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Information Model for Abstraction and Control of TE Networks (ACTN)

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Abstract

This draft provides an information model for abstraction and control of Traffic Engineered (TE) networks (ACTN).

Status of this Memo

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1. Introduction

This draft provides an information model for the requirements identified in the ACTN requirements [ACTN-Req] and the ACTN interfaces identified in the ACTN architecture and framework document [ACTN-Frame].

The purpose of this draft is to put all information elements of ACTN in one place before proceeding to development work necessary for protocol extensions and data models.

The ACTN reference architecture identified a three-tier control hierarchy as depicted in Figure 1:

- Customer Network Controllers (CNC)
- Multi-Domain Service Coordinator (MDSC)
- Physical Network Controllers (PNC).

```
+-------+                 +-------+                   +-------+
| CNC-A |                 | CNC-B |                   | CNC-C |
+-------+                 +-------+                   +-------+
      \___________            |             _____________ _/
       ----------             | CMI          ------------
                  \           |            /
                   +-----------------------+
                   |         MDSC          |
                   +-----------------------+
         _________/            |            \_________
         --------              | MPI          ------------____
        /                      |                          \
+-------+                 +-------+                   +-------+
|  PNC  |                 |  PNC  |                   |  PNC  |
+-------+                 +-------+                   +-------+
```

Figure 1: A Three-tier ACTN control hierarchy

The two interfaces with respect to the MDSC, one north of the MDSC and the other south of the MDSC are referred to as CMI (CNC-MDSC Interface) and MPI (MDSC-PNC Interface), respectively. It is intended to model these two interfaces and derivative interfaces thereof (e.g., MDSC to MSDC in a hierarchy of MDSCs) with one common model.

Appendix A provides some relevant ACTN use-cases extracted from [ACTN-Req]. Appendix A is information only and may help readers understand the context of key use-cases addressed in [ACTN-Req].

2. ACTN Common Interfaces Information Model

This section provides ACTN common interface information model to describe in terms of primitives, objects, their properties (represented as attributes), their relationships, and the resources for the service applications needed in the ACTN context.

Basic primitives (messages) are required between the CNC-MDSC and MDSC-PNC controllers. These primitives can then be used to support different ACTN network control functions like network topology request/query, VN service request, path computation and connection control, VN service policy negotiation, enforcement, routing options, etc.

The standard interface is described between a client controller and a server controller. A client-server relationship is recursive between a CNC and a MDSC and between a MDSC and a PNC. In the CMI, the client is a CNC while the server is a MDSC. In the MPI, the client is a MDSC and the server is a PNC. There may also be MDSC-MDSC interface(s) that need to be supported. This may arise in a hierarchy of MDSCs in which workloads may need to be partitioned to multiple MDSCs.

At a minimum, the following VN action primitives should be supported:

- VN Instantiate (See Section 2.1.1. for the description)

- VN Modify (See Section 2.1.2. for the description)

- VN Delete (See Section 2.1.3. for the description)

- VN Query (See Section 2.1.4. for the description)

- VN Path Compute (See Section 2.1.4. for the description)

- VN Update ((See Section 2.1.5. for the description)

The functionality below will be supported as part of already defined primitives as above.

- Security negotiation
- Local Domain path computation (related to PNC
- Coordination of multi-destination (<Coordination Multidestination>)

2.1. VN Action Primitives

This section provides a list of main primitives necessary to satisfy ACTN requirements specified in [ACTN-REQ].

<VN Action> describes main primitives. VN Action can be one of the following primitives: (i) instantiate; (ii) modify; (iii) delete; (iv) path compute; (v) query; (vi) update.

```
<VN Action> ::= <VN Instantiate> |

                <VN Modify> |

                <VN Delete> |

                <VN Path Compute> |

                <VN Query> |

                <VN Update>
```

2.1.1. VN Instantiate

<VN Instantiate> refers to an action from customers/applications to request their VNs. This primitive can also be applied from an MDSC to a PNC requesting a VN (if the domain the PNC supports can instantiate the entire VN) or a part of VN elements.

2.1.2. VN Modify

<VN Modify> refers to an action from customers/applications to modify an existing VN (i.e., instantiated VN). This primitive can also be applied from an MDSC to a PNC requesting a VN (if the domain the PNC supports can instantiate the entire VN) or a part of VN elements.

2.1.3. VN Delete

<VN Delete> refers to an action from customers/applications to delete an existing VN. This primitive can also be applied from an MDSC to a PNC requesting a VN (if the domain the PNC supports can instantiate the entire VN) or a part of VN elements.

