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A Yang Data Model for ACTN VN Operation

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Abstract

This document provides a YANG data model for the Abstraction and Control of Traffic Engineered (TE) networks (ACTN) Virtual Network Service (VNS) operation.

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Table of Contents

1. Introduction

Abstraction and Control of Traffic Engineered Networks (ACTN) describes a set of management and control functions used to operate one or more TE networks to construct virtual networks that can be represented to customers and that are built from abstractions of the underlying TE networks [RFC8453].

This document provides a YANG data model for the Abstraction and Control of Traffic Engineered (TE) networks (ACTN) Virtual Network Service (VNS) operation that is going to be implemented for the Customer Network Controller (CNC)- Multi-Domain Service Coordinator (MSDC) interface (CMI).

The YANG model on the CMI is also known as customer service model in [RFC8309]. The YANG model discussed in this document is used to operate customer-driven VNs during the VN instantiation, VN computation, and its life-cycle service management and operations.

The VN model defined in this document is applicable in generic sense outside of the ACTN context as an independent model in and of itself. The VN model defined in this document can also work together with other customer service models such as L3SM [RFC8299], L2SM [L2SM] and L1CSM [L1CSM] to provide a complete life-cycle service management and operations.

The YANG model discussed in this document basically provides the following:

- Characteristics of Access Points (APs) that describe customer's end point characteristics;
- Characteristics of Virtual Network Access Points (VNAP) that describe How an AP is partitioned for multiple VNs sharing the AP and its reference to a Link Termination Point (LTP) of the Provider Edge (PE) Node;
- Characteristics of Virtual Networks (VNs) that describe the customer's VNs in terms of VN Members comprising a VN, multi-source and/or multi-destination characteristics of VN Member, the VN's reference to TE-topology's Abstract Node;

The actual VN instantiation and computation is performed with Connectivity Matrices sub-module of TE-Topology Model [TE-Topo] which provides TE network topology abstraction and management operation. Once TE-topology Model is used in triggering VN instantiation over the networks, TE-tunnel [TE-tunnel] Model will inevitably interact with TE-Topology model for setting up actual tunnels and LSPs under the tunnels.

The ACTN VN operational state is included in the same tree as the configuration consistent with Network Management Datastore Architecture (NMDA) [RFC8342]. The origin of the data is indicated as per the origin metadata annotation.

1.1. Terminology

Refer to [RFC8453], [RFC7926], and [RFC8309] for the key terms used in this document.

1.2. Tree diagram

A simplified graphical representation of the data model is used in Section 5 of this this document. The meaning of the symbols in these diagrams is defined in [RFC8340].

1.3. Prefixes in Data Node Names

In this document, names of data nodes and other data model objects are prefixed using the standard prefix associated with the corresponding YANG imported modules, as shown in Table 1.

Prefix	YANG module	Reference
vn	ietf-vn	[RFCXXXX]
nw	ietf-network	[RFC8345]
te-types	ietf-te-types	[TE-Tunnel]
te-topo	ietf-te-topology	[TE-TOPO]

Table 1: Prefixes and corresponding YANG modules

Note: The RFC Editor will replace XXXX with the number assigned to the RFC once this draft becomes an RFC.

2. ACTN CMI context

The model presented in this document has the following ACTN context.

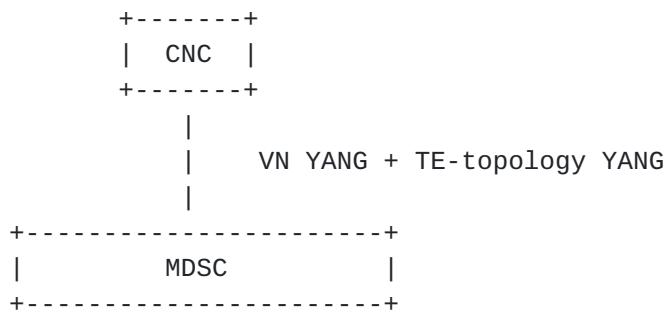


Figure 1. ACTN CMI

Both ACTN VN YANG and TE-topology models are used over the CMI to establish a VN over TE networks.

2.1. Type 1 VN

As defined in [RFC8453], a Virtual Network is a customer view of the TE network. To recapitulate VN types from [RFC8453], Type 1 VN is defined as follows:

The VN can be seen as a set of edge-to-edge abstract links (a Type 1 VN). Each abstract link is referred to as a VN member and is formed as an end-to-end tunnel across the underlying networks. Such tunnels may be constructed by recursive slicing or abstraction of paths in the underlying networks and can encompass edge points of the customer's network, access links, intra-domain paths, and inter-domain links.

If we were to create a VN where we have four VN-members as follows:

VN-Member 1	L1-L4
VN-Member 2	L1-L7
VN-Member 3	L2-L4
VN-Member 4	L3-L8

Where L1, L2, L3, L4, L7 and L8 correspond to a Customer End-Point, respectively.

This VN can be modeled as one abstract node representation as follows in Figure 2:

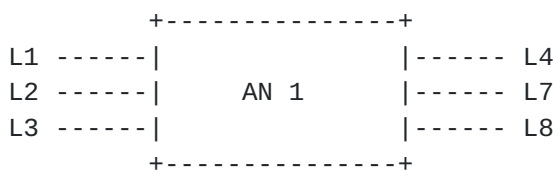


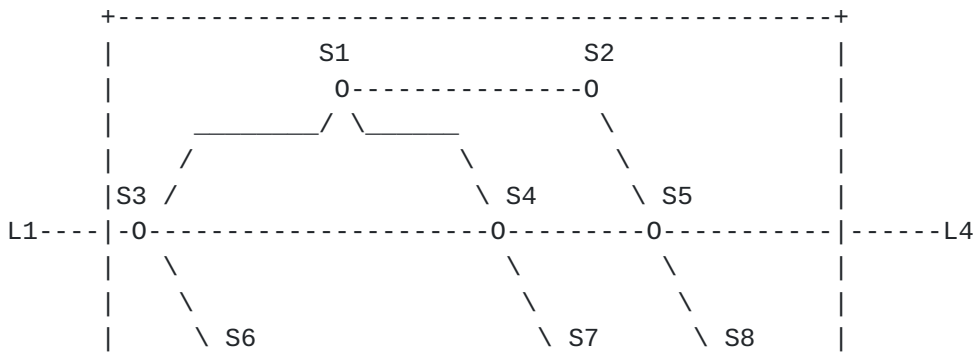
Figure 2. Abstract Node (One node topology)

Modeling a VN as one abstract node is the easiest way for customers to express their end-to-end connectivity; however, customers are not limited to express their VN only with one abstract node. In some cases, more than one abstract nodes can be employed to express their VN.

2.2. Type 2 VN

For some VN members of a VN, the customers are allowed to configure the actual path (i.e., detailed virtual nodes and virtual links) over the VN/abstract topology agreed mutually between CNC and MDSC prior to or a topology created by the MDSC as part of VN instantiation. Type 2 VN is always built on top of a Type 1 VN.

If a Type 2 VN is desired for some or all of VN members of a type 1 VN (see the example in Section 2.1), the TE-topology model can provide the following abstract topology (that consists of virtual nodes and virtual links) which is built on top of the Type 1 VN.



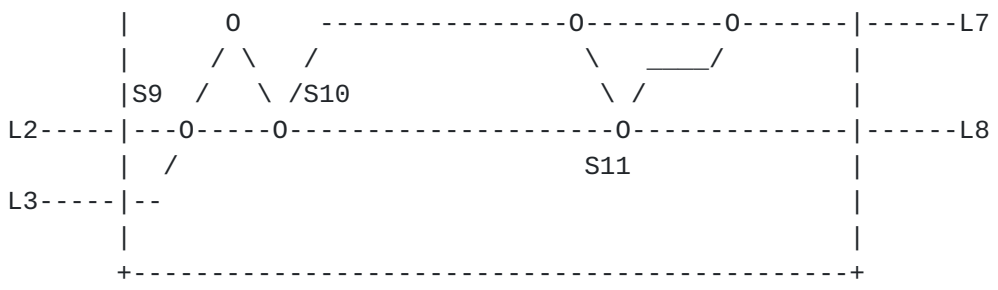


Figure 3. Type 2 topology

As you see from Figure 3, the Type 1 abstract node is depicted as a Type 1 abstract topology comprising of detailed virtual nodes and virtual links.

