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YANG models for Virtual Network (VN)/TE Performance Monitoring Telemetry and Scaling Intent Autonomics
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Abstract

This document provides YANG data models that describe the performance monitoring parameters and scaling intent mechanisms for TE-tunnels and Virtual Networks (VNs). Their performance monitoring parameters are exposed as the key telemetry data for tunnels and VN.

The models presented in this document allow customers to subscribe to and monitor the key performance data of the TE-tunnel or the VN. The models also provide customers with the ability to program autonomic scaling intent mechanisms on the level of TE-tunnel as well as VN.

Status of This Memo

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

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This Internet-Draft will expire on 23 October 2025.

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1. Introduction

The YANG [RFC7950] model in [RFC9731] is used to operate customer-driven Virtual Networks (VNs) during the computation of VN, its instantiation, and its life-cycle service management and operations. The YANG model in [I-D.ietf-teas-yang-te] is used to operate TE-tunnels during the tunnel instantiation, and their life-cycle management and operations.

The models presented in this document allow the applications hosted by the customers to subscribe to and monitor the key performance data of their interest on the level of VN [RFC9731] or TE-tunnel [I-D.ietf-teas-yang-te]. The key characteristic of the models presented in this document is their top-down programmability, which enables customer-hosted applications to subscribe to and monitor the key performance data of their interest, as well as utilize the autonomic scaling intent mechanism at both the VN and TE-tunnel levels.

According to the classification of [RFC8309], the YANG data models presented in this document can be classified as customer service models. These can be mapped to the CMI (Customer Network Controller (CNC)- Multi-Domain Service Coordinator (MSDC) interface) of Abstraction and Control of TE Networks (ACTN) [RFC8453].

[RFC8233] describes key network performance data to be considered for end-to-end path computation in TE networks. The services provided can be optimized to meet the requirements (such as traffic patterns, quality, and reliability) of the applications hosted by the customers.

This document provides YANG data models with performance monitoring parameters that can be subscribed to for monitoring and telemetry for any VN/TE-Tunnel via the mechanism specified in [RFC8641] and [RFC8640]. It also provides the ability to program their customized automatic scaling in/out intent. A client network controller can utilize these models and initiate the capabilities via a NETCONF [RFC8341] or a RESTCONF [RFC8040] interface.

The term ’Performance monitoring’ in this document refers to the subscription and publication of streaming telemetry data. Subscription is initiated by the client (e.g., CNC) while publication is provided by the network (e.g., MDSC/Provisioning Network Controller (PNC)) based on the client’s subscription. As per [RFC7799], this would be classified as a passive method. Note that the actual measurements might be done via any technique, though. As the scope of performance monitoring in this document is to augment the performance monitoring parameters (telemetry data) on the level

of a client's VN or TE-tunnel, the entity interfacing to the client (e.g., MDSC) has to provide VN or TE-tunnel level information. This requires the controller to be able to derive VN or TE-tunnel level performance data based on lower-level data collected via PM counters in the Network Elements (NE). How the controller entity derives such customized level data (i.e., VN or TE-tunnel level) is out of the scope of this document.

The data model includes configuration and state data according to the Network Management Datastore Architecture (NMDA) [RFC8342].

1.1. Terminology

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

Scaling: This refers to the network's ability to reshape its own resources. "Scale-out" refers to improving network performance by increasing the allocated resources, while "scale-in" refers to decreasing the allocated resources, typically because the existing resources are unnecessary.

Scaling Intent: Scaling intent is used to declare scaling conditions. Specifically, scaling intent refers to how the client programs or configures conditions that will be applied to their key performance data to trigger either scaling out or scaling in. Various conditions can be set for scaling intent on either the VN or TE-tunnel level.

Network Autonomics: This refers to the network automation capability that allows a client to initiate scaling intent mechanisms and provides the client with the status of the adjusted network resources based on the client's scaling intent in an automated fashion.

1.2. Tree Diagram

A simplified graphical representation of the data model is used in Section 4 and Section 8 of this document. The meaning of the symbols in these diagrams is defined in [RFC8340].

1.3. Prefixes in Data Node Names

In this document, the 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
te	ietf-te	[I-D.ietf-teas-yang-te]
te-types	ietf-te-types	[RFC8776]
rt-types	ietf-routing-types	[RFC8294]
te-tel	ietf-te-telemetry	[RFCXXXX]
vn	ietf-vn	[RFC9731]
vn-tel	ietf-vn-telemetry	[RFCXXXX]

Table 1: Prefixes and corresponding YANG modules

Note: The RFC Editor is requested to replace XXXX with the number assigned to the RFC once this draft becomes an RFC, and to remove this note.

Further, the following additional documents are referenced in the model defined in this document -

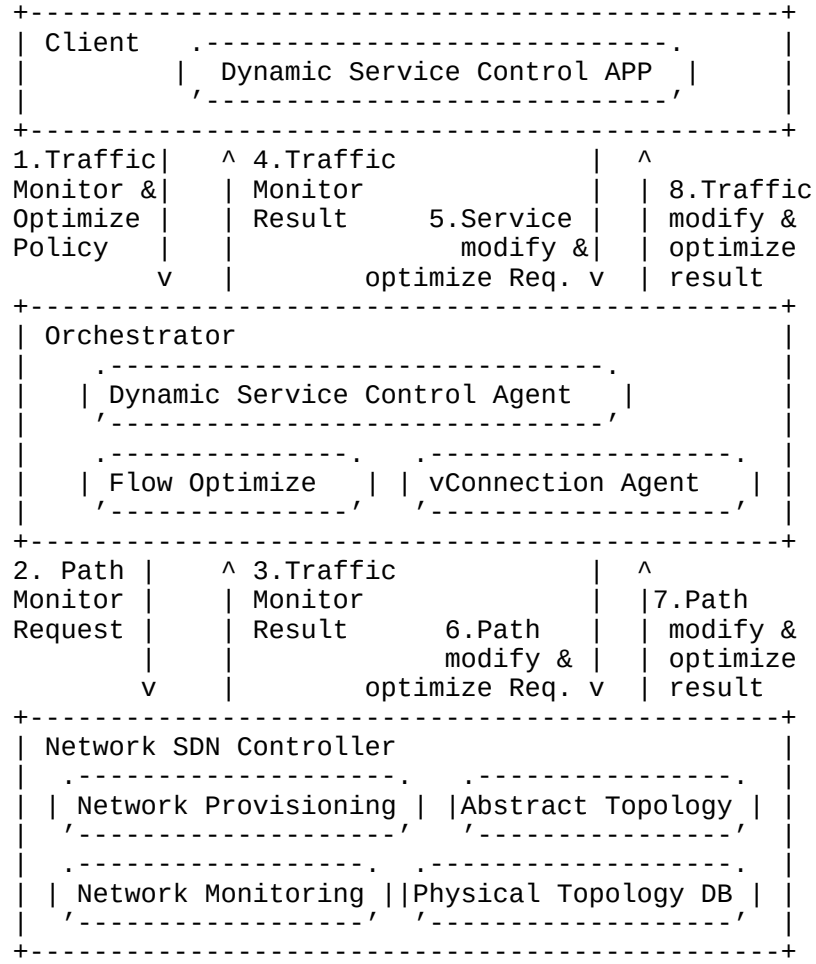
* [RFC7471] - OSPF Traffic Engineering (TE) Metric Extensions.