2.1.4. VN Path Compute

<VN Path Compute> refers to an action from customers/applications to request a VN path computation. This primitive can also be applied from an MDSC to a PNC requesting a VN (if the domain the PNC supports can instantiate the entire VN) or a part of VN elements.

This is to be differentiated from a VN Instantiate. The purpose of VN Path Compute is a priori exploration to estimate network resources availability before making a VN instantiate decision. Obviously an abstracted view of network resources topology is needed to permit this function. This action is also necessary for an MDSC to PNCs in determining end-to-end multi-domain paths. VN Instantiate may also trigger an MDSC for a VN Path Compute to lower-level PNCs in order to determine end-to-end paths that comprise of a VN.

2.1.5. VN Query

<VN Query> refers to any query pertaining to the VN that has been already instantiated. VN Query fulfills a pull model and permit to get topology view.

2.1.6. VN Update

<VN Update> refers to any update to the VN that need to be updated to the subscribers. VN Update fulfills a push model.

There are other existing and upcoming TE mechanisms to fulfill the same function as VN Update. VN Update can be built on these other existing TE mechanisms. The details are TDB.

[Editor's Note: The mapping of VN Primitives and their VN Objects will be provided in the future revision.]

2.2. VN Objects

This section provides a list of objects associated with VN action primitives.

2.2.1. VN Identifier

<VN Identifier> is an identifier that identifies a unique VN.

2.2.2. VN Topology Metric

<VN Topology Metric> describes the requirements/preferences of VNs that customers/applications want to instantiate.

```
<VN Topology Metric> ::= <VN Topology Type>

                         <VN Topology Attributes>

                         [<VN Topology Preference>]

                         [<VN Topology Objective Function>]
```

Where

```
      <VN Topology Type> ::= <Path Vector> | <Graph>
```

<VN Topology Attributes describes characteristics associated with any VN Topology link/path. These attributes could be reservable bandwidth, maximum link/path capacity, latency, SRLG, etc.

<VN Topology Preference> describes if the request is

- a single vs. a bulk request,

- Multiple VN diversity in case of a bulk request, whether VNs should be disjoint or not),
- Single VN diversity (node/link disjoint)
- Others TBD.

<VN Topology Objective Function> indicates a higher level of objective function applied to the VN level, for computing a path vector.VN is comprised of a set of paths and each one of these needs an objective function.

2.2.3. Traffic Matrix

<Traffic Matrix> describes connectivity-level attributes that need to be conveyed by the CNC to MDSC or the MDSC to PNCs.

```
<Traffic Matrix> ::= <End-Point List>

                     <Connectivity Type>

                     <Connectivity Metric>
```

Where

```
<End-Point List> ::= (<Interface Identifier>

                     [<Client Interface Capability>]

                     [<Source Indicator>])...
```

It is assumed that a list of interface identifiers has been known to the server prior to any VN actions. The Client Capability comprises the client interface capability (e.g., maximum interface bandwidth, etc.).

<Source Indicator> indicates if an End-point is source or not.

```
<Connectivity Type> ::= <P2P> | <P2MP> | <MP2MP> | <MP2P>
```

```
                                <Multi-destination>


      <Connectivity Metric> ::= <Bandwidth>

                                [<Latency>]

                                [<Latency-Variation>]

                                [<Packet-Loss>]
```

2.2.4. VN Survivability

<VN Survivability> describes all attributes related with the VN protection level and its survivability policy enforced by the customers/applications.

```
<VN Survivability> ::= <VN Protection Level>

                       <VN Survivability Policy>
```

Where

```
   <VN Protection Level> ::= <No Protection> | <1+1> | <1:N>

   <VN Survivability Policy> ::= <Local Reroute Allowed>

                                 [<Domain Preference>]

                                 <Push Allowed>

                                 <Incremental Update>
```

Where

<Local Reroute Allowed> is a delegation policy to the Server to allow or not a local reroute fix upon a failure of the primary LSP.

<Domain Preference> is only applied on the MPI where the MDSC (client) provides a domain preference to each PNC (server).

<Push Allowed> is a policy that allows a server to trigger an updated VN topology upon failure without an explicit request from the client. Push action can be set as default unless otherwise specified.

<Incremental Update> is another policy that triggers an incremental update from the server since the last period of update. Incremental update can be set as default unless otherwise specified.

2.2.5. VN Action Status

<VN Action Status> is the status indicator whether the VN has been successfully instantiated, modified, or deleted in the server network or not in response to a particular VN action.

