Internet Engineering Task Force (IETF)
Request for Comments: 8529
Category: Standards Track
ISSN: 2070-1721

L. Berger
C. Hopps
LabN Consulting, L.L.C.
A. Lindem
Cisco Systems
D. Bogdanovic
X. Liu
Volta Networks

March 2019

YANG Data Model for Network Instances

Abstract

This document defines a network instance module. This module can be used to manage the virtual resource partitioning that may be present on a network device. Examples of common industry terms for virtual resource partitioning are VPN Routing and Forwarding (VRF) instances and Virtual Switch Instances (VSIs).

The YANG data model in this document conforms to the Network Management Datastore Architecture (NMDA) defined in RFC 8342.

Status of This Memo

This is an Internet Standards Track document.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in Section 2 of RFC 7841.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at https://www.rfc-editor.org/info/rfc8529.

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1. Introduction

This document defines the second of two new modules that are defined to support the configuration and operation of network devices that allow for the partitioning of resources from both, or either, management and networking perspectives. Both leverage the YANG functionality enabled by YANG Schema Mount [RFC8528].

The YANG data model in this document conforms to the Network Management Datastore Architecture defined in [RFC8342].

The first form of resource partitioning provides a logical partitioning of a network device where each partition is separately managed as essentially an independent network element that is "hosted" by the base network device. These hosted network elements are referred to as logical network elements, or LNEs, and are supported by the logical-network-element module defined in [RFC8530]. That module is used to identify LNEs and associate resources from the network device with each LNE. LNEs themselves are represented in YANG as independent network devices; each is accessed independently. Examples of vendor terminology for an LNE include logical system or logical router and virtual switch, chassis, or fabric.

The second form, which is defined in this document, provides support for what are commonly referred to as VPN Routing and Forwarding (VRF) instances as well as Virtual Switch Instances (VSI); see [RFC4026] and [RFC4664]. In this form of resource partitioning, multiple control-plane and forwarding/bridging instances are provided by and managed through a single (physical or logical) network device. This form of resource partitioning is referred to as a Network Instance (NI) and is supported by the network instance module defined below. Configuration and operation of each network instance is always via the network device and the network instance module.

One notable difference between the LNE model and the NI model is that the NI model provides a framework for VRF and VSI management. This document envisions the separate definition of models specific to VRF and VSI -- i.e., L3 and L2 VPN -- technology. An example of such can be found in the emerging L3VPN model defined in [YANG-L3VPN] and the examples discussed below.

1.1. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

Readers are expected to be familiar with terms and concepts of YANG [RFC7950] and YANG Schema Mount [RFC8528].

This document uses the graphical representation of data models defined in [RFC8340].

2. Overview

In this document, we consider network devices that support protocols and functions defined within the IETF -- e.g., routers, firewalls, and hosts. Such devices may be physical or virtual, e.g., a classic router with custom hardware or one residing within a server-based virtual machine implementing a virtual network function (VNF). Each device may subdivide their resources into logical network elements (LNEs), each of which provides a managed logical device. Examples of vendor terminology for an LNE include logical system or logical router and virtual switch, chassis, or fabric. Each LNE may also support VRF and VSI functions, which are referred to below as network instances (NIs). This breakdown is represented in Figure 1.

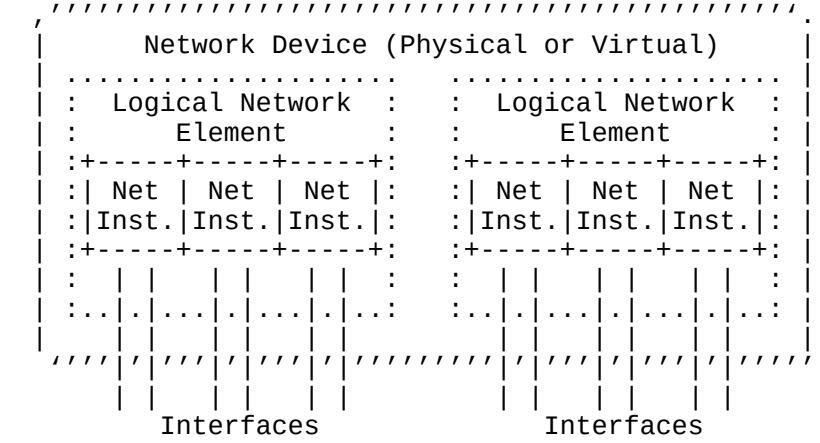

Figure 1: Module Element Relationships

A model for LNEs is described in [RFC8530], and the model for NIs is covered in Section 3 of this document.

The current interface management model [RFC8343] is impacted by the definition of LNEs and NIs. This document and [RFC8530] define augmentations to the interface module to support LNEs and NIs.

The network instance model supports the configuration of VRFs and VSIs. Each instance is supported by information that relates to the device -- for example, the route target used when advertising VRF routes via the mechanisms defined in [RFC4364], and information that relates to the internal operation of the NI, such as for routing protocols [RFC8349] and OSPF [YANG-OSPF]. This document defines the network instance module that provides a basis for the management of both types of information.

NI information that relates to the device, including the assignment of interfaces to NIs, is defined as part of this document. The defined module also provides a placeholder for the definition of NI-technology-specific information both at the device level and for NI internal operation. Information related to NI internal operation is supported via schema mount [RFC8528] and mounting appropriate modules under the mount point. Well-known mount points are defined for L3VPN, L2VPN, and L2+L3VPN NI types.

