   +--rw MA-name-null?  empty
        +--rw (connectivity-context)?
        | +--:(context-null)
        |   +--rw context-null?  empty
        +--rw cos-id?          uint8
        +--rw cc-enable?      boolean
        +--rw MEP* [mep-name]
          +--rw mep-name        MEP-name
          +--rw (MEP-ID)?
          | +--:(MEP-ID-int)
          |   +--rw MEP-ID-int?  int32
          +--rw MEP-ID-format?  identityref
          +--rw (mep-address)?
          | +--:(mac-address)
          | | +--rw mac-address?  yang:mac-address
          | | +--:(ipv4-address)
          | |   +--rw ipv4-address?  inet:ipv4-address
          | | +--:(ipv6-address)
          | |   +--rw ipv6-address?  inet:ipv6-address
          +--rw cos-id?        uint8
          +--rw cc-enable?    boolean
          +--rw session* [session-cookie]
            +--rw session-cookie      uint32
            +--rw destination-mep
              +--rw (MEP-ID)?
              | +--:(MEP-ID-int)
              | | +--rw MEP-ID-int?  int32
              | | +--rw MEP-ID-format?  identityref
            +--rw destination-mep-address
              +--rw (mep-address)?
              | +--:(mac-address)
              | | +--rw mac-address?  yang:mac-address

```

```

|         |         +---:(ipv4-address)
|         |         |   +---rw ipv4-address?   inet:ipv4-address
|         |         +---:(ipv6-address)
|         |         |   +---rw ipv6-address?   inet:ipv6-address
|         |         +---rw cos-id?             uint8
+---rw MIP* [interface] {mip}?
  +---rw interface           if:interface-ref
  +---rw (mip-address)?
    |   +---:(mac-address)
    |   |   +---rw mac-address?   yang:mac-address
    |   +---:(ipv4-address)
    |   |   +---rw ipv4-address?   inet:ipv4-address
    |   +---:(ipv6-address)
    |   |   +---rw ipv6-address?   inet:ipv6-address
  +---rw level?             MD-level

```

rpcs:

```

+---x continuity-check {continuity-check}?
  +---w input
    |   +---w technology?           identityref
    |   +---w MD-name-string   -> /domains/domain/MD-name-string
    |   +---w MA-name-string   -> /domains/domain/MAs/MA/MA-name-string
    |   +---w cos-id?           uint8
    |   +---w (ttl)?
    |   |   +---:(ip-ttl)
    |   |   |   +---w ip-ttl?           uint8
    |   |   +---:(mpls-ttl)
    |   |   |   +---w mpls-ttl?         uint8
    |   +---w sub-type?         identityref
    |   +---w source-mep?       -> /domains/domain/MAs/MA/MEP/mep-name
    |   +---w destination-mep
    |   |   +---w (mep-address)?
    |   |   |   +---:(mac-address)
    |   |   |   |   +---w mac-address?   yang:mac-address
    |   |   |   +---:(ipv4-address)
    |   |   |   |   +---w ipv4-address?   inet:ipv4-address
    |   |   |   +---:(ipv6-address)
    |   |   |   |   +---w ipv6-address?   inet:ipv6-address
    |   |   +---w (MEP-ID)?
    |   |   |   +---:(MEP-ID-int)
    |   |   |   |   +---w MEP-ID-int?     int32
    |   |   +---w MEP-ID-format?   identityref
    |   +---w count?             uint32
    |   +---w cc-transmit-interval? Interval
    |   +---w packet-size?       uint32
  +---ro output
    +---ro (monitor-stats)?
      +---:(monitor-null)

```

```

|           +--ro monitor-null?    empty
+---x continuity-verification {continuity-verification}?
|   +---w input
|   |   +---w MD-name-string  -> /domains/domain/MD-name-string
|   |   +---w MA-name-string  -> /domains/domain/MAs/MA/MA-name-string
|   |   +---w cos-id?         uint8
|   |   +---w (ttl)?
|   |   |   +---:(ip-ttl)
|   |   |   |   +---w ip-ttl?         uint8
|   |   |   +---:(mpls-ttl)
|   |   |   |   +---w mpls-ttl?      uint8
|   |   +---w sub-type?      identityref
|   |   +---w source-mep?    -> /domains/domain/MAs/MA/MEP/mep-name
|   |   +---w destination-mep
|   |   |   +---w (mep-address)?
|   |   |   |   +---:(mac-address)
|   |   |   |   |   +---w mac-address?  yang:mac-address
|   |   |   |   +---:(ipv4-address)
|   |   |   |   |   +---w ipv4-address?  inet:ipv4-address
|   |   |   |   +---:(ipv6-address)
|   |   |   |   |   +---w ipv6-address?  inet:ipv6-address
|   |   |   +---w (MEP-ID)?
|   |   |   |   +---:(MEP-ID-int)
|   |   |   |   |   +---w MEP-ID-int?    int32
|   |   |   +---w MEP-ID-format?  identityref
|   |   +---w count?           uint32
|   |   +---w interval?       Interval
|   |   +---w packet-size?    uint32
|   +--ro output
|   |   +--ro (monitor-stats)?
|   |   |   +---:(monitor-null)
|   |   |   +--ro monitor-null?    empty
+---x traceroute {traceroute}?
|   +---w input
|   |   +---w MD-name-string  -> /domains/domain/MD-name-string
|   |   +---w MA-name-string  -> /domains/domain/MAs/MA/MA-name-string
|   |   +---w cos-id?         uint8
|   |   +---w (ttl)?
|   |   |   +---:(ip-ttl)
|   |   |   |   +---w ip-ttl?         uint8
|   |   |   +---:(mpls-ttl)
|   |   |   |   +---w mpls-ttl?      uint8
|   |   +---w command-sub-type?  identityref
|   |   +---w source-mep?    -> /domains/domain/MAs/MA/MEP/mep-name
|   |   +---w destination-mep
|   |   |   +---w (mep-address)?
|   |   |   |   +---:(mac-address)
|   |   |   |   |   +---w mac-address?  yang:mac-address

```

```

| | | +---:(ipv4-address)
| | | | +---w ipv4-address?    inet:ipv4-address
| | | +---:(ipv6-address)
| | | | +---w ipv6-address?    inet:ipv6-address
| | | +---w (MEP-ID)?
| | | | +---:(MEP-ID-int)
| | | | | +---w MEP-ID-int?    int32
| | | | +---w MEP-ID-format?  identityref
| | | +---w count?            uint32
| | | +---w interval?        Interval
+--ro output
+--ro response* [response-index]
+--ro response-index        uint8
+--ro (ttl)?
| +---:(ip-ttl)
| | +--ro ip-ttl?            uint8
| +---:(mpls-ttl)
| | +--ro mpls-ttl?         uint8
+--ro destination-mep
| +--ro (mep-address)?
| | +---:(mac-address)
| | | +--ro mac-address?     yang:mac-address
| | +---:(ipv4-address)
| | | +--ro ipv4-address?    inet:ipv4-address
| | +---:(ipv6-address)
| | | +--ro ipv6-address?    inet:ipv6-address
| +--ro (MEP-ID)?
| | +---:(MEP-ID-int)
| | | +--ro MEP-ID-int?     int32
| | +--ro MEP-ID-format?    identityref
+--ro mip {mip}?
| +--ro interface?          if:interface-ref
| +--ro (mip-address)?
| | +---:(mac-address)
| | | +--ro mac-address?     yang:mac-address
| | +---:(ipv4-address)
| | | +--ro ipv4-address?    inet:ipv4-address
| | +---:(ipv6-address)
| | | +--ro ipv6-address?    inet:ipv6-address
+--ro (monitor-stats)?
+---:(monitor-null)
+--ro monitor-null?        empty

```

notifications:

```

+---n defect-condition-notification
| +--ro technology?         identityref
| +--ro MD-name-string     -> /domains/domain/MD-name-string
| +--ro MA-name-string     -> /domains/domain/MAs/MA/MA-name-string

```



```

|   +--ro mep-name?          -> /domains/domain/MAs/MA/MEP/mep-name
|   +--ro defect-type?      identityref
|   +--ro generating-mepid
|   |   +--ro (MEP-ID)?
|   |   |   +---:(MEP-ID-int)
|   |   |   |   +--ro MEP-ID-int?      int32
|   |   +--ro MEP-ID-format?  identityref
|   +--ro (defect)?
|   |   +---:(defect-null)
|   |   |   +--ro defect-null?          empty
|   |   +---:(defect-code)
|   |   |   +--ro defect-code?         int32
+---n defect-cleared-notification
|   +--ro technology?        identityref
|   +--ro MD-name-string    -> /domains/domain/MD-name-string
|   +--ro MA-name-string    -> /domains/domain/MAs/MA/MA-name-string
|   +--ro mep-name?        -> /domains/domain/MAs/MA/MEP/mep-name
|   +--ro defect-type?      identityref
|   +--ro generating-mepid
|   |   +--ro (MEP-ID)?
|   |   |   +---:(MEP-ID-int)
|   |   |   |   +--ro MEP-ID-int?      int32
|   |   +--ro MEP-ID-format?  identityref
+--ro (defect)?
|   +---:(defect-null)
|   |   +--ro defect-null?          empty
+---:(defect-code)
|   +--ro defect-code?         int32

```

data hierarchy of OAM

## 5. OAM YANG Module

<CODE BEGINS> file "ietf-conn-oam.yang"

```

module ietf-conn-oam {
  namespace "urn:ietf:params:xml:ns:yang:ietf-conn-oam";
  prefix goam;

  import ietf-yang-types {
    prefix yang;
  }
  import ietf-inet-types {
    prefix inet;
  }
  import ietf-interfaces {
    prefix if;
  }
}

```

```
organization "IETF LIME Working Group";
contact
  "WG Web:      http://tools.ietf.org/wg/lime
  WG List:      mailto:lime@ietf.org
  WG Chair:     Carlos Pignataro cpignata@cisco.com
  WG Chair:     Ron Bonica rbonica@juniper.net
  Editor:       Deepak Kumar dekumar@cisco.com
  Editor:       Qin Wu bill.wu@huawei.com
  Editor:       Zitao Wang wangzitao@huawei.com";
description
  "This YANG module defines the generic configuration,
  statistics and rpc for connection oriented OAM
  to be used within IETF in a protocol independent manner.
  Functional level abstraction is independent
  with YANG modeling. 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 2017-02-10 {
  description
    "Initial revision. - 07 version";

  reference "draft-ietf-lime-yang-oam-model";
}

/* features */
feature connectivity-verification {
  description
    "This feature indicates that the server supports
    executing connectivity verification OAM command and
    returning a response. Servers that do not advertise
    this feature will not support executing
    connectivity verification command or rpc model for
    connectivity verification command.";
}
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 model for
    continuity check command.";
}

feature traceroute{
  description
```

```
        "This feature indicates that the server supports
        executing traceroute OAM command and
        returning a response. Servers that do not advertise
        this feature will not support executing
        traceroute command or rpc model for
        traceroute command.";
    }
feature mip {
    description
    "This feature indicates that the MIP (Maintenance Intermediate Point)
    need to
    be explicit configured";
}
/* Identities */

identity technology-types {
    description
    "This is the base identity of technology types which are
    TRILL,MPLS-TP,vpls etc";
}

identity command-sub-type {
    description
    "Defines different rpc command subtypes,
    e.g rfc6905 trill OAM, this is optional for most cases";
}

identity on-demand {
    base command-sub-type;
    description
    "On demand activation - indicates that the tool is activated
    manually to detect a specific anomaly.";
}

identity proactive {
    base command-sub-type;
    description
    "Proactive activation - indicates that the tool is activated on a
    continual basis, where messages are sent periodically, and errors
    are detected when a certain number of expected messages are not
    received.";
}

identity name-format {

    description
    "This defines the name format, IEEE 802lag CFM defines varying
    styles of names. It is expected name format as an identity ref
```

```
    to be extended with new types.";
}

identity name-format-null {
  base name-format;
  description
    "Defines name format as null";
}

identity identifier-format {
  description
    "Identifier-format identity can be augmented to define other
    format identifiers used in MEP-ID etc";
}

identity identifier-format-integer {
  base identifier-format;
  description
    "Defines identifier-format to be integer";
}

}

identity defect-types {
  description
    "Defines different defect types, e.g. remote rdi,
    mis-connection defect, loss of continuity";
}

identity rdi {
  base defect-types;
  description
    "Indicates the aggregate health of the remote MEPs. ";
}

identity remote-mep-defect{
  base defect-types;
  description
    "Indicates that one or more of the remote MEPs is
    reporting a failure ";
}

identity loss-of-continuity{
  base defect-types;
  description
    "If no proactive CC OAM packets from the source
    MEP (and in the case of CV, this includes the
    requirement to have the expected globally unique
    Source MEP identifier) are received within the interval. ";
}
}
```

```
identity invalid-oam-defect{
  base defect-types;
  description
    "Indicates that one or more invalid OAM messages has been
    received and that 3.5 times that OAM message transmission
    interval has not yet expired.";
}

identity cross-connect-defect{
  base defect-types;
  description
    "Indicates that one or more cross-connect defect
    (for example, a service ID does not match the VLAN.)
    messages has been received and that 3.5 times that OAM message
    transmission interval has not yet expired.";
}

/* typedefs */

typedef MEP-name {
  type string;
  description
    "Generic administrative name for a MEP";
}

typedef Interval{
  type decimal64{
    fraction-digits 2;
  }
  units "milliseconds";
  description
    "Interval between packets in milliseconds.
    0 means no packets are sent.";
}

typedef MD-name-string {
  type string;
  description
    "Generic administrative name for an MD";
}

typedef MA-name-string {
  type string;
  description
    "Generic administrative name for an MA";
}

typedef oam-counter32 {
```

```
    type yang:zero-based-counter32;
    description
      "Defines 32 bit counter for OAM";
  }

  typedef MD-level {
    type uint32 {

      range "0..255";
    }
    description
      "Maintenance Domain level. The level may be restricted in
      certain protocols (eg to 0-7)";
  }

  /* groupings */

  grouping maintenance-domain-reference {
    description
      "This grouping uniquely identifies a maintenance domain.";

    leaf maintenance-domain {
      type leafref {
        path "/goam:domains/goam:domain/goam:MD-name-string";
      }
    }
    description
      "A reference to a specific Maintenance Domain.";
  }

  grouping maintenance-association-reference {
    description
      "This grouping uniquely identifies a
      maintenance association. It consists
      of a maintenance-domain-reference and
      a maintenance-association leafref";
    uses maintenance-domain-reference;
    leaf maintenance-association {
      type leafref {
        path "/goam:domains/goam:domain"
          + "[goam:MD-name-string = current()/"
          + "../maintenance-domain]/goam:MA"
          + "/goam:MA/goam:MA-name-string";
      }
    }
    description
      "A reference to a specific Maintenance Association.";
  }
}
```

