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Authors:			
	T. Zhou, Ed. Huawei	J. Guichard Futurewei	F. Brockners Cisco Systems
	S. Raghavan Cisco Systems		

A YANG Data Model for In-Situ OAM

Abstract

In-situ Operations, Administration, and Maintenance (IOAM) records operational and telemetry information in user packets while the packets traverse a path between two points in the network. This document defines a YANG module for the IOAM function.

Status of This Memo

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1. Introduction

In-situ Operations, Administration, and Maintenance (IOAM) [I-D.ietf-ippm-ioam-data] records OAM information within user packets while the packets traverse a network. The data types and data formats for IOAM data records have been defined in [I-D.ietf-ippm-ioam-data]. The IOAM data can be embedded in many protocol encapsulations such as Network Services Header (NSH) and IPv6.

This document defines a data model for IOAM capabilities using the YANG data modeling language [RFC7950]. This YANG model supports five IOAM options, which are Incremental Tracing Option, Pre-allocated Tracing Option, Direct Export Option[I-D.ietf-ippm-ioam-direct-export], Proof of Transit (PoT) Option, and Edge-to-Edge Option.

2. Conventions used in this document

The keywords "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP14, [RFC2119], [RFC8174] when, and only when, they appear in all capitals, as shown here.

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

*augment

*data model

*data node

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

2.1. Tree Diagrams

Tree diagrams used in this document follow the notation defined in [RFC8340].

3. Design of the IOAM YANG Data Model

3.1. Overview

The IOAM model is organized as list of profiles as shown in the following figure. Each profile associates with one flow and the corresponding IOAM information.

The "ioam-info" is a container for all the read only assistant information, so that monitoring systems can interpret the IOAM data.

```
module: ietf-ioam
   +--rw ioam
      +--ro ioam-info
      |  +--ro timestamp-type?        identityref
      |  +--ro available-interface* [if-name]
      |     +--ro if-name    -> if:interfaces/interface/name
      +--rw ioam-profiles
         +--rw admin-config
         |  +--rw enabled?   boolean
         +--rw ioam-profile* [profile-name]
            +--rw profile-name                    string
            +--rw filter
            |  +--rw filter-type?   ioam-filter-type
            |  +--rw ace-name?      -> /acl:acls/acl/aces/ace/name
            +--rw protocol-type?                  ioam-protocol-type
            +--rw incremental-tracing-profile {incremental-trace}?
            |  ...
            +--rw preallocated-tracing-profile {preallocated-trace}?
            |  ...
            +--rw direct-export-profile {direct-export}?
            |  ...
            +--rw pot-profile {proof-of-transit}?
            |  ...
            +--rw e2e-profile {edge-to-edge}?
               ...
```

In the "ioam-profiles", the "enabled" is an administrative configuration. When it is set to true, IOAM configuration is enabled for the system. Meanwhile, the IOAM data-plane functionality is enabled.

The "filter" is used to identify a flow, where the IOAM profile can apply. There may be multiple filter types. ACL [RFC8519] is a common way to specify a flow. Each IOAM profile can associate with an ACE(Access Control Entry). IOAM actions MUST be driven by the accepted packets, when the matched ACE "forwarding" action is "accept".

The IOAM data can be encapsulated into multiple protocols, e.g., IPv6 [I-D.ietf-ippm-ioam-ipv6-options] and NSH [I-D.ietf-sfc-ioam-nsh]. The "protocol-type" is used to indicate where the IOAM is applied. For example, if the "protocol-type" is IPv6, the IOAM ingress node will encapsulate the associated flow with the IPv6-IOAM [I-D.ietf-ippm-ioam-ipv6-options] format.

IOAM data includes five encapsulation types, i.e., incremental tracing data, preallocated tracing data, direct export data, prove of transit data and end to end data. In practice, multiple IOAM data types can be encapsulated into the same IOAM header. The "ioam-profile" contains a set of sub-profiles, each of which relates to one encapsulation type. The configured object may not support all the sub-profiles. The supported sub-profiles are indicated by 5 defined features, i.e., "incremental-trace", "preallocated-trace", "direct export", "proof-of-transit", "edge-to-edge".