3. Network Instances

The network instance container is used to represent VRFs and VSIs. VRFs and VSIs are commonly used to isolate routing and switching domains -- for example, to create virtual private networks, each with their own active protocols and routing/switching policies. The model supports both core/provider and virtual instances. Core/provider instance information is accessible at the top level of the server, while virtual instance information is accessible under the root schema mount points.

```
module: ietf-network-instance
  +--rw network-instances
     +--rw network-instance* [name]
        +--rw name           string
        +--rw enabled?       boolean
        +--rw description?   string
        +--rw (ni-type)?
        +--rw (root-type)
           +--:(vrf-root)
           |  +--mp vrf-root
           +--:(vsi-root)
           |  +--mp vsi-root
           +--:(vv-root)
              +--mp vv-root
augment /if:interfaces/if:interface:
  +--rw bind-ni-name?   -> /network-instances/network-instance/name
augment /if:interfaces/if:interface/ip:ipv4:
  +--rw bind-ni-name?   -> /network-instances/network-instance/name
augment /if:interfaces/if:interface/ip:ipv6:
  +--rw bind-ni-name?   -> /network-instances/network-instance/name

notifications:
  +---n bind-ni-name-failed
     +--ro name          -> /if:interfaces/interface/name
     +--ro interface
     |  +--ro bind-ni-name?
     |                   -> /if:interfaces/interface/ni:bind-ni-name
     +--ro ipv4
     |  +--ro bind-ni-name?
     |           -> /if:interfaces/interface/ip:ipv4/ni:bind-ni-name
     +--ro ipv6
     |  +--ro bind-ni-name?
     |           -> /if:interfaces/interface/ip:ipv6/ni:bind-ni-name
     +--ro error-info?   string
```

A network instance is identified by a "name" string. This string is used both as an index within the network instance module and to associate resources with a network instance, as shown above in the interface augmentation. The ni-type and root-type choice statements are used to support different types of L2 and L3 VPN technologies. The bind-ni-name-failed notification is used in certain failure cases.

3.1. NI Types and Mount Points

The network instance module is structured to facilitate the definition of information models for specific types of VRFs and VSIs using augmentations. For example, the information needed to support L2VPN, such as VPLS and EVPN, are likely to be quite different. Example models under development that could be restructured to take advantage on NIs include models for L3VPNs [YANG-L3VPN] and L2VPNs [YANG-L2VPN].

Documents defining new YANG data models for the support of specific types of network instances should augment the network instance module. The basic structure that should be used for such augmentations includes a case statement with containers for configuration and state data and, when needed, a type-specific mount point. Generally, NI types are expected to not need to define type-specific mount points but rather reuse one of the well-known mount points, as defined in the next section. The following is an example type-specific augmentation:

```
 augment "/ni:network-instances/ni:network-instance/ni:ni-type" {
   case l3vpn {
     container l3vpn {
         ...
     }
     container l3vpn-state {
         ...
     }
   }
 }
```

3.1.1. Well-Known Mount Points

YANG Schema Mount [RFC8528] identifies mount points by name within a module. This definition allows for the definition of mount points whose schema can be shared across NI types. As discussed above, ni-types largely differ in the configuration information needed in the core/top-level instance to support the NI, rather than in the information represented within an NI. This allows the use of shared mount points across certain NI types.

The expectation is that there are actually very few different schemas that need to be defined to support NIs for an implementation. In particular, it is expected that the following three forms of NI schema are needed, and each can be defined with a well-known mount point that can be reused by future modules defining NI types.

The three well-known mount points are:

vrf-root
: vrf-root is intended for use with L3VPN-type NI types.

vsi-root
: vsi-root is intended for use with L2VPN-type Ni types.

vv-root
: vv-root is intended for use with NI types that simultaneously support L2VPN bridging and L3VPN routing capabilities.

Future model definitions should use the above mount points whenever possible. When a well-known mount point isn’t appropriate, a model may define a type-specific mount point via augmentation.

3.1.2. NI Type Example

The following is an example of an L3VPN VRF using a hypothetical augmentation to the network instance schema defined in [YANG-L3VPN]. More detailed examples can be found in Appendix A.

```
module: ietf-network-instance
  +--rw network-instances
     +--rw network-instance* [name]
        +--rw name           string
        +--rw enabled?       boolean
        +--rw description?   string
        +--rw (ni-type)?
        |  +--:(l3vpn)
        |     +--rw l3vpn:l3vpn
        |     |  ... // config data
        |     +--ro l3vpn:l3vpn-state
        |     |  ... // state data
        +--rw (root-type)
           +--:(vrf-root)
              +--mp vrf-root
                 +--rw rt:routing/
                 |  +--rw router-id?                 yang:dotted-quad
                 |  +--rw control-plane-protocols
                 |     +--rw control-plane-protocol* [type name]
                 |     +--rw ospf:ospf
                 |          +--rw area* [area-id]
                 |             +--rw interfaces
                 |                +--rw interface* [name]
                 |                   +--rw name if:interface-ref
                 |                   +--rw cost?   uint16
                 +--ro if:interfaces@
                 |  ...
```

This shows YANG Routing Management [RFC8349] and YANG OSPF [YANG-OSPF] as mounted modules. The mounted modules can reference interface information via a parent-reference to the containers defined in [RFC8343].

3.2. NIs and Interfaces

Interfaces are a crucial part of any network device’s configuration and operational state. They generally include a combination of raw physical interfaces, link-layer interfaces, addressing configuration, and logical interfaces that may not be tied to any physical interface. Several system services and Layer 2 and Layer 3 protocols

may also associate configuration or operational state data with different types of interfaces (these relationships are not shown for simplicity). The interface management model is defined by [RFC8343].

As shown below, the network instance module augments the existing interface management model by adding a name that is used on interface or sub-interface types to identify an associated network instance. Similarly, this name is also added for IPv4 and IPv6 types, as defined in [RFC8344].

The following is an example of envisioned usage. The interfaces container includes a number of commonly used components as examples:

```
module: ietf-interfaces
   +--rw interfaces
   |  +--rw interface* [name]
   |     +--rw name                        string
   |     +--rw ip:ipv4!
   |     |  +--rw ip:enabled?                      boolean
   |     |  +--rw ip:forwarding?                   boolean
   |     |  +--rw ip:mtu?                          uint16
   |     |  +--rw ip:address* [ip]
   |     |  |  +--rw ip:ip               inet:ipv4-address-no-zone
   |     |  |  +--rw (ip:subnet)
   |     |  |     +--:(ip:prefix-length)
   |     |  |     |  +--rw ip:prefix-length?   uint8
   |     |  |     +--:(ip:netmask)
   |     |  |        +--rw ip:netmask?         yang:dotted-quad
   |     |  +--rw ip:neighbor* [ip]
   |     |  |  +--rw ip:ip                  inet:ipv4-address-no-zone
   |     |  |  +--rw ip:link-layer-address yang:phys-address
   |     |  +--rw ni:bind-network-instance-name?   string
   |     +--rw ni:bind-network-instance-name?   string
```

The "ietf-interfaces" module [RFC8343] is structured to include all interfaces in a flat list, without regard to virtual instances (e.g., VRFs) supported on the device. The bind-network-instance-name leaf provides the association between an interface and its associated NI (e.g., VRF or VSI). Note that as currently defined, to assign an interface to both an LNE and an NI, the interface would first be assigned to the LNE using the mechanisms defined in [RFC8530] and then, within that LNE’s interface module, the LNE’s representation of that interface would be assigned to an NI.

