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        **Framework for Abstraction and Control of Transport Networks**

                 [draft-ceccarelli-actn-framework-05.txt](draft-ceccarelli-actn-framework-05.txt)


Status of this Memo

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Abstract

   This draft provides a framework for abstraction and control of
   transport networks.

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**1. Introduction**

   Transport networks have a variety of mechanisms to facilitate
   separation of data plane and control plane including distributed
   signaling for path setup and protection, centralized path
   computation for planning and traffic engineering, and a range of
   management and provisioning protocols to configure and activate
   network resources. These mechanisms represent key technologies for
   enabling flexible and dynamic networking.

   Transport networks in this draft refer to a set of different type of
   connection-oriented networks, primarily Connection-Oriented Circuit
   Switched (CO-CS) networks and Connection-Oriented Packet Switched
   (CO-PS) networks. This implies that at least the following transport
   networks are in scope of the discussion of this draft: Layer 1(L1)
   and Layer 0 (L0) optical networks (e.g., Optical Transport Network
   (OTN), Optical Channel Data Unit (ODU), Optical Channel
   (OCh)/Wavelength Switched Optical Network (WSON)), Multi-Protocol
   Label Switching - Transport Profile (MPLS-TP), Multi-Protocol Label
   Switching - Traffic Engineering (MPLS-TE), as well as other emerging
   technologies with connection-oriented behavior. One of the
   characteristics of these network types is the ability of dynamic
   provisioning and traffic engineering such that resource guarantee
   can be provided to their clients.

   One of the main drivers for Software Defined Networking (SDN) is a
   decoupling of the network control plane from the data plane. This
   separation of the control plane from the data plane has been already

achieved with the development of MPLS/GMPLS [GMPLS] and PCE [PCE]
for TE-based transport networks. One of the advantages of SDN is its
logically centralized control regime that allows a global view of
the underlying network under its control. Centralized control in SDN
helps improve network resources utilization from a distributed
network control. For TE-based transport network control, PCE is
essentially equivalent to a logically centralized control for path
computation function.

Two key aspects that need to be solved by SDN are:

   . Network and service abstraction
   . End to end coordination of multiple SDN and pre-SDN domains
      e.g. NMS, MPLS-TE or GMPLS.

As transport networks evolve, the need to provide network and
service abstraction has emerged as a key requirement for operators;
this implies in effect the virtualization of network resources so
that the network is "sliced" for different tenants shown as a
dedicated portion of the network resources

Particular attention needs to be paid to the multi-domain case,
where Abstraction and Control of Transport Networks (ACTN) can
facilitate virtual network operation via the creation of a single
virtualized network or a seamless service. This supports operators
in viewing and controlling different domains (at any dimension:
applied technology, administrative zones, or vendor-specific
technology islands) as a single virtualized network.

Network virtualization, in general, refers to allowing the customers
to utilize a certain amount of network resources as if they own them
and thus control their allocated resources in a way most optimal
with higher layer or application processes. This empowerment of
customer control facilitates introduction of new services and
applications as the customers are permitted to create, modify, and
delete their virtual network services. More flexible, dynamic
customer control capabilities are added to the traditional VPN along
with a customer specific virtual network view. Customers control a
view of virtual network resources, specifically allocated to each
one of them. This view is called an abstracted network topology.
Such a view may be specific to the set of consumed services as well
as to a particular customer. As the Customer Network Controller is
envisioned to support a plethora of distinct applications, there
would be another level of virtualization from the customer to
individual applications.

The framework described in this draft is named Abstraction and
Control of Transport Network (ACTN) and facilitates:

- Abstraction of the underlying network resources to higher-layer
  applications and users (customers); abstraction for a specific
  application or customer is referred to as virtualization in the
  ONF SDN architecture. [ONF-ARCH]

- Slicing infrastructure to connect multiple customers to meet
  specific customer's service requirements;

- Creation of a virtualized environment allowing operators to
  view and control multi-subnet multi-technology networks into a
  single virtualized network;

- Possibility of providing a customer with abstracted network or
  abstracted services (totally hiding the network).


- A virtualization/mapping network function that adapts customer
  requests to the virtual resources (allocated to them) to the
  supporting physical network control and performs the necessary
  mapping, translation, isolation and security/policy
  enforcement, etc.; This function is often referred to as
  orchestration.

- The multi-domain coordination of the underlying transport
  domains, presenting it as an abstracted topology to the
  customers via open and programmable interfaces. This allows for
  the recursion of controllers in a customer-provider
  relationship.

