       Transport Northbound Interface Applicability Statement and Use Cases
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Abstract

   Transport network domains, including Optical Transport Network (OTN)
   and Wavelength Division Multiplexing (WDM) networks, are typically
   deployed based on a single vendor or technology platforms. They are
   often managed using proprietary interfaces to dedicated Element
   Management Systems (EMS), Network Management Systems (NMS) and
   increasingly Software Defined Network (SDN) controllers.

   A well-defined open interface to each domain management system or
   controller is required for network operators to facilitate control
   automation and orchestrate end-to-end services across multi-domain
   networks. These functions may be enabled using standardized data
   models (e.g. YANG), and appropriate protocol (e.g., RESTCONF).

   This document describes the key use cases and requirements for
   transport network control and management. It reviews proposed and
   existing IETF transport network data models, their applicability,
   and highlights gaps and requirements.

Table of Contents

1. Introduction

Transport of packet services are critical for a wide-range of
applications and services, including: data center and LAN
interconnects, Internet service backhauling, mobile backhaul and
enterprise Carrier Ethernet Services. These services are typically
setup using stovepipe NMS and EMS platforms, often requiring
propriety management platforms and legacy management interfaces. A
clear goal of operators will be to automate setup of transport
services across multiple transport technology domains.

A common open interface (API) to each domain controller and or
management system is pre-requisite for network operators to control
multi-vendor and multi-domain networks and enable also service
provisioning coordination/automation. This can be achieved by using
standardized YANG models, used together with an appropriate protocol
(e.g., [RESTCONF]).

This document describes key use cases for analyzing the
applicability of the existing models defined by the IETF for
transport networks. The intention of this document is to become an
applicability statement that provides detailed descriptions of how
IETF transport models are applied to solve the described use cases
and requirements.

1.1. Scope of this document

This document assumes a reference architecture, including
interfaces, based on the Abstraction and Control of Traffic-
Engineered Networks (ACTN), defined in [ACTN-Frame]

The focus of this document is on the MPI (interface between the
Multi Domain Service Coordinator (MDSC) and a Physical Network
Controller (PNC), controlling a transport network domain).

The relationship between the current IETF YANG models and the type
of ACTN interfaces can be found in [ACTN-YANG].

The ONF Technical Recommendations for Functional Requirements for
the transport API in [ONF TR-527] and the ONF transport API multi-
layer examples in [ONF GitHub] have been considered as an input for
this work.

Considerations about the CMI (interface between the Customer Network
Controller (CNC) and the MDSC) are outside the scope of this
document.

2. Terminology

E-LINE: Ethernet Line

EPL: Ethernet Private Line

EVPL: Ethernet Virtual Private Line

OTH: Optical Network Hierarchy

OTN: Optical Transport Network

3. Conventions used in this document

3.1. Topology and traffic flow processing

The traffic flow between different nodes is specified as an ordered
list of nodes, separated with commas, indicating within the brackets
the processing within each node:

    <node> (<processing>){, <node> (<processing>)}

The order represents the order of traffic flow being forwarded
through the network.

The processing can be either an adaptation of a client layer into a
server layer "(client -> server)" or switching at a given layer
"([switching])". Multi-layer switching is indicated by two layer
switching with client/server adaptation: "([client] -> [server])".

For example, the following traffic flow:

    C-R1 (|PKT| -> ODU2), S3 (|ODU2|), S5 (|ODU2|), S6 (|ODU2|),
    C-R3 (ODU2 -> |PKT|)

Node C-R1 is switching at the packet (PKT) layer and mapping packets
into a ODU2 before transmission to node S3. Nodes S3, S5 and S6 are
switching at the ODU2 layer: S3 sends the ODU2 traffic to S5 which
then sends it to S6 which finally sends to C-R3. Node C-R3
terminates the ODU2 from S6 before switching at the packet (PKT)
layer.

The paths of working and protection transport entities are specified
as an ordered list of nodes, separated with commas:

    <node> {, <node>}

The order represents the order of traffic flow being forwarded
through the network in the forward direction. In case of
bidirectional paths, the forward and backward directions are
selected arbitrarily, but the convention is consistent between
working/protection path pairs as well as across multiple domains.

4. Use Case 1: Single-domain with single-layer

4.1. Reference Network

The current considerations discussed in this document are based on
the following reference networks:

      - single transport domain: OTN network

4.1.1. Single Transport Domain - OTN Network

As shown in Figure 1 the network physical topology composed of a
single-domain transport network providing transport services to an
IP network through five access links.
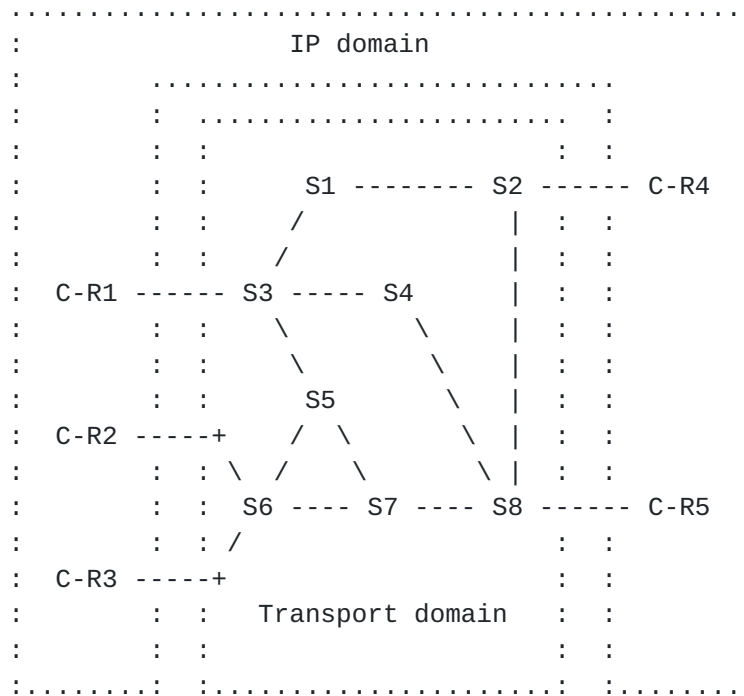
```
              ...............................................
              :                    IP domain                :      :
              :        ..............................        :      :
              :       :  ......................  :           :      :
              :       :  :                       :  :        :      :
              :       :  :          S1 -------- S2 ------ C-R4      :
              :       :  :        /              | :  :           :
              :       :  :       /               | :  :           :
              :   C-R1 ------ S3 ----- S4         | :  :           :
              :       :  :      \          \      | :  :           :
              :       :  :       \          \     | :  :           :
              :       :  :        S5          \   | :  :           :
              :   C-R2 -----+    /  \           \  | :  :           :
              :       :  : \  /     \           \ |  :  :           :
              :       :  :   S6 ---- S7 ---- S8 ------ C-R5   :
              :       :  : /                        :  :        :
              :   C-R3 -----+                        :  :        :
              :       :  :    Transport domain       :  :        :
              :       :  :  :                         :  :        :
              :........:  :.......................:   :.........:
                     Figure 1 Reference network for Use Case 1
```

   The IP and transport (OTN) domains are respectively composed by five
   routers C-R1 to C-R5 and by eight ODU switches S1 to S8. The
   transport domain acts as a transit network providing connectivity
   for IP layer services.

   The behavior of the transport domain is the same whether the
   ingress or egress service nodes in the IP domain are only attached
   to the transport domain, or if there are other routers in between
   the ingress or egress nodes of the IP domain not also attached to
   the transport domain. In other words, the behavior of the transport
   network does not depend on whether C-R1, C-R2, ..., C-R5 are PE or P
   routers for the IP services.

   The transport domain control plane architecture follows the ACTN
   architecture and framework document [ACTN-Frame], and functional
   components:

   o Customer Network Controller (CNC) act as a client with respect to
      the Multi-Domain Service Coordinator (MDSC) via the CNC-MDSC
      Interface (CMI);

o MDSC is connected to a plurality of Physical Network Controllers
  (PNCs), one for each domain, via a MDSC-PNC Interface (MPI). Each
  PNC is responsible only for the control of its domain and the
  MDSC is the only entity capable of multi-domain functionalities
  as well as of managing the inter-domain links;

The ACTN framework facilitates the detachment of the network and
service control from the underlying technology and help the customer
express the network as desired by business needs. Therefore, care
must be taken to keep minimal dependency on the CMI (or no
dependency at all) with respect to the network domain technologies.
The MPI instead requires some specialization according to the domain
technology.

```
                        +-----+
                        | CNC |
                        +-----+
                           |
                           |CMI I/F
                           |
              +------------------------+
              |         MDSC           |
              +------------------------+
                           |
                           |MPI I/F
                           |
                       +-------+
                       | PNC   |
                       +-------+
                           |
                         -----
                      (        )
                      (   OTN   )
                      ( Physical )
                      ( Network )
                      (        )
                         -----
```
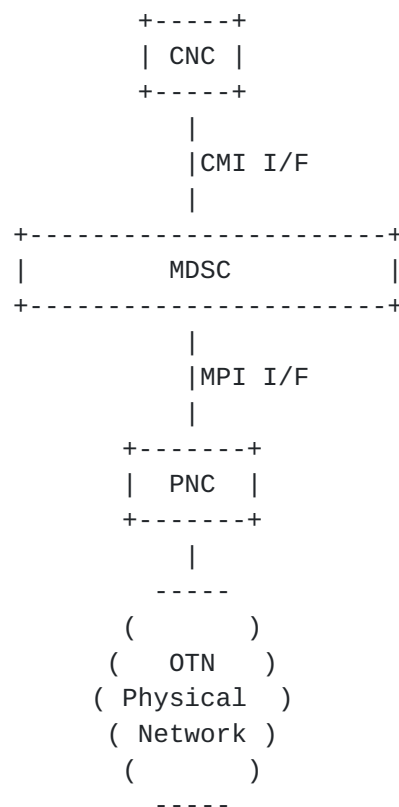
            Figure 2 Controlling Hierarchy for Use Case 1

Once the service request is processed by the MDSC the mapping of the
client IP traffic between the routers (across the transport network)
is made in the IP routers only and is not controlled by the
transport PNC, and therefore transparent to the transport nodes.

4.2. Topology Abstractions

Abstraction provides a selective method for representing
connectivity information within a domain. There are multiple methods
to abstract a network topology. This document assumes the
abstraction method defined in [RFC7926]:

  "Abstraction is the process of applying policy to the available TE
  information within a domain, to produce selective information that
  represents the potential ability to connect across the domain.
  Thus, abstraction does not necessarily offer all possible
  connectivity options, but presents a general view of potential
  connectivity according to the policies that determine how the
  domain's administrator wants to allow the domain resources to be
  used."

[TE-Topo] describes a YANG base model for TE topology without any
technology specific parameters. Moreover, it defines how to abstract
for TE-network topologies.