2.2.6. VN Topology

<VN Topology> describes VN topology. Details of <VN Topology> are TBD.

VN Topology can be defined using existing TE mechanisms. Details are TBD.

2.2.7. VN Connectivity Topology

<VN Connectivity Topology> describes the instantiated VN property. Details are TBD.

[Editor's Note: This may be combined with <VN Topology>.]

2.2.8. VN Service Preference

```
<VN Service Preference> ::= <Location Service Preference >

                            <Client-specific Preference >

                            <End-Point Dynamic Selection Preference >
```

Where

<Location Service Preference> describes the End-Point Location's support for certain Virtual Network Functions (VNFs) (e.g., security function, firewall capability, etc.).

<Client-specific Preference> describes any preference related to Virtual Network Service (VNS) that application/client can enforce via CNC towards lower level controllers. For example, permission the correct selection from the network of the destination related to the indicated VNF It is e.g. the case of VM migration among data center and CNC can enforce specific policy that can permit MDSC/PNC to calculate the correct path for the connectivity supporting the data center interconnection required by application.

<End-Point Dynamic Selection Preference> describes if the End-Point can support load balancing, disaster recovery or VM migration and so can be part of the selection by MDSC following service Preference enforcement by CNC.

3. References

3.1. Informative References

[ACTN-Req] Y. Lee, et al., "Requirements for Abstraction and Control of Transport Networks", draft-lee-teas-actn-requirements, work in progress.

[ACTN-Frame] D. Ceccarelli, et al., "Framework for Abstraction and Control of Transport Networks", draft-ceccarelli-teas-actn-framework, work in progress.

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Appendix A: ACTN Applications

A.1. Coordination of Multi-destination Service Requirement/Policy

```
                              +----------------+
                              |       CNC      |
                              |   (Global DC   |
                              |   Operation    |
                              |    Control)    |
                              +--------+-------+
                                       | |  Service Requirement/Policy:
                                       | |  - Endpoint/DC location info
                                       | |  - Endpoint/DC dynamic
                                       | |    selection policy
                                       | |    (for VM migration, DR, LB)
                                       | v
                             +---------+---------+
                             |  Multi-domain     | Service policy-driven
                             |Service Coordinator| dynamic DC selection
                             +-----+---+---+-----+
                                   |   |   |
                                   |   |   |
                   +----------------+   |   +----------------+
                   |                    |                    |
            +-----+-----+       +-----+------+      +------+-----+
            |   PNC for |       |  PNC for   |      |  PNC for   |
            | Transport |       | Transport  |      | Transport  |
            | Network A |       | Network B  |      | network C  |
            +-----------+       +------------+      +------------+
                  |                    |                  |
+---+      ------               ------              ------       +---+
|DC1|--////      \\\\       ////      \\\\      ////      \\\\---+DC5|
+---+ |              |     |              |    |              |  +---+
      |     TN A     +-----+     TN B     +----+      TN C    |
      /              |     |              |    |              |
     / \\\\      ////     / \\\\      ////      \\\\      ////
   +---+   ------        /      ------    \         ------ \
   |DC2|                /                  \                \+---+
   +---+               /                    \                |DC6|
                     +---+                   \ +---+         +---+
                     |DC3|                    \|DC4|
                     +---+                     +---+

                                                DR: Disaster Recovery
                                                LB: Load Balancing
```

Figure A.1: Service Policy-driven Data Center Selection

Figure A.1 shows how VN service policies from the CNC are incorporated by the MDSC to support multi-destination applications. Multi-destination applications refer to applications in which the selection of the destination of a network path for a given source needs to be decided dynamically to support such applications.

Data Center selection problems arise for VM mobility, disaster recovery and load balancing cases. VN's service policy plays an important role for virtual network operation. Service policy can be static or dynamic. Dynamic service policy for data center selection may be placed as a result of utilization of data center resources supporting VNs. The MDSC would then incorporate this information to meet the service objective of this application.