3.3. Network Instance Management

Modules that may be used to represent network instance information will be available under the "root" mount point specific to the ni-type. The "shared-schema" method defined in the "ietf-yang-schema-mount" module [RFC8528] MUST be used to identify accessible modules. A future version of this document could relax this requirement. Mounted modules SHOULD be defined with access, via the appropriate schema mount parent-references [RFC8528], to device resources such as interfaces. An implementation MAY choose to restrict parent-referenced information to information related to a specific instance. For example, it might only allow references to interfaces that have a "bind-network-instance-name" that is identical to the instance's "name".

All modules that represent control-plane and data-plane information may be present at the "root" mount point and accessible via paths modified per [RFC8528]. The list of available modules is expected to be implementation dependent, as is the method used by an implementation to support NIs.

For example, the following could be used to define the data organization of the example NI shown in Section 3.1.2:

```
  "ietf-yang-schema-mount:schema-mounts": {
    "mount-point": [
      {
        "module": "ietf-network-instance",
        "label": "vrf-root",
        "shared-schema": {
          "parent-reference": [
            "/*[namespace-uri() = 'urn:ietf:...:ietf-interfaces']"
          ]
        }
      }
    ]
  }
```

Module data identified according to the ietf-yang-schema-mount module will be instantiated under the mount point identified under "mount-point". These modules will be able to reference information for nodes belonging to top-level modules that are identified under "parent-reference". Parent-referenced information is available to clients via their top-level paths only and not under the associated mount point.

To allow a client to understand the previously mentioned instance restrictions on parent-referenced information, an implementation MAY represent such restrictions in the "parent-reference" leaf-list. For example:

```
  "namespace": [
    {
      "prefix": "if",
      "uri": "urn:ietf:params:xml:ns:yang:ietf-interfaces"
    },
    {
      "prefix": "ni",
      "uri": "urn:ietf:params:xml:ns:yang:ietf-network-instance"
    }
  ],
  "mount-point": [
    {
      "module": "ietf-network-instance",
      "label": "vrf-root",
      "shared-schema": {
        "parent-reference": [
          "/if:interfaces/if:interface
             [ni:bind-network-instance-name = current()/../ni:name]",
          "/if:interfaces/if:interface/ip:ipv4
             [ni:bind-network-instance-name = current()/../ni:name]",
          "/if:interfaces/if:interface/ip:ipv6
             [ni:bind-network-instance-name = current()/../ni:name]"
        ]
      }
    }
  ],
```

The same such "parent-reference" restrictions for non-NMDA implementations can be represented based on [RFC8343] and [RFC8344] as:

```
  "namespace": [
    {
      "prefix": "if",
      "uri": "urn:ietf:params:xml:ns:yang:ietf-interfaces"
    },
    {
      "prefix": "ni",
      "uri": "urn:ietf:params:xml:ns:yang:ietf-network-instance"
    }
  ],
  "mount-point": [
    {
      "module": "ietf-network-instance",
      "label": "vrf-root",
      "shared-schema": {
        "parent-reference": [
          "/if:interfaces/if:interface
             [ni:bind-network-instance-name = current()/../ni:name]",
          "/if:interfaces-state/if:interface
             [if:name = /if:interfaces/if:interface
               [ni:bind-ni-name = current()/../ni:name]/if:name]",
          "/if:interfaces/if:interface/ip:ipv4
             [ni:bind-network-instance-name = current()/../ni:name]",
          "/if:interfaces-state/if:interface/ip:ipv4
             [if:name = /if:interfaces/if:interface/ip:ipv4
               [ni:bind-ni-name = current()/../ni:name]/if:name]",
          "/if:interfaces/if:interface/ip:ipv6
             [ni:bind-network-instance-name = current()/../ni:name]",
          "/if:interfaces-state/if:interface/ip:ipv6
             [if:name = /if:interfaces/if:interface/ip:ipv6
               [ni:bind-ni-name = current()/../ni:name]/if:name]"
        ]
      }
    }
  ],
```

3.4. Network Instance Instantiation

Network instances may be controlled by clients using existing list operations. When a list entry is created, a new instance is instantiated. The models mounted under an NI root are expected to be dependent on the server implementation. When a list entry is deleted, an existing network instance is destroyed. For more information, see Section 7.8.6 of [RFC7950].

Once instantiated, host network device resources can be associated with the new NI. As previously mentioned, this document augments ietf-interfaces with the bind-ni-name leaf to support such associations for interfaces. When a bind-ni-name is set to a valid NI name, an implementation MUST take whatever steps are internally necessary to assign the interface to the NI or provide an error message (defined below) with an indication of why the assignment failed. It is possible for the assignment to fail while processing the set operation or after asynchronous processing. Error notification in the latter case is supported via a notification.

4. Security Considerations

The YANG modules specified in this document define a schema for data that is designed to be accessed via network management protocols such as NETCONF [RFC6241] or RESTCONF [RFC8040]. The lowest NETCONF layer is the secure transport layer, and the mandatory-to-implement secure transport is Secure Shell (SSH) [RFC6242]. The lowest RESTCONF layer is HTTPS, and the mandatory-to-implement secure transport is TLS [RFC8446].

The Network Configuration Access Control Model (NACM) [RFC8341] provides the means to restrict access for particular NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

There are two different sets of security considerations to consider in the context of this document. One set is security related to information contained within mounted modules. The security considerations for mounted modules are not substantively changed based on the information being accessible within the context of an NI. For example, when considering the modules defined in [RFC8349], the security considerations identified in that document are equally applicable, whether those modules are accessed at a server’s root or under an NI instance’s root node.

The second area for consideration is information contained in the NI module itself. NI information represents network configuration and route distribution policy information. As such, the security of this information is important, but it is fundamentally no different than any other interface or routing configuration information that has already been covered in [RFC8343] and [RFC8349].