```
grouping maintenance-association-end-point-reference {
  description
    "This grouping uniquely identifies
    a maintenance association. It consists
    of a maintenance-association-reference and
    a maintenance-association-end-point leafref";
  uses maintenance-association-reference;
  leaf maintenance-association-end-point {
    type leafref {
      path "/goam:domains/goam:domain"
        + "[goam:MD-name-string = current()/"
        + "../maintenance-domain]/goam:MA"
        + "/goam:MA[goam:MA-name-string = "
        + "current()/../maintenance-association]"
        + "/goam:MEP/goam:mep-name";
    }
  }
  description
    "A reference to a specific Maintenance
    association End Point.";
}
}

grouping time-to-live {
  choice ttl{
    case ip-ttl{
      leaf ip-ttl{
        type uint8;
        default "255";
        description
          "Time to live";
      }
    }
    case mpls-ttl{
      leaf mpls-ttl{

        type uint8;
        description
          "Time to live. When an IP packet is imposed with a label,
          the IP TTL value is first decremented then copied into
          the MPLS TTL. As each LSR the MPLS frame's TTL is
          decremented. This behavior can be modified with no
          mpls ip ttl. When a MPLS label is popped, the MPLS
          TTL value is decremented then copied in the IP TTL
          field. If the MPLS TTL value is great than IP TTL,
          that values is not copied over. This is to prevent
          a possible condition of forwarding loop and TTL
          never reaching 0. When two MPLS labels are swapped,
          decrement by 1 and copy over the result into the new label."
        }
      }
    }
  }
}
```

```
    When a new MPLS labels is pushed, decrement by 1 and copy
    over the result into the new label. When a new MPLS labels
    is popped, decrement by 1 and copy over the result into
    the label below.[RFC3443]";

    }
  }
  description
    "Time to Live.";
}
description
  "Time to Live grouping.";
}
grouping defect-message {
  choice defect {
    case defect-null {
      description

        "This is a placeholder when no defect status is needed";
      leaf defect-null {
        type empty;
        description
          "there is no defect define, it will be defined in
          technology specific model.";
      }
    }
    case defect-code {
      description
        "This is a placeholder to display defect code.";
      leaf defect-code {
        type int32;
        description
          "Defect code is integer value specific to technology.";
      }
    }
  }
  description
    "Defect Message choices.";
}
description
  "Defect Message.";
}

grouping mep-address {
  choice mep-address {
    case mac-address {
      leaf mac-address {
```



```
        type yang:mac-address;
        description
          "MAC Address";
      }
    description
      "MAC Address based MEP Addressing.";
  }
  case ipv4-address {
    leaf ipv4-address {
      type inet:ipv4-address;
      description
        "IPv4 Address";
    }
  }
  description
    "IP Address based MEP Addressing.";
  }
  case ipv6-address {
    leaf ipv6-address {
      type inet:ipv6-address;
      description
        "IPv6 Address";
    }
  }
  description
    "IPv6 Address based MEP Addressing.";
  }
  description
    "MEP Addressing.";
  }
  description
    "MEP Address";
  }
}
grouping mip-address {
  choice mip-address {
    case mac-address {
      leaf mac-address {
        type yang:mac-address;
        description
          "MAC Address";
      }
    }
  }
  description
    "MAC Address based MIP Addressing.";
  }
  case ipv4-address {
    leaf ipv4-address {
      type inet:ipv4-address;
      description
        "IPv4 Address";
    }
  }
}
```

```
description
  "IP Address based MIP Addressing.";
}
case ipv6-address {
  leaf ipv6-address {
    type inet:ipv6-address;
    description
      "IPv6 Address";
  }
  description
    "IPv6 Address based MIP Addressing.";
}
description
  "MIP Addressing.";
}
description
  "MIP Address";
}
grouping maintenance-domain-id {
  description
    "Grouping containing leaves sufficient to identify an MD";
  leaf technology {

    type identityref {
      base technology-types;
    }
    mandatory true;

    description
      "Defines the technology";
  }
  leaf MD-name-string {
    type MD-name-string;
    mandatory true;
    description
      "Defines the generic administrative maintenance domain name";
  }
}
}
grouping MD-name {
  leaf MD-name-format {
    type identityref {
      base name-format;
    }
    description
      "Name format.";
  }
  choice MD-name {
```

```
    case MD-name-null {
      leaf MD-name-null {
        when "'../..../MD-name-format' = 'name-format-null'" {
          description
            "MD name format is equal to null format.";
        }
        type empty;
        description
          "MD name Null.";
      }
    }
    description
      "MD name.";
  }
  description
    "MD name";
}

grouping ma-identifier {
  description
    "Grouping containing leaves sufficient to identify an MA";
  leaf MA-name-string {
    type MA-name-string;

    description
      "MA name string.";
  }
}

grouping MA-name {
  description
    "MA name";
  leaf MA-name-format {
    type identityref {
      base name-format;
    }
    description
      "Ma name format";
  }
  choice MA-name {
    case MA-name-null {
      leaf MA-name-null {
        when "'../..../MA-name-format' = 'name-format-null'" {
          description
            "MA";
        }
      }
    }
    type empty;
  }
}
```

```
        description
          "Empty";
      }
    }
    description
      "MA name";
  }
}

grouping MEP-ID {
  choice MEP-ID {
    default "MEP-ID-int";
    case MEP-ID-int {
      leaf MEP-ID-int {
        type int32;
      }
    }
    description
      "MEP ID in integer format";
  }
  description
    "MEP-ID";
}

leaf MEP-ID-format {
  type identityref {
    base identifier-format;
  }
  description
    "MEP ID format.";
}
description
  "MEP-ID";
}

grouping MEP {
  description
    "Defines elements within the MEP";
  leaf mep-name {
    type MEP-name;
    mandatory true;
    description
      "Generic administrative name of the MEP";
  }
  uses MEP-ID;
  uses mep-address;
}
```

```
grouping monitor-stats {
  description
    "grouping for monitoring statistics, this will be augmented
    by others who use this component";
  choice monitor-stats {

    default "monitor-null";
    case monitor-null {
      description
        "This is a place holder when
        no monitoring statistics is needed";
      leaf monitor-null {
        type empty;
        description
          "There is no monitoring statistics to be defined";
        }
      }
      description
        "Define the monitor stats";
    }
  }
}

grouping connectivity-context {
  description
    "Grouping defining the connectivity context for an MA; for
    example, a VRF for VPLS, or an LSP for MPLS-TP. This will be
    augmented by each protocol who use this component";
  choice connectivity-context {
    default "context-null";
    case context-null {
      description
        "This is a place holder when no context is needed";
      leaf context-null {
        type empty;
        description
          "There is no context define";
        }
      }
    }
  description
    "Connectivity context";
}

grouping cos {
  description

    "Priority used in transmitted packets; for example, in the
    EXP field in MPLS-TP.";
```

```
    leaf cos-id {
      type uint8;
      description
        "Class of service";
    }
  }
  grouping MIP-grouping {
    uses mip-address;
    leaf level {
      type MD-level;
      description
        "Configure a level of maintenance intermediate point (MIP)
        for the interface. The MIP level range is 0 to 7.";
    }
  }
  description
    "Grouping for MIP configuration";
}

container domains {
  description
    "Contains configuration related data. Within the container
    is list of fault domains. Wihin each domian has List of MA.";
  list domain {
    key "technology MD-name-string";

    ordered-by system;
    description

      "Define the list of Domains within the IETF-OAM";
    uses maintenance-domain-id;
    uses MD-name;
    leaf md-level {
      type MD-level;
      description
        "Defines the MD-Level";
    }
  }
  container MAs {
    description
      "This container defines MA, within that have multiple MA
      and within MA have MEP";
    list MA {
      key "MA-name-string";
      ordered-by system;
      uses ma-identifier;
      uses MA-name;
      uses connectivity-context;
      uses cos {
        description
```

```
        "Default class of service for this MA,
          which may be overridden
          for particular MEPs,
          sessions or operations.";
    }
    leaf cc-enable{
        type boolean;
        description
        "Indicate whether the CC enable.";
    }
list MEP {
    key "mep-name";

    ordered-by system;
    description
    "Contain list of MEPS";
    uses MEP;
    uses cos;
        leaf cc-enable{
            type boolean;
            description
            "Indicate whether the CC enable.";
        }
list session {
    key "session-cookie";
    ordered-by user;
    description
    "Monitoring session to/from a particular remote MEP.
     Depending on the protocol, this could represent CC
     messages received from a single remote MEP (if the
     protocol uses multicast CCs) or a target to which
     unicast echo request CCs are sent and from which
     responses are received (if the protocol uses a
     unicast request/response mechanism).";
    leaf session-cookie {
        type uint32;
        description
        "Cookie to identify different sessions, when there
         are multiple remote MEPs or multiple sessions to
         the same remote MEP.";
    }
    container destination-mep {
        uses MEP-ID;
        description
        "Destination MEP";
    }
    container destination-mep-address {
        uses mep-address;
    }
}
```

```
        description
          "Destination MEP Address";
      }
      uses cos;
    }
  }

  list MIP {
    if-feature mip;
    key "interface";
    leaf interface {
      type if:interface-ref;
      description
        "Interface";
    }
    uses MIP-grouping;
    description
      "List for MIP";
  }

  description
    "Maintenance Association list";
}
}

notification defect-condition-notification {
  description
    "When defect condition is met this notification is sent";
  leaf technology {
    type identityref {
      base technology-types;
    }
    description
      "The technology";
  }
  leaf MD-name-string {
    type leafref{
      path "/domains/domain/MD-name-string";
    }
    mandatory true;
    description
      "Indicate which MD is seeing the defect";
  }
  leaf MA-name-string{
    type leafref{
      path "/domains/domain/MAs/MA/MA-name-string";
    }
  }
}
```



```
    }
    mandatory true;
    description
    "Indicate which MA is seeing the defect";
  }
  leaf mep-name {
    type leafref{
      path "/domains/domain/MAs/MA/MEP/mep-name";
    }
    description
    "Indicate which MEP is seeing the defect";
  }
  leaf defect-type {
    type identityref {
      base defect-types;
    }
    description

    "The currently active defects on the specific MEP.";
  }
  container generating-mepid {

    uses MEP-ID;
    description
    "Who is generating the defect (if known) if
    unknown make it 0.";
  }
  uses defect-message {
    description
    "Defect message to indicate more details.";
  }
}

notification defect-cleared-notification {
  description
  "When defect cleared is met this notification is sent";
  leaf technology {
    type identityref {
      base technology-types;
    }
    description
    "The technology";
  }
  leaf MD-name-string {
    type leafref{
      path "/domains/domain/MD-name-string";
    }
    mandatory true;
  }
}
```

```
    description
      "Indicate which MD is seeing the defect";
  }
  leaf MA-name-string{
    type leafref{
      path "/domains/domain/MAs/MA/MA-name-string";
    }
    mandatory true;
    description
      "Indicate which MA is seeing the defect";
  }
  leaf mep-name {
    type leafref{
      path "/domains/domain/MAs/MA/MEP/mep-name";
    }
    description
      "Indicate which MEP is seeing the defect";
  }
}

leaf defect-type {
  type identityref {
    base defect-types;
  }
  description
    "The currently active defects on the specific MEP.";
}
container generating-mepid {
  uses MEP-ID;
  description
    "Who is generating the defect (if known) if
    unknown make it 0.";
}
uses defect-message {
  description
    "Defect message to indicate more details.";
}
}

rpc continuity-check {
  if-feature "continuity-check";
  description
    "Generates continuity-check as per RFC7276 Table 4.";
  input {
    leaf technology {
      type identityref {
        base technology-types;
      }
    }
  }
}
```

```
    }
    description
      "The technology";
  }
  leaf MD-name-string {
    type leafref{
      path "/domains/domain/MD-name-string";
    }
    mandatory true;
    description
      "Indicate which MD is seeing the defect";
  }
  leaf MA-name-string{
    type leafref{
      path "/domains/domain/MAs/MA/MA-name-string";
    }
    mandatory true;
    description
      "Indicate which MA is seeing the defect";
  }
  uses cos;
  uses time-to-live;
  leaf sub-type {

    type identityref {
      base command-sub-type;
    }
    description
      "Defines different command types";
  }
  leaf source-mep {
    type leafref{
      path "/domains/domain/MAs/MA/MEP/mep-name";
    }
    description
      "Source MEP";
  }
  container destination-mep {
    uses mep-address;
    uses MEP-ID {
      description
        "Only applicable if the destination is a MEP";
    }
    description
      "Destination MEP";
  }
  leaf count {
```

```
    type uint32;
    default "3";
    description
      "Number of continuity-check message to send";
  }
  leaf cc-transmit-interval {
    type Interval;
    description

      "Interval between echo requests";
  }
  leaf packet-size {
    type uint32 {
      range "0..10000";
    }
    default "64";
    description
      "Size of continuity-check packets, in octets";
  }
}
output {
  uses monitor-stats {
    description
      "Stats of continuity check.";
  }
}
}

rpc continuity-verification {
  if-feature connectivity-verification;
  description
    "Generates continuity-verification as per RFC7276 Table 4.";
  input {
    leaf MD-name-string {
      type leafref{
        path "/domains/domain/MD-name-string";
      }
      mandatory true;
      description
        "Indicate which MD is seeing the defect";
    }
    leaf MA-name-string{
      type leafref{
        path "/domains/domain/MAs/MA/MA-name-string";
      }
      mandatory true;
      description

```

```
"Indicate which MA is seeing the defect";
}
uses cos;
uses time-to-live;
leaf sub-type {

    type identityref {
        base command-sub-type;
    }
    description
        "Defines different command types";
}
leaf source-mep {
    type leafref{
        path "/domains/domain/MAs/MA/MEP/mep-name";
    }
    description
        "Source MEP";
}
container destination-mep {
    uses mep-address;
    uses MEP-ID {
        description "Only applicable if the destination is a MEP";
    }
    description
        "Destination MEP";
}
}
leaf count {
    type uint32;
    default "3";
    description
        "Number of continuity-verification message to send";
}
leaf interval {
    type Interval;
    description
        "Interval between echo requests";
}
}
leaf packet-size {
    type uint32 {
        range "64..10000";
    }
    default "64";
    description
        "Size of continuity-verification packets, in octets";
}
}
```