3.2. Preallocated Tracing Profile

The IOAM tracing data is expected to be collected at every node that a packet traverses to ensure visibility into the entire path a packet takes within an IOAM domain. The preallocated tracing option will create pre-allocated space for each node to populate its information . The "preallocated-tracing-profile" contains the detailed information for the preallocated tracing data. The information includes:

*enabled: indicates whether the preallocated tracing profile is enabled.

*node-action: indicates the operation (e.g., encapsulate IOAM header, transit the IOAM data, or decapsulate IOAM header) applied to the dedicated flow.

*use-namespace: indicate the namespace used for the trace types.

*trace-type: indicates the per-hop data to be captured by the IOAM enabled nodes and included in the node data list.

*Loopback mode is used to send a copy of a packet back towards the source.

*Active mode indicates that a packet is used for active measurement.

```
+--rw preallocated-tracing-profile {preallocated-trace}?
   +--rw enabled?                boolean
   +--rw node-action?            ioam-node-action
   +--rw trace-types
   |  +--rw use-namespace?   ioam-namespace
   |  +--rw trace-type*      ioam-trace-type
   +--rw enable-loopback-mode?   boolean
   +--rw enable-active-mode?   boolean
```

3.3. Incremental Tracing Profile

The incremental tracing option contains a variable node data fields where each node allocates and pushes its node data immediately following the option header. The "incremental-tracing-profile" contains the detailed information for the incremental tracing data. The detailed information is the same as the Preallocated Tracing Profile, but with one more variable, "max-length", which restricts the length of the IOAM header.

```
+--rw incremental-tracing-profile {incremental-trace}?
   +--rw enabled?                boolean
   +--rw node-action?            ioam-node-action
   +--rw trace-types
   |  +--rw use-namespace?   ioam-namespace
   |  +--rw trace-type*   ioam-trace-type
   +--rw enable-loopback-mode?   boolean
   +--rw enable-active-mode?   boolean
   +--rw max-length?             uint32
```

3.4. Direct Export Profile

The direct export option is used as a trigger for IOAM nodes to export IOAM data to a receiving entity (or entities). The "direct-export-profile" contains the detailed information for the direct export data. The detailed information is the same as the Preallocated Tracing Profile, but with one more optional variable, "flow-id", which is used to correlate the exported data of the same flow from multiple nodes and from multiple packets.

```
+--rw direct-export-profile {direct-export}?
   +--rw enabled?                boolean
   +--rw node-action?            ioam-node-action
   +--rw trace-types
   |  +--rw use-namespace?   ioam-namespace
   |  +--rw trace-type*      ioam-trace-type
   +--rw enable-loopback-mode?   boolean
   +--rw enable-active-mode?   boolean
   +--rw flow-id?             uint32
```

3.5. Proof of Transit Profile

The IOAM Proof of Transit data is to support the path or service function chain verification use cases. The "pot-profile" contains the detailed information for the proof of transit data. "pot-type" indicates a particular POT variant that specifies the POT data that is included. There may be several POT types, which have different configuration data. To align with [I-D.ietf-ippm-ioam-data], this document only defines IOAM POT type 0. User need to augment this module for the configuration of a specifc POT type.

```
+--rw pot-profile {proof-of-transit}?
   +--rw enabled?    boolean
   +--rw pot-type?   ioam-pot-type
```

3.6. Edge to Edge Profile

The IOAM edge to edge option is to carry data that is added by the IOAM encapsulating node and interpreted by IOAM decapsulating node. The "e2e-profile" contains the detailed information for the edge to edge data. The detailed information includes:

*enabled: indicates whether the edge to edge profile is enabled.

*node-action is the same semantic as in Section 2.2.

*use-namespace: indicate the namespace used for the edge to edge types.