A.2. Application Service Policy-aware Network Operation

```
                            +----------------+
                            |       CNC      |
                            |   (Global DC   |
                            |   Operation    |
                            |    Control)    |
                            +--------+-------+
                                     | | Application Service Policy
                                     | | - VNF requirement (e.g.
                                     | |   security function, etc.)
                                     | | - Location profile for each VNF
                                     | v
                           +---------+---------+
                           |  Multi-domain     |  Dynamically select the
                           |Service Coordinator|  network destination to
                           +-----+---+---+-----+  meet VNF requirement.
                                 |   |   |
                                 |   |   |
                  +---------------+   |   +----------------+
                  |                   |                    |
           +------+-----+       +-----+------+      +------+-----+
           |   PNC for  |       |  PNC for   |      |  PNC for   |
           | Transport  |       | Transport  |      | Transport  |
           | Network A  |       | Network B  |      | network C  |
           |            |       |            |      |            |
           +------------+       +------------+      +------------+
                  |                   |                    |
{VNF b}           |                   |                    |  {VNF b,c}
+---+      ------                ------               ------     +---+
|DC1|--////      \\\\       ////      \\\\      ////      \\\\-|DC5|
+---+ |              |     |              |    |              |+---+
     |      TN A      +---+     TN B       +--+      TN C      |
      /              |     |              |    |              |
     / \\\\      ////     / \\\\      ////      \\\\      ////
   +---+   ------        /      ------    \         ------ \
   |DC2|                /                  \                \\+---+
   +---+               /                    \                 |DC6|
    {VNF a}         +---+                    +---+            +---+
                    |DC3|                    |DC4|      {VNF a,b,c}
                    +---+                    +---+
            {VNF a, b}                      {VNF a, c}
```

Figure A.2: Application Service Policy-aware Network Operation

This scenario is similar to the previous case in that the VN service policy for the application can be met by a set of multiple destinations that provide the required virtual network functions (VNF). Virtual network functions can be, for example, security functions required by the VN application. The VN service policy by the CNC would indicate the locations of a certain VNF that can be fulfilled. This policy information is critical in finding the optimal network path subject to this constraint. As VNFs can be dynamically moved across different DCs, this policy should be dynamically enforced from the CNC to the MDSC and the PNCs.

A.3. Network Function Virtualization Service Enabled Connectivity

```
                          +----------------+
                          |       CNC      |
                          |   (Global DC   |
                          |   Operation    |
                          |    Control)    |
                          +--------+-------+
                                   | | Service Policy related to VNF
                                   | | (e.g., firewall, traffic
                                   | | optimizer)
                                   | |
                                   | v
                         +---------+---------+
                         |  Multi-domain     | Select network
                         |Service Coordinator| connectivity subject to
                         +-----+---+---+-----+ meeting service policy
                               |   |   |
                               |   |   |
                +---------------+   |   +----------------+
                |                   |                    |
         +------+-----+       +-----+------+      +------+-----+
         |   PNC for  |       |  PNC for   |      |  PNC for   |
         | Transport  |       | Transport  |      | Transport  |
         | Network A  |       | Network B  |      | network C  |
         |            |       |            |      |            |
         +------------+       +------------+      +------------+
                |                   |                    |
                |                   |                    |
+---+      ------               ------               ------     +---+
|DC1|--////      \\\\       ////      \\\\      ////      \\\\-|DC5|
+---+ |              |     |              |    |              |+---+
     |      TN A      +---+     TN B       +--+      TN C      |
      /              |     |              |    |              |
     / \\\\      ////     / \\\\      ////      \\\\      ////
   +---+   ------        /      ------    \         ------ \
   |DC2|                /                  \                \\+---+
   +---+               /                    \                 |DC6|
                    +---+                    +---+            +---+
                    |DC3|                    |DC4|
                    +---+                    +---+
```

Figure A.3: Network Function Virtualization Service Enabled Connectivity

Network Function Virtualization Services are usually setup between customers' premises and service provider premises and are provided mostly by cloud providers or content delivery providers. The context may include, but not limited to a security function like firewall, a traffic optimizer, the provisioning of storage or computation capacity where the customer does not care whether the service is implemented in a given data center or another. The customer has to provide (and CNC is providing this)the type of VNF he needs and the policy associated with it (e.g. metric like estimated delay to reach where VNF is located in the DC). The policy linked to VNF is requested as part of the VN instantiation. These services may be hosted virtually by the provider or physically part of the network. This allows the service provider to hide his own resources (both network and data centers) and divert customer requests where most suitable. This is also known as "end points mobility" case and introduces new concepts of traffic and service provisioning and resiliency (e.g., Virtual Machine mobility).