```
output {
  uses monitor-stats {
    description
      "Stats of continuity check.";
  }
}
}
rpc traceroute {
  if-feature traceroute;
  description
    "Generates Traceroute or Path Trace and return response.
    Referencing RFC7276 for common Toolset name, for
    MPLS-TP OAM it's Route Tracing, and for TRILL OAM It's
    Path Tracing tool. Starts with TTL of one and increment
    by one at each hop. Untill destination reached or TTL
    reach max value";
  input {
    leaf MD-name-string {
      type leafref{
        path "/domains/domain/MD-name-string";
      }
      mandatory true;
      description
        "Indicate which MD is seeing the defect";
    }
    leaf MA-name-string{
      type leafref{
        path "/domains/domain/MAs/MA/MA-name-string";
      }
      mandatory true;
      description
        "Indicate which MA is seeing the defect";
    }
    uses cos;
    uses time-to-live;
    leaf command-sub-type {
      type identityref {
        base command-sub-type;
      }
      description
        "Defines different command types";
    }
    leaf source-mep {
      type leafref{
        path "/domains/domain/MAs/MA/MEP/mep-name";
      }
    }
  }
}
```

```
    description
      "Source MEP";
  }
  container destination-mep {
    uses mep-address;
    uses MEP-ID {
      description
        "Only applicable if the destination is a MEP";
    }
    description
      "Destination MEP";
  }
  leaf count {
    type uint32;
    default "1";
    description
      "Number of traceroute probes to send. In protocols where a
      separate message is sent at each TTL, this is the number
      of packets to send at each TTL.";
  }
  leaf interval {
    type Interval;
    description
      "Interval between echo requests";
  }
}
output {
  list response {
    key "response-index";

    leaf response-index {
      type uint8;
      description
        "Arbitrary index for the response. In protocols that
        guarantee there is only a single response at each TTL
        , the TTL can be used as the response
        index.";
    }
  }
  uses time-to-live;
  container destination-mep {
    description "MEP from which the response has been received";
    uses mep-address;
    uses MEP-ID {
      description
        "Only applicable if the destination is a MEP";
    }
  }
  container mip {
```

```
        if-feature mip;
        leaf interface {
            type if:interface-ref;
            description
                "MIP interface";
        }
        uses mip-address;
        description
            "MIP responding with traceroute";
    }
    uses monitor-stats {
        description
            "Stats of traceroute.";
    }
    description
        "List of response.";
}
}
```

<CODE ENDS>

## 6. Base Mode

The Base Mode ('default mode' described in section 4) defines default configuration that MUST be present in the devices that comply with this document. Base Mode allows users to have "zero-touch" experience. Several parameters require technology specific definition.

### 6.1. MEP Address

In the Base Mode of operation, the MEP Address is by default the IP address of the interface on which the MEP is located.

### 6.2. MEP ID for Base Mode

In the Base Mode of operation, each device creates a single UP MEP associated with a virtual OAM port with no physical layer (NULL PHY). The MEP-ID associated with this MEP is zero (0). The choice of MEP-ID zero is explained below.

MEP-ID is 2 octet field by default. It is never used on the wire except when using CCM. It is important to have method that can derive MEP-ID of base mode in an automatic manner with no user



intervention. IP address cannot be directly used for this purpose as the MEP-ID is much smaller field. For Base Mode of operation we propose to use MEP-ID zero (0) as the default MEP-ID.

CCM packet use MEP-ID on the payload. CCM MUST NOT be used in the Base Mode. Hence CCM MUST be disabled on the Maintenance Association of the Base Mode.

If CCM is required, users MUST configure a separate Maintenance association and assign unique value for the corresponding MEP IDs.

CFM [IEEE802.1ag] defines MEP ID as an unsigned integer in the range 1 to 8191. In this document we propose extend the range to 0 to 65535. Value 0 is reserved for MEP-ID of Base Mode operation and MUST NOT be used for other purposes.

### 6.3. Maintenance Association

The ID of the Maintenance Association (MA-ID) [IEEE802.1ag] has a flexible format and includes two parts: Maintenance Domain Name and Short MA name. In the Based Mode of operation, the value of the Maintenance Domain Name must be the character string "GenericBaseMode" (excluding the quotes "). In Base Mode operation Short MA Name format is set to 2-octet integer format (value 3 in Short MA Format field [IEEE802.1ag]) and Short MA name set to 65532 (0xFFFC).

## 7. Connection-oriented OAM YANG model applicability

"ietf-conn-oam" model defined in this document provides technology-independent abstraction of key OAM constructs for connection oriented 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 connection-oriented OAM model.

This section demonstrates the usability of the connection-oriented YANG OAM data model to various connection-oriented OAM technologies, e.g., TRILL and MPLS-TP. 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.

## 7.1. Generic YANG Model extension for TRILL OAM

The TRILL YANG module is augmenting connection oriented OAM module for both configuration and RPC commands.

The TRILL YANG module requires the base TRILL module ([I-D.ietf-trill-yang]) to be supported as there is a strong relationship between those modules.

The configuration extensions for connection oriented OAM include MD configuration extension, Technology type extension, MA configuration extension, Connectivity-Context Extension, MEP Configuration Extension, ECMP extension. In the RPC extension, the continuity-check and path-discovery RPC are extended with TRILL specific.

### 7.1.1. MD Configuration Extension

MD level configuration parameters are management information which can be inherited in the TRILL OAM model and set by connection oriented base model as default values. For example domain name can be set to area-ID in the TRILL OAM case. In addition, at the Maintenance Domain level, domain data node at root level can be augmented with technology type.

Note that MD level configuration parameters provides context information for management system to correlate faults, defects, network failures with location information, which helps quickly identify root causes of network failures.

#### 7.1.1.1. Technology Type Extension

No TRILL technology type has been defined in the connection oriented base model. Therefore a technology type extension is required in the TRILL OAM model. The technology type "trill" is defined as an identity that augments the base "technology-types" defined in the connection oriented base model:

```
identity trill{
  base goam:technology-types;
  description
    "trill type";
}
```

### 7.1.2. MA Configuration Extension

MA level configuration parameters are management information which can be inherited in the TRILL OAM model and set by connection oriented base model as default values. In addition, at the

Maintenance Association(MA) level, MA data node at the second level can be augmented with connectivity-context extension.

Note that MA level configuration parameters provides context information for management system to correlate faults, defects, network failures with location information, which helps quickly identify root causes of network failures.

#### 7.1.2.1. Connectivity-Context Extension

In TRILL OAM, one example of connectivity-context is either a 12 bit VLAN ID or a 24 bit Fine Grain Label. The connection oriented base model defines a placeholder for context-id. This allows other technologies to easily augment that to include technology specific extensions. The snippet below depicts an example of augmenting connectivity-context to include either VLAN ID or Fine Grain Label.

```
augment /goam:domains/goam:domain/goam:MAS
/goam:MA /goam:connectivity-context:
  +--:(connectivity-context-vlan)
  |   +--rw connectivity-context-vlan?   vlan
  +--:(connectivity-context-fgl)
  |   +--rw connectivity-context-fgl?   fgl
```

#### 7.1.3. MEP Configuration Extension

The MEP configuration definition in the connection oriented base model already supports configuring the interface of MEP with either MAC address or IP address. In addition, the MEP address can be represented using a 2 octet RBridge Nickname in TRILL OAM . Hence, the TRILL OAM model augments the MEP configuration in base model to add a nickname case into the MEP address choice node as follows:

```
augment /goam:domains/goam:domain/goam:MAS
/goam:MA/ goam:MEP/goam:mep-address:
  +--:( mep-address-trill)
  |   +--rw mep-address-trill?   trill-rb-nickname
```

In addition, at the Maintenance Association Endpoint(MEP) level, MEP data node at the third level can be augmented with ECMP extension.

#### 7.1.3.1. ECMP Extension

Since TRILL supports ECMP path selection, flow-entropy in TRILL is defined as a 96 octet field in the LIME model extension for TRILL OAM. The snippet below illustrates its extension.

```

augment /goam:domains/goam:domain/goam:MA/goam:MA/goam:MEP:
  +--rw flow-entropy-trill?  flow-entropy-trill
augment /goam:domains/goam:domain/goam:MA/goam:MA/goam:MEP
/goam:session:
  +--rw flow-entropy-trill?  flow-entropy-trill

```

#### 7.1.4. RPC extension

In the TRILL OAM YANG model, the continuity-check and path-discovery RPC commands are extended with TRILL specific requirements. The snippet below depicts an example of illustrates the TRILL OAM RPC extension.

```

augment /goam:continuity-check/goam:input:
  +--ro (out-of-band)?
  | +--:(ipv4-address)
  | | +--ro ipv4-address?      inet:ipv4-address
  | +--:(ipv6-address)
  | | +--ro ipv6-address?      inet:ipv6-address
  | +--:(trill-nickname)
  |   +--ro trill-nickname?    tril-rb-nickname
  +--ro diagnostic-vlan?  boolean
augment /goam:continuity-check/goam:input:
  +--ro flow-entropy-trill?  flow-entropy-trill
augment /goam:continuity-check/goam:output:
  +--ro upstream-rbridge?    tril-rb-nickname
  +--ro next-hop-rbridge*    tril-rb-nickname
augment /goam:path-discovery/goam:input:
  +--ro (out-of-band)?
  | +--:(ipv4-address)
  | | +--ro ipv4-address?      inet:ipv4-address
  | +--:(ipv6-address)
  | | +--ro ipv6-address?      inet:ipv6-address
  | +--:(trill-nickname)
  |   +--ro trill-nickname?    tril-rb-nickname
  +--ro diagnostic-vlan?    boolean
augment /goam:path-discovery/goam:input:
  +--ro flow-entropy-trill?  flow-entropy-trill
augment /goam:path-discovery/goam:output/goam:response:
  +--ro upstream-rbridge?    tril-rb-nickname
  +--ro next-hop-rbridge*    tril-rb-nickname

```

#### 7.2. Generic YANG Model extension for MPLS-TP OAM

The MPLS-TP OAM YANG module can augment connection oriented OAM Module with some technology-specific details. And the [mpls-tp-oam-yang] presents the YANG Data model for MPLS-TP OAM.

The configuration extensions for connection oriented OAM include MD configuration extension, Technology type extension, Sub Technology Type Extension ,MA configuration extension, MEP Configuration Extension.

#### 7.2.1. MD Configuration Extension

MD level configuration parameters are management information which can be inherited in the MPLS-TP OAM model and set by LIME base model as default values. For example domain name can be set to area-ID or the provider's Autonomous System Number(ASN) [RFC6370] in the MPLS-TP OAM case. In addition, at the Maintenance Domain level, domain data node at root level can be augmented with technology type and sub-technology type.

Note that MD level configuration parameters provides context information for management system to correlate faults, defects, network failures with location information, which helps quickly identify root causes of network failures

##### 7.2.1.1. Technology Type Extension

No MPLS-TP technology type has been defined in the connection oriented base model, hence it is required in the MPLS OAM model. The technology type "mpls-tp" is defined as an identity that augments the base "technology-types" defined in the connection oriented base model:

```
identity mpls-tp{
    base goam:technology-types;
    description
        "mpls-tp type";
}
```

##### 7.2.1.2. Sub Technology Type Extension

In MPLS-TP, since different encapsulation types such as IP/UDP Encapsulation, PW-ACH encapsulation can be employed, the "technology-sub-type" data node is defined and added into the MPLS OAM model to further identify the encapsulation types within the MPLS-TP OAM model. Based on it, we also define a technology sub-type for IP/UDP encapsulation and PW-ACH encapsulation. Other Encapsulation types can be defined in the same way. The snippet below depicts an example of several encapsulation types.

```
identity technology-sub-type {
  description
    "certain implementations can have different
    encapsulation types such as ip/udp, pw-ach and so on.
    Instead of defining separate models for each
    encapsulation, we define a technology sub-type to
    further identify different encapsulations.
    Technology sub-type is associated at the MA level"; }

  identity technology-sub-type-udp {
    base technology-sub-type;
    description
      "technology sub-type is IP/UDP encapsulation";
  }

  identity technology-sub-type-ach {
    base technology-sub-type;
    description
      "technology sub-type is PW-ACH encapsulation";
  }

  augment "/goam:domains/goam:domain/goam:MAS/goam:MA" {
    leaf technology-sub-type {
      type identityref {
        base technology-sub-type;
      }
    }
  }
}
```

#### 7.2.2. MA Configuration Extension

MA level configuration parameters are management information which can be inherited in the MPLS-TP OAM model and set by Connection Oriented base model as default values. One example of MA Name could be MEG LSP ID or MEG Section ID or MEG PW ID[RFC6370].

Note that MA level configuration parameters provides context information for management system to correlate faults, defects, network failures with location information, which helps quickly identify root causes of network failures.

#### 7.2.3. MEP Configuration Extension

In MPLS-TP, MEP-ID is either a variable length label value in case of G-ACH encapsulation or a 2 octet unsigned integer value in case of IP/UDP encapsulation. One example of MEP-ID is MPLS-TP LSP\_MEP\_ID [RFC6370]. In the connection-oriented base model, MEP-ID is defined

as a choice/case node which can supports an int32 value, and the same definition can be used for MPLS-TP with no further modification. In addition, at the Maintenance Association Endpoint(MEP) level, MEP data node at the third level can be augmented with Session extension and interface extension.

## 8. Security Considerations

The YANG module defined in this memo is designed to be accessed via the NETCONF protocol [RFC6241] [RFC6241]. The lowest NETCONF layer is the secure transport layer and the mandatory-to-implement secure transport is SSH [RFC6242] [RFC6242]. The NETCONF access control model [RFC6536] [RFC6536] provides the means to restrict access for particular NETCONF users to a pre-configured subset of all available NETCONF protocol operations and content.

There are a number of data nodes defined in the YANG module which 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:

```
/goam:domains/goam:domain/
```

```
/goam:domains/goam:domain/goam:MAS/goam:MA/
```

```
/goam:domains/goam:domain/goam:MAS/goam:MA/goam:MEP
```

```
/goam:domains/goam:domain/goam:MAS/goam:MA/goam:MEP/goam:session/
```

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.

## 9. IANA Considerations

This document registers a URI in the IETF XML registry [RFC3688] [RFC3688]. Following the format in RFC 3688, the following registration is requested to be made:

URI: urn:ietf:params:xml:ns:yang:ietf-gen-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-gen-oam namespace: urn:ietf:params:xml:ns:yang:ietf-gen-oam  
prefix: goam reference: RFC XXXX

## 10. Acknowledgments

Giles Heron came up with the idea of developing a YANG model as a way of creating a unified OAM API set (interface), work in this document is largely an inspiration of that. Alexander Clemm provided many valuable tips, comments and remarks that helped to refine the YANG model presented in this document.

Carlos Pignataro, David Ball, Mahesh Jethanandani, Benoit Claise, Ladislav Lhotka, GUBALLA JENS, Yuji Tochio, Gregory Mirsky, Huub van Helvoort, Tom Taylor, Dapeng Liu, Mishael Wexler, Adi Molkho participated and contributed to this document.

## 11. References

### 11.1. Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<http://www.rfc-editor.org/info/rfc2119>>.
- [RFC3688] Mealling, M., "The IETF XML Registry", BCP 81, RFC 3688, DOI 10.17487/RFC3688, January 2004, <<http://www.rfc-editor.org/info/rfc3688>>.
- [RFC6020] Bjorklund, M., Ed., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC 6020, DOI 10.17487/RFC6020, October 2010, <<http://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, <<http://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, <<http://www.rfc-editor.org/info/rfc6242>>.
- [RFC6370] Bocci, M., Swallow, G., and E. Gray, "MPLS Transport Profile (MPLS-TP) Identifiers", RFC 6370, DOI 10.17487/RFC6370, September 2011, <<http://www.rfc-editor.org/info/rfc6370>>.
- [RFC6536] Bierman, A. and M. Bjorklund, "Network Configuration Protocol (NETCONF) Access Control Model", RFC 6536, DOI 10.17487/RFC6536, March 2012, <<http://www.rfc-editor.org/info/rfc6536>>.

## 11.2. Informative References

- [G.8013] "OAM functions and mechanisms for Ethernet based networks", ITU-T Recommendation G.8013/Y.1731, 2013.
- [IEEE802.1ag]  
"Connectivity Fault Management", IEEE Std 802.1ag-2011, August 2011.
- [mpls-tp-oam-yang]  
Zhang, L., Zheng, L., Aldrin, S., and G. Mirsky, "YANG Data Model for MPLS-TP Operations, Administration, and Maintenance", draft-zhang-mpls-tp-yang-oam (work in progress), 2016.
- [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, <<http://www.rfc-editor.org/info/rfc6136>>.
- [RFC6291] Andersson, L., van Helvoort, H., Bonica, R., Romascanu, D., and S. Mansfield, "Guidelines for the Use of the "OAM" Acronym in the IETF", BCP 161, RFC 6291, DOI 10.17487/RFC6291, June 2011, <<http://www.rfc-editor.org/info/rfc6291>>.
- [RFC6325] Perlman, R., Eastlake 3rd, D., Dutt, D., Gai, S., and A. Ghanwani, "Routing Bridges (RBridges): Base Protocol Specification", RFC 6325, DOI 10.17487/RFC6325, July 2011, <<http://www.rfc-editor.org/info/rfc6325>>.

- [RFC6371] Busi, I., Ed. and D. Allan, Ed., "Operations, Administration, and Maintenance Framework for MPLS-Based Transport Networks", RFC 6371, DOI 10.17487/RFC6371, September 2011, <<http://www.rfc-editor.org/info/rfc6371>>.
- [RFC7174] Salam, S., Senevirathne, T., Aldrin, S., and D. Eastlake 3rd, "Transparent Interconnection of Lots of Links (TRILL) Operations, Administration, and Maintenance (OAM) Framework", RFC 7174, DOI 10.17487/RFC7174, May 2014, <<http://www.rfc-editor.org/info/rfc7174>>.
- [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, <<http://www.rfc-editor.org/info/rfc7276>>.
- [RFC7455] Senevirathne, T., Finn, N., Salam, S., Kumar, D., Eastlake 3rd, D., Aldrin, S., and Y. Li, "Transparent Interconnection of Lots of Links (TRILL): Fault Management", RFC 7455, DOI 10.17487/RFC7455, March 2015, <<http://www.rfc-editor.org/info/rfc7455>>.

#### Appendix A. Contributors' Addresses

Tissa Senevirathne  
Consultant

Email: [tsenevir@gmail.com](mailto:tsenevir@gmail.com)

Norman Finn  
CISCO Systems  
510 McCarthy Blvd  
Milpitas, CA 95035  
USA

Email: [nfinn@cisco.com](mailto:nfinn@cisco.com)

Samer Salam  
CISCO Systems  
595 Burrard St. Suite 2123  
Vancouver, BC V7X 1J1  
Canada

Email: [ssalam@cisco.com](mailto:ssalam@cisco.com)

Authors' Addresses

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

Email: [dekumar@cisco.com](mailto:dekumar@cisco.com)

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

Email: [bill.wu@huawei.com](mailto:bill.wu@huawei.com)

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

Email: [wangzitao@huawei.com](mailto:wangzitao@huawei.com)

Network Working Group  
Internet-Draft  
Intended status: Standards Track  
Expires: October 11, 2017

D. Kumar  
Cisco  
Q. Wu  
M. Wang  
Huawei  
April 9, 2017

Generic YANG Data Model for Connection Oriented Operations,  
Administration, and Maintenance(OAM) protocols  
draft-ietf-lime-yang-oam-model-10

Abstract

This document presents a base YANG Data model for connection oriented OAM protocols. It provides a technology-independent abstraction of key OAM constructs for such protocols. The model presented here can be extended to include technology specific details. This guarantees uniformity in the management of OAM protocols and provides support for nested OAM workflows (i.e., performing OAM functions at different levels through a unified interface)

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <http://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on October 11, 2017.

Copyright Notice

Copyright (c) 2017 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<http://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents

carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

## Table of Contents

1. Introduction . . . . .	3
2. Conventions used in this document . . . . .	4
2.1. Terminology . . . . .	5
3. Architecture of Generic YANG Model for OAM . . . . .	6
4. Overview of the OAM Model . . . . .	7
4.1. Maintenance Domain (MD) configuration . . . . .	8
4.2. Maintenance Association (MA) configuration . . . . .	9
4.3. Maintenance Endpoint (MEP) configuration . . . . .	9
4.4. RPC definitions . . . . .	10
4.5. Notifications . . . . .	13
4.6. Monitor statistics . . . . .	13
4.7. OAM data hierarchy . . . . .	13
5. OAM YANG Module . . . . .	18
6. Base Mode . . . . .	40
6.1. MEP Address . . . . .	40
6.2. MEP ID for Base Mode . . . . .	41
6.3. Maintenance Association . . . . .	41
7. Connection-oriented OAM YANG model applicability . . . . .	41
7.1. Generic YANG Model extension for TRILL OAM . . . . .	42
7.1.1. MD Configuration Extension . . . . .	42
7.1.2. MA Configuration Extension . . . . .	43
7.1.3. MEP Configuration Extension . . . . .	43
7.1.4. RPC extension . . . . .	44
7.2. Generic YANG Model extension for MPLS-TP OAM . . . . .	45
7.2.1. MD Configuration Extension . . . . .	45
7.2.2. MA Configuration Extension . . . . .	47
7.2.3. MEP Configuration Extension . . . . .	47
8. Security Considerations . . . . .	48
9. IANA Considerations . . . . .	48
10. Acknowledgments . . . . .	49
11. References . . . . .	49
11.1. Normative References . . . . .	49
11.2. Informative References . . . . .	50
Appendix A. Contributors' Addresses . . . . .	51
Authors' Addresses . . . . .	52

## 1. Introduction

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

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

An overview of OAM tools is presented in [RFC7276]. Over the years, many technologies have developed similar tools for fault and performance management.

[IEEE802.1ag] Connectivity Fault Management is a well-established OAM standard that is widely adopted for Ethernet networks. ITU-T [G.8013], MEF Service OAM, MPLS-TP [RFC6371], TRILL [RFC7455] all define OAM mechanisms based on the manageability frame work of CFM [IEEE802.1ag].

Given the wide adoption of the underlying OAM concepts defined in CFM [IEEE802.1ag], it is a reasonable choice to develop the unified management framework for connection oriented OAM based on those concepts. In this document, we take the CFM [IEEE802.1ag] model and extend it to a technology independent framework and define the corresponding YANG model accordingly. The YANG model presented in this document is the base model for connection oriented OAM protocols and supports generic continuity check, connectivity verification and path discovery (traceroute). The generic YANG model for connection oriented OAM is designed to be extensible to other connection oriented technologies. Technology dependent nodes and remote process call (RPC) commands are defined in technology specific YANG models, which use and extend the base model defined here. As an example, VXLAN uses source UDP port number for flow entropy, while TRILL uses either MAC addresses, the VLAN tag or fine grain label, and/or IP addresses for flow entropy in the hashing for multipath selection. To capture this variation, corresponding YANG models would define the applicable structures as augmentation to the generic base model presented here. This accomplishes three goals: First it keeps each YANG model smaller and more manageable. Second, it allows independent development of corresponding YANG models. Third, implementations can limit support to only the applicable set of YANG models. (e.g. TRILL RBridge may only need to implement Generic model and the TRILL YANG model).

All implementations that follow the YANG framework presented in this document MUST implement the generic connection oriented YANG model presented here.

The YANG data model presented in this document is generated at the management layer. Encapsulations and state machines may differ according to each OAM protocol. A user who wishes to issues a Continuity Check command or a Loopback or initiate a performance monitoring session can do so in the same manner regardless of the underlying protocol or technology or specific vendor implementation.

As an example, consider a scenario where Loopback from device A to Device B fails. Between device A and B there are IEEE 802.1 bridges a, b and c. Let's assume a,b and c are using CFM [IEEE802.1ag]. Upon detecting the Loopback failures, a user may decide to drill down to the lower level at different segments of the path and issue the corresponding fault verification (LBM) and fault isolation (LTM) tools, using the same API. This ability to drill down to a lower layer of the protocol stack at a specific segment within a path for fault localization and troubleshooting is referred to as "nested OAM workflow". It is a useful concept that leads to efficient network troubleshooting and maintenance workflows. The connection oriented OAM YANG model presented in this document facilitates that without needing changes to the underlying protocols.

## 2. Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119]. In this document, these words will appear with that interpretation only when in ALL CAPS. Lower case uses of these words are not to be interpreted as carrying [RFC2119] significance.

The following notations are used within the data tree and carry the meaning as below.

Each node is printed as:

<status> <flags> <name> <opts> <type>

<status> is one of:

+ for current

<flags> is one of:

rw for configuration data  
ro for non-configuration data  
-x for rpcs  
-n for notifications  
-w for writable

<name> is the name of the node

If the node is augmented into the tree from another module, its name is printed as <prefix>:<name>.

<opts> is one of:

? for an optional leaf or choice  
! for a presence container  
\* for a leaf-list or list  
[<keys>] for a list's keys  
(choice)/:(case) Parentheses enclose choice and case nodes,  
and case nodes are also marked with a colon (":")

<type> is the name of the type for leafs and leaf-lists

## 2.1. Terminology

- CCM - Continuity Check Message [IEEE802.1ag].
- ECMP - Equal Cost Multipath.
- LBM - Loopback Message [IEEE802.1ag].
- MP - Maintenance Point [IEEE802.1ag].
- MEP - Maintenance End Point [RFC7174] (Maintenance association End Point [IEEE802.1ag], MEG End Points [RFC6371]).
- MIP - Maintenance Intermediate Point [RFC7174] (Maintenance domain Intermediate Point [IEEE802.1ag], MEG Intermediate Point [RFC6371]).
- MA - Maintenance Association [IEEE802.1ag] [RFC7174].

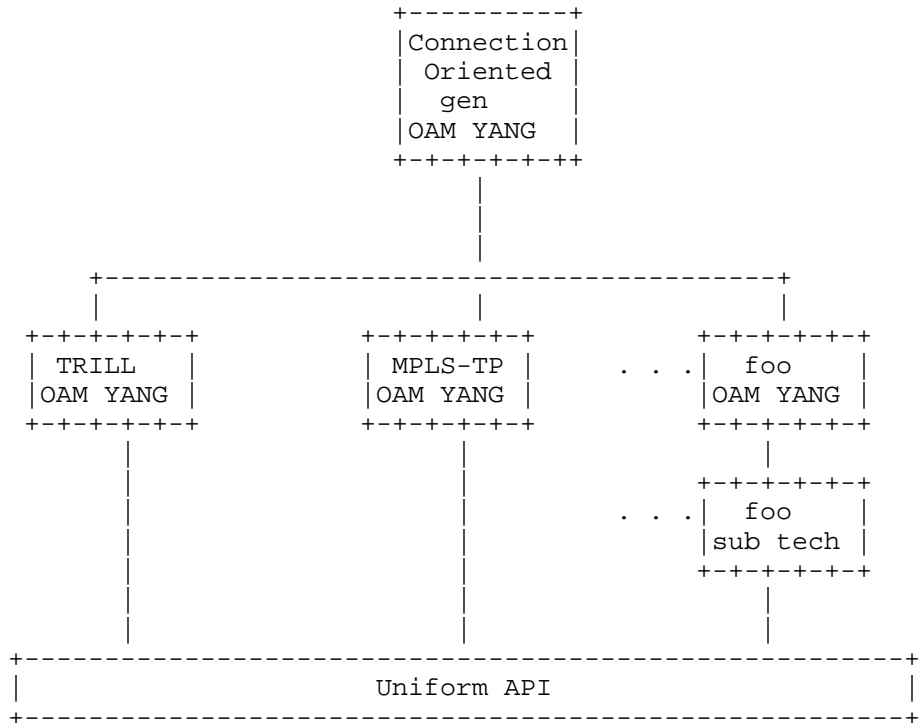


- MD - Maintenance Domain [IEEE802.1ag]
  - MEG - Maintenance Entity Group [RFC6371]
  - MTV - Multi-destination Tree Verification Message.
  - OAM - Operations, Administration, and Maintenance [RFC6291].
  - TRILL - Transparent Interconnection of Lots of Links [RFC6325].
  - CFM - Connectivity Fault Management [RFC7174] [IEEE802.1ag].
  - RPC - Remote Process Call.
  - CC - Continuity Check [RFC7276]. Continuity Checks are used to verify that a destination is reachable and therefore also referred to as reachability verification.
  - CV - Connectivity Verification [RFC7276]. Connectivity Verification are used to verify that a destination is connected. It are also referred to as path verification and used to verify not only that the two MPs are connected, but also that they are connected through the expected path, allowing detection of unexpected topology changes.
- Proactive OAM - The proactive OAM refers to OAM actions which are carried out continuously to permit proactive reporting of fault. Proactive OAM method requires persistent configuration.
- On-demand OAM - The on-demand OAM refers to OAM actions which are initiated via manual intervention for a limited time to carry out diagnostics. On-demand OAM method requires only transient configuration.

### 3. Architecture of Generic YANG Model for OAM

In this document we define a generic YANG model for connection oriented OAM protocols. The YANG model defined here is generic in a sense that other technologies can extend it for technology specific needs. The Generic YANG model acts as the root for other OAM YANG models. This allows users to traverse between different OAM protocols with ease through a uniform API set. This also enables a nested OAM workflow. Figure 1 depicts the relationship of different OAM YANG models to the Generic YANG Model for connection oriented OAM. The Generic YANG model for OAM provides a framework where technology- specific YANG models can inherit constructs from the base YANG models without needing to redefine them within the sub-technology.

Figure 1 depicts relationship of different YANG modules.



Relationship of OAM YANG model to generic (base) YANG model

4. Overview of the OAM Model

In this document we adopt the concepts of the CFM [IEEE802.1ag] model and structure it such that it can be adapted to different connection oriented OAM protocols.

At the top of the Model is the Maintenance Domain. Each Maintenance Domain is associated with a Maintenance Name and a Domain Level.

Under each Maintenance Domain there is one or more Maintenance Association (MA). In TRILL this can be per Fine-Grained Label or for VPLS this can be per VPLS instance [RFC6136].

Under each MA, there can be two or more MEPs (Maintenance End Points). MEPs are addressed by their respective technology specific address identifiers. The YANG model presented here provides flexibility to accommodate different addressing schemes.

In the vertical direction orthogonal to the Maintenance Domain, presented are the commands. Those, in YANG terms, are the RPC commands. These RPC commands provide uniform APIs for continuity check, connectivity verification, path discovery(traceroute) and their equivalents as well as other OAM commands.

The OAM entities in the generic YANG model defined here will be either explicitly or implicitly configured using any of the OAM tools. The OAM tools used here are limited to OAM toolset specified in section 5.1 of [RFC7276]. In order to facilitate zero-touch experience, this document defines a default mode of OAM. The default mode of OAM is referred to as the Base Mode and specifies default values for each of model parameters, such as Maintenance Domain Level, Name of the Maintenance Association, Addresses of MEPs and so on. The default values of these depend on the technology. Base Mode for TRILL is defined in [RFC7455]. Base mode for other technologies and future extensions developed in IETF will be defined in their corresponding documents.

It is important to note that, no specific enhancements are needed in the YANG model to support Base Mode. Implementations that comply with this document, by default implement the data nodes of the applicable technology. Data nodes of the Base Mode are read-only nodes.

#### 4.1. Maintenance Domain (MD) configuration

The container "domains" is the top level container within the gen-oam module. Within the container "domains", separate list is maintained per MD. The MD list uses the key MD-name-string for indexing. MD-name-string is a leaf and derived from type string. Additional name formats as defined in [IEEE802.lag] or other standards can be included by association of the MD-name-format with an identity-ref. MD-name-format indicates the format of the augmented MD-names. MD-name is presented as choice/case construct. Thus, it is easily augmentable by derivative work.