As an example, if VN-member 1 (L1-L4) is chosen to configure its own path over Type 2 topology, it can select, say, a path that consists of the ERO {S3,S4,S5} based on the topology and its service requirement. This capability is enacted via TE-topology configuration by the customer.

3. High-Level Control Flows with Examples

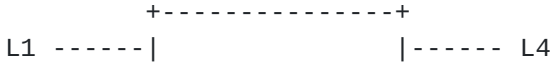
3.1. Type 1 VN Illustration

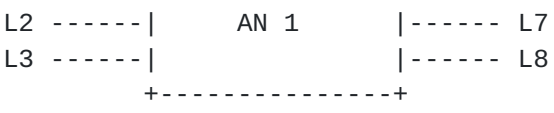
If we were to create a VN where we have four VN-members as follows:

VN-Member 1	L1-L4
VN-Member 2	L1-L7
VN-Member 3	L2-L4
VN-Member 4	L3-L8

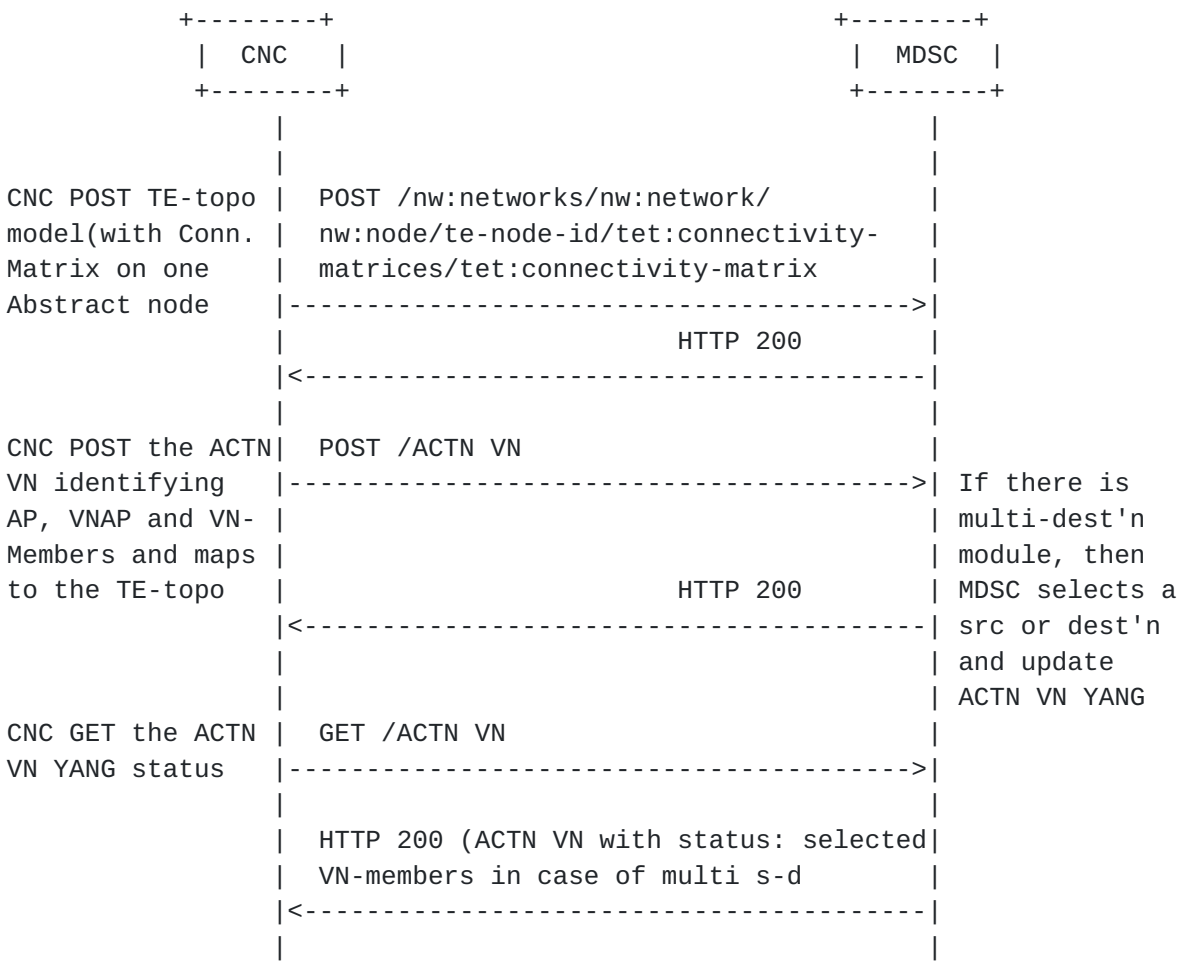
Where L1, L2, L3, L4, L7 and L8 correspond to Customer End-Point, respectively.

This VN can be modeled as one abstract node representation as follows:



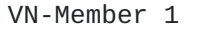


If this VN is Type 1, the following diagram shows the message flow between CNC and MDSC to instantiate this VN using ACTN VN and TE-Topology Model.



3.2. Type 2 VN Illustration

For some VN members, the customer may want to "configure" explicit routes over the path that connects its two end-points. Let us consider the following example.

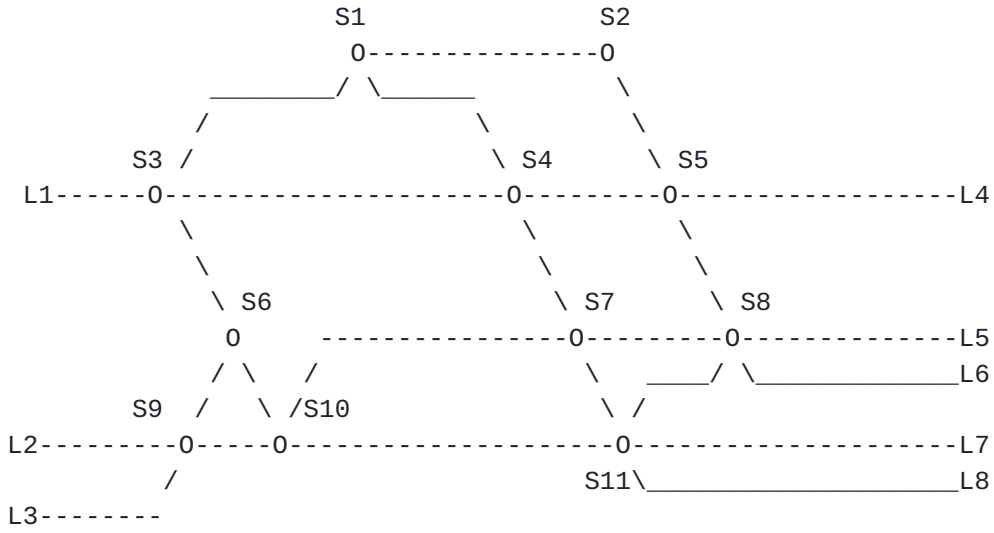


VN-Member 2 L1-L7 (via S4 and S7)