The vulnerable "config true" parameters and subtrees are the following:

/network-instances/network-instance: This list specifies the network instances and the related control plane protocols configured on a device.

/if:interfaces/if:interface/*/bind-network-instance-name: This leaf indicates the NI instance to which an interface is assigned.

Unauthorized access to any of these lists can adversely affect the routing subsystem of both the local device and the network. This may lead to network malfunctions, delivery of packets to inappropriate destinations, and other problems.

5. IANA Considerations

This document registers a URI in the "IETF XML Registry" [RFC3688].

URI: urn:ietf:params:xml:ns:yang:ietf-network-instance

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-network-instance
namespace:    urn:ietf:params:xml:ns:yang:ietf-network-instance
prefix:       ni
reference:    RFC 8529
```

6. Network Instance Model

The structure of the model defined in this document is described by the YANG module below.

```
<CODE BEGINS> file "ietf-network-instance@2019-01-21.yang"
module ietf-network-instance {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-network-instance";
  prefix ni;

  // import some basic types

  import ietf-interfaces {
    prefix if;
    reference
      "RFC 8343: A YANG Data Model for Interface Management";
  }
  import ietf-ip {
    prefix ip;
    reference
      "RFC 8344: A YANG Data Model for IP Management";
  }
  import ietf-yang-schema-mount {
    prefix yangmnt;
    reference
      "RFC 8528: YANG Schema Mount";
  }

  organization
    "IETF Routing Area (rtgwg) Working Group";
  contact
    "WG Web:   <https://datatracker.ietf.org/wg/rtgwg>
     WG List:  <mailto:rtgwg@ietf.org>

     Author:   Lou Berger
               <mailto:lberger@labn.net>
     Author:   Christian Hopps
               <mailto:chopps@chopps.org>
     Author:   Acee Lindem
               <mailto:acee@cisco.com>
     Author:   Dean Bogdanovic
               <mailto:ivandean@gmail.com>";
  description
    "This module is used to support multiple network instances
     within a single physical or virtual device.  Network
     instances are commonly known as VRFs (VPN Routing and
     Forwarding) and VSIs (Virtual Switching Instances).
```

```
      The key words 'MUST', 'MUST NOT', 'REQUIRED', 'SHALL',
      'SHALL NOT', 'SHOULD', 'SHOULD NOT', 'RECOMMENDED',
      'NOT RECOMMENDED', 'MAY', and 'OPTIONAL' in this document
      are to be interpreted as described in BCP 14 (RFC 2119)
      (RFC 8174) when, and only when, they appear in all capitals,
       as shown here.

      Copyright (c) 2019 IETF Trust and the persons identified as
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      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
      (https://trustee.ietf.org/license-info).

      This version of this YANG module is part of RFC 8529; see
      the RFC itself for full legal notices.";

    revision 2019-01-21 {
      description
        "Initial revision.";
      reference
        "RFC 8529";
    }

    // top-level device definition statements

    container network-instances {
      description
        "Network instances, each of which consists of
         VRFs and/or VSIs.";
      reference
        "RFC 8349: A YANG Data Model for Routing Management";
      list network-instance {
        key "name";
        description
          "List of network instances.";
        leaf name {
          type string;
          mandatory true;
          description
            "device-scoped identifier for the network
             instance.";
        }
        leaf enabled {
          type boolean;
```

```
        default "true";
        description
          "Flag indicating whether or not the network
           instance is enabled.";
      }
      leaf description {
        type string;
        description
          "Description of the network instance
           and its intended purpose.";
      }
      choice ni-type {
        description
          "This node serves as an anchor point for different types
           of network instances.  Each 'case' is expected to
           differ in terms of the information needed in the
           parent/core to support the NI and may differ in their
           mounted-schema definition.  When the mounted schema is
           not expected to be the same for a specific type of NI,
           a mount point should be defined.";
      }
      choice root-type {
        mandatory true;
        description
          "Well-known mount points.";
        container vrf-root {
          description
            "Container for mount point.";
          yangmnt:mount-point "vrf-root" {
            description
              "Root for L3VPN-type models.  This will typically
               not be an inline-type mount point.";
          }
        }
        container vsi-root {
          description
            "Container for mount point.";
          yangmnt:mount-point "vsi-root" {
            description
              "Root for L2VPN-type models.  This will typically
               not be an inline-type mount point.";
          }
        }
        container vv-root {
          description
            "Container for mount point.";
          yangmnt:mount-point "vv-root" {
            description
```

```
                "Root models that support both L2VPN-type bridging
                 and L3VPN-type routing.  This will typically
                 not be an inline-type mount point.";
            }
          }
        }
      }
    }

    // augment statements

    augment "/if:interfaces/if:interface" {
      description
        "Add a node for the identification of the network
         instance associated with the information configured
         on a interface.

         Note that a standard error will be returned if the
         identified leafref isn't present.  If an interface cannot
         be assigned for any other reason, the operation SHALL fail
         with an error-tag of 'operation-failed' and an
         error-app-tag of 'ni-assignment-failed'.  A meaningful
         error-info that indicates the source of the assignment
         failure SHOULD also be provided.";
      leaf bind-ni-name {
        type leafref {
          path "/network-instances/network-instance/name";
        }
        description
          "Network instance to which an interface is bound.";
      }
    }
    augment "/if:interfaces/if:interface/ip:ipv4" {
      description
        "Add a node for the identification of the network
         instance associated with the information configured
         on an IPv4 interface.

         Note that a standard error will be returned if the
         identified leafref isn't present.  If an interface cannot
         be assigned for any other reason, the operation SHALL fail
         with an error-tag of 'operation-failed' and an
         error-app-tag of 'ni-assignment-failed'.  A meaningful
         error-info that indicates the source of the assignment
         failure SHOULD also be provided.";
      leaf bind-ni-name {
        type leafref {
          path "/network-instances/network-instance/name";
```

```
        }
        description
          "Network instance to which IPv4 interface is bound.";
      }
    }
    augment "/if:interfaces/if:interface/ip:ipv6" {
      description
        "Add a node for the identification of the network
         instance associated with the information configured
         on an IPv6 interface.