* [RFC8570] - IS-IS Traffic Engineering (TE) Metric Extensions.

* [RFC7823] - Performance-Based Path Selection for Explicitly Routed Label Switched Paths (LSPs) Using TE Metric Extensions.

2. Use-Cases

There is a need for real-time (or semi-real-time) traffic monitoring of the network to optimize the network and the traffic distribution. Figure 1 shows an example of a high-level workflow for dynamic service control based on traffic monitoring that could use the mechanism described in this document.



APP: Application
DB: Database
Req: Request

Figure 1: Workflow for dynamic service control based on traffic monitoring

Some of the key points are as follows:

* Network traffic monitoring is important to facilitate the automatic discovery of the imbalance of network traffic, and initiate network optimization, thus helping the network operator or the virtual network service provider to use the network more efficiently and save Capital Expenses (CAPEX) and Operating Expenses (OPEX).

* Customer services have various Service Level Agreements (SLA) requirements, such as service availability, latency, jitter, packet loss rate, Bit Error Rate (BER), etc. The TE network can satisfy service availability and BER requirements by providing different protection and restoration mechanisms. However, for other SLA requirements (like latency), there are no such mechanisms. In order to provide high-quality services according to the customer SLA, one possible solution is to measure the SLA-related performance parameters, and dynamically provision and optimize services based on the performance monitoring results.

* Performance monitoring in a large-scale network could generate a huge amount of performance information. Therefore, the appropriate way to deliver the information to the client and network interfaces should be carefully considered.

3. Design of the Data Models

This document describes two YANG models:

(i) TE Telemetry Model, which provides the TE-Tunnel level of

performance monitoring mechanism and scaling intent mechanism that allows scale in/out programming by the customer. (See Section 3.1 & Section 9.1 for details).

(ii) VN Telemetry Model, which provides the VN level of the

aggregated performance monitoring mechanism and scaling intent mechanism that allows scale-in/out programming by the customer (See Section 3.2 & Section 9.2 for details).

3.1. TE Telemetry Model

This model describes the performance telemetry for the TE tunnel. The telemetry data is augmented to the TE tunnel. This model also allows autonomic traffic engineering scaling-intent configuration mechanism on the TE-tunnel level. Various conditions can be set for auto-scaling based on the telemetry data (See Section 6 for details)

As shown in Figure 2, the TE Telemetry Model augments the TE-Tunnel Model to enhance TE performance monitoring capability. This monitoring capability will facilitate the re-optimization and reconfiguration of TE tunnels based on the performance monitoring data collected via the TE Telemetry YANG model.

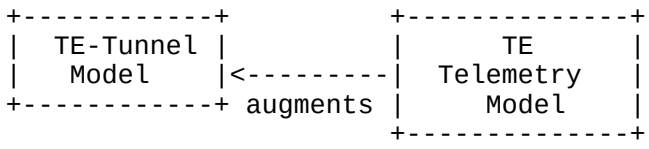


Figure 2: TE Telemetry Model Relationship

3.2. VN Telemetry Model

As shown in Figure 3, the VN Telemetry Model augments the basic VN model to enhance VN monitoring capability. This monitoring capability will facilitate re-optimization and reconfiguration of VNs based on the performance monitoring data collected via the VN Telemetry YANG model. This model also imports the TE telemetry model to reuse the groupings.

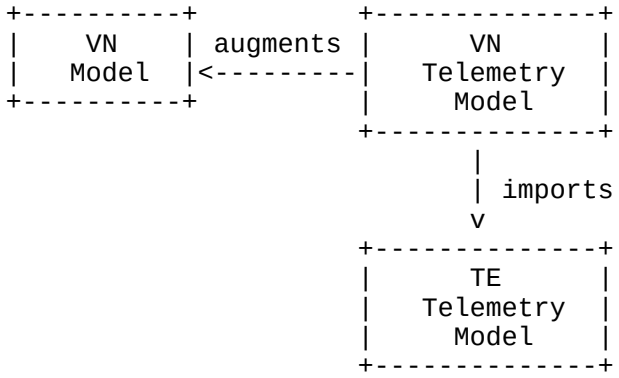


Figure 3: VN Telemetry Model Relationships

This model describes the performance telemetry for the VN model. The telemetry data is augmented to the VN model at the VN Level as well as at the individual VN member level. This model also allows autonomic traffic engineering scaling intent configuration mechanism on the VN level. Scale-in/out criteria might be used for network autonomics in order for the controller to react to a certain set of variations in monitored parameters (See Section 4 for illustrations).

Moreover, this model also provides a mechanism to define aggregated VN telemetry parameters as a grouping of underlying VN-member level telemetry parameters. This is unique to the VN model as a VN comprises multiple VN-members, and each VN-member could be further set across multiple TE tunnels. Grouping operations (such as maximum and mean) could be set at the time of configuration. For example, if the "maximum" grouping operation is used for delay at the VN level, the VN telemetry data is reported as the maximum of {delay_vn_member_1, delay_vn_member_2,... delay_vn_member_N}. Thus, this telemetry aggregation mechanism allows the aggregation (or grouping) of a certain common set of telemetry values under a grouping operation. This can also be done at the VN-member level to suggest how the end-to-end (E2E) telemetry can be inferred from the per-domain tunnels created and monitored by PNCs. Figure 4 provides an example of interactions.