[ACTN-Frame] provides the context of topology abstraction in the
ACTN architecture and discusses a few alternatives for the
abstraction methods for both packet and optical networks. This is an
important consideration since the choice of the abstraction method
impacts protocol design and the information it carries. According
to [ACTN-Frame], there are three types of topology:

o White topology: This is a case where the Physical Network
   Controller (PNC) provides the actual network topology to the
   multi-domain Service Coordinator (MDSC) without any hiding or
   filtering. In this case, the MDSC has the full knowledge of the
   underlying network topology;

o Black topology: The entire domain network is abstracted as a
   single virtual node with the access/egress links without
   disclosing any node internal connectivity information;

o Grey topology: This abstraction level is between black topology
   and white topology from a granularity point of view. This is
   abstraction of TE tunnels for all pairs of border nodes. We may
   further differentiate from a perspective of how to abstract
   internal TE resources between the pairs of border nodes:

     - Grey topology type A: border nodes with a TE links between
       them in a full mesh fashion;

        - Grey topology type B: border nodes with some internal
          abstracted nodes and abstracted links.

   For single-domain with single-layer use-case, the white topology may
   be disseminated from the PNC to the MDSC in most cases. There may be
   some exception to this in the case where the underlay network may
   have complex optical parameters, which do not warrant the
   distribution of such details to the MDSC. In such case, the topology
   disseminated from the PNC to the MDSC may not have the entire TE
   information but a streamlined TE information. This case would incur
   another action from the MDSC's standpoint when provisioning a path.
   The MDSC may make a path compute request to the PNC to verify the
   feasibility of the estimated path before making the final
   provisioning request to the PNC, as outlined in [Path-Compute].

   Topology abstraction for the CMI is for further study (to be
   addressed in future revisions of this document).

4.3. Service Configuration

   In the following use cases, the Multi Domain Service Coordinator
   (MDSC) needs to be capable to request service connectivity from the
   transport Physical Network Controller (PNC) to support IP routers
   connectivity. The type of services could depend of the type of
   physical links (e.g. OTN link, ETH link or SDH link) between the
   routers and transport network.

   As described in section 4.1.1, the control of different adaptations
   inside IP routers, C-Ri (PKT -> foo) and C-Rj (foo -> PKT), are
   assumed to be performed by means that are not under the control of,
   and not visible to, transport PNC. Therefore, these mechanisms are
   outside the scope of this document.

4.3.1. ODU Transit

   This use case assumes that the physical links interconnecting the IP
   routers and the transport network are OTN links. The
   physical/optical interconnection below the ODU layer is supposed to
   be pre-configured and not exposed at the MPI to the MDSC.

   To setup a 10Gb IP link between C-R1 to C-R3, an ODU2 end-to-end
   data plane connection needs to be created between C-R1 and C-R3,
   crossing transport nodes S3, S5, and S6.

   The traffic flow between C-R1 and C-R3 can be summarized as:

```
   C-R1 (|PKT| -> ODU2), S3 (|ODU2|), S5 (|ODU2|), S6 (|ODU2|),
   C-R3 (ODU2 -> |PKT|)
```

The MDSC should be capable via the MPI to request the setup of an
ODU2 transit service with enough information that enable the
transport PNC to instantiate and control the ODU2 data plane
connection segment through nodes S3, S5, S6.

[4.3.2](#). EPL over ODU

This use case assumes that the physical links interconnecting the IP
routers and the transport network are Ethernet links.

In order to setup a 10Gb IP link between C-R1 to C-R3, an EPL
service needs to be created between C-R1 and C-R3, supported by an
ODU2 end-to-end connection between S3 and S6, crossing transport
node S5.

The traffic flow between C-R1 and C-R3 can be summarized as:

```
   C-R1 (|PKT| -> ETH), S3 (ETH -> |ODU2|), S5 (|ODU2|),
   S6 (|ODU2| -> ETH), C-R3 (ETH-> |PKT|)
```

The MDSC should be capable via the MPI to request the setup of an
EPL service with enough information that can permit the transport
PNC to instantiate and control the ODU2 end-to-end data plane
connection through nodes S3, S5, S6, as well as the adaptation
functions inside S3 and S6: S3&S6 (ETH -> ODU2) and S9&S6 (ODU2 ->
ETH).

[4.3.3](#). Other OTN Client Services

[ITU-T G.709-2016] defines mappings of different client layers into
ODU. Most of them are used to provide Private Line services over
an OTN transport network supporting a variety of types of physical
access links (e.g., Ethernet, SDH STM-N, Fibre Channel, InfiniBand,
etc.).

This use case assumes that the physical links interconnecting the IP
routers and the transport network are any one of these possible
options.

In order to setup a 10Gb IP link between C-R1 to C-R3 using, for
example STM-64 physical links between the IP routers and the
transport network, an STM-64 Private Line service needs to be
created between C-R1 and C-R3, supported by an ODU2 end-to-end data
plane connection between S3 and S6, crossing transport node S5.

   The traffic flow between C-R1 and C-R3 can be summarized as:

      C-R1 (|PKT| -> STM-64), S3 (STM-64 -> |ODU2|), S5 (|ODU2|),
      S6 (|ODU2| -> STM-64), C-R3 (STM-64 -> |PKT|)

   The MDSC should be capable via the MPI to request the setup of an
   STM-64 Private Line service with enough information that can permit
   the transport PNC to instantiate and control the ODU2 end-to-end
   connection through nodes S3, S5, S6, as well as the adaptation
   functions inside S3 and S6: S3&S6 (STM-64 -> ODU2) and S9&S3 (STM-64
   -> PKT).

4.3.4. EVPL over ODU

   This use case assumes that the physical links interconnecting the IP
   routers and the transport network are Ethernet links and that
   different Ethernet services (e.g, EVPL) can share the same physical
   link using different VLANs.

   In order to setup two 1Gb IP links between C-R1 to C-R3 and between
   C-R1 and C-R4, two EVPL services need to be created, supported by
   two ODU0 end-to-end connections respectively between S3 and S6,
   crossing transport node S5, and between S3 and S2, crossing
   transport node S1.