         Note that a standard error will be returned if the
         identified leafref isn't present.  If an interface cannot
         be assigned for any other reason, the operation SHALL fail
         with an error-tag of 'operation-failed' and an
         error-app-tag of 'ni-assignment-failed'.  A meaningful
         error-info that indicates the source of the assignment
         failure SHOULD also be provided.";
      leaf bind-ni-name {
        type leafref {
          path "/network-instances/network-instance/name";
        }
        description
          "Network instance to which IPv6 interface is bound.";
      }
    }

    // notification statements

    notification bind-ni-name-failed {
      description
        "Indicates an error in the association of an interface to an
         NI.  Only generated after success is initially returned when
         bind-ni-name is set.

         Note: Some errors may need to be reported for multiple
         associations, e.g., a single error may need to be reported
         for an IPv4 and an IPv6 bind-ni-name.

         At least one container with a bind-ni-name leaf MUST be
         included in this notification.";
      leaf name {
        type leafref {
          path "/if:interfaces/if:interface/if:name";
        }
        mandatory true;
        description
          "Contains the interface name associated with the
```

```
            failure.";
        }
        container interface {
          description
            "Generic interface type.";
          leaf bind-ni-name {
            type leafref {
              path "/if:interfaces/if:interface"
                 + "/ni:bind-ni-name";
            }
            description
              "Contains the bind-ni-name associated with the
               failure.";
          }
        }
        container ipv4 {
          description
            "IPv4 interface type.";
          leaf bind-ni-name {
            type leafref {
              path "/if:interfaces/if:interface/ip:ipv4/ni:bind-ni-name";
            }
            description
              "Contains the bind-ni-name associated with the
               failure.";
          }
        }
        container ipv6 {
          description
            "IPv6 interface type.";
          leaf bind-ni-name {
            type leafref {
              path "/if:interfaces/if:interface/ip:ipv6"
                 + "/ni:bind-ni-name";
            }
            description
              "Contains the bind-ni-name associated with the
               failure.";
          }
        }
        leaf error-info {
          type string;
          description
            "Optionally, indicates the source of the assignment
             failure.";
        }
      }
    }
```

<CODE ENDS>

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Appendix A. Example NI Usage

The following subsections provide example uses of NIs.

A.1. Configuration Data

The following shows an example where two customer-specific network instances are configured:

```
{
  "ietf-network-instance:network-instances": {
    "network-instance": [
      {
        "name": "vrf-red",
        "vrf-root": {
          "ietf-routing:routing": {
            "router-id": "192.0.2.1",
            "control-plane-protocols": {
              "control-plane-protocol": [
                {
                  "type": "ietf-routing:ospf",
                  "name": "1",
                  "ietf-ospf:ospf": {
                    "af": "ipv4",
                    "areas": {
                      "area": [
                        {
                          "area-id": "203.0.113.1",
                          "interfaces": {
                            "interface": [
                              {
                                "name": "eth1",
                                "cost": 10
                              }
                            ]
                          }
                        }
                      ]
                    }
                  }
                }
              ]
            }
          }
        }
      },
      {
        "name": "vrf-blue",
```

```
          "vrf-root": {
            "ietf-routing:routing": {
              "router-id": "192.0.2.2",
              "control-plane-protocols": {
                "control-plane-protocol": [
                  {
                    "type": "ietf-routing:ospf",
                    "name": "1",
                    "ietf-ospf:ospf": {
                      "af": "ipv4",
                      "areas": {
                        "area": [
                          {
                            "area-id": "203.0.113.1",
                            "interfaces": {
                              "interface": [
                                {
                                  "name": "eth2",
                                  "cost": 10
                                }
                              ]
                            }
                          }
                        ]
                      }
                    }
                  }
                ]
              }
            }
          }
        ]
      },

      "ietf-interfaces:interfaces": {
        "interface": [
          {
            "name": "eth0",
            "type": "iana-if-type:ethernetCsmacd",
            "ietf-ip:ipv4": {
              "address": [
                {
                  "ip": "192.0.2.10",
                  "prefix-length": 24
                }
              ]
            },
```

```
          "ietf-ip:ipv6": {
            "address": [
              {
                "ip": "2001:db8:0:2::10",
                "prefix-length": 64
              }
            ]
          }
        },
        {
          "name": "eth1",
          "type": "iana-if-type:ethernetCsmacd",
          "ietf-ip:ipv4": {
            "address": [
              {
                "ip": "192.0.2.11",
                "prefix-length": 24
              }
            ]
          },
          "ietf-ip:ipv6": {
            "address": [
              {
                "ip": "2001:db8:0:2::11",
                "prefix-length": 64
              }
            ]
          },
          "ietf-network-instance:bind-network-instance-name": "vrf-red"
        },
        {
          "name": "eth2",
          "type": "iana-if-type:ethernetCsmacd",
          "ietf-ip:ipv4": {
            "address": [
              {
                "ip": "192.0.2.11",
                "prefix-length": 24
              }
            ]
          },
          "ietf-ip:ipv6": {
            "address": [
              {
                "ip": "2001:db8:0:2::11",
                "prefix-length": 64
              }
            ]
          },
          "ietf-network-instance:bind-network-instance-name": "vrf-blue"
        }
      ]
    }
  }
}
```

```
            },
            "ietf-network-instance:bind-network-instance-name":
            "vrf-blue"
          }
        ]
      },

      "ietf-system:system": {
        "authentication": {
          "user": [
            {
              "name": "john",
              "password": "$0$password"
            }
          ]
        }
      }
    }
```

A.2. State Data - Non-NMDA Version

The following shows state data for the configuration example above based on [RFC8343], [RFC8344], and [RFC8349].