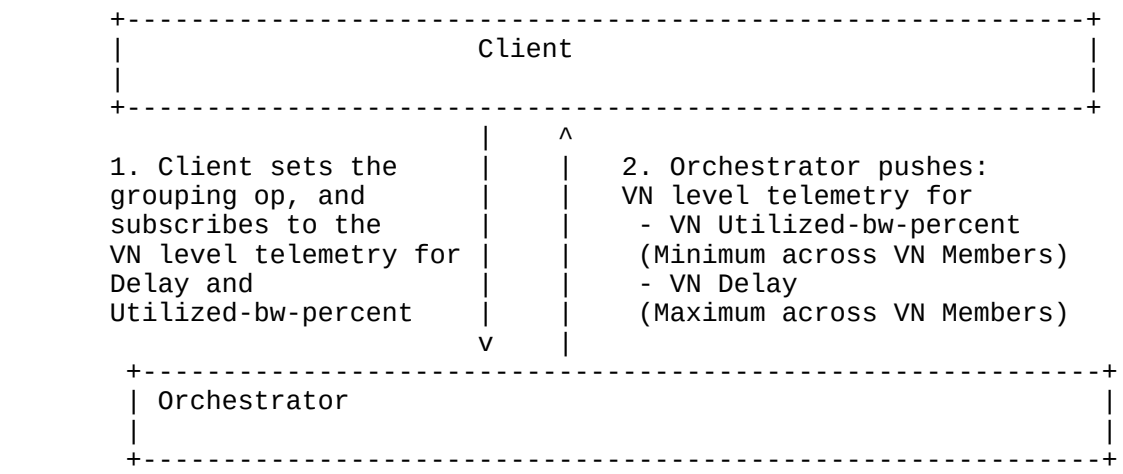


Figure 4: TE Telemetry Model Interactions

3.3. VPN Service Performance Monitoring

The YANG model in [I-D.ietf-opsawg-yang-vpn-service-pm] provides network performance monitoring (PM) and VPN service performance monitoring that can be used to monitor and manage network performance on the topology at higher layers or the service topology between VPN sites. Thus the YANG models in this document could be used alongside ietf-network-vpn-pm to understand and correlate the performance monitoring at the VPN service and the underlying TE level.

4. Autonomic Scaling Intent Mechanism

The scaling intent configuration mechanism allows the client to configure automatic scale-in and scale-out mechanisms on both the TE-tunnel and the VN level. Various conditions can be set for auto-scaling based on the PM telemetry data.

There are several parameters involved in the mechanism:

* Scale-out-intent or Scale-in-intent: whether to scale-out or scale-in.

* Performance-type: performance metric type (e.g., one-way-delay, one-way-delay-min, one-way-delay-max, two-way-delay, two-way-delay-min, two-way-delay-max, utilized bandwidth, etc.)

* Threshold-value: the threshold value for a certain Performance-type that triggers scale-in or scale-out.

* scaling-operation-type: in the case where the scaling condition can be set with one or more performance types, then scaling-operation-type (AND, OR, MIN, MAX, etc.) is applied to these selected performance types and their threshold values.

* Threshold-time: the duration for which the criteria need to hold true.

* Cooldown-time: the duration after a scaling action has been triggered, for which there will be no further operation.

The tree in Figure 5 is a part of ietf-te-telemetry tree whose model is presented in full detail in Sections 6 & 7.

```
module: ietf-te-telemetry

  augment /te:te/te:tunnels/te:tunnel:
    +--rw te-scaling-intent
    |  +--rw scale-in-intent
    |  |  +--rw threshold-time?      uint32
    |  |  +--rw cooldown-time?       uint32
    |  |  +--rw scaling-condition* [performance-type]
    |  |  |  +--rw performance-type           identityref
    |  |  |  +--rw threshold-value?           scale-value
    |  |  |  +--rw scale-in-operation-type?
    |  |  |          scaling-criteria-operation
    |  |  +--rw scale-in-op?         scale-op
    |  |  +--rw scale?               scale-value
    |  +--rw scale-out-intent
    |     +--rw threshold-time?      uint32
    |     +--rw cooldown-time?       uint32
    |     +--rw scaling-condition* [performance-type]
    |     |  +--rw performance-type            identityref
    |     |  +--rw threshold-value?            scale-value
    |     |  +--rw scale-out-operation-type?
    |     |          scaling-criteria-operation
    |     +--rw scale-out-op?        scale-op
    |     +--rw scale?               scale-value
```

Figure 5: The scaling intent

Let’s say the client wants to set the scaling out operation based on two performance-types (e.g., two-way-delay and utilized-bandwidth for a te-tunnel), it can be done as follows:

* Set Threshold-time: x (sec) (duration for which the criteria must hold true)

* Set Cooldown-time: y (sec) (the duration after a scaling action has been triggered, for which there will be no further operation)

* Set AND for the scale-out-operation-type

In the scaling condition’s list, the following two components can be set:

List 1: Scaling Condition for Two-way-delay

* performance type: Two-way-delay

* threshold-value: z milli-seconds

List 2: Scaling Condition for Utilized bandwidth

* performance type: Utilized bandwidth

* threshold-value: w megabytes

Refer to Section 7 for some examples of scaling intent.