   Since the two EVPL services are sharing the same Ethernet physical
   link between C-R1 and S3, different VLAN IDs are associated with
   different EVPL services: for example VLAN IDs 10 and 20
   respectively.

   The traffic flow between C-R1 and C-R3 can be summarized as:

      C-R1 (|PKT| -> VLAN), S3 (VLAN -> |ODU0|), S5 (|ODU0|),
      S6 (|ODU0| -> VLAN), C-R3 (VLAN -> |PKT|)

   The traffic flow between C-R1 and C-R4 can be summarized as:

      C-R1 (|PKT| -> VLAN), S3 (VLAN -> |ODU0|), S1 (|ODU0|),
      S2 (|ODU0| -> VLAN), C-R4 (VLAN -> |PKT|)

   The MDSC should be capable via the MPI to request the setup of these
   EVPL services with enough information that can permit the transport
   PNC to instantiate and control the ODU0 end-to-end data plane
   connections as well as the adaptation functions on the boundary
   nodes: S3&S2&S6 (VLAN -> ODU0) and S3&S2&S6 (ODU0 -> VLAN).

. **EVPLAN and EVPTree Services**

   This use case assumes that the physical links interconnecting the IP
   routers and the transport network are Ethernet links and that
   different Ethernet services (e.g, EVPL, EVPLAN and EVPTree) can
   share the same physical link using different VLANs.

   Note - it is assumed that EPLAN and EPTree services can be supported
   by configuring EVPLAN and EVPTree with port mapping.

   In order to setup an IP subnet between C-R1, C-R2, C-R3 and C-R4, an
   EVPLAN/EVPTree service needs to be created, supported by two ODUflex
   end-to-end connections respectively between S3 and S6, crossing
   transport node S5, and between S3 and S2, crossing transport node
   S1.

   In order to support this EVPLAN/EVPTree service, some Ethernet
   Bridging capabilities are required on some nodes at the edge of the
   transport network: for example Ethernet Bridging capabilities can be
   configured in nodes S3 and S6 but not in node S2.

   Since this EVPLAN/EVPTree service can share the same Ethernet
   physical links between IP routers and transport nodes (e.g., with
   the EVPL services described in section 4.3.4), a different VLAN ID
   (e.g., 30) can be associated with this EVPLAN/EVPTree service.

   In order to support an EVPTree service instead of an EVPLAN,
   additional configuration of the Ethernet Bridging capabilities on
   the nodes at the edge of the transport network is required.

   The MAC bridging function in node S3 is needed to select, based on
   the MAC Destination Address, whether the Ethernet frames form C-R1
   should be sent to the ODUflex terminating on node S6 or to the other
   ODUflex terminating on node S2.

   The MAC bridging function in node S6 is needed to select, based on
   the MAC Destination Address, whether the Ethernet frames received
   from the ODUflex should be set to C-R2 or C-R3, as well as whether
   the Ethernet frames received from C-R2 (or C-R3) should be sent to
   C-R3 (or C-R2) or to the ODUflex.

   For example, the traffic flow between C-R1 and C-R3 can be
   summarized as:

      C-R1 (|PKT| -> VLAN), S3 (VLAN -> |MAC| -> |ODUflex|),
      S5 (|ODUflex|), S6 (|ODUflex| -> |MAC| -> VLAN),
      C-R3 (VLAN -> |PKT|)

The MAC bridging function in node S3 is also needed to select, based
on the MAC Destination Address, whether the Ethernet frames one
ODUflex should be sent to C-R1 or to the other ODUflex.

For example, the traffic flow between C-R3 and C-R4 can be
summarized as:

```
C-R3 (|PKT| -> VLAN), S6 (VLAN -> |MAC| -> |ODUflex|),
S5 (|ODUflex|), S3 (|ODUflex| -> |MAC| -> |ODUflex|),
S1 (|ODUflex|), S2 (|ODUflex| -> VLAN), C-R4 (VLAN -> |PKT|)
```

In node S2 there is no need for any MAC bridging function since all
the Ethernet frames received from C-R4 should be sent to the ODUflex
toward S3 and viceversa.

The traffic flow between C-R1 and C-R4 can be summarized as:

```
C-R1 (|PKT| -> VLAN), S3 (VLAN -> |MAC| -> |ODUflex|),
S1 (|ODUflex|), S2 (|ODUflex| -> VLAN), C-R4 (VLAN -> |PKT|)
```

The MDSC should be capable via the MPI to request the setup of this
EVPLAN/EVPTree services with enough information that can permit the
transport PNC to instantiate and control the ODUflex end-to-end data
plane connections as well as the Ethernet Bridging and adaptation
functions on the boundary nodes: S3&S6 (VLAN -> MAC -> ODU2), S3&S6
(ODU2 -> ETH -> VLAN), S2 (VLAN -> ODU2) and S2 (ODU2 -> VLAN).

4.4. Multi-functional Access Links

This use case assumes that some physical links interconnecting the
IP routers and the transport network can be configured in different
modes, e.g., as OTU2 or STM-64 or 10GE.

This configuration can be done a-priori by means outside the scope
of this document. In this case, these links will appear at the MPI
either as an ODU Link or as an STM-64 Link or as a 10GE Link
(depending on the a-priori configuration) and will be controlled at
the MPI as discussed in section 4.3.

It is also possible not to configure these links a-priori and give
the control to the MPI to decide, based on the service
configuration, how to configure it.