*e2e-type indicates data to be carried from the ingress IOAM node to the egress IOAM node.

```
+--rw e2e-profile {edge-to-edge}?
   +--rw enabled?       boolean
   +--rw node-action?   ioam-node-action
   +--rw e2e-types
      +--rw use-namespace?   ioam-namespace
      +--rw e2e-type*        ioam-e2e-type
```

4. IOAM YANG Module

```
<CODE BEGINS> file "ietf-ioam@2021-01-12.yang"

module ietf-ioam {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-ioam";
  prefix "ioam";

  import ietf-access-control-list {
    prefix "acl";
    reference
      "RFC 8519: YANG Data Model for Network Access Control
       Lists (ACLs)";
  }

  import ietf-interfaces {
    prefix "if";
    reference
      "RFC 8343: A YANG Data Model for Interface Management";
  }

  import ietf-lime-time-types {
    prefix "lime";
    reference
      "RFC RFC 8532: Generic YANG Data Model for the Management of
       Operations, Administration, and Maintenance (OAM) Protocols
       That Use Connectionless Communications";
  }

  organization
    "IETF IPPM (IP Performance Metrics) Working Group";

  contact
    "WG Web: <http://tools.ietf.org/wg/ippm>
     WG List: <ippm@ietf.org>
     Editor: zhoutianran@huawei.com
     Editor: james.n.guichard@futurewei.com
     Editor: fbrockne@cisco.com
     Editor: srihari@cisco.com";

  description
    "This YANG module specifies a vendor-independent data
     model for the In Situ OAM (IOAM).

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    authors of the code.  All rights reserved.

    Redistribution and use in source and binary forms, with or
    without modification, is permitted pursuant to, and subject
    to the license terms contained in, the Simplified BSD License
    set forth in Section 4.c of the IETF Trust's Legal Provisions
```

```
     Relating to IETF Documents
     (http://trustee.ietf.org/license-info).

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

   revision 2022-01-12 {
     description "Firstd revision.";
     reference "draft-ietf-ippm-ioam-yang";
   }

  /*
   * FEATURES
   */

   feature incremental-trace
   {
     description
       "This feature indicated that the incremental tracing option is
        supported";
     reference "draft-ietf-ippm-ioam-data";
   }

   feature preallocated-trace
   {
     description
       "This feature indicated that the preallocated tracing option is
        supported";
     reference "draft-ietf-ippm-ioam-data";
   }

   feature direct-export
   {
     description
       "This feature indicated that the direct export option is
        supported";
     reference "ietf-ippm-ioam-direct-export";
   }

   feature proof-of-transit
   {
     description
       "This feature indicated that the proof of transit option is
        supported";
     reference "draft-ietf-ippm-ioam-data";
   }

   feature edge-to-edge
   {
     description
     "This feature indicated that the edge to edge option is
      supported";
   reference "draft-ietf-ippm-ioam-data";
 }

/*
 * IDENTITIES
 */
 identity base-filter {
   description
     "Base identity to represent a filter. A filter is used to
     specify the flow to apply the IOAM profile. ";
 }

 identity acl-filter {
   base base-filter;
   description
     "Apply ACL rules to specify the flow.";
 }

 identity base-protocol {
   description
     "Base identity to represent the carrier protocol. It's used to
      indicate what layer and protocol the IOAM data is embedded.";
 }

 identity ipv6-protocol {
   base base-protocol;
   description
     "The described IOAM data is embedded in IPv6 protocol.";
   reference "ietf-ippm-ioam-ipv6-options";
 }

 identity nsh-protocol  {
   base base-protocol;
   description
     "The described IOAM data is embedded in NSH.";
   reference "ietf-sfc-ioam-nsh";
 }

 identity base-node-action {
   description
     "Base identity to represent the node actions. It's used to
      indicate what action the node will take.";
 }

 identity action-encapsulate {
   base base-node-action;
   description
```

```
    "indicate the node is to encapsulate the IOAM packet";
}

identity action-decapsulate {
  base base-node-action;
  description
    "indicate the node is to decapsulate the IOAM packet";
}

identity base-trace-type {
  description
    "Base identity to represent trace types";
}

identity trace-hop-lim-node-id {
  base base-trace-type;
  description
    "indicates presence of Hop_Lim and node_id in the
     node data.";
}

identity trace-if-id {
  base base-trace-type;
  description
    "indicates presence of ingress_if_id and egress_if_id in the
     node data.";
}

identity trace-timestamp-seconds {
  base base-trace-type;
  description
    "indicates presence of time stamp seconds in the node data.";
}

identity trace-timestamp-nanoseconds {
  base base-trace-type;
  description
    "indicates presence of time stamp nanoseconds in the node data.";
}

identity trace-transit-delay {
  base base-trace-type;
  description
    "indicates presence of transit delay in the node data.";
}

identity trace-namespace-data {
  base base-trace-type;
  description
    "indicates presence of namespace specific data (short format)
```

```
     in the node data.";
}

identity trace-queue-depth {
  base base-trace-type;
  description
    "indicates presence of queue depth in the node data.";
}

identity trace-opaque-state-snapshot {
  base base-trace-type;
  description
    "indicates presence of variable length Opaque State Snapshot
     field.";
}

identity trace-hop-lim-node-id-wide {
  base base-trace-type;
  description
    "indicates presence of Hop_Lim and node_id wide in the
     node data.";
}

identity trace-if-id-wide {
  base base-trace-type;
  description