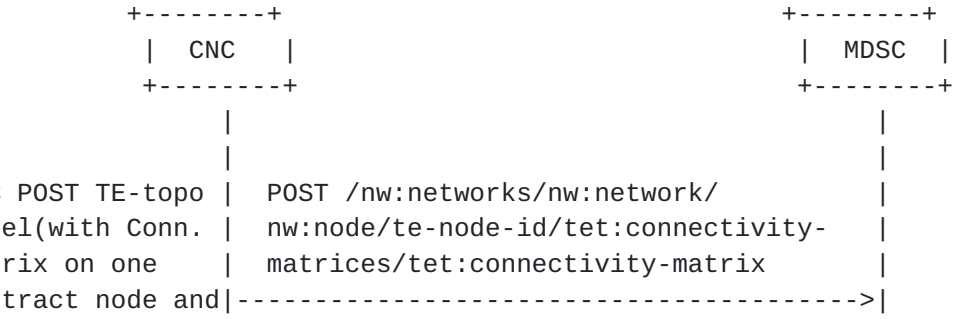
VN-Member 3 L2-L4

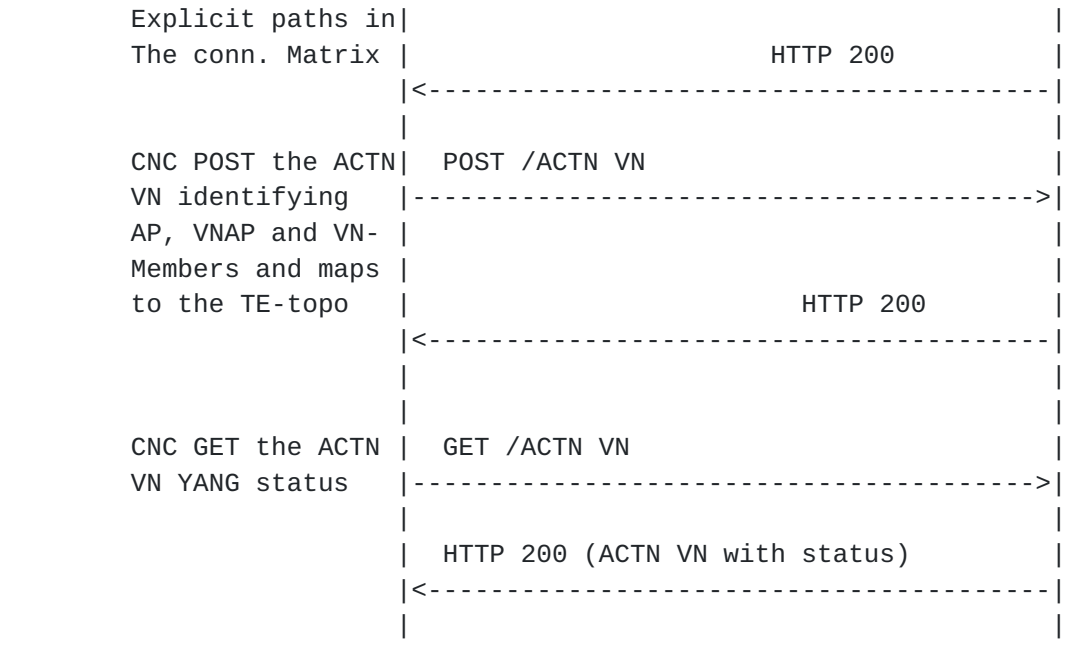
VN-Member 4 L3-L8 (via S10)

Where the following topology is the underlay for Abstraction Node 1 (AN1).

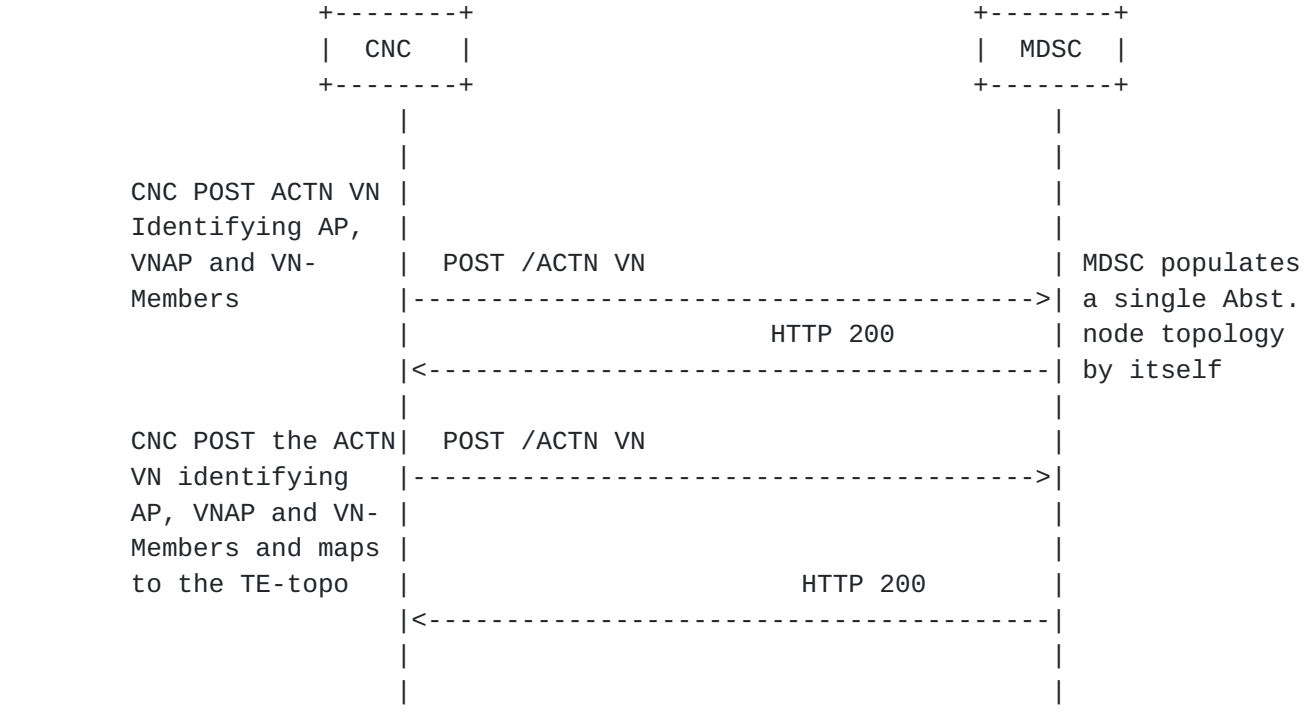


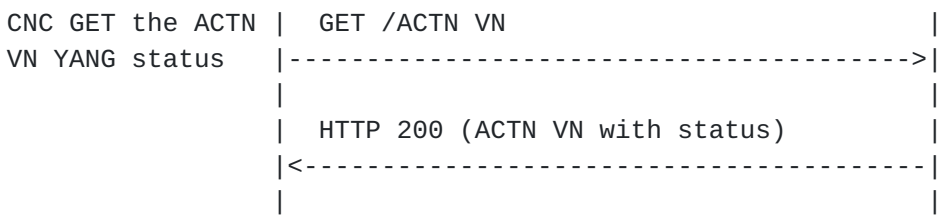
If CNC creates the single abstract topology, the following diagram shows the message flow between CNC and MDSC to instantiate this VN using ACTN VN and TE-Topology Model.





On the other hand, if MDSC create single node topology based ACTN VN YANG posted by the CNC, the following diagram shows the message flow between CNC and MDSC to instantiate this VN using ACTN VN and TE-Topology Model.





4. ACTN VN Model Usage

4.1. Customer view of VN

The VN-Yang model allows to define a customer view, and allows the customer to communicate using the VN constructs as described in the [ACTN-INFO]. It also allows to group the set of edge-to-edge links (i.e., VN members) under a common umbrella of VN. This allows the customer to instantiate and view the VN as one entity, making it easier for some customers to work on VN without worrying about the details of the provider based YANG models.

This is similar to the benefits of having a separate YANG model for the customer services as described in [RFC8309], which states that service models do not make any assumption of how a service is actually engineered and delivered for a customer.

4.2. Auto-creation of VN by MDSC

The VN could be configured at the MDSC explicitly by the CNC using the ACTN VN yang model. In some other cases, the VN is not explicitly configured, but created automatically by the MDSC based on the customer service model and local policy, even in these case the ACTN VN yang model can be used by the CNC to learn details of the underlying VN created to meet the requirements of customer service model.

4.3. Innovative Services

4.3.1. VN Compute

ACTN VN supports VN compute (pre-instantiation mode) to view the full VN as a single entity before instantiation. Achieving this via path computation or "compute only" tunnel setup does not provide the same functionality.