5. Performance Monitoring Parameters

This model augments the Tunnel model to include performance parameters from the grouping performance-metrics-attributes from te-types [RFC8776]:

* one-way-delay

* one-way-delay-normality

* one-way-residual-bandwidth

* one-way-residual-bandwidth-normality

* one-way-available-bandwidth

* one-way-available-bandwidth-normality

* one-way-utilized-bandwidth

* one-way-utilized-bandwidth-normality

* two-way-delay

* two-way-delay-normality

```
      +--ro te-telemetry
         +--ro performance-metrics-one-way
         |  +--ro one-way-delay?                          uint32
         |  +--ro one-way-delay-normality?
         |  |       te-types:performance-metrics-normality
         |  +--ro one-way-residual-bandwidth?
         |  |       rt-types:bandwidth-ieee-float32
         |  +--ro one-way-residual-bandwidth-normality?
         |  |       te-types:performance-metrics-normality
         |  +--ro one-way-available-bandwidth?
         |  |       rt-types:bandwidth-ieee-float32
         |  +--ro one-way-available-bandwidth-normality?
         |  |       te-types:performance-metrics-normality
         |  +--ro one-way-utilized-bandwidth?
         |  |       rt-types:bandwidth-ieee-float32
         |  +--ro one-way-utilized-bandwidth-normality?
         |          te-types:performance-metrics-normality
         +--ro performance-metrics-two-way
            +--ro two-way-delay?             uint32
            +--ro two-way-delay-normality?
                    te-types:performance-metrics-normality
```

Figure 6: Performance Monitoring Parameters

6. Notification

This model does not define specific notifications. To enable notifications, the mechanism defined in [RFC8641] and [RFC8640] can be used. This mechanism currently allows the user to:

* Subscribe to notifications on a per-client basis.

* Specify subtree filters or xpath filters so that only interested contents will be sent.

* Specify either periodic or on-demand notifications.

6.1. YANG Push Subscription Examples

[RFC8641] allows subscriber applications to request a continuous, customized stream of updates from a YANG datastore.

The example in Figure 7 shows the way for a client to subscribe to the telemetry information for a particular tunnel (Tunnel1). The telemetry parameter that the client is interested in is one-way-delay.

```
<netconf:rpc netconf:message-id="101"
    xmlns:netconf="urn:ietf:params:xml:ns:netconf:base:1.0">
    <establish-subscription
       xmlns="urn:ietf:params:xml:ns:yang:ietf-yang-push:1.0">
       <filter netconf:type="subtree">
          <te xmlns="urn:ietf:params:xml:ns:yang:ietf-te">
             <tunnels>
                <tunnel>
                  <name>Tunnel1</name>
                    <te-telemetry xmlns="urn:ietf:params:xml:ns:yang:
                                         ietf-te-telemetry">
                        <performance-metrics-one-way>
                           <one-way-delay/>
                        </performance-metrics-one-way>
                     </te-telemetry>
                  </tunnel>
              </tunnels>
          </te>
       </filter>
       <period>500</period>
       <encoding>encode-xml</encoding>
    </establish-subscription>
 </netconf:rpc>
```

Figure 7: TE Tunnel Subscription Example

The example in Figure 8 shows the way for a client to subscribe to the telemetry information for all VNs. The telemetry parameter that the client is interested in is one-way-delay and one-way-utilized-bandwidth.

```
<netconf:rpc netconf:message-id="101"
    xmlns:netconf="urn:ietf:params:xml:ns:netconf:base:1.0">
  <establish-subscription
     xmlns="urn:ietf:params:xml:ns:yang:ietf-yang-push:1.0">
     <filter netconf:type="subtree">
        <virtual-network xmlns="urn:ietf:params:xml:ns:yang:ietf-vn">
           <vn>
                <vn-id/>
                <vn-telemetry xmlns="urn:ietf:params:xml:ns:yang:
                                        ietf-vn-telemetry">
                  <params>
                    <performance-metrics-one-way>
                      <one-way-delay/>
                      <one-way-utilized-bandwidth/>
                    </performance-metrics-one-way>
                  </params>
                </vn-telemetry>
            </vn>
        </virtual-network>
     </filter>
     <period>500</period>
  </establish-subscription>
</netconf:rpc>
```

Figure 8: VN Subscription Example

7. Scaling Examples

The example in Figure 9 shows the way to configure a TE tunnel with the scaling-out intent to re-optimize when the the scaling condition of two-way-delay crossing 100 milliseconds (100000 microseconds) for a threshold of 1 min (60 seconds).

```
<edit-config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
   <target>
     <running/>
   </target>
   <config>
     <te xmlns="urn:ietf:params:xml:ns:yang:ietf-te">
         <tunnels>
            <tunnel>
              <name>Tunnel1</name>
                <te-scaling-intent
                  xmlns="urn:ietf:params:xml:ns:yang:
                         ietf-te-telemetry">
                    <scale-out-intent>
                       <threshold-time>
                        60
                      </threshold-time>
                      <scaling-condition>
                        <performance-type>
                          two-way-delay
                        </performance-type>
                        <threshold-value>
                          100000
                        </threshold-value>
                      </scaling-condition>
                    </scale-out-intent>
                </te-scaling-intent>
              </tunnel>
          </tunnels>
     </te>
   </config>
</edit-config>
```

Figure 9: TE Tunnel Scaling Example

The example in Figure 10 shows the way to configure a VN with the scaling-in intent to reduce bandwidth when the the scaling condition of utilized-percentage crossing 50 percent for a threshold of 5 minutes (300 seconds).

```
<edit-config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
   <target>
     <running/>
   </target>
   <config>
     <virtual-network xmlns="urn:ietf:params:xml:ns:yang:ietf-vn">
          <vn>
              <vn-id>VN1</vn-id>
                <vn-scaling-intent
                  xmlns="urn:ietf:params:xml:ns:yang:
                         ietf-vn-telemetry">
                    <scale-in-intent>
                      <threshold-time>300</threshold-time>
                      <scaling-condition>
                        <performance-type>
                          utilized-percentage
                        </performance-type>
                        <threshold-value>
                          50
                        </threshold-value>
                      </scaling-condition>
                    </scale-in-intent>
              </vn-scaling-intent>
          </vn>
     </virtual-network>
   </config>
</edit-config>
```