```

module: ietf-conn-oam
+--rw domains
  +--rw domain* [technology MD-name-string]
    +--rw technology          identityref
    +--rw MD-name-string      MD-name-string
    +--rw MD-name-format?    identityref
    +--rw (MD-name)?
      | +--:(MD-name-null)
      |   +--rw MD-name-null?      empty
    +--rw md-level?          MD-level

```

Snippet of data hierarchy related to OAM domains

#### 4.2. Maintenance Association (MA) configuration

Within a given Maintenance Domain there can be one or more Maintenance Associations (MA). MAs are represented as a list and indexed by the MA-name-string. Similar to MD-name defined previously, additional name formats can be added by augmenting the name-format identity-ref and adding applicable case statements to MA-name.

```

module: ietf-conn-oam
+--rw domains
  +--rw domain* [technology MD-name-string]
    .
    .
  +--rw MAs
    +--rw MA* [MA-name-string]
      +--rw MA-name-string      MA-name-string
      +--rw MA-name-format?    identityref
      +--rw (MA-name)?
        | +--:(MA-name-null)
        |   +--rw MA-name-null?      empty

```

Snippet of data hierarchy related to Maintenance Associations (MA)

#### 4.3. Maintenance Endpoint (MEP) configuration

Within a given Maintenance Association (MA), there can be one or more Maintenance End Points (MEP). MEPs are represented as a list within the data hierarchy and indexed by the key MEP-name.

```

module: ietf-conn-oam
  +--rw domains
    +--rw domain* [technology MD-name-string]
      +--rw technology          identityref
      .
      .
    +--rw MAs
      +--rw MA* [MA-name-string]
        +--rw MA-name-string    MA-name-string
        .
        .
      +--rw MEP* [mep-name]
        +--rw mep-name          MEP-name
        +--rw (MEP-ID)?
          +--:(MEP-ID-int)
            +--rw MEP-ID-int?    int32
        +--rw MEP-ID-format?    identityref
        +--rw (mep-address)?
          +--:(mac-address)
            +--rw mac-address?   yang:mac-address
          +--:(ipv4-address)
            +--rw ipv4-address?  inet:ipv4-address
          +--:(ipv6-address)
            +--rw ipv6-address?  inet:ipv6-address
        .
        .
        .

```

Snippet of data hierarchy related to Maintenance Endpoint (MEP)

#### 4.4. RPC definitions

The RPC model facilitates issuing commands to a NETCONF server (in this case to the device that need to execute the OAM command) and obtain a response. RPC model defined here abstracts OAM specific commands in a technology independent manner.

There are several RPC commands defined for the purpose of OAM. In this section we present a snippet of the continuity check command for illustration purposes. Please refer to Section 4.5 for the complete data hierarchy and Section 5 for the YANG model.

```

module: ietf-conn-oam
  +--rw domains
    +--rw domain* [technology MD-name-string]
      +--rw technology          identityref
      .
      .

```

```

rpcs:
  +---x continuity-check {continuity-check}?
  |   +---w input
  |   |   +---w technology?           identityref
  |   |   +---w MD-name-string  -> /domains/domain/MD-name-string
  |   |   +---w md-level?       -> /domains/domain/md-level
  |   |   +---w MA-name-string  -> /domains/domain/MAs/MA/MA-name-string
  |   |   +---w cos-id?         uint8
  |   |   +---w ttl?           uint8
  |   |   +---w sub-type?      identityref
  |   |   +---w source-mep?    -> /domains/domain/MAs/MA/MEP/mep-name
  |   |   +---w destination-mep
  |   |   |   +---w (mep-address)?
  |   |   |   |   +---:(mac-address)
  |   |   |   |   |   +---w mac-address?       yang:mac-address
  |   |   |   |   +---:(ipv4-address)
  |   |   |   |   |   +---w ipv4-address?     inet:ipv4-address
  |   |   |   |   +---:(ipv6-address)
  |   |   |   |   |   +---w ipv6-address?     inet:ipv6-address
  |   |   |   +---w (MEP-ID)?
  |   |   |   |   +---:(MEP-ID-int)
  |   |   |   |   |   +---w MEP-ID-int?       int32
  |   |   |   |   +---w MEP-ID-format?      identityref
  |   |   +---w count?                 uint32
  |   |   +---w cc-transmit-interval?   Interval
  |   |   +---w packet-size?           uint32
  |   +--ro output
  |   |   +--ro (monitor-stats)?
  |   |   |   +---:(monitor-null)
  |   |   |   +--ro monitor-null?      empty
  |   +---x continuity-verification {connectivity-verification}?
  |   |   +---w input
  |   |   |   +---w MD-name-string  -> /domains/domain/MD-name-string
  |   |   |   +---w md-level?       -> /domains/domain/md-level
  |   |   |   +---w MA-name-string  -> /domains/domain/MAs/MA/MA-name-string
  |   |   |   +---w cos-id?         uint8
  |   |   |   +---w ttl?           uint8
  |   |   |   +---w sub-type?      identityref
  |   |   |   +---w source-mep?    -> /domains/domain/MAs/MA/MEP/mep-name
  |   |   |   +---w destination-mep
  |   |   |   |   +---w (mep-address)?
  |   |   |   |   |   +---:(mac-address)
  |   |   |   |   |   |   +---w mac-address?       yang:mac-address
  |   |   |   |   |   +---:(ipv4-address)
  |   |   |   |   |   |   +---w ipv4-address?     inet:ipv4-address
  |   |   |   |   |   +---:(ipv6-address)
  |   |   |   |   |   |   +---w ipv6-address?     inet:ipv6-address
  |   |   |   |   +---w (MEP-ID)?

```

```

| | | | +---:(MEP-ID-int)
| | | | | +---w MEP-ID-int? int32
| | | | | +---w MEP-ID-format? identityref
| | | | +---w count? uint32
| | | | +---w interval? Interval
| | | | +---w packet-size? uint32
| | | +--ro output
| | | | +--ro (monitor-stats)?
| | | | | +---:(monitor-null)
| | | | | | +--ro monitor-null? empty
+---x traceroute {traceroute}?
+---w input
| +---w MD-name-string -> /domains/domain/MD-name-string
| +---w md-level? -> /domains/domain/md-level
| +---w MA-name-string -> /domains/domain/MAs/MA/MA-name-string
| +---w cos-id? uint8
| +---w ttl? uint8
| +---w command-sub-type? identityref
| +---w source-mep? -> /domains/domain/MAs/MA/MEP/mep-name
| +---w destination-mep
| | +---w (mep-address)?
| | | +---:(mac-address)
| | | | +---w mac-address? yang:mac-address
| | | | +---:(ipv4-address)
| | | | | +---w ipv4-address? inet:ipv4-address
| | | | | +---:(ipv6-address)
| | | | | +---w ipv6-address? inet:ipv6-address
| | +---w (MEP-ID)?
| | | +---:(MEP-ID-int)
| | | | +---w MEP-ID-int? int32
| | | | +---w MEP-ID-format? identityref
| +---w count? uint32
| +---w interval? Interval
+--ro output
+--ro response* [response-index]
|--ro response-index uint8
--ro ttl? uint8
+--ro destination-mep
| +--ro (mep-address)?
| | +---:(mac-address)
| | | +--ro mac-address? yang:mac-address
| | | +---:(ipv4-address)
| | | | +--ro ipv4-address? inet:ipv4-address
| | | | +---:(ipv6-address)
| | | | +--ro ipv6-address? inet:ipv6-address
+--ro (MEP-ID)?
| +---:(MEP-ID-int)
| | +--ro MEP-ID-int? int32

```

```

|   +--ro MEP-ID-format?   identityref
+--ro mip {mip}?
|   +--ro interface?       if:interface-ref
|   +--ro (mip-address)?
|   |   +--:(mac-address)
|   |   |   +--ro mac-address?   yang:mac-address
|   |   |   +--:(ipv4-address)
|   |   |   |   +--ro ipv4-address?   inet:ipv4-address
|   |   |   |   +--:(ipv6-address)
|   |   |   |   |   +--ro ipv6-address?   inet:ipv6-address
+--ro (monitor-stats)?
|   +--:(monitor-null)
|   |   +--ro monitor-null?       empty

```

Snippet of data hierarchy related to RPC call continuity-check

#### 4.5. Notifications

Notification is sent on defect condition and defect clears with Maintenance Domain Name, MA Name, defect-type (The currently active defects), generating-mepid, and defect-message to indicate more details.

#### 4.6. Monitor statistics

Grouping for monitoring statistics is to be used by Yang modules which Augment Yang to provide statistics due to pro-active OAM like CCM Messages. For example CCM Transmit, CCM Receive, CCM Errors, etc.

#### 4.7. OAM data hierarchy

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

```

module: ietf-conn-oam
+--rw domains
|   +--rw domain* [technology MD-name-string]
|   |   +--rw technology       identityref
|   |   +--rw MD-name-string   MD-name-string
|   |   +--rw MD-name-format?  identityref
|   |   +--rw (MD-name)?
|   |   |   +--:(MD-name-null)
|   |   |   |   +--rw MD-name-null?   empty
|   |   +--rw md-level?       MD-level
|   +--rw MAs
|   |   +--rw MA* [MA-name-string]
|   |   |   +--rw MA-name-string   MA-name-string

```



```

+--rw MA-name-format?  identityref
+--rw (MA-name)?
|   +---:(MA-name-null)
|       +--rw MA-name-null?      empty
+--rw (connectivity-context)?
|   +---:(context-null)
|       +--rw context-null?      empty
+--rw cos-id?          uint8
+--rw cc-enable?      boolean
+--rw MEP* [mep-name]
|   +--rw mep-name      MEP-name
|   +--rw (MEP-ID)?
|       +---:(MEP-ID-int)
|           +--rw MEP-ID-int?    int32
+--rw MEP-ID-format?  identityref
+--rw (mep-address)?
|   +---:(mac-address)
|       | +--rw mac-address?      yang:mac-address
|       +---:(ipv4-address)
|           | +--rw ipv4-address?  inet:ipv4-address
|           +---:(ipv6-address)
|               +--rw ipv6-address?  inet:ipv6-address
+--rw cos-id?          uint8
+--rw cc-enable?      boolean
+--rw session* [session-cookie]
|   +--rw session-cookie      uint32
|   +--rw destination-mep
|       | +--rw (MEP-ID)?
|       | | +---:(MEP-ID-int)
|       | | | +--rw MEP-ID-int?    int32
|       | | +--rw MEP-ID-format?  identityref
+--rw destination-mep-address
|   +--rw (mep-address)?
|       | +--rw mac-address?      yang:mac-address
|       | +---:(ipv4-address)
|       | | +--rw ipv4-address?  inet:ipv4-address
|       | +---:(ipv6-address)
|       | | +--rw ipv6-address?  inet:ipv6-address
+--rw cos-id?          uint8
+--rw MIP* [interface] {mip}?
|   +--rw interface      if:interface-ref
+--rw (mip-address)?
|   +---:(mac-address)
|       | +--rw mac-address?      yang:mac-address
|       +---:(ipv4-address)
|           | +--rw ipv4-address?  inet:ipv4-address
|           +---:(ipv6-address)

```

```

+--rw ipv6-address?   inet:ipv6-address

```

```

rpcs:

```

```

+---x continuity-check {continuity-check}?
|
| +---w input
| |
| | +---w technology?           identityref
| | +---w MD-name-string   -> /domains/domain/MD-name-string
| | +---w md-level?        -> /domains/domain/md-level
| | +---w MA-name-string   -> /domains/domain/MAs/MA/MA-name-string
| | +---w cos-id?          uint8
| | +---w ttl?             uint8
| | +---w sub-type?        identityref
| | +---w source-mep?      -> /domains/domain/MAs/MA/MEP/mep-name
| | +---w destination-mep
| | |
| | | +---w (mep-address)?
| | | |
| | | | +---:(mac-address)
| | | | | +---w mac-address?   yang:mac-address
| | | | +---:(ipv4-address)
| | | | | +---w ipv4-address?  inet:ipv4-address
| | | | +---:(ipv6-address)
| | | | | +---w ipv6-address?  inet:ipv6-address
| | | +---w (MEP-ID)?
| | | |
| | | | +---:(MEP-ID-int)
| | | | | +---w MEP-ID-int?    int32
| | | | +---w MEP-ID-format?  identityref
| | +---w count?             uint32
| | +---w cc-transmit-interval? Interval
| | +---w packet-size?      uint32
| +--ro output
| |
| | +--ro (monitor-stats)?
| | |
| | | +---:(monitor-null)
| | | +--ro monitor-null?   empty
+---x continuity-verification {connectivity-verification}?
|
| +---w input
| |
| | +---w MD-name-string   -> /domains/domain/MD-name-string
| | +---w md-level?        -> /domains/domain/md-level
| | +---w MA-name-string   -> /domains/domain/MAs/MA/MA-name-string
| | +---w cos-id?          uint8
| | +---w ttl?             uint8
| | +---w sub-type?        identityref
| | +---w source-mep?      -> /domains/domain/MAs/MA/MEP/mep-name
| | +---w destination-mep
| | |
| | | +---w (mep-address)?
| | | |
| | | | +---:(mac-address)
| | | | | +---w mac-address?   yang:mac-address
| | | | +---:(ipv4-address)
| | | | | +---w ipv4-address?  inet:ipv4-address
| | | | +---:(ipv6-address)

```