4.3.2. Multi-sources and Multi-destinations

In creating a virtual network, the list of sources or destinations or both may not be pre-determined by the customer. For instance, for a given source, there may be a list of multiple-destinations to which the optimal destination may be chosen depending on the network resource situations. Likewise, for a given destination, there may also be multiple-sources from which the optimal source may be chosen. In some cases, there may be a pool of multiple sources and destinations from which the optimal source-destination may be chosen. The following YANG module is shown for describing source container and destination container. The following YANG tree shows how to model multi-sources and multi-destinations.

```
+--rw actn
       . . .
       +--rw vn
          +--rw vn-list* [vn-id]
             +--rw vn-id             uint32
             +--rw vn-name?          string
             +--rw vn-topology-id?   te-types:te-topology-id
             +--rw abstract-node?    -> /nw:networks/network/node/tet:te-node-
id
             +--rw vn-member-list* [vn-member-id]
             |  +--rw vn-member-id            uint32
             |  +--rw src
             |  |  +--rw src?           -> /actn/ap/access-point-list/access-
point-id
             |  |  +--rw src-vn-ap-id?   -> /actn/ap/access-point-list/vn-ap/
vn-ap-id
             |  |  +--rw multi-src?      boolean {multi-src-dest}?
             |  +--rw dest
             |  |  +--rw dest?           -> /actn/ap/access-point-list/access-
point-
id
             |  |  +--rw dest-vn-ap-id?   -> /actn/ap/access-point-list/vn-ap/
vn-ap-id
             |  |  +--rw multi-dest?      boolean {multi-src-dest}?
             |  +--rw connetivity-matrix-id?   -> /nw:networks/network/node/
tet:te/te-
node-attributes/connectivity-matrices/connectivity-matrix/id
             |  +--ro oper-status?            identityref
             +--ro if-selected?      boolean {multi-src-dest}?
             +--rw admin-status?     identityref
             +--ro oper-status?      identityref
```

4.3.3. Others

The VN Yang model can be easily augmented to support the mapping of VN to the Services such as L3SM and L2SM as described in [TE-MAP].

The VN Yang model can be extended to support telemetry, performance monitoring and network autonomics as described in [ACTN-PM].

4.3.4. Summary

This section summarizes the innovative service features of the ACTN VN Yang.

- Maintenance of AP and VNAP along with VN.
- VN construct to group of edge-to-edge links
- VN Compute (pre-instantiate)
- Multi-Source / Multi-Destination
- Ability to support various VN and VNS Types
  - VN Type 1: Customer configures the VN as a set of VN Members.
    No other details need to be set by customer, making for a simplified operations for the customer.
  - VN Type 2: Along with VN Members, the customer could also provide an abstract topology, this topology is provided by the Abstract TE Topology Yang Model.

5. ACTN VN YANG Model (Tree Structure)

```
module: ietf-vn
    +--rw actn
       +--rw ap
       |  +--rw access-point-list* [access-point-id]
       |     +--rw access-point-id      uint32
       |     +--rw access-point-name?   string
       |     +--rw max-bandwidth?       te-types:te-bandwidth
       |     +--rw avl-bandwidth?       te-types:te-bandwidth
       |     +--rw vn-ap* [vn-ap-id]
       |        +--rw vn-ap-id         uint32
       |        +--rw vn?              -> /actn/vn/vn-list/vn-id
       |        +--rw abstract-node?   -> /nw:networks/network/node/tet:te-
node-id
       |        +--rw ltp?             te-types:te-tp-id
       +--rw vn
          +--rw vn-list* [vn-id]
```

```
               +--rw vn-id                uint32
               +--rw vn-name?             string
               +--rw vn-topology-id?      te-types:te-topology-id
               +--rw abstract-node?       -> /nw:networks/network/node/
tet:te-node-id
               +--rw vn-member-list* [vn-member-id]
               |  +--rw vn-member-id            uint32
               |  +--rw src
               |  |  +--rw src?           -> /actn/ap/access-point-list/
access-point-id
               |  |  +--rw src-vn-ap-id?   -> /actn/ap/access-point-list/vn-
ap/vn-ap-id
               |  |  +--rw multi-src?     boolean {multi-src-dest}?
               |  +--rw dest
               |  |  +--rw dest?           -> /actn/ap/access-point-list/
access-point-id
               |  |  +--rw dest-vn-ap-id?   -> /actn/ap/access-point-list/vn-
ap/vn-ap-id
               |  |  +--rw multi-dest?     boolean {multi-src-dest}?
               |  +--rw connetivity-matrix-id?   -> /nw:networks/network/node/
tet:te/te-node-
   attributes/connectivity-matrices/connectivity-matrix/id
               |  +--ro oper-status?            identityref
               +--ro if-selected?         boolean {multi-src-dest}?
               +--rw admin-status?        identityref
               +--ro oper-status?         identityref
               +--rw vn-level-diversity?  vn-disjointness

     rpcs:
       +---x vn-compute
          +---w input
          |  +---w abstract-node?       -> /nw:networks/network/node/tet:te-
node-id
          |  +---w vn-member-list* [vn-member-id]
          |  |  +---w vn-member-id            uint32
          |  |  +---w src
          |  |  |  +---w src?           -> /actn/ap/access-point-list/access-
point-id
          |  |  |  +---w src-vn-ap-id?   -> /actn/ap/access-point-list/vn-ap/
vn-ap-id
          |  |  |  +---w multi-src?     boolean {multi-src-dest}?
          |  |  +---w dest
          |  |  |  +---w dest?           -> /actn/ap/access-point-list/access-
point-id
          |  |  |  +---w dest-vn-ap-id?   -> /actn/ap/access-point-list/vn-ap/
vn-ap-id
          |  |  |  +---w multi-dest?     boolean {multi-src-dest}?
          |  |  +---w connetivity-matrix-id?   -> /nw:networks/network/node/
```

```
tet:te/te-node-
   attributes/connectivity-matrices/connectivity-matrix/id
          |  +---w vn-level-diversity?   vn-disjointness
          +--ro output
             +--ro vn-member-list* [vn-member-id]
                +--ro vn-member-id            uint32
                +--ro src
                |  +--ro src?           -> /actn/ap/access-point-list/access-
point-id
                |  +--ro src-vn-ap-id?   -> /actn/ap/access-point-list/vn-ap/
vn-ap-id
                |  +--ro multi-src?      boolean {multi-src-dest}?
                +--ro dest
                |  +--ro dest?           -> /actn/ap/access-point-list/access-
point-id
                |  +--ro dest-vn-ap-id?   -> /actn/ap/access-point-list/vn-ap/
vn-ap-id
                |  +--ro multi-dest?      boolean {multi-src-dest}?
                +--ro connetivity-matrix-id?   -> /nw:networks/network/node/
tet:te/te-node-
   attributes/connectivity-matrices/connectivity-matrix/id
                +--ro if-selected?            boolean {multi-src-dest}?
                +--ro compute-status?         identityref
```

6. ACTN-VN YANG Code

The YANG code is as follows:

<CODE BEGINS> file "ietf-vn@2018-12-30.yang"

```
module ietf-vn {
    namespace "urn:ietf:params:xml:ns:yang:ietf-vn";
    prefix "vn";

    /* Import network */
    import ietf-network {
        prefix "nw";
    }

    /* Import TE generic types */
    import ietf-te-types {
        prefix "te-types";
    }

    /* Import Abstract TE Topology */
    import ietf-te-topology {
        prefix "tet";
    }

    organization
        "IETF Traffic Engineering Architecture and Signaling (TEAS)
        Working Group";
    contact
        "Editor: Young Lee <leeyoung@huawei.com>
               : Dhruv Dhody <dhruv.ietf@gmail.com>";
    description
        "This module contains a YANG module for the ACTN VN. It
        describes a VN operation module that takes place in the
        context of the CNC-MDSC Interface (CMI) of the ACTN
        architecture where the CNC is the actor of a VN
        Instantiation/modification /deletion.";
    revision 2018-12-30 {
        description
            "initial version.";
        reference
```

```
            "TBD";
    }
    /*
     * Features
     */
    feature multi-src-dest {
        description
          "Support for selection of one src or destination
          among multiple.";
    }

    /*identity path-metric-delay {
       base te-types:path-metric-type;
       description
         "delay  path metric";
     }
     identity path-metric-delay-variation {
       base te-types:path-metric-type;
       description
         "delay-variation path metric";
     }
     identity path-metric-loss {
       base te-types:path-metric-type;
       description
         "loss path metric";
     }*/

     identity vn-state-type {
       description
         "Base identity for VN state";
     }
     identity vn-state-up {
         base vn-state-type;
         description "VN state up";
     }
     identity vn-state-down {
         base vn-state-type;
         description "VN state down";
     }
     identity vn-admin-state-type {
         description
           "Base identity for VN admin states";
     }
     identity vn-admin-state-up {
         base vn-admin-state-type;
```

```
        description "VN administratively state up";
      }
      identity vn-admin-state-down {
        base vn-admin-state-type;
        description "VN administratively state down";
      }
      identity vn-compute-state-type {
        description
          "Base identity for compute states";
      }
      identity vn-compute-state-computing {
        base vn-compute-state-type;
        description
          "State path compute in progress";
      }
      identity vn-compute-state-computation-ok {
        base vn-compute-state-type;
        description
          "State path compute successful";
      }
      identity vn-compute-state-computatione-failed {
        base vn-compute-state-type;
        description
          "State path compute failed";
      }
     /*
      * Groupings
      */

      typedef vn-disjointness {
           type bits {
                bit node {
                     position 0;
                     description "node disjoint";
                }
                bit link {
                     position 1;
                     description "link disjoint";
                }
                bit srlg {
                     position 2;
                     description "srlg disjoint";
                }
           }
           description
```

```
              "type of the resource disjointness for
               VN level applied across all VN members
               in a VN";
     }

    grouping vn-ap {
        description
            "VNAP related information";
        leaf vn-ap-id {
            type uint32;
            description
                "unique identifier for the referred
                VNAP";
        }
        leaf vn {
            type leafref {
               path "/actn/vn/vn-list/vn-id";
            }
            description
                 "reference to the VN";
        }
          leaf abstract-node {
               type leafref {
                    path "/nw:networks/nw:network/nw:node/"
                    + "tet:te-node-id";
                    }
               description
                    "a reference to the abstract node in TE
                    Topology";
          }
        leaf ltp {
            type te-types:te-tp-id;
            description
                "Reference LTP in the TE-topology";
        }
    }
    grouping access-point{
        description
            "AP related information";
        leaf access-point-id {
            type uint32;
            description
                "unique identifier for the referred
                access point";
        }
```

```
        leaf access-point-name {
            type string;
            description
                "ap name";
        }

        leaf max-bandwidth {
            type te-types:te-bandwidth;
            description
                "max bandwidth of the AP";
        }
        leaf avl-bandwidth {
            type te-types:te-bandwidth;
            description
                "available bandwidth of the AP";
        }
        /*add details and any other properties of AP,
        not associated by a VN
        CE port, PE port etc.
        */
        list vn-ap {
             key vn-ap-id;
             uses vn-ap;
             description
                 "list of VNAP in this AP";
        }
    }//access-point
    grouping vn-member {
        description
            "vn-member is described by this container";
        leaf vn-member-id {
            type uint32;
            description
                "vn-member identifier";
        }
        container src
        {
            description
                "the source of VN Member";
            leaf src {
                type leafref {
                    path "/actn/ap/access-point-list/access-point-id";
                }
                description
                    "reference to source AP";
```

```
            }
            leaf src-vn-ap-id{
                type leafref {
                    path "/actn/ap/access-point-list/vn-ap/vn-ap-id";
                }
                description
                    "reference to source VNAP";
            }
            leaf multi-src {
                if-feature multi-src-dest;
                type boolean;
                description
                    "Is source part of multi-source, where
                    only one of the source is enabled";
            }
        }
        container dest
        {
            description
                "the destination of VN Member";
            leaf dest {
                type leafref {
                    path "/actn/ap/access-point-list/access-point-id";
                }
                description
                    "reference to destination AP";
            }
            leaf dest-vn-ap-id{
                type leafref {
                    path "/actn/ap/access-point-list/vn-ap/vn-ap-id";
                }
                description
                    "reference to dest VNAP";
            }
            leaf multi-dest {
                if-feature multi-src-dest;
                type boolean;
                description
                    "Is destination part of multi-destination, where
                    only one of the destination is enabled";
            }
        }
        leaf connetivity-matrix-id{
            type leafref {
                path "/nw:networks/nw:network/nw:node/tet:te/"
```

```
                + "tet:te-node-attributes/"
                + "tet:connectivity-matrices/"
                + "tet:connectivity-matrix/tet:id";
            }
            description
                "reference to connetivity-matrix";
        }
    }//vn-member
    /*
    grouping policy {
        description
            "policy related to vn-member-id";
        leaf local-reroute {
            type boolean;
            description
                "Policy to state if reroute
                can be done locally";
        }
        leaf push-allowed {
            type boolean;
            description
                "Policy to state if changes
                can be pushed to the customer";
        }
        leaf incremental-update {
            type boolean;
            description
                "Policy to allow only the
                changes to be reported";
        }
    }//policy
    */
      grouping vn-policy {
           description
                "policy for VN-level diverisity";
           leaf vn-level-diversity {
                   type vn-disjointness;
                   description
                        "the type of disjointness on the VN level
                        (i.e., across all VN members)";
           }
      }
    /*
    grouping metrics-op {
        description
```

```
            "metric related information";
        list metric{
            key "metric-type";
            config false;
            description
                "The list of metrics for VN";
            leaf metric-type {
                type identityref {
                    base te-types:path-metric-type;
                }
                description
                    "The VN metric type.";
            }
            leaf value{
                type uint32;
                description
                    "The limit value";
            }
        }
    }
    */
    /*
    grouping metrics {
        description
            "metric related information";
        list metric{
            key "metric-type";
            description
                "The list of metrics for VN";
            uses te:path-metrics-bounds_config;
            container optimize{
                description
                    "optimizing constraints";
                leaf enabled{
                    type boolean;
                    description
                        "Metric to optimize";
                 }
                 leaf value{
                     type uint32;
                     description
                        "The computed value";
                }
            }
        }
```

```
    }
    */
    /*
    grouping service-metric {
        description
            "service-metric";
        uses te:path-objective-function_config;
        uses metrics;
        uses te-types:common-constraints_config;
        uses te:protection-restoration-params_config;
        uses policy;
    }//service-metric
    */
    /*
     * Configuration data nodes
     */
    container actn {
        description
            "actn is described by this container";
        container ap {
            description
                "AP configurations";
             list access-point-list {
                key "access-point-id";
                description
                    "access-point identifier";
                uses access-point{
                    description
                        "access-point information";
                }
             }
        }
        container vn {
            description
                "VN configurations";
            list vn-list {
                key "vn-id";
                description
                    "a virtual network is identified by a vn-id";
                leaf vn-id {
                    type uint32;
                    description
                        "a unique vn identifier";
                }
                leaf vn-name {
```

```
                    type string;
                    description "vn name";
                }
                leaf vn-topology-id{
                    type te-types:te-topology-id;
                    description
                        "An optional identifier to the TE Topology
                         Model where the abstract nodes and links
                         of the Topology can be found for Type 2
                         VNS";
                }
                leaf abstract-node {
                     type leafref {
                       path "/nw:networks/nw:network/nw:node/"
                            + "tet:te-node-id";
                     }
                     description
                       "a reference to the abstract node in TE
                        Topology";
                }
                list vn-member-list{
                    key "vn-member-id";
                    description
                        "List of VN-members in a VN";
                    uses vn-member;
                    /*uses metrics-op;*/
                    leaf oper-status {
                        type identityref {
                            base vn-state-type;
                        }
                        config false;
                        description
                            "VN-member operational state.";
                    }

                }
                  leaf if-selected{
                    if-feature multi-src-dest;
                      type boolean;
                      default false;
                    config false;
                      description
                          "Is the vn-member is selected among the
                           multi-src/dest options";
                  }
```

```
                /*
                container multi-src-dest{
                    if-feature multi-src-dest;
                    config false;
                    description
                        "The selected VN Member when multi-src
                        and/or mult-destination is enabled.";
                    leaf selected-vn-member{
                        type leafref {
                            path "/actn/vn/vn-list/vn-member-list"
                                 + "/vn-member-id";
                        }
                        description
                            "The selected VN Member along the set
                            of source and destination configured
                            with multi-source and/or multi-destination";
                    }
                }
                */
                /*uses service-metric;*/
                leaf admin-status {
                    type identityref {
                        base vn-admin-state-type;
                    }
                    default vn-admin-state-up;
                    description "VN administrative state.";
                }
                leaf oper-status {
                    type identityref {
                        base vn-state-type;
                    }
                    config false;
                    description "VN operational state.";
                }
                    uses vn-policy;
            }//vn-list
        }//vn
    }//actn
    /*
    * Notifications - TBD
    */
    /*
    * RPC
    */
    rpc  vn-compute{
```

```
        description
            "The VN computation without actual
            instantiation";
        input {
            leaf abstract-node {
                type leafref {
                  path "/nw:networks/nw:network/nw:node/"
                       + "tet:te-node-id";
                  }
                  description
                       "a reference to the abstract node in TE
                        Topology";
            }
            list vn-member-list{
                key "vn-member-id";
                description
                    "List of VN-members in a VN";
                uses vn-member;
            }
               uses vn-policy;
            /*uses service-metric;*/
        }
        output {
            list vn-member-list{
                key "vn-member-id";
                description
                    "List of VN-members in a VN";
                uses vn-member;
                  leaf if-selected{
                    if-feature multi-src-dest;
                      type boolean;
                      default false;
                      description
                          "Is the vn-member is selected among
                           the multi-src/dest options";
                  }
                /*uses metrics-op;*/
                leaf compute-status {
                    type identityref {
                        base vn-compute-state-type;
                    }
                    description
                        "VN-member compute state.";
                }
            }
```

```
            /*
            container multi-src-dest{
                if-feature multi-src-dest;
                description
                    "The selected VN Member when multi-src
                    and/or mult-destination is enabled.";
                leaf selected-vn-member-id{
                    type uint32;
                    description
                        "The selected VN Member-id from the
                        input";
                }
            }*/
        }
    }
}
```