The organization of this draft is as follows. Section 2 provides a
discussion for a Business Model, Section 3 ACTN Architecture,
Section 4 ACTN Applicability, and Section 5 ACTN Interface
requirements.

## 2. Business Model of ACTN

The traditional Virtual Private Network (VPN) and Overlay Network
(ON) models are built on the premise that one single network
provider provides all virtual private or overlay networks to its
customers. This model is simple to operate but has some
disadvantages in accommodating the increasing need for flexible and
dynamic network virtualization capabilities.

The ACTN model is built upon entities that reflect the current landscape of network virtualization environments. There are three key entities in the ACTN model [ACTN-PS]:

   - Customers
   - Service Providers
   - Network Providers


 2.1. Customers

Within the ACTN framework, different types of customers may be taken into account depending on the type of their resource needs, on their number and type of access. As example, it is possible to group them into two main categories:

Basic Customer: Basic customers include fixed residential users, mobile users and small enterprises. Usually the number of basic customers is high; they require small amounts of resources and are characterized by steady requests (relatively time invariant). A typical request for a basic customer is for a bundle of voice service and internet access. Moreover basic customers do not modify their services themselves; if a service change is needed, it is performed by the provider as proxy and they generally has very few dedicated resources (subscriber drop), with everything else shared on the basis of some SLA, which is usually best-efforts.

Advanced Customer: Advanced customers typically include enterprises, governments and utilities. Such customers can ask for both point to point and multipoint connectivity with high resource demand significantly varying in time and from customer to customer. This is one of reasons why a bundled services offer is not enough but it is desirable to provide each of them with customized virtual network services. Advanced customers may own dedicated virtual resources, or share resources, but shared resources are likely to be governed by more complex SLA agreements; moreover they may have the ability to modify their service parameters directly (within the scope of their virtualized environments).As customers are geographically spread over multiple network provider domains, the necessary control and data interfaces to support such customer needs is no longer a single interface between the customer and one single network provider. With this premise, customers have to interface multiple providers to get their end-to-end network connectivity service and the associated topology information. Customers may have to support multiple virtual network services with different service objectives and QoS requirements. For flexible and dynamic applications, customers may want to control their allocated virtual network resources in a

dynamic fashion. To allow that, customers should be given an
abstracted view of topology on which they can perform the necessary
control decisions and take the corresponding actions. ACTN's primary
focus is Advanced Customers.

Customers of a given service provider can in turn offer a service to
other customers in a recursive way. An example of recursiveness with
2 service providers is shown below.

   - Customer (of service B)
   - Customer (of service A) & Service Provider (of service B)
   - Service Provider (of service A)
   - Network Provider

```
+------------------------------------------------------------------+   ---
|                                                                  |    ^
|                                            Customer (of service B)|    .
| +--------------------------------------------------------------+ |    B
| |                                                              | |--- .
| |     Customer (of service A) & Service Provider(of service B)| | ^   .
| | +----------------------------------------------------------+ | | .   .
| | |                                                          | | | .   .
| | |                              Service Provider (of service A)| | | A   .
| | |+------------------------------------------------+         | | | .   .
| | ||                                                |         | | | .   .
| | ||                            Network provider|         | | | v   v
| | |+------------------------------------------------+         | | |------
| | +----------------------------------------------------------+ | |
| +--------------------------------------------------------------+ |
+------------------------------------------------------------------+
```
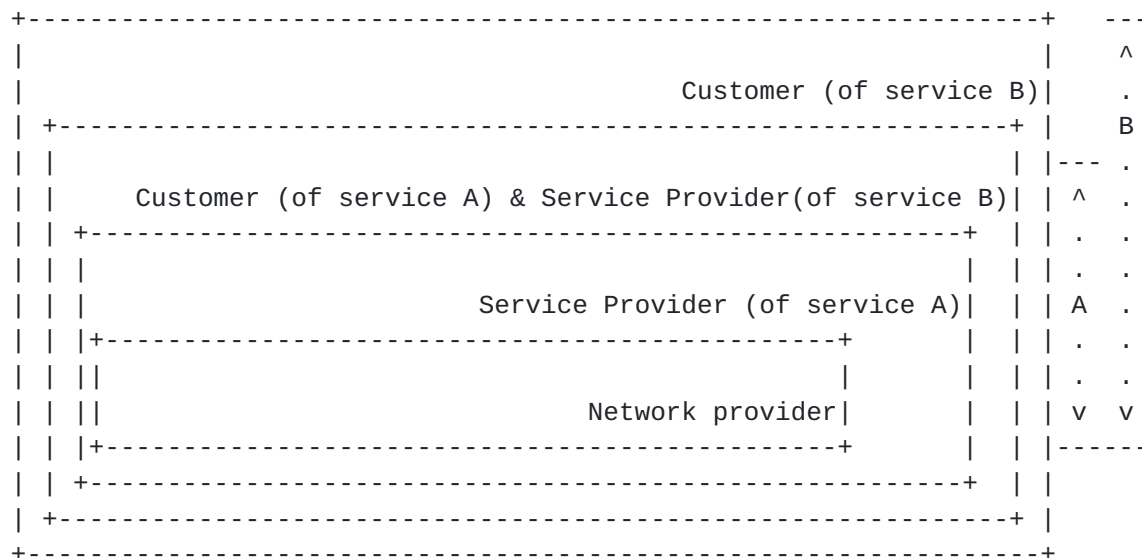
                    Figure 1: Network Recursiveness.