    "indicates presence of ingress_if_id and egress_if_id wide in
     the node data.";
}

identity trace-namespace-data-wide {
  base base-trace-type;
  description
    "indicates presence of namespace specific data in wide format
     in the node data.";
}

identity trace-buffer-occupancy {
  base base-trace-type;
  description
    "indicates presence of buffer occupancy in the node data.";
}

identity trace-checksum-complement {
  base base-trace-type;
  description
    "indicates presence of the Checksum Complement node data.";
}

identity base-pot-type {
    description
      "Base identity to represent Proof of Transit(PoT) types";
  }

  identity pot-type-0 {
    base base-pot-type;
    description
      "POT data is a 16 Octet field to carry data associated to
       POT procedures.";
  }

  identity base-e2e-type {
    description
      "Base identity to represent e2e types";
  }

  identity e2e-seq-num-64 {
    base base-e2e-type;
    description
      "indicates presence of a 64-bit sequence number";
  }

  identity e2e-seq-num-32 {
    base base-e2e-type;
    description
      "indicates presence of a 32-bit sequence number";
  }

  identity e2e-timestamp-seconds {
    base base-e2e-type;
    description
      "indicates presence of timestamp seconds for the
       transmission of the frame";
  }

  identity e2e-timestamp-subseconds {
    base base-e2e-type;
    description
      "indicates presence of timestamp subseconds for the
       transmission of the frame";
  }

  identity base-namespace {
    description
      "Base identity to represent the namespace";
  }

  identity namespace-ietf {
    base base-namespace;
    description
```

```
       "namespace that specified in IETF.";
   }

  /*
   * TYPE DEFINITIONS
   */
   typedef ioam-filter-type {
     type identityref {
       base base-filter;
     }
     description
       "Specifies a known type of filter.";
   }

   typedef ioam-protocol-type {
     type identityref {
       base base-protocol;
     }
     description
       "Specifies a known type of carrier protocol for the IOAM data.";
   }

   typedef ioam-node-action {
     type identityref {
       base base-node-action;
     }
     description
       "Specifies a known type of node action.";
   }

   typedef ioam-trace-type {
     type identityref {
       base base-trace-type;
     }
     description
       "Specifies a known trace type.";
   }

   typedef ioam-pot-type {
     type identityref {
       base base-pot-type;
     }
     description
       "Specifies a known pot type.";
   }

   typedef ioam-e2e-type {
     type identityref {
       base base-e2e-type;
```

```
      }
      description
        "Specifies a known e2e type.";
    }

    typedef ioam-namespace {
      type identityref {
        base base-namespace;
      }
      description
        "Specifies the supported namespace.";
    }

   /*
    * GROUP DEFINITIONS
    */

    grouping ioam-filter {
      description "A grouping for IOAM filter definition";

      leaf filter-type {
        type ioam-filter-type;
        description "filter type";
      }

      leaf ace-name {
        when "../filter-type = 'ioam:acl-filter'";
        type leafref {
          path "/acl:acls/acl:acl/acl:aces/acl:ace/acl:name";
        }
        description "Access Control Entry name.";
      }
    }

    grouping encap-tracing {
      description
        "A grouping for the generic configuration for
         tracing profile.";

      container trace-types {
        description
          "the list of trace types for encapsulate";

        leaf use-namespace {
          type ioam-namespace;
          description
            "the namespace used for the encapsulation";
        }

        leaf-list trace-type {
```

```
      type ioam-trace-type;
      description
        "The trace type is only defined at the encapsulation node.";
    }
  }

  leaf enable-loopback-mode {
    type boolean;
    default false;
    description
      "Loopback mode is used to send a copy of a packet back towards
      the source. The loopback mode is only defined at the
      encapsulation node.";
  }

  leaf enable-active-mode {
    type boolean;
    default false;
    description
      "Active mode indicates that a packet is used for active
       measurement. An IOAM decapsulating node that receives a
       packet with the Active flag set in one of its Trace options
       must terminate the packet.";
  }
}

grouping ioam-incremental-tracing-profile {
  description
    "A grouping for incremental tracing profile.";

  leaf node-action {
    type ioam-node-action;
    description "node action";
  }

  uses encap-tracing {
    when "node-action = 'ioam:action-encapsulate'";
  }

  leaf max-length {
    when "../node-action = 'ioam:action-encapsulate'";
    type uint32;
    units bytes;
    description
      "This field specifies the maximum length of the node data list
      in octets. The max-length is only defined at the
      encapsulation node. And it's only used for the incremental
      tracing mode.";
  }
  }

  grouping ioam-preallocated-tracing-profile {
    description
      "A grouping for incremental tracing profile.";


    leaf node-action {
      type ioam-node-action;
      description "node action";
    }

    uses encap-tracing {
      when "node-action = 'ioam:action-encapsulate'";
    }
  }

  grouping ioam-direct-export-profile {
    description
      "A grouping for direct export profile.";

    leaf node-action {
      type ioam-node-action;
      description "node action";
    }

    uses encap-tracing {
      when "node-action = 'ioam:action-encapsulate'";
    }

    leaf flow-id {
      when "../node-action = 'ioam:action-encapsulate'";