For example, if the physical link between C-R1 and S3 is a multi-
functional access link while the physical links between C-R3 and S6
and between C-R4 and S2 are STM-64 and 10GE physical links
respectively, it is possible at the MPI to configure either an STM-

64 Private Line service between C-R1 and C-R3 or an EPL service
between C-R1 and C-R4.

The traffic flow between C-R1 and C-R3 can be summarized as:

    C-R1 (|PKT| -> STM-64), S3 (STM-64 -> |ODU2|), S5 (|ODU2|),
    S6 (|ODU2| -> STM-64), C-R3 (STM-64 -> |PKT|)

The traffic flow between C-R1 and C-R4 can be summarized as:

    C-R1 (|PKT| -> ETH), S3 (ETH -> |ODU2|), S1 (|ODU2|),
    S2 (|ODU2| -> ETH), C-R4 (ETH-> |PKT|)

The MDSC should be capable via the MPI to request the setup of
either service with enough information that can permit the transport
PNC to instantiate and control the ODU2 end-to-end data plane
connection as well as the adaptation functions inside S3 and S2 or
S6.

4.5. Protection Requirements

Protection switching provides a pre-allocated survivability
mechanism, typically provided via linear protection methods and
would be configured to operate as 1+1 unidirectional (the most
common OTN protection method), 1+1 bidirectional or 1:n
bidirectional. This ensures fast and simple service survivability.

The MDSC needs to be capable to request the transport PNC to
configure protection when requesting the setup of the connectivity
services described in section 4.3.

Since in this use case it is assumed that switching within the
transport network domain is performed only in one layer, also
protection switching within the transport network domain can only be
provided at the OTN ODU layer, for all the services defined in
section 4.3.

It may be necessary to consider not only protection, but also
restoration functions in the future. Restoration methods would
provide capability to reroute and restore connectivity traffic
around network faults, without the network penalty imposed with
dedicated 1+1 protection schemes.

4.5.1. Linear Protection

   It is possible to protect any service defined in section 4.3 from
   failures within the OTN transport domain by configuring OTN linear
   protection in the data plane between node S3 and node S6.

   It is assumed that the OTN linear protection is configured to with
   1+1 unidirectional protection switching type, as defined in [ITU-T
   G.808.1-2014] and [ITU-T G.873.1-2014], as well as in [RFC4427].

   In these scenarios, a working transport entity and a protection
   transport entity, as defined in [ITU-T G.808.1-2014], (or a working
   LSP and a protection LSP, as defined in [RFC4427]) should be
   configured in the data plane, for example:

      Working transport entity: S3, S5, S6

      Protection transport entity: S3, S4, S8, S7, S6

   The Transport PNC should be capable to report to the MDSC which is
   the active transport entity, as defined in [ITU-T G.808.1-2014], in
   the data plane.

   Given the fast dynamic of protection switching operations in the
   data plane (50ms recovery time), this reporting is not expected to
   be in real-time.

   It is also worth noting that with unidirectional protection
   switching, e.g., 1+1 unidirectional protection switching, the active
   transport entity may be different in the two directions.

5. Use Case 2: Single-domain with multi-layer

5.1. Reference Network

   The current considerations discussed in this document are based on
   the following reference network:

        - single transport domain: OTN and OCh multi-layer network

   In this use case, the same reference network shown in Figure 1 is
   considered. The only difference is that all the transport nodes are
   capable to switch in the ODU as well as in the OCh layer.

   All the physical links within the transport network are therefore
   assumed to be OCh links. Therefore, with the exception of the access

links, no ODU internal link exists before an OCh end-to-end data
plane connection is created within the network.

The controlling hierarchy is the same as described in Figure 2.

The interface within the scope of this document is the Transport MPI
which should be capable to control both the OTN and OCh layers.

5.2. Topology Abstractions

A grey topology type B abstraction is assumed: abstract nodes and
links exposed at the MPI corresponds 1:1 with the physical nodes and
links controlled by the PNC but the PNC abstracts/hides at least
some optical parameters to be used within the OCh layer.

5.3. Service Configuration

The same service scenarios, as described in section 4.3, are also
applicable to these use cases with the only difference that end-to-
end OCh data plane connections will need to be setup before ODU data
plane connections.

6. Use Case 3: Multi-domain with single-layer

6.1. Reference Network

In this section we focus on a multi-domain reference network with
homogeneous technologies:

    - multiple transport domains: OTN networks

Figure 3 shows the network physical topology composed of three
transport network domains providing transport services to an IP
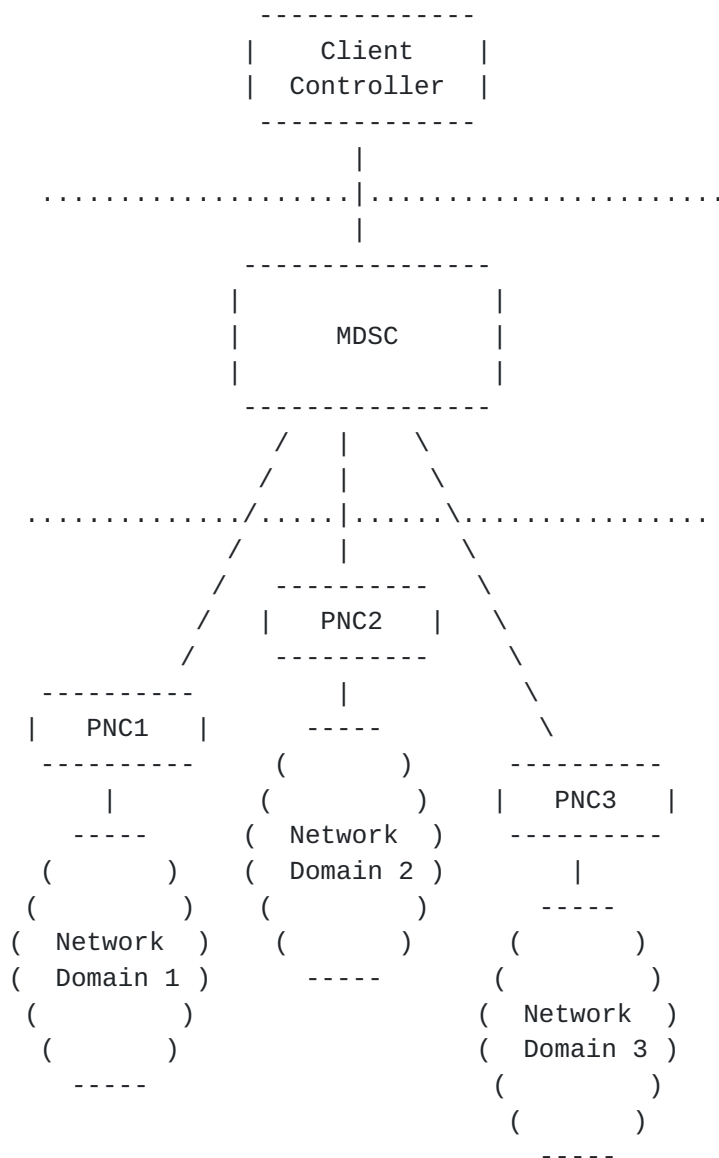customer network through eight access links:

```
                    .........................
      ..........    :                         :
      :        :    :     Network domain 1    :    ............
      :        :    :                         :    :          :
      :Customer:    :                         :    :          :
      :domain 1:    :      S1 -------+        :    :  Network  :
      :        :    :      /          \       :    :  domain 3 :    ..........
      :  C-R1 ------- S3 ----- S4     \       :    :           :    :        :
      :        :    :    \            \    S2 --------+        :    :Customer:
      :        :    :     \            \    |  :    :   \       :    :domain 3:
      :        :    :      S5           \   |  :    :    \      :    :        :
      :  C-R2 ------+     / \            \  |  :    :     S31 --------- C-R7   :
      :        :    : \  /   \            \ |  :    :    /  \    :    :        :
      :        :    :  S6 ---- S7 ---- S8 ------ S32   S33 ------ C-R8   :
      :        :    : /        |        |  :    : / \   /   :    :........:
      :  C-R3 ------+          |        |  :    :/   S34    :
      :        :    :.........|.......|...:   /    /      :
      :........:              |        |        /:.../.......:
                             |        |      /    /
                  ..........|.......|..../...../...
                  :         |        |  /    /   :    ..........
                  : Network |        | /    /    :    :        :
                  : domain 2 |       | /   /     :    :Customer:
                  :          S11 ---- S12  /      :    :domain 2:
                  :        /          | \ /      :    :        :
                  :     S13     S14   | S15 ------------- C-R4   :
                  :     | \    /  \   |   \      :    :        :
                  :     |  S16     \  |    \     :    :        :
                  :     | /          S17 -- S18 --------- C-R5   :
                  :     | /            \   /     :    :        :
                  :     S19 ---- S20 ---- S21 ------------ C-R6   :
                  :                          :    :        :
                  :..............................:    :........:
```

                 Figure 3 Reference network for Use Case 3

   It is worth noting that the network domain 1 is identical to the
   transport domain shown in Figure 1.

```
                      --------------
                      |    Client   |
                      |  Controller |
                      --------------
                             |
    ....................|........................
                             |
                      ----------------
                     |                |
                     |      MDSC      |
                     |                |
                      ----------------
                       /   |     \
                      /    |      \
    .............../.....|.......\...............
                   /      |        \
                  /    ----------     \
                 /    |   PNC2    |     \
                /      ----------        \
          ----------        |             \
         |   PNC1   |     -----            \
          ----------     (       )      ----------
              |         (         )    |   PNC3   |
            -----      (  Network  )    ----------
           (     )     (  Domain 2 )        |
          (       )     (         )       -----
         (  Network  )   (       )      (       )
         (  Domain 1 )    -----        (         )
          (         )               (   Network  )
           (       )                (   Domain 3 )
            -----                    (           )
                                      (         )
                                        -----
```

              Figure 4 Controlling Hierarchy for Use Case 3

   In this section we address the case where the CNC controls the
   customer IP network and requests transport connectivity among IP
   routers, via the CMI, to an MDSC which coordinates, via three MPIs,
   the control of a multi-domain transport network through three PNCs.

   The interfaces within the scope of this document are the three MPIs
   while the interface between the CNC and the IP routers is out of its
   scope and considerations about the CMI are outside the scope of this
   document.

6.2. Topology Abstractions

   Each PNC should provide the MDSC a topology abstraction of the
   domain's network topology.

   Each PNC provides topology abstraction of its own domain topology
   independently from each other and therefore it is possible that
   different PNCs provide different types of topology abstractions.

   As an example, we can assume that:

   o PNC1 provides a white topology abstraction (likewise use case 1
     described in section 4.2)

   o PNC2 provides a type A grey topology abstraction

   o PNC3 provides a type B grey topology abstraction, with two
     abstract nodes (AN31 and AN32). They abstract respectively nodes
     S31+S33 and nodes S32+S34. At the MPI, only the abstract nodes
     should be reported: the mapping between the abstract nodes (AN31
     and AN32) and the physical nodes (S31, S32, S33 and S34) should
     be done internally by the PNC.

   The MDSC should be capable to glue together these different abstract
   topologies to build its own view of the multi-domain network
   topology. This might require proper administrative configuration or
   other mechanisms (to be defined/analysed).

6.3. Service Configuration

   In the following use cases, it is assumed that the CNC is capable to
   request service connectivity from the MDSC to support IP routers
   connectivity.