 2.2. Service Providers

Service providers are the providers of virtual network services to
their customers. Service providers may or may not own physical
network resources. When a service provider is the same as the
network provider, this is similar to traditional VPN models. This
model works well when the customer maintains a single interface with
a single provider.  When customer location spans across multiple
independent network provider domains, then it becomes hard to

facilitate the creation of end-to-end virtual network services with
this model.

A more interesting case arises when network providers only provide
infrastructure while service providers directly interface their
customers. In this case, service providers themselves are customers
of the network infrastructure providers. One service provider may
need to keep multiple independent network providers as its end-users
span geographically across multiple network provider domains.

```
Customer              X ----------------------------------X

Service Provider A  X ----------------------------------X

Network Provider B                     X-----------------X

Network Provider A  X-----------------X
```

The ACTN network model is predicated upon this three tier model and
is summarized in figure below:

```
                   +---------------------+
                   |      customer       |
                   +---------------------+
                            |
                            |   /\  Service/Customer specific
                            |   ||  Abstract Topology
                            |   ||
                   +---------------------+  E2E abstract
                   |  Service Provider   | topology creation
                   +---------------------+
                  /          |          \
                 /           |           \  Network Topology
                /            |            \ (raw or abstract)
               /             |             \
     +-----------------+   +-----------------+   +-----------------+
     |Network Provider 1|   |Network Provider 2|   |Network Provider 3|
     +-----------------+   +-----------------+   +-----------------+
```
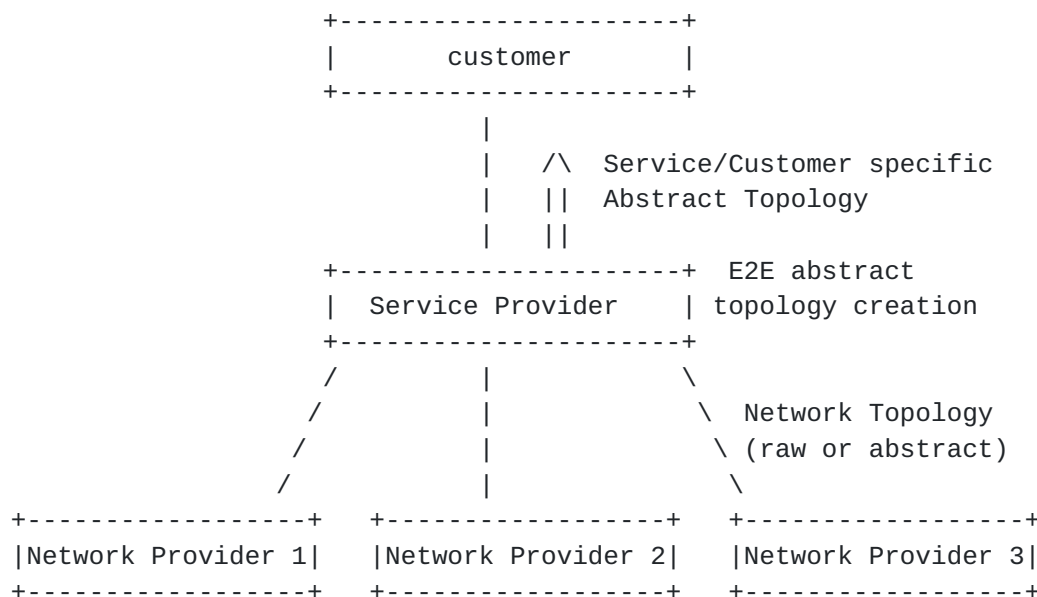
Figure 2: Three tier model.