      type uint32;
      description
        "A 32-bit flow identifier. The field is set at the
         encapsulating node. The Flow ID can be uniformly assigned
         by a central controller or algorithmically generated by the
         encapsulating node. The latter approach cannot guarantee
         the uniqueness of Flow ID, yet the conflict probability is
         small due to the large Flow ID space.flow-id is used to
         correlate the exported data of the same flow from multiple
         nodes and from multiple packets.";
    }
  }

  grouping ioam-e2e-profile {
    description
      "A grouping for end to end profile.";

    leaf node-action {
     type ioam-node-action;
     description
       "indicate how the node act for this profile";
   }

   container e2e-types {
     when "../node-action = 'ioam:action-encapsulate'";
     description
       "the list of e2e types for encapsulate";

     leaf use-namespace {
       type ioam-namespace;
       description
         "the namespace used for the encapsulation";
     }

     leaf-list e2e-type {
       type ioam-e2e-type;
       description
         "The e2e type is only defined at the encapsulation node.";
     }
   }
 }

 grouping ioam-admin-config {
   description
     "IOAM top-level administrative configuration.";

   leaf enabled {
     type boolean;
     default false;
     description
       "When true, IOAM configuration is enabled for the system.
        Meanwhile, the IOAM data-plane functionality is enabled.";
   }
 }

/*
 * DATA NODES
 */

 container ioam {
   description "IOAM top level container";

   container ioam-info {
     config false;
     description
       "Describes assistant information such as units or timestamp
        format. So that monitoring systems can interpret the IOAM
        data.";
```

```
    leaf timestamp-type {
      type identityref {
        base lime:timestamp-type;
      }
      description
        "Type of timestamp, such as Truncated PTP or NTP.";
    }

    list available-interface {
      key "if-name";
      ordered-by user;
      description
        "A list of available interfaces that support IOAM.";
      leaf if-name {
        type leafref {
          path "/if:interfaces/if:interface/if:name";
        }
        description "Interface name.";
      }
    }
  }

  container ioam-profiles {
    description
      "Contains a list of IOAM profiles.";

    container admin-config {
      description
        "Contains all the administrative configurations related to
         the IOAM functionalities and all the IOAM profiles.";

      uses ioam-admin-config;
    }

    list ioam-profile {
      key "profile-name";
      ordered-by user;
      description
        "A list of IOAM profiles that configured on the node.";

      leaf profile-name {
        type string;
        mandatory true;
        description
          "Unique identifier for each IOAM profile";
      }

      container filter {
        uses ioam-filter;
      description
        "The filter which is used to indicate the flow to apply
        IOAM.";
    }

    leaf protocol-type {
      type ioam-protocol-type;
      description
        "This item is used to indicate the carrier protocol where
        the IOAM is applied.";
    }

    container incremental-tracing-profile {
      if-feature incremental-trace;
      description
        "describe the profile for incremental tracing option";

      leaf enabled {
        type boolean;
        default false;
        description
          "When true, apply incremental tracing option to the
           specified flow identified by the filter.";
      }

      uses ioam-incremental-tracing-profile;
    }

    container preallocated-tracing-profile {
      if-feature preallocated-trace;
      description
        "describe the profile for preallocated tracing option";

      leaf enabled {
        type boolean;
        default false;
        description
          "When true, apply preallocated tracing option to the
           specified flow identified by the following filter.";
      }

      uses ioam-preallocated-tracing-profile;
    }

    container direct-export-profile {
      if-feature direct-export;
      description
        "describe the profile for direct-export option";

      leaf enabled {
```

```
             type boolean;
             default false;
             description
               "When true, apply direct-export option to the
                specified flow identified by the following filter.";
           }

           uses ioam-direct-export-profile;
         }

         container pot-profile {
           if-feature proof-of-transit;
           description
             "describe the profile for PoT option";

           leaf enabled {
             type boolean;
             default false;
             description
               "When true, apply Proof of Transit option to the
                specified flow identified by the following filter.";
           }

           leaf pot-type {
             type ioam-pot-type;
             description
               "The type of a particular POT variant that specifies
                the POT data that is included..";
           }
         }

         container e2e-profile {
           if-feature edge-to-edge;
           description
             "describe the profile for e2e option";

           leaf enabled {
             type boolean;
             default false;
             description
               "When true, apply End to end option to the
                specified flow identified by the following filter.";
           }

           uses ioam-e2e-profile;
         }
       }
     }
   }
```

```
}

<CODE ENDS>
```