```
{
  "ietf-network-instance:network-instances": {
    "network-instance": [
      {
        "name": "vrf-red",
        "vrf-root": {
          "ietf-yang-library:modules-state": {
            "module-set-id": "123e4567-e89b-12d3-a456-426655440000",
            "module": [
              {
                "name": "ietf-yang-library",
                "revision": "2019-01-04",
                "namespace":
                  "urn:ietf:params:xml:ns:yang:ietf-yang-library",
                "conformance-type": "implement"
              },
              {
                "name": "ietf-ospf",
                "revision": "2019-01-24",
                "namespace": "urn:ietf:params:xml:ns:yang:ietf-ospf",
                "conformance-type": "implement"
              },
              {
                "name": "ietf-routing",
```

```
              "revision": "2018-03-13",
              "namespace": "urn:ietf:params:xml:ns:yang:ietf-routing",
              "conformance-type": "implement"
            }
          ]
        },
        "ietf-routing:routing-state": {
          "router-id": "192.0.2.1",
          "control-plane-protocols": {
            "control-plane-protocol": [
              {
                "type": "ietf-routing:ospf",
                "name": "1",
                "ietf-ospf:ospf": {
                  "af": "ipv4",
                  "areas": {
                    "area": [
                      {
                        "area-id": "203.0.113.1",
                        "interfaces": {
                          "interface": [
                            {
                              "name": "eth1",
                              "cost": 10
                            }
                          ]
                        }
                      }
                    ]
                  }
                }
              }
            ]
          }
        }
      },
      {
        "name": "vrf-blue",
        "vrf-root": {
          "ietf-yang-library:modules-state": {
            "module-set-id": "123e4567-e89b-12d3-a456-426655440000",
            "module": [
              {
                "name": "ietf-yang-library",
                "revision": "2019-01-04",
                "namespace":
                  "urn:ietf:params:xml:ns:yang:ietf-yang-library",
```

```
              "conformance-type": "implement"
            },
            {
              "name": "ietf-ospf",
              "revision": "2019-01-24",
              "namespace": "urn:ietf:params:xml:ns:yang:ietf-ospf",
              "conformance-type": "implement"
            },
            {
              "name": "ietf-routing",
              "revision": "2018-03-13",
              "namespace": "urn:ietf:params:xml:ns:yang:ietf-routing",
              "conformance-type": "implement"
            }
          ]
        },
        "ietf-routing:routing-state": {
          "router-id": "192.0.2.2",
          "control-plane-protocols": {
            "control-plane-protocol": [
              {
                "type": "ietf-routing:ospf",
                "name": "1",
                "ietf-ospf:ospf": {
                  "af": "ipv4",
                  "areas": {
                    "area": [
                      {
                        "area-id": "203.0.113.1",
                        "interfaces": {
                          "interface": [
                            {
                              "name": "eth2",
                              "cost": 10
                            }
                          ]
                        }
                      }
                    ]
                  }
                }
              }
            ]
          }
        }
      }
    ]
```

```
  },

  "ietf-interfaces:interfaces-state": {
    "interface": [
      {
        "name": "eth0",
        "type": "iana-if-type:ethernetCsmacd",
        "oper-status": "up",
        "phys-address": "00:01:02:A1:B1:C0",
        "statistics": {
          "discontinuity-time": "2017-06-26T12:34:56-05:00"
        },
        "ietf-ip:ipv4": {
          "address": [
            {
              "ip": "192.0.2.10",
              "prefix-length": 24
            }
          ]
        },
        "ietf-ip:ipv6": {
          "address": [
            {
              "ip": "2001:db8:0:2::10",
              "prefix-length": 64
            }
          ]
        }
      },
      {
        "name": "eth1",
        "type": "iana-if-type:ethernetCsmacd",
        "oper-status": "up",
        "phys-address": "00:01:02:A1:B1:C1",
        "statistics": {
          "discontinuity-time": "2017-06-26T12:34:56-05:00"
        },
        "ietf-ip:ipv4": {
          "address": [
            {
              "ip": "192.0.2.11",
              "prefix-length": 24
            }
          ]
        },
        "ietf-ip:ipv6": {
          "address": [
            {
```

```
              "ip": "2001:db8:0:2::11",
              "prefix-length": 64
            }
          ]
        }
      },
      {
        "name": "eth2",
        "type": "iana-if-type:ethernetCsmacd",
        "oper-status": "up",
        "phys-address": "00:01:02:A1:B1:C2",
        "statistics": {
          "discontinuity-time": "2017-06-26T12:34:56-05:00"
        },
        "ietf-ip:ipv4": {
          "address": [
            {
              "ip": "192.0.2.11",
              "prefix-length": 24
            }
          ]
        },
        "ietf-ip:ipv6": {
          "address": [
            {
              "ip": "2001:db8:0:2::11",
              "prefix-length": 64
            }
          ]
        }
      }
    ]
  },

  "ietf-system:system-state": {
    "platform": {
      "os-name": "NetworkOS"
    }
  },

  "ietf-yang-library:modules-state": {
    "module-set-id": "123e4567-e89b-12d3-a456-426655440000",
    "module": [
      {
        "name": "iana-if-type",
        "revision": "2018-07-03",
        "namespace": "urn:ietf:params:xml:ns:yang:iana-if-type",
        "conformance-type": "import"
```

```
      },
      {
        "name": "ietf-inet-types",
        "revision": "2013-07-15",
        "namespace": "urn:ietf:params:xml:ns:yang:ietf-inet-types",
        "conformance-type": "import"
      },
      {
        "name": "ietf-interfaces",
        "revision": "2018-02-20",
        "feature": [
          "arbitrary-names",
          "pre-provisioning"
        ],
        "namespace": "urn:ietf:params:xml:ns:yang:ietf-interfaces",
        "conformance-type": "implement"
      },
      {
        "name": "ietf-ip",
        "revision": "2018-01-09",
        "namespace": "urn:ietf:params:xml:ns:yang:ietf-ip",
        "conformance-type": "implement"
      },
      {
        "name": "ietf-network-instance",
        "revision": "2018-02-03",
        "feature": [
          "bind-network-instance-name"
        ],
        "namespace":
          "urn:ietf:params:xml:ns:yang:ietf-network-instance",
        "conformance-type": "implement"
      },
      {
        "name": "ietf-ospf",
        "revision": "2019-01-24",
        "namespace": "urn:ietf:params:xml:ns:yang:ietf-ospf",
        "conformance-type": "implement"
      },
      {
        "name": "ietf-routing",
        "revision": "2018-03-13",
        "namespace": "urn:ietf:params:xml:ns:yang:ietf-routing",
        "conformance-type": "implement"
      },
      {
        "name": "ietf-system",
        "revision": "2014-08-06",
```