Figure 10: VN Scaling Example

The example in Figure 11 shows the way to configure a VN with the scaling-in when the the scaling condition of one-way-delay-variation crossing 100 milliseconds (100000 microseconds) OR one-way-delay crossing 50 milliseconds (50000 microseconds) for a threshold of 2 minutes (120 seconds).

```
<edit-config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
   <target>
     <running/>
   </target>
   <config>
     <virtual-network xmlns="urn:ietf:params:xml:ns:yang:ietf-vn">
          <vn>
              <vn-id>VN2</vn-id>
                <vn-scaling-intent
                  xmlns="urn:ietf:params:xml:ns:yang:
                         ietf-vn-telemetry">
                    <scale-in-intent>
                      <threshold-time>120</threshold-time>
                      <scaling-condition>
                        <performance-type>
                          one-way-delay-variation
                        </performance-type>
                        <threshold-value>
                          100000
                        </threshold-value>
                        <scale-in-operation-type>
                          OR
                        </scale-in-operation-type>
                      </scaling-condition>
                      <scaling-condition>
                        <performance-type>
                          one-way-delay
                        </performance-type>
                        <threshold-value>
                          50000
                        </threshold-value>
                        <scale-in-operation-type>
                          OR
                        </scale-in-operation-type>
                      </scaling-condition>
                    </scale-in-intent>
              </vn-scaling-intent>
          </vn>
     </virtual-network>
   </config>
</edit-config>
```

Figure 11: VN Scaling Example with OR condition

The example in Figure 12 shows the way to configure a grouping operation at the VN level to require that the VN level one-way-delay needs to be the reported as the max of the one-way-delay at the VN-member level, where as the utilized-percentage is the mean.

```
<edit-config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
   <target>
     <running/>
   </target>
   <config>
     <virtual-network xmlns="urn:ietf:params:xml:ns:yang:ietf-vn">
          <vn>
              <vn-id>VN1</vn-id>
              <vn-telemetry
                xmlns="urn:ietf:params:xml:ns:yang:
                       ietf-vn-telemetry">
                <operation>
                  <performance-type>
                    one-way-delay
                  </performance-type>
                  <grouping-operation>
                    maximum
                  </grouping-operation>
                </operation>
                <operation>
                  <performance-type>
                    utilized-percentage
                  </performance-type>
                  <grouping-operation>
                    mean
                  </grouping-operation>
                </operation>
              </vn-telemetry>
          </vn>
     </virtual-network>
   </config>
</edit-config>
```

Figure 12: VN Grouping Operation Example

8. YANG Data Tree

```
   module: ietf-te-telemetry

     augment /te:te/te:tunnels/te:tunnel:
       +--rw te-scaling-intent
       |  +--rw scale-in-intent
       |  |  +--rw threshold-time?      uint32
       |  |  +--rw cooldown-time?       uint32
       |  |  +--rw scaling-condition* [performance-type]
       |  |  |  +--rw performance-type           identityref
       |  |  |  +--rw threshold-value?           scale-value
       |  |  |  +--rw scale-in-operation-type?
       |  |  |          scaling-criteria-operation
       |  |  +--rw scale-in-op?         scale-op
       |  |  +--rw scale?               scale-value
       |  +--rw scale-out-intent
       |     +--rw threshold-time?      uint32
       |     +--rw cooldown-time?       uint32
       |     +--rw scaling-condition* [performance-type]
       |     |  +--rw performance-type           identityref
       |     |  +--rw threshold-value?           scale-value
       |     |  +--rw scale-out-operation-type?
       |     |          scaling-criteria-operation
       |     +--rw scale-out-op?        scale-op
       |     +--rw scale?               scale-value
       +--ro te-telemetry
          +--ro performance-metrics-one-way
          |  +--ro one-way-delay?                          uint32
          |  +--ro one-way-delay-normality?
          |  |       te-types:performance-metrics-normality
          |  +--ro one-way-residual-bandwidth?
          |  |       rt-types:bandwidth-ieee-float32
          |  +--ro one-way-residual-bandwidth-normality?
          |  |       te-types:performance-metrics-normality
          |  +--ro one-way-available-bandwidth?
          |  |       rt-types:bandwidth-ieee-float32
          |  +--ro one-way-available-bandwidth-normality?
          |  |       te-types:performance-metrics-normality
          |  +--ro one-way-utilized-bandwidth?
          |  |       rt-types:bandwidth-ieee-float32
          |  +--ro one-way-utilized-bandwidth-normality?
          |          te-types:performance-metrics-normality
          +--ro performance-metrics-two-way
             +--ro two-way-delay?             uint32
             +--ro two-way-delay-normality?
                     te-types:performance-metrics-normality
```

Figure 13: ietf-te-telemetry YANG model tree

```
   module: ietf-vn-telemetry

     augment /vn:virtual-network/vn:vn:
       +--rw vn-scaling-intent
       |  +--rw scale-in-intent
       |  |  +--rw threshold-time?      uint32
       |  |  +--rw cooldown-time?       uint32
       |  |  +--rw scaling-condition* [performance-type]
       |  |  |  +--rw performance-type           identityref
       |  |  |  +--rw threshold-value?           scale-value
       |  |  |  +--rw scale-in-operation-type?
       |  |  |          scaling-criteria-operation
       |  |  +--rw scale-in-op?         scale-op
       |  |  +--rw scale?               scale-value
       |  +--rw scale-out-intent
       |     +--rw threshold-time?      uint32
       |     +--rw cooldown-time?       uint32
       |     +--rw scaling-condition* [performance-type]
       |     |  +--rw performance-type            identityref
       |     |  +--rw threshold-value?            scale-value
       |     |  +--rw scale-out-operation-type?
       |     |          scaling-criteria-operation
       |     +--rw scale-out-op?        scale-op
       |     +--rw scale?               scale-value
       +--rw vn-telemetry
          +--ro params
          |  +--ro performance-metrics-one-way
          |  |  +--ro one-way-delay?                              uint32
          |  |  +--ro one-way-delay-normality?
          |  |  |       te-types:performance-metrics-normality
          |  |  +--ro one-way-residual-bandwidth?
          |  |  |       rt-types:bandwidth-ieee-float32
          |  |  +--ro one-way-residual-bandwidth-normality?
          |  |  |       te-types:performance-metrics-normality
          |  |  +--ro one-way-available-bandwidth?
          |  |  |       rt-types:bandwidth-ieee-float32
          |  |  +--ro one-way-available-bandwidth-normality?
          |  |  |       te-types:performance-metrics-normality
          |  |  +--ro one-way-utilized-bandwidth?
          |  |  |       rt-types:bandwidth-ieee-float32
          |  |  +--ro one-way-utilized-bandwidth-normality?
          |  |          te-types:performance-metrics-normality
          |  +--ro performance-metrics-two-way
          |     +--ro two-way-delay?             uint32
          |     +--ro two-way-delay-normality?
          |             te-types:performance-metrics-normality
          +--rw operation* [performance-type]
             +--rw performance-type      identityref
```

```
          +--rw grouping-operation?   identityref
     augment /vn:virtual-network/vn:vn/vn:vn-member:
       +--rw vn-member-telemetry
          +--ro params
          |  +--ro performance-metrics-one-way
          |  |  +--ro one-way-delay?                              uint32
          |  |  +--ro one-way-delay-normality?
          |  |  |       te-types:performance-metrics-normality
          |  |  +--ro one-way-residual-bandwidth?
          |  |  |       rt-types:bandwidth-ieee-float32
          |  |  +--ro one-way-residual-bandwidth-normality?
          |  |  |       te-types:performance-metrics-normality
          |  |  +--ro one-way-available-bandwidth?
          |  |  |       rt-types:bandwidth-ieee-float32
          |  |  +--ro one-way-available-bandwidth-normality?
          |  |  |       te-types:performance-metrics-normality
          |  |  +--ro one-way-utilized-bandwidth?
          |  |  |       rt-types:bandwidth-ieee-float32
          |  |  +--ro one-way-utilized-bandwidth-normality?
          |  |          te-types:performance-metrics-normality
          |  +--ro performance-metrics-two-way
          |  |  +--ro two-way-delay?              uint32
          |  |  +--ro two-way-delay-normality?
          |  |          te-types:performance-metrics-normality
          |  +--ro te-tunnel-ref*
          |             -> /te:te/tunnels/tunnel/name
          +--rw operation* [performance-type]
             +--rw performance-type      identityref
             +--rw grouping-operation?   identityref
```