A.4. Dynamic Service Control Policy Enforcement for Performance and Fault Management

```
+-----------------------------------------------+
|           Customer Network Controller         |
+-----------------------------------------------+
1.Traffic|  /|\4.Traffic           | /|\
Monitor& |   |  Monitor            |  | 8.Traffic
Optimize |   |  Result   5.Service |  | modify &
Policy   |   |             modify& |  | optimize
        \|/  |       optimize Req.\|/ | result
+-----------------------------------------------+
|         Multi-domain Service Coordinator      |
+-----------------------------------------------+
2. Path  |  /|\3.Traffic           | /|\
Monitor  |   | Monitor             |  |7.Path
Request  |   | Result     6.Path   |  | modify &
         |   |            modify&  |  | optimize
        \|/  |       optimize Req.\|/ | result
+-----------------------------------------------+
|          Physical Network Controller          |
+-----------------------------------------------+
```

Figure A.4: Dynamic Service Control for Performance and Fault Management

Figure A.4 shows the flow of dynamic service control policy enforcement for performance and fault management initiated by customer per VN. The feedback loop and filtering mechanism tailored for VNs performed by the MDSC differentiates this ACTN scope from traditional network management paradigm. VN level dynamic OAM data model is a building block to support this capability.

A.5. E2E VN Survivability and Multi-Layer (Packet-Optical) Coordination for Protection/Restoration

```
                        +----------------+
                        |   Customer     |
                        |   Network      |
                        |   Controller   |
                        +--------*-------+
                                 *  |     E2E VN Survivability Req.
                                 *  |     - VN Protection/Restoration
                                 *  v        - 1+1, Restoration, etc.
                          +------*-----+   - End Point (EP) info.
                          |            |
                          |    MDSC    | MDSC enforces VN survivability
                          |            | requirement, determining the
                          |            | optimal combination of Packet/
                          +------*-----+ Optical protection/restoration
                                 *       Optical bypass, etc.
                                 *
                                 *
              ********************************************
              *               *             *              *
         +----*-----+    +----*----+   +----*-----+   +----*----+
         |PNC for   |    |PNC for  |   |PNC for   |   |PNC for  |
         |Access N. |    |Packet C.|   |Optical C.|   |Access N.|
         +----*-----+    +----*----+   +----*-----+   +---*-----+
              *             --*---          *             *
              *          ///      \\\       *             *
            --*---      |   Packet   |      *         ----*-
         ///      \\\   |    Core    +------+------///      \\\
        |  Access    +----\\      ///       *     |   Access   |
        |  Network   |      ---+--          *     |   Network  |  +---+
        |\\\      ///          |            *      \\\      ///---+EP6|
        |   +---+-  |          |       -----*         -+---+      +---+
      +-+-+     |   |          +----///      \\\       |   |
      |EP1|     |   +--------------+  Optical   |      |   |  +---+
      +---+     |                  |    Core    +------+   +--+EP5|
              +-+-+                 \\\      ///              +---+
              |EP2|                    ------ |
              +---+                     |     |
                                  +--++   ++--+
                                  |EP3|   |EP4|
                                  +---+   +---+
```

Figure A.5: E2E VN Survivability and Multi-layer Coordination for Protection and Restoration

Figure A.5 shows the need for E2E protection/restoration control coordination that involves CNC, MDSC and PNCs to meet the VN survivability requirement. VN survivability requirement and its policy need to be translated into multi-domain and multi-layer network protection and restoration scenarios across different controller types. After an E2E path is setup successfully, the MDSC has a unique role to enforce policy-based flexible VN survivability requirement by coordinating all PNC domains.

As seen in Figure A.5, multi-layer (i.e., packet/optical) coordination is a subset of this E2E protection/restoration control operation. The MDSC has a role to play in determining an optimal protection/restoration level based on the customer's VN survivability requirement. For instance, the MDSC needs to interface the PNC for packet core as well as the PNC for optical core and enforce protection/restoration policy as part of the E2E protection/restoration. Neither the PNC for packet core nor the PNC for optical core is in a position to be aware of the E2E path and its protection/restoration situation. This role of the MDSC is unique for this reason. In some cases, the MDSC will have to determine and enforce optical bypass to find a feasible reroute path upon packet core network failure which cannot be resolved the packet core network itself.

To coordinate this operation, the PNCs will need to update its domain level abstract topology upon resource changes due to a network failure or other factors. The MDSC will incorporate all these update to determine if an alternative E2E reroute path is necessary or not based on the changes reported from the PNCs. It will need to update the E2E abstract topology and the affected CN's VN topology in real-time. This refers to dynamic synchronization of topology from Physical topology to abstract topology to VN topology.

MDSC will also need to perform the path restoration signaling to the affected PNCs whenever necessary.