```

| | | | +---w ipv6-address?    inet:ipv6-address
| | | | +---w (MEP-ID)?
| | | | | +---:(MEP-ID-int)
| | | | | +---w MEP-ID-int?    int32
| | | | | +---w MEP-ID-format?  identityref
| | | | +---w count?          uint32
| | | | +---w interval?      Interval
| | | | +---w packet-size?    uint32
| | | +--ro output
| | | | +--ro (monitor-stats)?
| | | | | +---:(monitor-null)
| | | | | +--ro monitor-null?  empty
| | +---x traceroute {traceroute}?
| | | +---w input
| | | | +---w MD-name-string -> /domains/domain/MD-name-string
| | | | +---w md-level?      -> /domains/domain/md-level
| | | | +---w MA-name-string -> /domains/domain/MAs/MA/MA-name-string
| | | | +---w cos-id?        uint8
| | | | +---w ttl?          uint8
| | | | +---w command-sub-type?  identityref
| | | | +---w source-mep?     -> /domains/domain/MAs/MA/MEP/mep-name
| | | | +---w destination-mep
| | | | | +---w (mep-address)?
| | | | | | +---:(mac-address)
| | | | | | | +---w mac-address?    yang:mac-address
| | | | | | | +---:(ipv4-address)
| | | | | | | | +---w ipv4-address?  inet:ipv4-address
| | | | | | | | +---:(ipv6-address)
| | | | | | | | +---w ipv6-address?  inet:ipv6-address
| | | | | +---w (MEP-ID)?
| | | | | | +---:(MEP-ID-int)
| | | | | | +---w MEP-ID-int?    int32
| | | | | | +---w MEP-ID-format?  identityref
| | | | | +---w count?          uint32
| | | | | +---w interval?      Interval
| | | +--ro output
| | | | +--ro response* [response-index]
| | | | | +--ro response-index    uint8
| | | | | +--ro ttl?            uint8
| | | | | +--ro destination-mep
| | | | | | +--ro (mep-address)?
| | | | | | | +---:(mac-address)
| | | | | | | | +--ro mac-address?    yang:mac-address
| | | | | | | | +---:(ipv4-address)
| | | | | | | | | +--ro ipv4-address?  inet:ipv4-address
| | | | | | | | | +---:(ipv6-address)
| | | | | | | | | +--ro ipv6-address?  inet:ipv6-address
| | | | | | +--ro (MEP-ID)?

```

```

| | +---:(MEP-ID-int)
| |   +---ro MEP-ID-int?      int32
| | +---ro MEP-ID-format?    identityref
+---ro mip {mip}?
|   +---ro interface?       if:interface-ref
|   +---ro (mip-address)?
|   |   +---:(mac-address)
|   |   |   +---ro mac-address?    yang:mac-address
|   |   +---:(ipv4-address)
|   |   |   +---ro ipv4-address?   inet:ipv4-address
|   |   +---:(ipv6-address)
|   |   |   +---ro ipv6-address?   inet:ipv6-address
+---ro (monitor-stats)?
|   +---:(monitor-null)
|   |   +---ro monitor-null?      empty

```

## notifications:

```

+---n defect-condition-notification
| +---ro technology?          identityref
| +---ro MD-name-string -> /domains/domain/MD-name-string
| +---ro MA-name-string -> /domains/domain/MAs/MA/MA-name-string
| +---ro mep-name?          -> /domains/domain/MAs/MA/MEP/mep-name
| +---ro defect-type?       identityref
+---ro generating-mepid
|   +---ro (MEP-ID)?
|   |   +---:(MEP-ID-int)
|   |   |   +---ro MEP-ID-int?    int32
|   |   +---ro MEP-ID-format?    identityref
+---ro (defect)?
|   +---:(defect-null)
|   |   +---ro defect-null?       empty
|   +---:(defect-code)
|   |   +---ro defect-code?       int32
+---n defect-cleared-notification
+---ro technology?          identityref
+---ro MD-name-string -> /domains/domain/MD-name-string
+---ro MA-name-string -> /domains/domain/MAs/MA/MA-name-string
+---ro mep-name?          -> /domains/domain/MAs/MA/MEP/mep-name
+---ro defect-type?       identityref
+---ro generating-mepid
|   +---ro (MEP-ID)?
|   |   +---:(MEP-ID-int)
|   |   |   +---ro MEP-ID-int?    int32
|   |   +---ro MEP-ID-format?    identityref
+---ro (defect)?
|   +---:(defect-null)
|   |   +---ro defect-null?       empty
|   +---:(defect-code)

```

+-ro defect-code? int32

data hierarchy of OAM

## 5. OAM YANG Module

```
<CODE BEGINS> file "ietf-conn-oam.yang"

module ietf-conn-oam {
  namespace "urn:ietf:params:xml:ns:yang:ietf-conn-oam";
  prefix goam;

  import ietf-yang-types {
    prefix yang;
  }
  import ietf-inet-types {
    prefix inet;
  }
  import ietf-interfaces {
    prefix if;
  }

  organization "IETF LIME Working Group";
  contact
    "WG Web:      http://tools.ietf.org/wg/lime
    WG List:      mailto:lime@ietf.org
    WG Chair:     Carlos Pignataro cpignata@cisco.com
    WG Chair:     Ron Bonica rbonica@juniper.net
    Editor:       Deepak Kumar dekumar@cisco.com
    Editor:       Qin Wu bill.wu@huawei.com
    Editor:       Zitao Wang wangzitao@huawei.com";
  description
    "This YANG module defines the generic configuration,
    statistics and rpc for connection oriented OAM
    to be used within IETF in a protocol independent manner.
    Functional level abstraction is indendent
    with YANG modeling. 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 2017-04-10 {
    description
      "Initial revision. - 08 version";

    reference "draft-ietf-lime-yang-oam-model";
  }
}
```

```
/* features */
feature connectivity-verification {
  description
    "This feature indicates that the server supports
    executing connectivity verification OAM command and
    returning a response. Servers that do not advertise
    this feature will not support executing
    connectivity verification command or rpc model for
    connectivity verification command.";
}
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 model for
    continuity check command.";
}

feature traceroute{
  description
    "This feature indicates that the server supports
    executing traceroute OAM command and
    returning a response. Servers that do not advertise
    this feature will not support executing
    traceroute command or rpc model for
    traceroute command.";
}
feature mip {
  description
    "This feature indicates that the MIP (Maintenance Intermediate Point)
    need to
    be explicit configured";
}
/* Identities */

identity technology-types {
  description
    "This is the base identity of technology types which are
    TRILL,MPLS-TP,vpls etc";
}

identity command-sub-type {
  description
    "Defines different rpc command subtypes,
    e.g rfc6905 trill OAM, this is optional for most cases";
}
```

```
identity on-demand {
  base command-sub-type;
  description
  "On demand activation - indicates that the tool is activated
  manually to detect a specific anomaly.
  On-demand OAM method requires only transient configuration.";
}

identity proactive {
  base command-sub-type;
  description
  "Proactive activation - indicates that the tool is activated on a
  continual basis, where messages are sent periodically, and errors
  are detected when a certain number of expected messages are not
  received. Proactive OAM method requires persistent configuration.";
}

identity name-format {

  description
  "This defines the name format, IEEE 802lag CFM defines varying
  styles of names. It is expected name format as an identity ref
  to be extended with new types.";
}

identity name-format-null {
  base name-format;
  description
  "Defines name format as null";
}

identity identifier-format {
  description
  "Identifier-format identity can be augmented to define other
  format identifiers used in MEP-ID etc";
}

identity identifier-format-integer {
  base identifier-format;
  description
  "Defines identifier-format to be integer";
}

identity defect-types {
  description
  "Defines different defect types, e.g. rdi
  (Remote Defect Indication), loss of continuity";
}
```

```
}
identity rdi {
  base defect-types;
  description
    "Indicates the aggregate health of the remote MEPs. ";
}

identity remote-mep-defect{
  base defect-types;
  description
    "Indicates that one or more of the remote MEPs is
    reporting a failure ";
}

identity loss-of-continuity{
  base defect-types;
  description
    "If no proactive CC OAM packets from the source
    MEP (and in the case of CV, this includes the
    requirement to have the expected unique,
    technology dependent source MEP identifier)
    are received within the interval. ";
}

identity cv-defect {
  base defect-types;
  description
    "This function should support monitoring between the MEPs and,
    in addition, between a MEP and MIP.[RFC6371] highlights,
    when performing Connectivity Verification, the need for the
    Continuity Check and Connectivity Verification (CC-V) messages
    to include unique identification of the MEG that is being
    monitored and the MEP that originated the message.";
}

identity invalid-oam-defect{
  base defect-types;
  description
    "Indicates that one or more invalid OAM messages has been
    received and that 3.5 times that OAM message transmission
    interval has not yet expired.";
}

identity cross-connect-defect{
  base defect-types;
  description
    "Indicates that one or more cross-connect defect
```



```
(for example, a service ID does not match the VLAN.)
messages has been received and that 3.5 times that OAM message
transmission interval has not yet expired.";
}

/* typedefs */

typedef MEP-name {
    type string;
    description
        "Generic administrative name for a MEP";
}

typedef Interval{
    type decimal64{
        fraction-digits 2;
    }
    units "milliseconds";
    description
        "Interval between packets in milliseconds.
        0 means no packets are sent.";
}

typedef MD-name-string {
    type string;
    description
        "Generic administrative name for an MD";
}

typedef MA-name-string {
    type string;
    description
        "Generic administrative name for an MA";
}

typedef oam-counter32 {
    type yang:zero-based-counter32;
    description
        "Defines 32 bit counter for OAM";
}

typedef MD-level {
    type uint32 {
        range "0..255";
    }
    description
        "Maintenance Domain level. The level may be restricted in
        certain protocols (eg to 0-7)";
}
```

```
    }

    /* groupings */

    grouping maintenance-domain-reference {
    description
        "This grouping uniquely identifies a maintenance domain.";
    leaf maintenance-domain {
        type leafref {
            path "/goam:domains/goam:domain/goam:MD-name-string";
        }
    }
    description
        "A reference to a specific Maintenance Domain.";
    }
}

grouping maintenance-association-reference {
    description
        "This grouping uniquely identifies a
        maintenance association. It consists
        of a maintenance-domain-reference and
        a maintenance-association leafref";
    uses maintenance-domain-reference;
    leaf maintenance-association {
        type leafref {
            path "/goam:domains/goam:domain"
                + "[goam:MD-name-string = current()/"
                + "../maintenance-domain]/goam:MA"
                + "goam:MA/goam:MA-name-string";
        }
    }
    description
        "A reference to a specific Maintenance Association.";
    }
}

grouping maintenance-association-end-point-reference {
    description
        "This grouping uniquely identifies
        a maintenance association. It consists
        of a maintenance-association-reference and
        a maintenance-association-end-point leafref";
    uses maintenance-association-reference;
    leaf maintenance-association-end-point {
        type leafref {
            path "/goam:domains/goam:domain"
                + "[goam:MD-name-string = current()/"
                + "../maintenance-domain]/goam:MA"
                + "goam:MA[goam:MA-name-string = "
```

```
        +"current()/../maintenance-association]"
        +"/goam:MEP/goam:mep-name";
    }
    description
        "A reference to a specific Maintenance
        association End Point.";
}
}

grouping time-to-live {
    leaf ttl{
        type uint8;
        description
            "Time to Live.";
    }
    description
        "Time to Live grouping.";
}
grouping defect-message {
    choice defect {
        case defect-null {
            description
                "This is a placeholder when no defect status is needed";
            leaf defect-null {
                type empty;
                description
                    "there is no defect define, it will be defined in
                    technology specific model.";
            }
        }
        case defect-code {
            description
                "This is a placeholder to display defect code.";
            leaf defect-code {
                type int32;
                description
                    "Defect code is integer value specific to technology.";
            }
        }
    }
    description
        "Defect Message choices.";
}

description
    "Defect Message.";
}
```

```
grouping mep-address {
  choice mep-address {
    case mac-address {
      leaf mac-address {
        type yang:mac-address;
        description
          "MAC Address";
      }
    }
    description
      "MAC Address based MEP Addressing.";
  }
  case ipv4-address {
    leaf ipv4-address {
      type inet:ipv4-address;
      description
        "IPv4 Address";
    }
    description
      "IP Address based MEP Addressing.";
  }
  case ipv6-address {
    leaf ipv6-address {
      type inet:ipv6-address;
      description
        "IPv6 Address";
    }
    description
      "IPv6 Address based MEP Addressing.";
  }
  description
    "MEP Addressing.";
}
description
  "MEP Address";
}
grouping mip-address {
  choice mip-address {
    case mac-address {
      leaf mac-address {
        type yang:mac-address;
        description
          "MAC Address";
      }
    }
    description
      "MAC Address based MIP Addressing.";
  }
  case ipv4-address {
    leaf ipv4-address {
```

```
        type inet:ipv4-address;
        description
        "IPv4 Address";
    }

    description
    "IP Address based MIP Addressing.";
}
case ipv6-address {
    leaf ipv6-address {
        type inet:ipv6-address;
        description
        "IPv6 Address";
    }
    description
    "IPv6 Address based MIP Addressing.";
}
description
"MIP Addressing.";
}
description
"MIP Address";
}
grouping maintenance-domain-id {
    description
    "Grouping containing leaves sufficient to identify an MD";
    leaf technology {
        type identityref {
            base technology-types;
        }
        mandatory true;
        description
        "Defines the technology";
    }
    leaf MD-name-string {
        type MD-name-string;
        mandatory true;
        description
        "Defines the generic administrative maintenance domain name";
    }
}

grouping MD-name {
    leaf MD-name-format {
        type identityref {
            base name-format;
        }
        description
```