Figure 14: ietf-vn-telemetry YANG model tree

9. YANG Data Model

9.1. ietf-te-telemetry model

The YANG code is as follows:

```
<CODE BEGINS> file "ietf-te-telemetry@2025-04-22.yang"
module ietf-te-telemetry {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-te-telemetry";
  prefix te-tel;

  /* Import TE */

  import ietf-te {
    prefix te;
```

```
  reference
    "I-D.ietf-teas-yang-te: A YANG Data Model for Traffic
     Engineering Tunnels and Interfaces";
}

/* Import TE Common types */

import ietf-te-types {
  prefix te-types;
  reference
    "RFC 8776: Common YANG Data Types for Traffic Engineering";
}

/* Import Routing Common types */

import ietf-routing-types {
  prefix rt-types;
  reference
    "RFC 8294: Common YANG Data Types for the Routing Area";
}

organization
  "IETF Traffic Engineering Architecture and Signaling (TEAS)
   Working Group";
contact
  "WG Web:  <https://datatracker.ietf.org/wg/teas/>
   WG List: <mailto:teas@ietf.org>
   Editor:  Young Lee <younglee.tx@gmail.com>
            Dhruv Dhody <dhruv.ietf@gmail.com>";
description
  "This module describes the YANG data model for performance
   monitoring parameters (telemetry data) for TE tunnels.

   Copyright (c) 2025 IETF Trust and the persons identified as
   authors of the code.  All rights reserved.

   Redistribution and use in source and binary forms, with or
   without modification, is permitted pursuant to, and subject to
   the license terms contained in, the Revised 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 XXXX; see the
   RFC itself for full legal notices.";

/* Note: The RFC Editor will replace XXXX with the number
   assigned to the RFC once draft-ietf-teas-pm-telemetry-
```

```
        autonomics becomes an RFC.*/

      revision 2025-04-22 {
        description
          "Initial revision.";
        reference
          "RFC XXXX: YANG models for VN/TE Performance Monitoring
           Telemetry and Scaling Intent Autonomics";
      }

      identity telemetry-param-type {
        description
          "Base identity for telemetry parameter types";
      }

      identity one-way-delay {
        base telemetry-param-type;
        description
          "To specify average Delay in one (forward) direction
           in microseconds.

           At the VN level, it is the maximum delay of the
           VN-members.

           The threshold-value for this type is interpreted as
           microseconds.";
        reference
          "RFC 7471: OSPF Traffic Engineering (TE) Metric Extensions.
           RFC 8570: IS-IS Traffic Engineering (TE) Metric Extensions.
           RFC 7823: Performance-Based Path Selection for Explicitly
           Routed Label Switched Paths (LSPs) Using TE Metric
           Extensions";
      }

      identity two-way-delay {
        base telemetry-param-type;
        description
          "To specify average Delay in both (forward and reverse)
           directions in microseconds.

           At the VN level, it is the maximum delay of the
           VN-members.

           The threshold-value for this type is interpreted as
           microseconds.";
        reference
          "RFC 7471: OSPF Traffic Engineering (TE) Metric Extensions.
           RFC 8570: IS-IS Traffic Engineering (TE) Metric Extensions.
```

```
          RFC 7823: Performance-Based Path Selection for Explicitly
          Routed Label Switched Paths (LSPs) Using TE Metric
          Extensions";
      }

      identity one-way-delay-variation {
        base telemetry-param-type;
        description
          "To specify average Delay Variation in one (forward) direction
           in microseconds.

           At the VN level, it is the max delay variation of the
           VN-members.

           The threshold-value for this type is interpreted as
           microseconds.";
        reference
          "RFC 7471: OSPF Traffic Engineering (TE) Metric Extensions.
           RFC 8570: IS-IS Traffic Engineering (TE) Metric Extensions.
           RFC 7823: Performance-Based Path Selection for Explicitly
           Routed Label Switched Paths (LSPs) Using TE Metric
           Extensions";
      }

      identity two-way-delay-variation {
        base telemetry-param-type;
        description
          "To specify average Delay Variation in both (forward and
           reverse) directions in microseconds.

           At the VN level, it is the max delay variation of the
           VN-members.

           The threshold-value for this type is interpreted as
           microseconds.";
        reference
          "RFC 7471: OSPF Traffic Engineering (TE) Metric Extensions.
           RFC 8570: IS-IS Traffic Engineering (TE) Metric Extensions.
           RFC 7823: Performance-Based Path Selection for Explicitly
           Routed Label Switched Paths (LSPs) Using TE Metric
           Extensions";
      }

      identity utilized-bandwidth {
        base telemetry-param-type;
        description
          "To specify utilized bandwidth over the specified source
           and destination in bytes per second.
```

```
          The threshold-value for this type is interpreted as
          bytes per second.";
      reference
        "RFC 7471: OSPF Traffic Engineering (TE) Metric Extensions.