5. Security Considerations

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

The NETCONF access control model [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. These are the subtrees and data nodes and their sensitivity/vulnerability:

*/ioam/ioam-profiles/admin-config

The items in the container above include the top level administrative configurations related to the IOAM functionalities and all the IOAM profiles. Unexpected changes to these items could lead to the IOAM function disruption and/ or misbehavior of all the IOAM profiles.

*/ioam/ioam-profiles/ioam-profile

The entries in the list above include the whole IOAM profile configurations which indirectly create or modify the device configurations. Unexpected changes to these entries could lead to the mistake of the IOAM behavior for the corresponding flows.

6. IANA Considerations

RFC Ed.: In this section, replace all occurrences of 'XXXX' with the actual RFC number (and remove this note).

IANA is requested to assign a new URI from the IETF XML Registry [RFC3688]. The following URI is suggested:

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

This document also requests a new YANG module name in the YANG Module Names registry [RFC7950] with the following suggestion:

```
name: ietf-ioam
namespace: urn:ietf:params:xml:ns:yang:ietf-ioam
prefix: ioam
reference: RFC XXXX
```

7. Acknowledgements

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8. References

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Appendix A. Examples

This appendix is non-normative.

tbd

Authors' Addresses

Tianran Zhou
Huawei
156 Beiqing Rd.
Beijing
100095
China

Email: zhoutianran@huawei.com

Jim Guichard
Futurewei
United States of America

Email: james.n.guichard@futurewei.com

Frank Brockners
Cisco Systems
Hansaallee 249, 3rd Floor
40549 Duesseldorf
Germany

Email: fbrockne@cisco.com

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

Email: srihari@cisco.com