```
        "Name format.";
    }
    choice MD-name {
        case MD-name-null {
            leaf MD-name-null {
                when "'../ ../ ../MD-name-format' = 'name-format-null'" {
                    description
                        "MD name format is equal to null format.";
                }
                type empty;
                description
                    "MD name Null.";
            }
        }
        description
            "MD name.";
    }
    description
        "MD name";
}

grouping ma-identifier {
    description
        "Grouping containing leaves sufficient to identify an MA";
    leaf MA-name-string {
        type MA-name-string;

        description

            "MA name string.";
    }
}

grouping MA-name {
    description
        "MA name";
    leaf MA-name-format {
        type identityref {
            base name-format;
        }
        description
            "Ma name format";
    }
    choice MA-name {
        case MA-name-null {
            leaf MA-name-null {
                when "'../ ../ ../MA-name-format' = 'name-format-null'" {
                    description

```

```
        "MA";
    }
    type empty;

    description
        "Empty";
    }
}
description
    "MA name";
}
}

grouping MEP-ID {
    choice MEP-ID {
        default "MEP-ID-int";
        case MEP-ID-int {
            leaf MEP-ID-int {
                type int32;
            }
        }
    }
    description
        "MEP ID in integer format";
}
description
    "MEP-ID";
}

leaf MEP-ID-format {
    type identityref {
        base identifier-format;
    }
    description
        "MEP ID format.";
}
description
    "MEP-ID";
}

grouping MEP {
    description
        "Defines elements within the MEP";
    leaf mep-name {
        type MEP-name;
        mandatory true;
        description
            "Generic administrative name of the MEP";
    }
}
```

```
    uses MEP-ID;
    uses mep-address;
}

grouping monitor-stats {
  description
    "grouping for monitoring statistics, this will be augmented
    by others who use this component";
  choice monitor-stats {

    default "monitor-null";
    case monitor-null {
      description
        "This is a place holder when
        no monitoring statistics is needed";
      leaf monitor-null {
        type empty;
        description
          "There is no monitoring statistics to be defined";
      }
    }
    description
      "Define the monitor stats";
  }
}

grouping connectivity-context {
  description
    "Grouping defining the connectivity context for an MA; for
    example, a VRF for VPLS, or an LSP for MPLS-TP. This will be
    augmented by each protocol who use this component";
  choice connectivity-context {
    default "context-null";
    case context-null {
      description
        "This is a place holder when no context is needed";
      leaf context-null {
        type empty;
        description
          "There is no context define";
      }
    }
    description
      "Connectivity context";
  }
}
grouping cos {
  description
```



```
"Priority used in transmitted packets; for example, in the
EXP field in MPLS-TP.";

leaf cos-id {
  type uint8;
  description
    "Class of service";
}
}
grouping MIP-grouping {
  uses mip-address;
  description
    "Grouping for MIP configuration";
}

container domains {
  description
    "Contains configuration related data. Within the container
    is list of fault domains. Within each domain has List of MA.";
  list domain {
    key "technology MD-name-string";
    ordered-by system;
    description
      "Define the list of Domains within the IETF-OAM";
    uses maintenance-domain-id;
    uses MD-name;
    leaf md-level {
      type MD-level;
      description
        "Defines the MD-Level";
    }
  }
  container MAs {
    description
      "This container defines MA, within that have multiple MA
      and within MA have MEP";
    list MA {
      key "MA-name-string";
      ordered-by system;
      uses ma-identifier;
      uses MA-name;
      uses connectivity-context;
      uses cos {
        description
          "Default class of service for this MA,
          which may be overridden
          for particular MEPs,
          sessions or operations.";
      }
    }
  }
}
```

```
    leaf cc-enable{
      type boolean;
      description
        "Indicate whether the CC enable.";
    }
  list MEP {
    key "mep-name";

    ordered-by system;
    description
      "Contain list of MEPS";
    uses MEP;
    uses cos;
    leaf cc-enable{
      type boolean;
      description
        "Indicate whether the CC enable.";
    }
  list session {
    key "session-cookie";
    ordered-by user;
    description
      "Monitoring session to/from a particular remote MEP.
      Depending on the protocol, this could represent CC
      messages received from a single remote MEP (if the
      protocol uses multicast CCs) or a target to which
      unicast echo request CCs are sent and from which
      responses are received (if the protocol uses a
      unicast request/response mechanism).";
    leaf session-cookie {
      type uint32;
      description
        "Cookie to identify different sessions, when there
        are multiple remote MEPS or multiple sessions to
        the same remote MEP.";
    }
    container destination-mep {
      uses MEP-ID;
      description
        "Destination MEP";
    }
    container destination-mep-address {
      uses mep-address;
      description
        "Destination MEP Address";
    }
  }
  uses cos;
}
```

```
    }
    list MIP {
      if-feature mip;
      key "interface";
      leaf interface {
        type if:interface-ref;
        description
          "Interface";
      }
      uses MIP-grouping;
      description
        "List for MIP";
    }
    description
      "Maintenance Association list";
  }
}

notification defect-condition-notification {
  description
    "When defect condition is met this notification is sent";
  leaf technology {
    type identityref {
      base technology-types;
    }
    description
      "The technology";
  }
  leaf MD-name-string {
    type leafref{
      path "/domains/domain/MD-name-string";
    }
    mandatory true;
    description
      "Indicate which MD is seeing the defect";
  }
  leaf MA-name-string{
    type leafref{
      path "/domains/domain/MAs/MA/MA-name-string";
    }
    mandatory true;
    description
      "Indicate which MA is seeing the defect";
  }
  leaf mep-name {
```

```
    type leafref{
      path "/domains/domain/MAs/MA/MEP/mep-name";
    }
    description
      "Indicate which MEP is seeing the defect";
  }
  leaf defect-type {
    type identityref {
      base defect-types;
    }
    description
      "The currently active defects on the specific MEP.";
  }
  container generating-mepid {

    uses MEP-ID;
    description
      "Who is generating the defect (if known) if
      unknown make it 0.";
  }
  uses defect-message {
    description
      "Defect message to indicate more details.";
  }
}

notification defect-cleared-notification {
  description
    "When defect cleared is met this notification is sent";
  leaf technology {
    type identityref {
      base technology-types;
    }
    description
      "The technology";
  }
  leaf MD-name-string {
    type leafref{
      path "/domains/domain/MD-name-string";
    }
    mandatory true;
    description
      "Indicate which MD is seeing the defect";
  }
  leaf MA-name-string{
    type leafref{
      path "/domains/domain/MAs/MA/MA-name-string";
    }
  }
}
```

```
    mandatory true;
    description
      "Indicate which MA is seeing the defect";
  }
  leaf mep-name {
    type leafref{
      path "/domains/domain/MAs/MA/MEP/mep-name";
    }
    description
      "Indicate which MEP is seeing the defect";
  }

  leaf defect-type {
    type identityref {
      base defect-types;
    }
    description
      "The currently active defects on the specific MEP.";
  }
  container generating-mepid {
    uses MEP-ID;
    description
      "Who is generating the defect (if known) if
      unknown make it 0.";
  }
  uses defect-message {
    description
      "Defect message to indicate more details.";
  }
}

rpc continuity-check {
  if-feature "continuity-check";
  description
    "Generates continuity-check as per RFC7276 Table 4.";
  input {
    leaf technology {
      type identityref {
        base technology-types;
      }
      description
        "The technology";
    }
    leaf MD-name-string {
      type leafref{
        path "/domains/domain/MD-name-string";
      }
      mandatory true;
    }
  }
}
```

```
    description
      "Indicate which MD is seeing the defect";
  }
  leaf md-level {
    type leafref {
      path "/domains/domain/md-level";
    }
    description
      "The maintenance domain level.";
  }
  leaf MA-name-string{
    type leafref{
      path "/domains/domain/MAs/MA/MA-name-string";
    }
    mandatory true;
    description
      "Indicate which MA is seeing the defect";
  }
  uses cos;
  uses time-to-live;
  leaf sub-type {
    type identityref {
      base command-sub-type;
    }
    description
      "Defines different command types";
  }
  leaf source-mep {
    type leafref{
      path "/domains/domain/MAs/MA/MEP/mep-name";
    }
    description
      "Source MEP";
  }
  container destination-mep {
    uses mep-address;
    uses MEP-ID {
      description
        "Only applicable if the destination is a MEP";
    }
    description
      "Destination MEP";
  }
  leaf count {
    type uint32;
    default "3";
    description
```

```
        "Number of continuity-check message to send";
    }
    leaf cc-transmit-interval {
        type Interval;
        description
            "Interval between echo requests";
    }
    leaf packet-size {
        type uint32 {
            range "0..10000";
        }
        default "64";
        description
            "Size of continuity-check packets, in octets";
    }
}
output {
    uses monitor-stats {
        description
            "Stats of continuity check.";
    }
}
}

rpc continuity-verification {
    if-feature connectivity-verification;
    description
        "Generates continuity-verification as per RFC7276 Table 4.";
    input {
        leaf MD-name-string {
            type leafref{
                path "/domains/domain/MD-name-string";
            }
            mandatory true;
            description
                "Indicate which MD is seeing the defect";
        }

        leaf md-level {
            type leafref {
                path "/domains/domain/md-level";
            }
            description
                "The maintenance domain level.";
        }

        leaf MA-name-string{
```

```
type leafref{
path "/domains/domain/MAs/MA/MA-name-string";
}
mandatory true;
description
"Indicate which MA is seeing the defect";
}
uses cos;
uses time-to-live;
leaf sub-type {
type identityref {
base command-sub-type;
}
description
"Defines different command types";
}
leaf source-mep {
type leafref{
path "/domains/domain/MAs/MA/MEP/mep-name";
}
description
"Source MEP";
}
container destination-mep {
uses mep-address;
uses MEP-ID {
description "Only applicable if the destination is a MEP";
}
description
"Destination MEP";
}
}
leaf count {
type uint32;
default "3";
description
"Number of continuity-verification message to send";
}
leaf interval {
type Interval;
description
"Interval between echo requests";
}
leaf packet-size {
type uint32 {
range "64..10000";
}
default "64";
}
```



```
        description
            "Size of continuity-verification packets, in octets";
    }
}

output {
    uses monitor-stats {
        description
            "Stats of continuity check.";
    }
}
}

rpc traceroute {
    if-feature traceroute;
    description
        "Generates Traceroute or Path Trace and return response.
        Referencing RFC7276 for common Toolset name, for
        MPLS-TP OAM it's Route Tracing, and for TRILL OAM It's
        Path Tracing tool. Starts with TTL of one and increment
        by one at each hop. Untill destination reached or TTL
        reach max value";
    input {
        leaf MD-name-string {
            type leafref{
                path "/domains/domain/MD-name-string";
            }
            mandatory true;
            description
                "Indicate which MD is seeing the defect";
        }

        leaf md-level {
            type leafref {
                path "/domains/domain/md-level";
            }
            description
                "The maintenance domain level.";
        }

        leaf MA-name-string{
            type leafref{
                path "/domains/domain/MAs/MA/MA-name-string";
            }
            mandatory true;
            description
                "Indicate which MA is seeing the defect";
        }
    }
    uses cos;
}
```

```
uses time-to-live;
leaf command-sub-type {
  type identityref {
    base command-sub-type;
  }
  description
    "Defines different command types";
}
leaf source-mep {
  type leafref{
    path "/domains/domain/MAs/MA/MEP/mep-name";
  }
  description
    "Source MEP";
}
container destination-mep {
  uses mep-address;
  uses MEP-ID {
    description
      "Only applicable if the destination is a MEP";
  }
  description
    "Destination MEP";
}
leaf count {
  type uint32;
  default "1";
  description
    "Number of traceroute probes to send. In protocols where a
    separate message is sent at each TTL, this is the number
    of packets to send at each TTL.";
}
leaf interval {
  type Interval;
  description
    "Interval between echo requests";
}
}
output {
  list response {
    key "response-index";

    leaf response-index {
      type uint8;
      description
        "Arbitrary index for the response. In protocols that
        guarantee there is only a single response at each TTL,
        the TTL can be used as the response index.";
    }
  }
}
```

```
    }
    uses time-to-live;
    container destination-mep {
      description "MEP from which the response has been received";
      uses mep-address;
      uses MEP-ID {
        description
          "Only applicable if the destination is a MEP";
      }
    }
    container mip {
      if-feature mip;
      leaf interface {
        type if:interface-ref;
        description
          "MIP interface";
      }
      uses mip-address;
      description
        "MIP responding with traceroute";
    }
    uses monitor-stats {
      description
        "Stats of traceroute.";
    }
    description
      "List of response.";
  }
}
```

<CODE ENDS>

## 6. Base Mode

The Base Mode ('default mode' described in section 4) defines default configuration that MUST be present in the devices that comply with this document. Base Mode allows users to have "zero-touch" experience. Several parameters require technology specific definition.

### 6.1. MEP Address

In the Base Mode of operation, the MEP Address is by default the IP address of the interface on which the MEP is located.

## 6.2. MEP ID for Base Mode

In the Base Mode of operation, each device creates a single MEP associated with a virtual OAM port with no physical layer (NULL PHY). The MEP-ID associated with this MEP is zero (0). The choice of MEP-ID zero is explained below.

MEP-ID is 2 octet field by default. It is never used on the wire except when using CCM. It is important to have method that can derive MEP-ID of base mode in an automatic manner with no user intervention. IP address cannot be directly used for this purpose as the MEP-ID is much smaller field. For Base Mode of operation we propose to use MEP-ID zero (0) as the default MEP-ID.

CCM packet use MEP-ID on the payload. CCM MUST NOT be used in the Base Mode. Hence CCM MUST be disabled on the Maintenance Association of the Base Mode.

If CCM is required, users MUST configure a separate Maintenance association and assign unique value for the corresponding MEP IDs.

CFM [IEEE802.1ag] defines MEP ID as an unsigned integer in the range 1 to 8191. In this document we propose extend the range to 0 to 65535. Value 0 is reserved for MEP-ID of Base Mode operation and MUST NOT be used for other purposes.

## 6.3. Maintenance Association

The ID of the Maintenance Association (MA-ID) [IEEE802.1ag] has a flexible format and includes two parts: Maintenance Domain Name and Short MA name. In the Based Mode of operation, the value of the Maintenance Domain Name must be the character string "GenericBaseMode" (excluding the quotes "). In Base Mode operation Short MA Name format is set to 2-octet integer format (value 3 in Short MA Format field [IEEE802.1ag]) and Short MA name set to 65532 (0xFFFC).

## 7. Connection-oriented OAM YANG model applicability

"ietf-conn-oam" model defined in this document provides technology-independent abstraction of key OAM constructs for connection oriented 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 connection-oriented OAM model.

This section demonstrates the usability of the connection-oriented YANG OAM data model to various connection-oriented OAM technologies, e.g., TRILL and MPLS-TP. 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.

#### 7.1. Generic YANG Model extension for TRILL OAM

The TRILL YANG module is augmenting connection oriented OAM module for both configuration and RPC commands.

The TRILL YANG module requires the base TRILL module ([I-D.ietf-trill-yang]) to be supported as there is a strong relationship between those modules.

The configuration extensions for connection oriented OAM include MD configuration extension, Technology type extension, MA configuration extension, Connectivity-Context Extension, MEP Configuration Extension, ECMP extension. In the RPC extension, the continuity-check and path-discovery RPC are extended with TRILL specific.

##### 7.1.1. MD Configuration Extension

MD level configuration parameters are management information which can be inherited in the TRILL OAM model and set by connection oriented base model as default values. For example domain name can be set to area-ID in the TRILL OAM case. In addition, at the Maintenance Domain level, domain data node at root level can be augmented with technology type.

Note that MD level configuration parameters provides context information for management system to correlate faults, defects, network failures with location information, which helps quickly identify root causes of network failures.

##### 7.1.1.1. Technology Type Extension

No TRILL technology type has been defined in the connection oriented base model. Therefore a technology type extension is required in the TRILL OAM model. The technology type "trill" is defined as an identity that augments the base "technology-types" defined in the connection oriented base model:

```

identity trill{
  base goam:technology-types;
  description
    "trill type";
}

```

### 7.1.2. MA Configuration Extension

MA level configuration parameters are management information which can be inherited in the TRILL OAM model and set by connection oriented base model as default values. In addition, at the Maintenance Association(MA) level, MA data node at the second level can be augmented with connectivity-context extension.

Note that MA level configuration parameters provides context information for management system to correlate faults, defects, network failures with location information, which helps quickly identify root causes of network failures.

#### 7.1.2.1. Connectivity-Context Extension

In TRILL OAM, one example of connectivity-context is either a 12 bit VLAN ID or a 24 bit Fine Grain Label. The connection oriented base model defines a placeholder for context-id. This allows other technologies to easily augment that to include technology specific extensions. The snippet below depicts an example of augmenting connectivity-context to include either VLAN ID or Fine Grain Label.