         RFC 8570: IS-IS Traffic Engineering (TE) Metric Extensions.
         RFC 7823: Performance-Based Path Selection for Explicitly
         Routed Label Switched Paths (LSPs) Using TE Metric
         Extensions";
    }

    identity utilized-percentage {
      base telemetry-param-type;
      description
        "To specify utilization percentage of the entity
         (e.g., tunnel, link, etc.)";
    }

    /* Typedef */

    typedef scale-op {
      type enumeration {
        enum UP {
          description
            "Scale up the bandwidth capacity";
        }
        enum DOWN {
          description
            "Scale down the bandwidth capacity";
        }
      }
      description
        "Scaling operation";
    }

    typedef scaling-criteria-operation {
      type enumeration {
        enum AND {
          description
            "AND operation";
        }
        enum OR {
          description
            "OR operation";
        }
      }
      description
        "Operations to analyze the list of scaling criteria.";
    }
```

```
  typedef scale-value {
    type union {
      type uint32;
      type rt-types:bandwidth-ieee-float32;
      type rt-types:percentage;
      type te-types:te-bandwidth;
    }
    description
      "Union of scale values of various types";
  }

  grouping scaling-duration {
    description
      "Base scaling criteria durations";
    leaf threshold-time {
      type uint32;
      units "seconds";
      description
        "The duration for which the criteria must hold true. The
         value of '0' indicates an immediate scaling with no
         duration to wait.";
    }
    leaf cooldown-time {
      type uint32;
      units "seconds";
      description
        "The duration after a scaling-in/scaling-out action has been
         triggered, for which there will be no further operation.
         The value of '0' indicates an immediate scaling action with
         no duration to wait.";
    }
  }

  grouping scaling-criteria {
    description
      "Grouping for scaling criteria";
    leaf performance-type {
      type identityref {
        base telemetry-param-type;
      }
      description
        "Reference to the tunnel level telemetry type";
    }
    leaf threshold-value {
      type scale-value;
      description
        "Scaling threshold for the telemetry parameter type. The
         value is it be interpreted as per the type.";
```

```
      }
    }

    grouping scaling-in-intent {
      description
        "Basic scaling in intent";
      uses scaling-duration;
      list scaling-condition {
        key "performance-type";
        description
          "Scaling conditions";
        uses scaling-criteria;
        leaf scale-in-operation-type {
          type scaling-criteria-operation;
          default "AND";
          description
            "Operation to be applied to check between scaling criteria
             if the scale-in threshold condition has been met.
             Defaults to AND.";
        }
      }
      leaf scale-in-op {
        type scale-op;
        default "DOWN";
        description
          "The scaling operation to be performed when scaling condition
           is met";
      }
      leaf scale {
        type scale-value;
        description
          "Additional scaling-by information to be interpreted as per
           the scale-in-op.";
      }
    }

    grouping scaling-out-intent {
      description
        "Basic scaling out intent";
      uses scaling-duration;
      list scaling-condition {
        key "performance-type";
        description
          "Scaling conditions";
        uses scaling-criteria;
        leaf scale-out-operation-type {
          type scaling-criteria-operation;
          default "OR";
```

```
          description
            "Operation to be applied to check between scaling criteria
             if the scale-out threshold condition has been met.
             Defaults to OR.";
        }
      }
      leaf scale-out-op {
        type scale-op;
        default "UP";
        description
          "The scaling operation to be performed when scaling condition
           is met.";
      }
      leaf scale {
        type scale-value;
        description
          "Additional scaling-by information to be interpreted as per
           the scale-out-op.";
      }
    }

    augment "/te:te/te:tunnels/te:tunnel" {
      description
        "Augmentation parameters for config scaling-criteria TE
         tunnel topologies. Scale in/out criteria might be used
         for network autonomics in order for the controller to
         react to a certain set of monitored parameters.";
      container te-scaling-intent {
        description
          "The scaling intent";
        container scale-in-intent {
          description
            "scale-in";
          uses scaling-in-intent;
        }
        container scale-out-intent {
          description
            "scale-out";
          uses scaling-out-intent;
        }
      }
      container te-telemetry {
        config false;
        description
          "Telemetry Data";
        uses te-types:performance-metrics-attributes;
      }
    }
```

```
   }
   <CODE ENDS>
```