   The same service scenarios, as described in section 4.3, are also
   application to this use cases with the only difference that the two
   IP routers to be interconnected are attached to transport nodes
   which belong to different PNCs domains and are under the control of
   the CNC.

   Likewise, the service scenarios in section 4.3, the type of services
   could depend of the type of physical links (e.g. OTN link, ETH link
   or SDH link) between the customer's routers and the multi-domain
   transport network and the configuration of the different adaptations
   inside IP routers is performed by means that are outside the scope
   of this document because not under control of and not visible to the
   MDSC nor to the PNCs. It is assumed that the CNC is capable to

request the proper configuration of the different adaptation
functions inside the customer's IP routers, by means which are
outside the scope of this document.

It is also assumed that the CNC is capable via the CMI to request
the MDSC the setup of these services with enough information that
enable the MDSC to coordinate the different PNCs to instantiate and
control the ODU2 data plane connection through nodes S3, S1, S2,
S31, S33, S34, S15 and S18, as well as the adaptation functions
inside nodes S3 and S18, when needed.

As described in section 6.2, the MDSC should have its own view of
the end-to-end network topology and use it for its own path
computation to understand that it needs to coordinate with PNC1,
PNC2 and PNC3 the setup and control of a multi-domain ODU2 data
plane connection.

6.3.1. ODU Transit

In order to setup a 10Gb IP link between C-R1 and C-R5, an ODU2 end-
to-end data plane connection needs be created between C-R1 and C-R5,
crossing transport nodes S3, S1, S2, S31, S33, S34, S15 and S18
which belong to different PNC domains.

The traffic flow between C-R1 and C-R5 can be summarized as:

    C-R1 (|PKT| -> ODU2), S3 (|ODU2|), S1 (|ODU2|), S2 (|ODU2|),
    S31 (|ODU2|), S33 (|ODU2|), S34 (|ODU2|),
    S15 (|ODU2|), S18 (|ODU2|), C-R5 (ODU2 -> |PKT|)

6.3.2. EPL over ODU

In order to setup a 10Gb IP link between C-R1 and C-R5, an EPL
service needs to be created between C-R1 and C-R5, supported by an
ODU2 end-to-end data plane connection between transport nodes S3 and
S18, crossing transport nodes S1, S2, S31, S33, S34 and S15 which
belong to different PNC domains.

The traffic flow between C-R1 and C-R5 can be summarized as:

    C-R1 (|PKT| -> ETH), S3 (ETH -> |ODU2|), S1 (|ODU2|),
    S2 (|ODU2|), S31 (|ODU2|), S33 (|ODU2|), S34 (|ODU2|),
    S15 (|ODU2|), S18 (|ODU2| -> ETH), C-R5 (ETH -> |PKT|)

6.3.3. Other OTN Client Services

In order to setup a 10Gb IP link between C-R1 and C-R5 using, for
example SDH physical links between the IP routers and the transport
network, an STM-64 Private Line service needs to be created between
C-R1 and C-R5, supported by ODU2 end-to-end data plane connection
between transport nodes S3 and S18, crossing transport nodes S1, S2,
S31, S33, S34 and S15 which belong to different PNC domains.

The traffic flow between C-R1 and C-R5 can be summarized as:

```
C-R1 (|PKT| -> STM-64), S3 (STM-64 -> |ODU2|), S1 (|ODU2|),
S2 (|ODU2|), S31 (|ODU2|), S33 (|ODU2|), S34 (|ODU2|),
S15 (|ODU2|), S18 (|ODU2| -> STM-64), C-R5 (STM-64 -> |PKT|)
```

6.3.4. EVPL over ODU

In order to setup two 1Gb IP links between C-R1 to C-R3 and between
C-R1 and C-R5, two EVPL services need to be created, supported by
two ODU0 end-to-end connections respectively between S3 and S6,
crossing transport node S5, and between S3 and S18, crossing
transport nodes S1, S2, S31, S33, S34 and S15 which belong to
different PNC domains.

The VLAN configuration on the access links is the same as described
in section 4.3.4.

The traffic flow between C-R1 and C-R3 is the same as described in
section 4.3.4.

The traffic flow between C-R1 and C-R5 can be summarized as:

```
C-R1 (|PKT| -> VLAN), S3 (VLAN -> |ODU2|), S1 (|ODU2|),
S2 (|ODU2|), S31 (|ODU2|), S33 (|ODU2|), S34 (|ODU2|),
S15 (|ODU2|), S18 (|ODU2| -> VLAN), C-R5 (VLAN -> |PKT|)
```

6.3.5. EVPLAN and EVPTree Services

In order to setup an IP subnet between C-R1, C-R2, C-R3 and C-R7, an
EVPLAN/EVPTree service needs to be created, supported by two ODUflex
end-to-end connections respectively between S3 and S6, crossing
transport node S5, and between S3 and S18, crossing transport nodes
S1, S2, S31, S33, S34 and S15 which belong to different PNC domains.

The VLAN configuration on the access links is the same as described
in section 4.3.5.

The configuration of the Ethernet Bridging capabilities on nodes S3
and S6 is the same as described in section 4.3.5 while the
configuration on node S18 similar to the configuration of node S2
described in section 4.3.5.

The traffic flow between C-R1 and C-R3 is the same as described in
section 4.3.5.

The traffic flow between C-R1 and C-R5 can be summarized as:

    C-R1 (|PKT| -> VLAN), S3 (VLAN -> |MAC| -> |ODUflex|),
    S1 (|ODUflex|), S2 (|ODUflex|), S31 (|ODUflex|),
    S33 (|ODUflex|), S34 (|ODUflex|),
    S15 (|ODUflex|), S18 (|ODUflex| -> VLAN), C-R5 (VLAN -> |PKT|)

6.4. Multi-functional Access Links

The same considerations of section 4.4 apply with the only
difference that the ODU data plane connections could be setup across
multiple PNC domains.