<CODE ENDS>

7. JSON Example

This section provides json implementation examples as to how ACTN VN YANG model and TE topology model are used together to instantiate virtual networks.

The example in this section includes following VN

- VN1 (Type 1): Which maps to the single node topology abstract1 (node D1) and consist of VN Members 104 (L1 to L4), 107 (L1 to L7), 204 (L2 to L4), 308 (L3 to L8) and 108 (L1 to L8). We also show how disjointness (node, link, srlg) is supported in the example on the global level (i.e., connectivity matrices level).

- VN2 (Type 2): Which maps to the single node topology abstract2 (node D2), this topology has an underlay topology (absolute) (see figure in section 3.2). This VN has a single VN member 105 (L1 to L5) and an underlay path (S4 and S7) has been set in the connectivity matrix of abstract2 topology;

- VN3 (Type 1): This VN has a multi-source, multi-destination feature enable for VN Member 104 (L1 to L4)/107 (L1 to L7) [multi-src] and VN Member 204 (L2 to L4)/304 (L3 to L4) [multi-dest] usecase. The selected VN-member is known via the field "if-selected" and the corresponding connectivity-matrix-id.

Note that the VN YANG model also include the AP and VNAP which shows various VN using the same AP.

7.1. VN JSON

```
{
   "actn":{
      "ap":{
         "access-point-list": [
              {
               "access-point-id": 101,
               "access-point-name": "101",
               "vn-ap": [
                  {
                     "vn-ap-id": 10101,
                     "vn": 1,
                     "abstract-node": "D1",
                     "ltp": "1-0-1"
                  },
                  {
                     "vn-ap-id": 10102,
                     "vn": 2,
                     "abstract-node": "D2",
                     "ltp": "1-0-1"
                  },
                  {
                     "vn-ap-id": 10103,
                     "vn": 3,
                     "abstract-node": "D3",
                     "ltp": "1-0-1"
                  },
               ]
            },
            {
               "access-point-id": 202,
               "access-point-name": "202",
               "vn-ap": [
                  {
                     "vn-ap-id": 20201,
                     "vn": 1,
                     "abstract-node": "D1",
                     "ltp": "2-0-2"
                  }
```

```
            ]
         },
         {
            "access-point-id": 303,
            "access-point-name": "303",
            "vn-ap": [
               {
                  "vn-ap-id": 30301,
                  "vn": 1,
                  "abstract-node": "D1",
                  "ltp": "3-0-3"
               },
               {
                  "vn-ap-id": 30303,
                  "vn": 3,
                  "abstract-node": "D3",
                  "ltp": "3-0-3"
               }
            ]
         },
         {
            "access-point-id": 440,
            "access-point-name": "440",
            "vn-ap": [
               {
                  "vn-ap-id": 44001,
                  "vn": 1,
                  "abstract-node": "D1",
                  "ltp": "4-4-0"
               }
            ]
         },
         {
            "access-point-id": 550,
            "access-point-name": "550",
            "vn-ap": [
               {
                  "vn-ap-id": 55002,
                  "vn": 2,
                  "abstract-node": "D2",
                  "ltp": "5-5-0"
               }
            ]
         },
         {
            "access-point-id": 770,
            "access-point-name": "770",
            "vn-ap": [
```

```
                        "vn-ap-id": 77001,
                        "vn": 1,
                        "abstract-node": "D1",
                        "ltp": "7-7-0"
                     },
                     {
                        "vn-ap-id": 77003,
                        "vn": 3,
                        "abstract-node": "D3",
                        "ltp": "7-7-0"
                     }
                  ]
               },
               {
                  "access-point-id": 880,
                  "access-point-name": "880",
                  "vn-ap": [
                     {
                        "vn-ap-id": 88001,
                        "vn": 1,
                        "abstract-node": "D1",
                        "ltp": "8-8-0"
                     },
                     {
                        "vn-ap-id": 88003,
                        "vn": 3,
                        "abstract-node": "D3",
                        "ltp": "8-8-0"
                     }
                  ]
               }
            ]
         },
         "vn":{
            "vn-list": [
               {
                  "vn-id": 1,
                  "vn-name": "vn1",
                  "vn-topology-id": "te-topology:abstract1",
                  "abstract-node": "D1",
                  "vn-member-list": [
                     {
                        "vn-member-id": 104,
                        "src": {
                           "src": 101,
                           "src-vn-ap-id": 10101,
                        },
                        "dest": {
```

"dest": 440,

```
            "dest-vn-ap-id": 44001,
          },
          "connectivity-matrix-id": 104
        },
        {
          "vn-member-id": 107,
          "src": {
            "src": 101,
            "src-vn-ap-id": 10101,
          },
          "dest": {
            "dest": 770,
            "dest-vn-ap-id": 77001,
          },
          "connectivity-matrix-id": 107
        },
        {
          "vn-member-id": 204,
          "src": {
            "src": 202,
            "dest-vn-ap-id": 20401,
          },
          "dest": {
            "dest": 440,
            "dest-vn-ap-id": 44001,
          },
          "connectivity-matrix-id": 204
        },
        {
          "vn-member-id": 308,
          "src": {
            "src": 303,
            "src-vn-ap-id": 30301,
          },
          "dest": {
            "dest": 880,
            "src-vn-ap-id": 88001,
          },
          "connectivity-matrix-id": 308
        },
        {
          "vn-member-id": 108,
          "src": {
            "src": 101,
            "src-vn-ap-id": 10101,
          },
          "dest": {
            "dest": 880,
```

"dest-vn-ap-id": 88001,

```
                    },
                    "connectivity-matrix-id": 108
                 }
              ]
           },
           {
              "vn-id": 2,
              "vn-name": "vn2",
              "vn-topology-id": "te-topology:abstract2",
              "abstract-node": "D2",
              "vn-member-list": [
                 {
                    "vn-member-id": 105,
                    "src": {
                       "src": 101,
                       "src-vn-ap-id": 10102,
                    },
                    "dest": {
                       "dest": 550,
                       "dest-vn-ap-id": 55002,
                    },
                    "connectivity-matrix-id": 105
                 }
              ]
           },
           {
              "vn-id": 3,
              "vn-name": "vn3",
              "vn-topology-id": "te-topology:abstract3",
              "abstract-node": "D3",
              "vn-member-list": [
                 {
                    "vn-member-id": 104,
                    "src": {
                       "src": 101,
                    },
                    "dest": {
                       "dest": 440,
                       "multi-dest": true
                    }
                 },
                 {
                    "vn-member-id": 107,
                    "src": {
                       "src": 101,
                       "src-vn-ap-id": 10103,
                    },
                    "dest": {
```

"dest": 770,

```
                        "dest-vn-ap-id": 77003,
                        "multi-dest": true
                     },
                     "connectivity-matrix-id": 107,
                     "if-selected":true,
                  },
                  {
                     "vn-member-id": 204,
                     "src": {
                        "src": 202,
                        "multi-src": true,
                     },
                     "dest": {
                        "dest": 440,
                     },
                  },
                  {
                     "vn-member-id": 304,
                     "src": {
                        "src": 303,
                        "src-vn-ap-id": 30303,
                        "multi-src": true,
                     },
                     "dest": {
                        "dest": 440,
                        "src-vn-ap-id": 44003,
                     },
                     "connectivity-matrix-id": 304,
                     "if-selected":true,
                  },
               ]
            },

         ]
      }

   }
}
```