```
        "namespace": "urn:ietf:params:xml:ns:yang:ietf-system",
        "conformance-type": "implement"
      },
      {
        "name": "ietf-yang-library",
        "revision": "2019-01-04",
        "namespace": "urn:ietf:params:xml:ns:yang:ietf-yang-library",
        "conformance-type": "implement"
      },
      {
        "name": "ietf-yang-schema-mount",
        "revision": "2019-01-14",
        "namespace":
          "urn:ietf:params:xml:ns:yang:ietf-yang-schema-mount",
        "conformance-type": "implement"
      },
      {
        "name": "ietf-yang-types",
        "revision": "2013-07-15",
        "namespace": "urn:ietf:params:xml:ns:yang:ietf-yang-types",
        "conformance-type": "import"
      }
    ]
  },

  "ietf-yang-schema-mount:schema-mounts": {
    "mount-point": [
      {
        "module": "ietf-network-instance",
        "label": "vrf-root",
        "shared-schema": {
          "parent-reference": [
            "/*[namespace-uri() = 'urn:ietf:...:ietf-interfaces']"
          ]
        }
      }
    ]
  }
}
```

A.3. State Data - NMDA Version

The following shows state data for the configuration example above based on [RFC8343], [RFC8344], and [RFC8349].

```
{
  "ietf-network-instance:network-instances": {
    "network-instance": [
      {
        "name": "vrf-red",
        "vrf-root": {
          "ietf-yang-library:yang-library": {
            "content-id": "41e2ab5dc325f6d86f743e8da3de323f1a61a801",
            "module-set": [
              {
                "name": "ni-modules",
                "module": [
                  {
                    "name": "ietf-yang-library",
                    "revision": "2019-01-04",
                    "namespace":
                      "urn:ietf:params:xml:ns:yang:ietf-yang-library"
                  },
                  {
                    "name": "ietf-ospf",
                    "revision": "2019-01-24",
                    "namespace":
                      "urn:ietf:params:xml:ns:yang:ietf-ospf"
                  },
                  {
                    "name": "ietf-routing",
                    "revision": "2018-03-13",
                    "namespace":
                      "urn:ietf:params:xml:ns:yang:ietf-routing"
                  }
                ],
                "import-only-module": [
                  {
                    "name": "ietf-inet-types",
                    "revision": "2013-07-15",
                    "namespace":
                      "urn:ietf:params:xml:ns:yang:ietf-inet-types"
                  },
                  {
                    "name": "ietf-yang-types",
                    "revision": "2013-07-15",
                    "namespace":
                      "urn:ietf:params:xml:ns:yang:ietf-yang-types"
```

```
            },
            {
              "name": "ietf-datastores",
              "revision": "2018-02-14",
              "namespace":
                "urn:ietf:params:xml:ns:yang:ietf-datastores"
            }
          ]
        }
      ],
      "schema": [
        {
          "name": "ni-schema",
          "module-set": [ "ni-modules" ]
        }
      ],
      "datastore": [
        {
          "name": "ietf-datastores:running",
          "schema": "ni-schema"
        },
        {
          "name": "ietf-datastores:operational",
          "schema": "ni-schema"
        }
      ]
    },
    "ietf-routing:routing": {
      "router-id": "192.0.2.1",
      "control-plane-protocols": {
        "control-plane-protocol": [
          {
            "type": "ietf-routing:ospf",
            "name": "1",
            "ietf-ospf:ospf": {
              "af": "ipv4",
              "areas": {
                "area": [
                  {
                    "area-id": "203.0.113.1",
                    "interfaces": {
                      "interface": [
                        {
                          "name": "eth1",
                          "cost": 10
                        }
                      ]
                    }
```

```
                        }
                      ]
                    }
                  }
                }
              ]
            }
          }
        }
      },
      {
        "name": "vrf-blue",
        "vrf-root": {
          "ietf-yang-library:yang-library": {
            "checksum": "41e2ab5dc325f6d86f743e8da3de323f1a61a801",
            "module-set": [
              {
                "name": "ni-modules",
                "module": [
                  {
                    "name": "ietf-yang-library",
                    "revision": "2019-01-04",
                    "namespace":
                      "urn:ietf:params:xml:ns:yang:ietf-yang-library",
                    "conformance-type": "implement"
                  },
                  {
                    "name": "ietf-ospf",
                    "revision": "2019-01-24",
                    "namespace":
                      "urn:ietf:params:xml:ns:yang:ietf-ospf",
                    "conformance-type": "implement"
                  },
                  {
                    "name": "ietf-routing",
                    "revision": "2018-03-13",
                    "namespace":
                      "urn:ietf:params:xml:ns:yang:ietf-routing",
                    "conformance-type": "implement"
                  }
                ],
                "import-only-module": [
                  {
                    "name": "ietf-inet-types",
                    "revision": "2013-07-15",
                    "namespace":
                      "urn:ietf:params:xml:ns:yang:ietf-inet-types"
                  },
```

```
                {
                  "name": "ietf-yang-types",
                  "revision": "2013-07-15",
                  "namespace":
                    "urn:ietf:params:xml:ns:yang:ietf-yang-types"
                },
                {
                  "name": "ietf-datastores",
                  "revision": "2018-02-14",
                  "namespace":
                    "urn:ietf:params:xml:ns:yang:ietf-datastores"
                }
              ]
            }
          ],
          "schema": [
            {
              "name": "ni-schema",
              "module-set": [ "ni-modules" ]
            }
          ],
          "datastore": [
            {
              "name": "ietf-datastores:running",
              "schema": "ni-schema"
            },
            {
              "name": "ietf-datastores:operational",
              "schema": "ni-schema"
            }
          ]
        },
        "ietf-routing:routing": {
          "router-id": "192.0.2.2",
          "control-plane-protocols": {
            "control-plane-protocol": [
              {
                "type": "ietf-routing:ospf",
                "name": "1",
                "ietf-ospf:ospf": {
                  "af": "ipv4",
                  "areas": {
                    "area": [
                      {
                        "area-id": "203.0.113.1",
                        "interfaces": {
                          "interface": [
                            {
```

```
                                  "name": "eth2",
                                  "cost": 10
                                }
                              ]
                            }
                          }
                        ]
                      }
                    }
                  }
                ]
              }
            }
          }
        }
      ]
    },