For example, if the physical link between C-R1 and S3 is a multi-
functional access link while the physical links between C-R7 and S31
and between C-R5 and S18 are STM-64 and 10GE physical links
respectively, it is possible to configure either an STM-64 Private
Line service between C-R1 and C-R7 or an EPL service between C-R1
and C-R5.

The traffic flow between C-R1 and C-R7 can be summarized as:

    C-R1 (|PKT| -> STM-64), S3 (STM-64 -> |ODU2|), S1 (|ODU2|),
    S2 (|ODU2|), S31 (|ODU2| -> STM-64), C-R3 (STM-64 -> |PKT|)

The traffic flow between C-R1 and C-R5 can be summarized as:

    C-R1 (|PKT| -> ETH), S3 (ETH -> |ODU2|), S1 (|ODU2|),
    S2 (|ODU2|), S31 (|ODU2|), S33 (|ODU2|), S34 (|ODU2|),
    S15 (|ODU2|), S18 (|ODU2| -> ETH), C-R5 (ETH -> |PKT|)

6.5. Protection Scenarios

The MDSC needs to be capable to coordinate different PNCs to
configure protection switching when requesting the setup of the
connectivity services described in section 6.3.

Since in this use case it is assumed that switching within the
transport network domain is performed only in one layer, also

protection switching within the transport network domain can only be
provided at the OTN ODU layer, for all the services defined in
section 6.3.

6.5.1. Linear Protection (end-to-end)

In order to protect any service defined in section 6.3 from failures
within the OTN multi-domain transport network, the MDSC should be
capable to coordinate different PNCs to configure and control OTN
linear protection in the data plane between nodes S3 and node S18.

The considerations in section 4.5.1 are also applicable here with
the only difference that MDSC needs to coordinate with different
PNCs the setup and control of the OTN linear protection as well as
of the working and protection transport entities (working and
protection LSPs).

Two cases can be considered.

In one case, the working and protection transport entities pass
through the same PNC domains:

```
   Working transport entity:   S3, S1, S2,
                       S31, S33, S34,
                       S15, S18

   Protection transport entity: S3, S4, S8,
                       S32,
                       S12, S17, S18
```

In another case, the working and protection transport entities can
pass through different PNC domains:

```
   Working transport entity:   S3, S5, S7,
                       S11, S12, S17, S18

   Protection transport entity: S3, S1, S2,
                       S31, S33, S34,
                       S15, S18
```

6.5.2. Segmented Protection

In order to protect any service defined in section 6.3 from failures
within the OTN multi-domain transport network, the MDSC should be
capable to request each PNC to configure OTN intra-domain protection
when requesting the setup of the ODU2 data plane connection segment.

If linear protection is used within a domain, the considerations in
section 4.5.1 are also applicable here only for the PNC controlling
the domain where intra-domain linear protection is provided.

If PNC1 provides linear protection, the working and protection
transport entities could be:

   Working transport entity: S3, S1, S2

   Protection transport entity: S3, S4, S8, S2

If PNC2 provides linear protection, the working and protection
transport entities could be:

   Working transport entity: S15, S18

   Protection transport entity: S15, S12, S17, S18

If PNC3 provides linear protection, the working and protection
transport entities could be:

   Working transport entity: S31, S33, S34

   Protection transport entity: S31, S32, S34

7. Use Case 4: Multi-domain and multi-layer

7.1. Reference Network

The current considerations discussed in this document are based on
the following reference network:

     - multiple transport domains: OTN and OCh multi-layer networks

In this use case, the reference network shown in Figure 3 is used.
The only difference is that all the transport nodes are capable to
switch either in the ODU or in the OCh layer.

All the physical links within each transport network domain are
therefore assumed to be OCh links, while the inter-domain links are
assumed to be ODU links as described in section 6.1 (multi-domain
with single layer - OTN network).

Therefore, with the exception of the access and inter-domain links,
no ODU link exists within each domain before an OCh single-domain
end-to-end data plane connection is created within the network.

The controlling hierarchy is the same as described in Figure 4.

The interfaces within the scope of this document are the three MPIs which should be capable to control both the OTN and OCh layers within each PNC domain.

7.2. Topology Abstractions

Each PNC should provide the MDSC a topology abstraction of its own network topology as described in section 5.2.

As an example, it is assumed that:

o PNC1 provides a type A grey topology abstraction (likewise in use case 2 described in section 5.2)

o PNC2 provides a type B grey topology abstraction (likewise in use case 3 described in section 6.2)

o PNC3 provides a type B grey topology abstraction with two abstract nodes, likewise in use case 3 described in section 6.2, and hiding at least some optical parameters to be used within the OCh layer, likewise in use case 2 described in section 5.2.

7.3. Service Configuration

The same service scenarios, as described in section 6.3, are also applicable to these use cases with the only difference that single-domain end-to-end OCh data plane connections needs to be setup before ODU data plane connections.

8. Security Considerations

Typically, OTN networks ensure a high level of security and data privacy through hard partitioning of traffic onto isolated circuits.

There may be additional security considerations applied to specific use cases, but common security considerations do exist and these must be considered for controlling underlying infrastructure to deliver transport services:

o use of RESCONF and the need to reuse security between RESTCONF components;

o use of authentication and policy to govern which transport services may be requested by the user or application;

o how secure and isolated connectivity may also be requested as an
    element of a service and mapped down to the OTN level.

9. IANA Considerations

This document requires no IANA actions.

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