7.2. TE-topology JSON

```
{
     "networks": {
       "network": [
         {
           "network-types": {
             "te-topology": {}
           },
```

```
            "network-id": "abstract1",
```

```
              "provider-id": 201,
              "client-id": 600,
              "te-topology-id": "te-topology:abstract1",
              "node": [
                {
                  "node-id": "D1",
                  "te-node-id": "2.0.1.1",
                  "te": {
                    "te-node-attributes": {
                      "domain-id" : 1,
                      "is-abstract": [null],
                      "connectivity-matrices": {
                        "is-allowed": true,
                        "path-constraints": {
                          "bandwidth-generic": {
                            "te-bandwidth": {
                              "generic": [
                                {
                                  "generic": "0x1p10",
                                }
                              ]
                            }
                          }
                          "disjointness": "node link srlg",

                        },
                        "connectivity-matrix": [
                          {
                            "id": 104,
                            "from": "1-0-1",
                            "to": "4-4-0"
                          },
                          {
                            "id": 107,
                            "from": "1-0-1",
                            "to": "7-7-0"
                          },
                          {
                            "id": 204,
                            "from": "2-0-2",
                            "to": "4-4-0"
                          },
                          {
                            "id": 308,
                            "from": "3-0-3",
                            "to": "8-8-0"
                          },
                          {
```

"id": 108,

```
                    "from": "1-0-1",
                    "to": "8-8-0"
                  },
                ]
              }
            }
          },
          "termination-point": [
            {
              "tp-id": "1-0-1",
              "te-tp-id": 10001,
              "te": {
                "interface-switching-capability": [
                  {
                    "switching-capability": "switching-otn",
                    "encoding": "lsp-encoding-oduk"
                    }
                ]
              }
            },
            {
              "tp-id": "1-1-0",
              "te-tp-id": 10100,
              "te": {
                "interface-switching-capability": [
                  {
                    "switching-capability": "switching-otn",
                      "encoding": "lsp-encoding-oduk"
                  }
                ]
              }
            },
            {
              "tp-id": "2-0-2",
              "te-tp-id": 20002,
              "te": {
                "interface-switching-capability": [
                  {
                    "switching-capability": "switching-otn",
                    "encoding": "lsp-encoding-oduk"
                  }
                ]
              }
            },
            {
              "tp-id": "2-2-0",
              "te-tp-id": 20200,
              "te": {
```

```
"interface-switching-capability": [
```

```
            {
              "switching-capability": "switching-otn",
              "encoding": "lsp-encoding-oduk"
            }
          ]
        }
      },
      {
        "tp-id": "3-0-3",
        "te-tp-id": 30003,
        "te": {
          "interface-switching-capability": [
            {
              "switching-capability": "switching-otn",
              "encoding": "lsp-encoding-oduk"
            }
          ]
        }
      },
      {
        "tp-id": "3-3-0",
        "te-tp-id": 30300,
        "te": {
          "interface-switching-capability": [
            {
              "switching-capability": "switching-otn",
              "encoding": "lsp-encoding-oduk"
            }
          ]
        }
      },
      {
        "tp-id": "4-0-4",
        "te-tp-id": 40004,
        "te": {
          "interface-switching-capability": [
            {
              "switching-capability": "switching-otn",
              "encoding": "lsp-encoding-oduk"
            }
          ]
        }
      },
      {
        "tp-id": "4-4-0",
        "te-tp-id": 40400,
        "te": {
          "interface-switching-capability": [
```

```
            "switching-capability": "switching-otn",
            "encoding": "lsp-encoding-oduk"
          }
        ]
      }
    },
    {
      "tp-id": "5-0-5",
      "te-tp-id": 50005,
      "te": {
        "interface-switching-capability": [
          {
            "switching-capability": "switching-otn",
            "encoding": "lsp-encoding-oduk"
          }
        ]
      }
    },
    {
      "tp-id": "5-5-0",
      "te-tp-id": 50500,
      "te": {
        "interface-switching-capability": [
          {
            "switching-capability": "switching-otn",
            "encoding": "lsp-encoding-oduk"
          }
        ]
      }
    },
    {
      "tp-id": "6-0-6",
      "te-tp-id": 60006,
      "te": {
        "interface-switching-capability": [
          {
            "switching-capability": "switching-otn",
            "encoding": "lsp-encoding-oduk"
          }
        ]
      }
    },
    {
      "tp-id": "6-6-0",
      "te-tp-id": 60600,
      "te": {
        "interface-switching-capability": [
          {
```

"switching-capability": "switching-otn",

```
            "encoding": "lsp-encoding-oduk"
          }
        ]
      }
    },
    {
      "tp-id": "7-0-7",
      "te-tp-id": 70007,
      "te": {
        "interface-switching-capability": [
          {
            "switching-capability": "switching-otn",
            "encoding": "lsp-encoding-oduk"
          }
        ]
      }
    },
    {
      "tp-id": "7-7-0",
      "te-tp-id": 70700,
      "te": {
        "interface-switching-capability": [
          {
            "switching-capability": "switching-otn",
            "encoding": "lsp-encoding-oduk"
          }
        ]
      }
    },
    {
      "tp-id": "8-0-8",
      "te-tp-id": 80008,
      "te": {
        "interface-switching-capability": [
          {
            "switching-capability": "switching-otn",
            "encoding": "lsp-encoding-oduk"
          }
        ]
      }
    },
    {
      "tp-id": "8-8-0",
      "te-tp-id": 80800,
      "te": {
        "interface-switching-capability": [
          {
            "switching-capability": "switching-otn",
```

```
"encoding": "lsp-encoding-oduk"
```

```
                          }
                        ]
                      }
                    }
                  ]
                }
              ]
            },
            {
              "network-types": {
                "te-topology": {}
              },
              "network-id": "abstract2",
              "provider-id": 201,
              "client-id": 600,
              "te-topology-id": "te-topology:abstract2",
              "node": [
               {
                  "node-id": "D2",
                  "te-node-id": "2.0.1.2",
                  "te": {
                    "te-node-attributes": {
                      "domain-id" : 1,
                      "is-abstract": [null],
                      "connectivity-matrices": {
                        "is-allowed": true,
                        "underlay": {
                           "enabled": true
                        },
                        "path-constraints": {
                          "bandwidth-generic": {
                            "te-bandwidth": {
                              "generic": [
                                {
                                  "generic": "0x1p10"
                                }
                              ]
                            }
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                               "objective-function-type": "of-maximize-
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   bandwidth"
                           }
                        },
                        "connectivity-matrix": [
```

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{
  "id": 105,
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                        "from": "1-0-1",
                        "to": "5-5-0",
                        "underlay": {
                           "enabled": true,
                           "primary-path": {
                               "network-ref": "absolute",
                               "path-element": [
                                 {
                                   "path-element-id": 1,
                                   "index": 1,
                                   "numbered-hop": {
                                     "address": "4.4.4.4",
                                     "hop-type": "STRICT"
                                    }
                                 },
                                 {
                                   "path-element-id": 2,
                                   "index": 2,
                                   "numbered-hop": {
                                     "address": "7.7.7.7",
                                     "hop-type": "STRICT"
                                   }
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                               ]
                           }
                        }
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              },
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                        "switching-capability": "switching-otn",
                        "encoding": "lsp-encoding-oduk"
                      }
                    ]
                  }
                },
                {
                  "tp-id": "1-1-0",
                  "te-tp-id": 10100,
                  "te": {
```

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```
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              "encoding": "lsp-encoding-oduk"
          }
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      "te-tp-id": 20002,
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        "interface-switching-capability": [
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            "switching-capability": "switching-otn",
            "encoding": "lsp-encoding-oduk"
          }
        ]
      }
    },
    {
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      "te-tp-id": 20200,
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          {
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            "encoding": "lsp-encoding-oduk"
          }
        ]
      }
    },
    {
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      "te-tp-id": 30003,
      "te": {
        "interface-switching-capability": [
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            "switching-capability": "switching-otn",
            "encoding": "lsp-encoding-oduk"
          }
        ]
      }
    },
    {
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      "te": {
        "interface-switching-capability": [
```

```
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            "encoding": "lsp-encoding-oduk"
          }
        ]
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    },
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            "encoding": "lsp-encoding-oduk"
          }
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            "encoding": "lsp-encoding-oduk"
          }
        ]
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      "te-tp-id": 50005,
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          {
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            "encoding": "lsp-encoding-oduk"
          }
        ]
      }
    },
    {
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      "te-tp-id": 50500,
      "te": {
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          {
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"switching-capability": "switching-otn",