```

augment /goam:domains/goam:domain/goam:MAS
/goam:MA /goam:connectivity-context:
  +--:(connectivity-context-vlan)
  |   +--rw connectivity-context-vlan?   vlan
  +--:(connectivity-context-fgl)
  |   +--rw connectivity-context-fgl?   fgl

```

### 7.1.3. MEP Configuration Extension

The MEP configuration definition in the connection oriented base model already supports configuring the interface of MEP with either MAC address or IP address. In addition, the MEP address can be represented using a 2 octet RBridge Nickname in TRILL OAM . Hence, the TRILL OAM model augments the MEP configuration in base model to add a nickname case into the MEP address choice node as follows:

```

augment /goam:domains/goam:domain/goam:MAS
/goam:MA/ goam:MEP/goam:mep-address:
  +--:( mep-address-trill)
  |   +--rw mep-address-trill?   trill-rb-nickname

```

In addition, at the Maintenance Association Endpoint(MEP) level, MEP data node at the third level can be augmented with ECMP extension.

#### 7.1.3.1. ECMP Extension

Since TRILL supports ECMP path selection, flow-entropy in TRILL is defined as a 96 octet field in the LIME model extension for TRILL OAM. The snippet below illustrates its extension.

```
augment /goam:domains/goam:domain/goam:MAS/goam:MA/goam:MEP:
  +--rw flow-entropy-trill?  flow-entropy-trill
augment /goam:domains/goam:domain/goam:MAS/goam:MA/goam:MEP
/goam:session:
  +--rw flow-entropy-trill?  flow-entropy-trill
```

#### 7.1.4. RPC extension

In the TRILL OAM YANG model, the continuity-check and path-discovery RPC commands are extended with TRILL specific requirements. The snippet below depicts an example of illustrates the TRILL OAM RPC extension.

```

augment /goam:continuity-check/goam:input:
  +--ro (out-of-band)?
  |   +--:(ipv4-address)
  |   |   +--ro ipv4-address?       inet:ipv4-address
  |   +--:(ipv6-address)
  |   |   +--ro ipv6-address?       inet:ipv6-address
  |   +--:(trill-nickname)
  |       +--ro trill-nickname?     tril-rb-nickname
  +--ro diagnostic-vlan?  boolean
augment /goam:continuity-check/goam:input:
  +--ro flow-entropy-trill?  flow-entropy-trill
augment /goam:continuity-check/goam:output:
  +--ro upstream-rbridge?    tril-rb-nickname
  +--ro next-hop-rbridge*    tril-rb-nickname
augment /goam:path-discovery/goam:input:
  +--ro (out-of-band)?
  |   +--:(ipv4-address)
  |   |   +--ro ipv4-address?       inet:ipv4-address
  |   +--:(ipv6-address)
  |   |   +--ro ipv6-address?       inet:ipv6-address
  |   +--:(trill-nickname)
  |       +--ro trill-nickname?     tril-rb-nickname
  +--ro diagnostic-vlan?    boolean
augment /goam:path-discovery/goam:input:
  +--ro flow-entropy-trill?  flow-entropy-trill
augment /goam:path-discovery/goam:output/goam:response:
  +--ro upstream-rbridge?    tril-rb-nickname
  +--ro next-hop-rbridge*    tril-rb-nickname

```

## 7.2. Generic YANG Model extension for MPLS-TP OAM

The MPLS-TP OAM YANG module can augment connection oriented OAM Module with some technology-specific details. And the [mpls-tp-oam-yang] presents the YANG Data model for MPLS-TP OAM.

The configuration extensions for connection oriented OAM include MD configuration extension, Technology type extension, Sub Technology Type Extension ,MA configuration extension, MEP Configuration Extension.

### 7.2.1. MD Configuration Extension

MD level configuration parameters are management information which can be inherited in the MPLS-TP OAM model and set by LIME base model as default values. For example domain name can be set to area-ID or the provider's Autonomous System Number(ASN) [RFC6370] in the MPLS-TP OAM case. In addition, at the Maintenance Domain level, domain data



node at root level can be augmented with technology type and sub-technology type.

Note that MD level configuration parameters provides context information for management system to correlate faults, defects, network failures with location information, which helps quickly identify root causes of network failures

#### 7.2.1.1. Technology Type Extension

No MPLS-TP technology type has been defined in the connection oriented base model, hence it is required in the MPLS OAM model. The technology type "mpls-tp" is defined as an identity that augments the base "technology-types" defined in the connection oriented base model:

```
identity mpls-tp{
    base goam:technology-types;
    description
        "mpls-tp type";
}
```

#### 7.2.1.2. Sub Technology Type Extension

In MPLS-TP, since different encapsulation types such as IP/UDP Encapsulation, PW-ACH encapsulation can be employed, the "technology-sub-type" data node is defined and added into the MPLS OAM model to further identify the encapsulation types within the MPLS-TP OAM model. Based on it, we also define a technology sub-type for IP/UDP encapsulation and PW-ACH encapsulation. Other Encapsulation types can be defined in the same way. The snippet below depicts an example of several encapsulation types.

```
identity technology-sub-type {
  description
    "certain implementations can have different
    encapsulation types such as ip/udp, pw-ach and so on.
    Instead of defining separate models for each
    encapsulation, we define a technology sub-type to
    further identify different encapsulations.
    Technology sub-type is associated at the MA level"; }

  identity technology-sub-type-udp {
    base technology-sub-type;
    description
      "technology sub-type is IP/UDP encapsulation";
  }

  identity technology-sub-type-ach {
    base technology-sub-type;
    description
      "technology sub-type is PW-ACH encapsulation";
  }

  augment "/goam:domains/goam:domain/goam:MAS/goam:MA" {
    leaf technology-sub-type {
      type identityref {
        base technology-sub-type;
      }
    }
  }
}
```

#### 7.2.2. MA Configuration Extension

MA level configuration parameters are management information which can be inherited in the MPLS-TP OAM model and set by Connection Oriented base model as default values. One example of MA Name could be MEG LSP ID or MEG Section ID or MEG PW ID[RFC6370].

Note that MA level configuration parameters provides context information for management system to correlate faults, defects, network failures with location information, which helps quickly identify root causes of network failures.

#### 7.2.3. MEP Configuration Extension

In MPLS-TP, MEP-ID is either a variable length label value in case of G-ACH encapsulation or a 2 octet unsigned integer value in case of IP/UDP encapsulation. One example of MEP-ID is MPLS-TP LSP\_MEP\_ID [RFC6370]. In the connection-oriented base model, MEP-ID is defined

as a choice/case node which can supports an int32 value, and the same definition can be used for MPLS-TP with no further modification. In addition, at the Maintenance Association Endpoint(MEP) level, MEP data node at the third level can be augmented with Session extension and interface extension.

## 8. Security Considerations

The YANG module defined in this memo is designed to be accessed via the NETCONF protocol [RFC6241] [RFC6241]. The lowest NETCONF layer is the secure transport layer and the mandatory-to-implement secure transport is SSH [RFC6242] [RFC6242]. The NETCONF access control model [RFC6536] [RFC6536] provides the means to restrict access for particular NETCONF users to a pre-configured subset of all available NETCONF protocol operations and content.

There are a number of data nodes defined in the YANG module which 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:

```
/goam:domains/goam:domain/
```

```
/goam:domains/goam:domain/goam:MAS/goam:MA/
```

```
/goam:domains/goam:domain/goam:MAS/goam:MA/goam:MEP
```

```
/goam:domains/goam:domain/goam:MAS/goam:MA/goam:MEP/goam:session/
```

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.

## 9. IANA Considerations

This document registers a URI in the IETF XML registry [RFC3688] [RFC3688]. Following the format in RFC 3688, the following registration is requested to be made:

URI: urn:ietf:params:xml:ns:yang:ietf-gen-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-gen-oam namespace: urn:ietf:params:xml:ns:yang:ietf-gen-oam  
prefix: goam reference: RFC XXXX

## 10. Acknowledgments

Giles Heron came up with the idea of developing a YANG model as a way of creating a unified OAM API set (interface), work in this document is largely an inspiration of that. Alexander Clemm provided many valuable tips, comments and remarks that helped to refine the YANG model presented in this document.

Carlos Pignataro, David Ball, Mahesh Jethanandani, Benoit Claise, Ladislav Lhotka, GUBALLA JENS, Yuji Tochio, Gregory Mirsky, Huub van Helvoort, Tom Taylor, Dapeng Liu, Mishael Wexler, Adi Molkho participated and contributed to this document.

## 11. References

### 11.1. Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<http://www.rfc-editor.org/info/rfc2119>>.
- [RFC3688] Mealling, M., "The IETF XML Registry", BCP 81, RFC 3688, DOI 10.17487/RFC3688, January 2004, <<http://www.rfc-editor.org/info/rfc3688>>.
- [RFC6020] Bjorklund, M., Ed., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC 6020, DOI 10.17487/RFC6020, October 2010, <<http://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, <<http://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, <<http://www.rfc-editor.org/info/rfc6242>>.
- [RFC6370] Bocci, M., Swallow, G., and E. Gray, "MPLS Transport Profile (MPLS-TP) Identifiers", RFC 6370, DOI 10.17487/RFC6370, September 2011, <<http://www.rfc-editor.org/info/rfc6370>>.
- [RFC6536] Bierman, A. and M. Bjorklund, "Network Configuration Protocol (NETCONF) Access Control Model", RFC 6536, DOI 10.17487/RFC6536, March 2012, <<http://www.rfc-editor.org/info/rfc6536>>.

## 11.2. Informative References

- [G.8013] "OAM functions and mechanisms for Ethernet based networks", ITU-T Recommendation G.8013/Y.1731, 2013.
- [IEEE802.1ag] "Connectivity Fault Management", IEEE Std 802.1ag-2011, August 2011.
- [mpls-tp-oam-yang] Zhang, L., Zheng, L., Aldrin, S., and G. Mirsky, "YANG Data Model for MPLS-TP Operations, Administration, and Maintenance", draft-zhang-mpls-tp-yang-oam (work in progress), 2016.
- [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, <<http://www.rfc-editor.org/info/rfc6136>>.
- [RFC6291] Andersson, L., van Helvoort, H., Bonica, R., Romascanu, D., and S. Mansfield, "Guidelines for the Use of the "OAM" Acronym in the IETF", BCP 161, RFC 6291, DOI 10.17487/RFC6291, June 2011, <<http://www.rfc-editor.org/info/rfc6291>>.
- [RFC6325] Perlman, R., Eastlake 3rd, D., Dutt, D., Gai, S., and A. Ghanwani, "Routing Bridges (RBridges): Base Protocol Specification", RFC 6325, DOI 10.17487/RFC6325, July 2011, <<http://www.rfc-editor.org/info/rfc6325>>.

- [RFC6371] Busi, I., Ed. and D. Allan, Ed., "Operations, Administration, and Maintenance Framework for MPLS-Based Transport Networks", RFC 6371, DOI 10.17487/RFC6371, September 2011, <<http://www.rfc-editor.org/info/rfc6371>>.
- [RFC7174] Salam, S., Senevirathne, T., Aldrin, S., and D. Eastlake 3rd, "Transparent Interconnection of Lots of Links (TRILL) Operations, Administration, and Maintenance (OAM) Framework", RFC 7174, DOI 10.17487/RFC7174, May 2014, <<http://www.rfc-editor.org/info/rfc7174>>.
- [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, <<http://www.rfc-editor.org/info/rfc7276>>.
- [RFC7455] Senevirathne, T., Finn, N., Salam, S., Kumar, D., Eastlake 3rd, D., Aldrin, S., and Y. Li, "Transparent Interconnection of Lots of Links (TRILL): Fault Management", RFC 7455, DOI 10.17487/RFC7455, March 2015, <<http://www.rfc-editor.org/info/rfc7455>>.

#### Appendix A. Contributors' Addresses

Tissa Senevirathne  
Consultant

Email: [tsenevir@gmail.com](mailto:tsenevir@gmail.com)

Norman Finn  
CISCO Systems  
510 McCarthy Blvd  
Milpitas, CA 95035  
USA

Email: [nfinn@cisco.com](mailto:nfinn@cisco.com)

Samer Salam  
CISCO Systems  
595 Burrard St. Suite 2123  
Vancouver, BC V7X 1J1  
Canada

Email: [ssalam@cisco.com](mailto:ssalam@cisco.com)

Authors' Addresses

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

Email: [dekumar@cisco.com](mailto:dekumar@cisco.com)

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

Email: [bill.wu@huawei.com](mailto:bill.wu@huawei.com)

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

Email: [wangzitao@huawei.com](mailto:wangzitao@huawei.com)