    "ietf-interfaces:interfaces": {
      "interface": [
        {
          "name": "eth0",
          "type": "iana-if-type:ethernetCsmacd",
          "oper-status": "up",
          "phys-address": "00:01:02:A1:B1:C0",
          "statistics": {
            "discontinuity-time": "2017-06-26T12:34:56-05:00"
          },
          "ietf-ip:ipv4": {
            "address": [
              {
                "ip": "192.0.2.10",
                "prefix-length": 24
              }
            ]
          },
          "ietf-ip:ipv6": {
            "address": [
              {
                "ip": "2001:db8:0:2::10",
                "prefix-length": 64
              }
            ]
          }
        },
        {
          "name": "eth1",
          "type": "iana-if-type:ethernetCsmacd",
```

```
          "oper-status": "up",
          "phys-address": "00:01:02:A1:B1:C1",
          "statistics": {
            "discontinuity-time": "2017-06-26T12:34:56-05:00"
          },
          "ietf-ip:ipv4": {
            "address": [
              {
                "ip": "192.0.2.11",
                "prefix-length": 24
              }
            ]
          },
          "ietf-ip:ipv6": {
            "address": [
              {
                "ip": "2001:db8:0:2::11",
                "prefix-length": 64
              }
            ]
          }
        },
        {
          "name": "eth2",
          "type": "iana-if-type:ethernetCsmacd",
          "oper-status": "up",
          "phys-address": "00:01:02:A1:B1:C2",
          "statistics": {
            "discontinuity-time": "2017-06-26T12:34:56-05:00"
          },
          "ietf-ip:ipv4": {
            "address": [
              {
                "ip": "192.0.2.11",
                "prefix-length": 24
              }
            ]
          },
          "ietf-ip:ipv6": {
            "address": [
              {
                "ip": "2001:db8:0:2::11",
                "prefix-length": 64
              }
            ]
          }
        }
      ]
```

```
    },

    "ietf-system:system-state": {
      "platform": {
        "os-name": "NetworkOS"
      }
    },

    "ietf-yang-library:yang-library": {
      "content-id": "75a43df9bd56b92aacc156a2958fbe12312fb285",
      "module-set": [
        {
          "name": "host-modules",
          "module": [
            {
              "name": "ietf-interfaces",
              "revision": "2018-02-20",
              "feature": [
                "arbitrary-names",
                "pre-provisioning"
              ],
              "namespace":
                "urn:ietf:params:xml:ns:yang:ietf-interfaces"
            },
            {
              "name": "ietf-ip",
              "revision": "2018-01-09",
              "namespace": "urn:ietf:params:xml:ns:yang:ietf-ip"
            },
            {
              "name": "ietf-network-instance",
              "revision": "2018-02-03",
              "feature": [
                "bind-network-instance-name"
              ],
              "namespace":
                "urn:ietf:params:xml:ns:yang:ietf-network-instance"
            },
            {
              "name": "ietf-ospf",
              "revision": "2019-01-24",
              "namespace":
                "urn:ietf:params:xml:ns:yang:ietf-ospf"
            },
            {
              "name": "ietf-routing",
              "revision": "2018-03-13",
              "namespace":
```

```
            "urn:ietf:params:xml:ns:yang:ietf-routing"
          },
          {
            "name": "ietf-system",
            "revision": "2014-08-06",
            "namespace": "urn:ietf:params:xml:ns:yang:ietf-system"
          },
          {
            "name": "ietf-yang-library",
            "revision": "2019-01-04",
            "namespace":
              "urn:ietf:params:xml:ns:yang:ietf-yang-library"
          },
          {
            "name": "ietf-yang-schema-mount",
            "revision": "2019-01-14",
            "namespace":
              "urn:ietf:params:xml:ns:yang:ietf-yang-schema-mount"
          }
        ],
        "import-only-module": [
          {
            "name": "iana-if-type",
            "revision": "2018-07-03",
            "namespace": "urn:ietf:params:xml:ns:yang:iana-if-type"
          },
          {
            "name": "ietf-inet-types",
            "revision": "2013-07-15",
            "namespace":
              "urn:ietf:params:xml:ns:yang:ietf-inet-types"
          },
          {
            "name": "ietf-yang-types",
            "revision": "2013-07-15",
            "namespace":
              "urn:ietf:params:xml:ns:yang:ietf-yang-types"
          },
          {
            "name": "ietf-datastores",
            "revision": "2018-02-14",
            "namespace":
              "urn:ietf:params:xml:ns:yang:ietf-datastores"
          }
        ]
      }
    ],
    "schema": [
```

```
        {
          "name": "host-schema",
          "module-set": [ "host-modules" ]
        }
      ],
      "datastore": [
        {
          "name": "ietf-datastores:running",
          "schema": "host-schema"
        },
        {
          "name": "ietf-datastores:operational",
          "schema": "host-schema"
        }
      ]
    },

    "ietf-yang-schema-mount:schema-mounts": {
      "mount-point": [
        {
          "module": "ietf-network-instance",
          "label": "vrf-root",
          "shared-schema": {
            "parent-reference": [
              "/*[namespace-uri() = 'urn:ietf:...:ietf-interfaces']"
            ]
          }
        }
      ]
    }
  }
```

Acknowledgments

The Routing Area Yang Architecture design team members included Acee Lindem, Anees Shaikh, Christian Hopps, Dean Bogdanovic, Lou Berger, Qin Wu, Rob Shakir, Stephane Litkowski, and Yan Gang. Martin Bjorklund and John Scudder provided useful review comments.

This document was motivated by, and derived from, "Network Device YANG Logical Organization" [YANG-NETWORK].

Thanks for Area Director and IETF last-call comments from Alia Atlas, Liang Xia, Benoit Claise, and Adam Roach.

Authors' Addresses

Lou Berger
LabN Consulting, L.L.C.

Email: lberger@labn.net

Christian Hopps
LabN Consulting, L.L.C.

Email: chopps@chopps.org

Acee Lindem
Cisco Systems
301 Midenhall Way
Cary, NC 27513
United States of America

Email: acee@cisco.com

Dean Bogdanovic
Volta Networks

Email: ivandean@gmail.com

Xufeng Liu
Volta Networks

Email: xufeng.liu.ietf@gmail.com