```
            "encoding": "lsp-encoding-oduk"
          }
        ]
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            "encoding": "lsp-encoding-oduk"
          }
        ]
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      "te-tp-id": 60600,
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            "encoding": "lsp-encoding-oduk"
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            "encoding": "lsp-encoding-oduk"
          }
        ]
      }
    },
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```
"encoding": "lsp-encoding-oduk"
```

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                          "encoding": "lsp-encoding-oduk"
                        }
                      ]
                    }
                  },
                  {
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                    "te-tp-id": 80800,
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                          "switching-capability": "switching-otn",
                          "encoding": "lsp-encoding-oduk"
                        }
                      ]
                    }
                  }
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            "provider-id": 201,
            "client-id": 600,
            "te-topology-id": "te-topology:abstract3",
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                    "domain-id" : 3,
                    "is-abstract": [null],
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                        "te-bandwidth": {
                          "generic": [
                            {
                              "generic": "0x1p10",
                            }
                          ]
                        }
                      }
                    },
                    "connectivity-matrix": [
                      {
                        "id": 107,
                        "from": "1-0-1",
                        "to": "7-7-0"
                      },
                      {
                        "id": 308,
                        "from": "3-0-3",
                        "to": "8-8-0"
                      },
                    ]
                  }
                }
              },
              "termination-point": [
                {
                  "tp-id": "1-0-1",
                  "te-tp-id": 10001,
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                    "interface-switching-capability": [
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                        "switching-capability": "switching-otn",
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                        }
                    ]
                  }
                },
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                    "interface-switching-capability": [
                      {
                        "switching-capability": "switching-otn",
                          "encoding": "lsp-encoding-oduk"
```

```
                        }
```

```
          ]
        }
      },
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              "switching-capability": "switching-otn",
              "encoding": "lsp-encoding-oduk"
            }
          ]
        }
      },
      {
        "tp-id": "2-2-0",
        "te-tp-id": 20200,
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          "interface-switching-capability": [
            {
              "switching-capability": "switching-otn",
              "encoding": "lsp-encoding-oduk"
            }
          ]
        }
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              "encoding": "lsp-encoding-oduk"
            }
          ]
        }
      },
      {
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        "te": {
          "interface-switching-capability": [
            {
              "switching-capability": "switching-otn",
              "encoding": "lsp-encoding-oduk"
            }
```

]

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            {
              "switching-capability": "switching-otn",
              "encoding": "lsp-encoding-oduk"
            }
          ]
        }
      },
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        "te-tp-id": 40400,
        "te": {
          "interface-switching-capability": [
            {
              "switching-capability": "switching-otn",
              "encoding": "lsp-encoding-oduk"
            }
          ]
        }
      },
      {
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        "te-tp-id": 50005,
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            {
              "switching-capability": "switching-otn",
              "encoding": "lsp-encoding-oduk"
            }
          ]
        }
      },
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        "te-tp-id": 50500,
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            {
              "switching-capability": "switching-otn",
              "encoding": "lsp-encoding-oduk"
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          ]
```

```
                    }
```

```
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                            "encoding": "lsp-encoding-oduk"
                          }
                        ]
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                            "encoding": "lsp-encoding-oduk"
                          }
                        ]
                      }
                    },
                    {
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                            "encoding": "lsp-encoding-oduk"
                          }
                        ]
                      }
                    },
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                        "interface-switching-capability": [
                          {
                            "switching-capability": "switching-otn",
                            "encoding": "lsp-encoding-oduk"
                          }
                        ]
                      }
```

```
                    },
```

```
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                            "encoding": "lsp-encoding-oduk"
                          }
                        ]
                      }
                    },
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                          }
                        ]
                      }
                    }
                  ]
                }
              ]
            },
          ]
        }
      }
```

8. Security Considerations

The configuration, state, and action data defined in this document are designed to be accessed via a management protocol with a secure transport layer, 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 NETCONF access control model [RFC8341] provides the means to restrict access for particular NETCONF users to a preconfigured subset of all available NETCONF protocol operations and content.

The model presented in this document is used in the interface between the Customer Network Controller (CNC) and Multi-Domain Service Coordinator (MDSC), which is referred to as CNC-MDSC Interface (CMI). Therefore, many security risks such as malicious attack and rogue elements attempting to connect to various ACTN components. Furthermore, some ACTN components (e.g., MSDC) represent a single point of failure and threat vector and must also manage policy conflicts and eavesdropping of communication between different ACTN components.

A number of configuration data nodes defined in this document are writable/deletable (i.e., "config true") These data nodes may be considered sensitive or vulnerable in some network environments.

These are the subtrees and data nodes and their sensitivity/vulnerability:

- access-point-list:
    - o access-point-id
    - o max-bandwidth
    - o avl-bandwidth

- vn-ap:
    - o vn-ap-id
    - o vn
    - o abstract-node
    - o ltp

- vn-list
    - o vn-id
    - o vn-topology-id
    - o abstract-node

- vn-member-id
    - o src
    - o src-vn-ap-id
    - o dest

- dest-vn-ap-id
- connectivity-matrix-id

9. IANA Considerations

This document registers the following namespace URIs in the IETF XML registry [RFC3688]:

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

This document registers the following YANG modules in the YANG Module

Names registry [RFC6020]:

```
---------------------------------------------------------------------
name:         ietf-vn
namespace:    urn:ietf:params:xml:ns:yang:ietf-vn
reference:    RFC XXXX (TDB)
---------------------------------------------------------------------
```

10. Acknowledgments

The authors would like to thank Xufeng Liu and Adrian Farrel for their helpful comments and valuable suggestions.

11. References

11.1. Normative References

[TE-TOPO] X. Liu, et al., "YANG Data Model for TE Topologies", work in progress: draft-ietf-teas-yang-te-topo.

[TE-tunnel] T. Saad, et al., "A YANG Data Model for Traffic Engineering Tunnels and Interfaces", work in progress: draft-ietf-teas-yang-te.

11.2. Informative References

[RFC7926] A. Farrel (Ed.), "Problem Statement and Architecture for Information Exchange between Interconnected Traffic-Engineered Networks", RFC 7926, July 2016.

[RFC8453] D. Ceccarelli and Y. Lee (Editors), "Framework for Abstraction and Control of Traffic Engineered Networks", RFC 8453, August 2018.

[TE-MAP] Y. Lee, D. Dhody, and D. Ceccarelli, "Traffic Engineering and Service Mapping Yang Model", draft-lee-teas-te-service-mapping-yang, work in progress.

[ACTN-PM] Y. Lee, et al., "YANG models for ACTN TE Performance Monitoring Telemetry and Network Autonomics", draft-lee-teas-actn-pm-telemetry-autonomics, work in progress.

[L1CSM] G. Fioccola, Ed. & Y. Lee, Ed., "A Yang Data Model for L1 Connectivity Service Model (L1CSM)", draft-ietf-ccamp-l1csm-yang, work in progress.

[L2SM] G. Fioccola, Ed., "A YANG Data Model for L2VPN Service Delivery", draft-ietf-l2sm-l2vpn-service-model, work in progress.

[RFC8299] Q. Wu, Ed., S. Litkowski, L. Tomotaki, and K. Ogaki, "YANG Data Model for L3VPN Service Delivery", RFC 8299, January 2018.

[RFC8309] Q. Wu, W. Cheng, and A. Farrel. "Service Models Explained", RFC 8309, January 2018.

[RFC8340] M. Bjorklund and L. Berger (Editors), "YANG Tree Diagrams", RFC 8340, March 2018.

[RFC8345] A. Clemm, et al, "A YANG Data Model for Network Topologies", RFC 8345, March 2018.

[RFC8342] Bjorklund, M., Schoenwaelder, J., Shafer, P., Watsen, K., and R. Wilton, "Network Management Datastore Architecture (NMDA)", RFC 8342, March 2018.

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