9.2. ietf-vn-telemetry model

The YANG code is as follows:

```
   <CODE BEGINS> file "ietf-vn-telemetry@2025-04-22.yang"
   module ietf-vn-telemetry {
     yang-version 1.1;
     namespace "urn:ietf:params:xml:ns:yang:ietf-vn-telemetry";
     prefix vn-tel;

     /* Import VN */

     import ietf-vn {
       prefix vn;
       reference
         "RFC 9731: A YANG Data Model for Virtual Network (VN)
          Operations";
     }

     /* Import TE */

     import ietf-te {
       prefix te;
       reference
         "I-D.ietf-teas-yang-te: A YANG Data Model for Traffic
          Engineering Tunnels and Interfaces";
     }

     /* Import TE Common types */

     import ietf-te-types {
       prefix te-types;
       reference
         "RFC 8776: Common YANG Data Types for Traffic Engineering";
     }

     /* Import TE Telemetry */

     import ietf-te-telemetry {
       prefix te-tel;
       reference
         "RFC XXXX: YANG models for VN/TE Performance Monitoring
          Telemetry and Scaling Intent Autonomics";
     }
```

```
     /* Note: The RFC Editor will replace XXXX with the number
        assigned to this draft.*/

     organization
       "IETF Traffic Engineering Architecture and Signaling (TEAS)
        Working Group";
     contact
       "WG Web:  <https://datatracker.ietf.org/wg/teas/>
        WG List: <mailto:teas@ietf.org>
        Editor:  Young Lee <younglee.tx@gmail.com>
                 Dhruv Dhody <dhruv.ietf@gmail.com>";
     description
       "This module describes YANG data models for performance
        monitoring parameters (telemetry data) for Virtual Network
        (VN).

        Copyright (c) 2025 IETF Trust and the persons identified as
        authors of the code.  All rights reserved.

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        without modification, is permitted pursuant to, and subject to
        the license terms contained in, the Revised 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 XXXX; see the
        RFC itself for full legal notices.";

     /* Note: The RFC Editor will replace XXXX with the number
        assigned to the RFC once draft-lee-teas-pm-telemetry-
        autonomics becomes an RFC.*/

     revision 2025-04-22 {
       description
         "Initial revision.";
       reference
         "RFC XXXX: YANG models for VN/TE Performance Monitoring
          Telemetry and Scaling Intent Autonomics";
     }

     identity grouping-op {
       description
         "Base identity for grouping-operation";
     }

     identity minimum {
       base grouping-op;
```

```
      description
        "Select the minimum of the monitored parameters";
    }

    identity maximum {
      base grouping-op;
      description
        "The maximum of the monitored parameters";
    }

    identity mean {
      base grouping-op;
      description
        "The mean of the monitored parameters";
    }

    identity standard-deviation {
      base grouping-op;
      description
        "The standard deviation of the monitored parameters";
    }

    identity sum {
      base grouping-op;
      description
        "The sum of the monitored parameters";
    }

    identity and {
      base grouping-op;
      description
        "Logical AND operation";
    }

    identity or {
      base grouping-op;
      description
        "Logical OR operation";
    }

    grouping grouping-operation {
      list operation {
        key "performance-type";
        leaf performance-type {
          type identityref {
            base te-tel:telemetry-param-type;
          }
          description
```

```
            "Reference to the tunnel level telemetry type";
        }
        leaf grouping-operation {
          type identityref {
            base grouping-op;
          }
          description
            "describes the operation to apply to the underlying
             TE tunnels";
        }
        description
          "Grouping operation for each performance-type";
      }
      description
        "Grouping operation for each performance-type";
    }

    augment "/vn:virtual-network/vn:vn" {
      description
        "Augmentation parameters for state TE VN topologies.";
      container vn-scaling-intent {
        description
          "scaling intent";
        container scale-in-intent {
          description
            "VN scale-in";
          uses te-tel:scaling-in-intent;
        }
        container scale-out-intent {
          description
            "VN scale-out";
          uses te-tel:scaling-out-intent;
        }
      }
      container vn-telemetry {
        description
          "VN telemetry params";
        container params {
          config false;
          description
            "Read-only telemetry parameters";
          uses te-types:performance-metrics-attributes;
        }
        uses grouping-operation;
      }
    }

    augment "/vn:virtual-network/vn:vn/vn:vn-member" {
```

```
      description
        "Augmentation parameters for state TE vn member topologies.";
      container vn-member-telemetry {
        description
          "VN member telemetry params";
        container params {
          config false;
          description
            "Read-only telemetry parameters";
          uses te-types:performance-metrics-attributes;
          leaf-list te-tunnel-ref {
            type leafref {
              path "/te:te/te:tunnels/te:tunnel/te:name";
            }
            description
              "A list of underlying TE tunnels that form the
               VN-member";
          }
        }
        uses grouping-operation;
      }
    }
  }
  <CODE ENDS>
```

10. 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.

Refer to the security considerations for TE-tunnel and VN Yang in [I-D.ietf-teas-yang-te] and [RFC9731] respectively.

There are a number of data nodes defined in this YANG module that are writable/creatable/deletable (i.e., config true, which is the default). These data nodes may be considered sensitive or vulnerable in some network environments. Write operations (e.g., edit-config) to these data nodes without proper protection can have a negative

effect on network operations. These are the subtrees with the write operation that can be exploited to impact the network monitoring. An incorrect condition could cause frequent scaling operations to be executed causing harm to the network:

* /te:te/te:tunnels/te:tunnel/te-scaling-intent/scale-in-intent

* /te:te/te:tunnels/te:tunnel/te-scaling-intent/scale-out-intent

* /vn:virtual-network/vn:vn/vn-scaling-intent/scale-in-intent

* /vn:virtual-network/vn:vn/vn-scaling-intent/scale-out-intent

Further, the following are the subtrees with the write operation that can be exploited by setting an incorrect grouping operation for the VN operation impacting the network monitoring:

* /vn:virtual-network/vn:vn/vn-telemetry/operation

* /vn:virtual-network/vn:vn/vn:vn-member/vn-member-telemetry/operation

Some of the readable data nodes in this YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control read access (e.g., via get, get-config, or notification) to these data nodes. These are the subtrees with the read operations that can be exploited to learn real-time (and sensitive) telemetry information about the TE tunnels and VN:

* /te:te/te:tunnels/te:tunnel/te-telemetry

* /vn:virtual-network/vn:vn/vn-telemetry

* /vn:virtual-network/vn:vn/vn:vn-member/vn-member-telemetry

11. IANA Considerations

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

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

---------------------------------------------------------------------
URI: urn:ietf:params:xml:ns:yang:ietf-vn-telemetry
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-te-telemetry
namespace:    urn:ietf:params:xml:ns:yang:ietf-te-telemetry
prefix:       te-tel
reference:    RFC XXXX
---------------------------------------------------------------------

---------------------------------------------------------------------
name:         ietf-vn-telemetry
namespace:    urn:ietf:params:xml:ns:yang:ietf-vn-telemetry
prefix:       vn-tel
reference:    RFC XXXX
---------------------------------------------------------------------
```

12. Acknowledgments

We thank Adrian Farrel, Rakesh Gandhi, Tarek Saad, Igor Bryskin, Kenichi Ogaki, and Greg Mirsky for useful discussions and their suggestions for this work.

Thanks to Reshad Rahman for an excellent YANGDOCTOR review.

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Appendix A. Out of Scope

This document exclusively focuses on performance monitoring telemetry and scaling intent mechanisms of the underlying transport (TE-tunnels and Virtual Networks (VNs)). The performance monitoring of the services is out of scope. See Section 3.3 for details about VPN performance monitoring. Similarly, performance monitoring of IETF network slices could be developed, and it is clearly out of the scope of this document.

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