There can be multiple types of service providers.

. Data Center providers: can be viewed as a service provider type
   as they own and operate data center resources to various WAN
   clients, they can lease physical network resources from network
   providers.
. Internet Service Providers (ISP): can be a service provider of
   internet services to their customers while leasing physical
   network resources from network providers.
. Mobile Virtual Network Operators (MVNO): provide mobile
   services to their end-users without owning the physical network
   infrastructure.

The network provider space is the one where recursiveness occurs. A
customer-provider relationship between multiple service providers
can be established leading to a hierarchical architecture of
controllers within service provider network.


 2.3. Network Providers

Network Providers are the infrastructure providers that own the
physical network resources and provide network resources to their
customers. The layered model proposed by this draft separates the
concerns of network providers and customers, with service providers
acting as aggregators of customer requests.

## [3]. ACTN architecture

This section provides a high-level control and interface model of
ACTN.

The ACTN architecture, while being aligned with the ONF SDN
architecture [ONF-ARCH], is presenting a 3-tiers reference model. It
allows for hierarchy and recursiveness not only of SDN controllers
but also of traditionally controlled domains. It defines three types
of controllers depending on the functionalities they implement. The
main functionalities that are identified are:

. Multi domain coordination function: With the definition of
   domain being "everything that is under the control of the same
   controller",it is needed to have a control entity that oversees
   the specific aspects of the different domains and to build a
   single abstracted end-to-end network topology in order to

coordinate end-to-end path computation and path/service
provisioning.

. Virtualization/Abstraction function: To provide an abstracted
  view of the underlying network resources towards customer,
  being it the client or a higher level controller entity. It
  includes computation of customer resource requests into virtual
  network paths based on the global network-wide abstracted
  topology and the creation of an abstracted view of network
  slices allocated to each customer, according to customer-
  specific virtual network objective functions, and to the
  customer traffic profile.

. Customer mapping function: In charge of mapping customer VN
  setup commands into network provisioning requests to the
  Physical Network Controller (PNC) according to business OSS/NMS
  provisioned static or dynamic policy. Moreover it provides
  mapping and translation of customer virtual network slices into
  physical network resources


. Virtual service coordination: Virtual service coordination
  function in ACTN incorporates customer service-related
  knowledge into the virtual network operations in order to
  seamlessly operate virtual networks while meeting customer's
  service requirements.


  The functionality is covering two types of services:

  - Service-aware Connectivity Services: This category includes
    all the network service operations used to provide
    connectivity between customer end-points while meeting
    policies, service related constraints. The data model for
    this category would include topology entities such as
    virtual nodes, virtual links, adaptation and termination
    points and service-related entities such as policies and
    service related constraints.

  - Network Function Virtualization Services: These kinds of
    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. 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)."

About the Customer service-related knowledge it includes:

- VN Service Requirements: The end customer would have
  specific service requirements for the VN including the
  customer endpoints access profile as well as the E2E
  customer service objectives. The ACTN framework
  architectural "entities" would monitor the E2E service
  during the lifetime of VN by focusing on both the
  connectivity provided by the network as well as the customer
  service objectives. These E2E service requirements go beyond
  the VN service requirements and include customer
  infrastructure as well.

- Application Service Policy: Apart for network connectivity,
  the customer may also require some policies for application
  specific features or services. The ACTN framework would take
  these application service policies and requirements into
  consideration while coordinating the virtual network
  operations, which require end customer connectivity for
  these advanced services.


While the "types" of controller defined are shown in Figure 3 below
and are the following:

  . CNC - Customer Network Controller
  . MDSC - Multi Domain Service Coordinator
  . PNC - Physical Network Controller

```
     VPN customer        NW Mobile Customer    ISP NW service Customer

         |                       |                       |

     +-------+               +-------+               +-------+

     | CNC-A |               | CNC-B |               | CNC-C |

     +-------+               +-------+               +-------+

        _____            |            _____/

             \            |          /

              +----------------------+

              |          MDSC        |

              +----------------------+

           _____/      |        _____

          /                 |                   \

     +-------+           +-------+           +-------+

     | PNC   |           | PNC   |           | PNC   |

     +-------+           +-------+           +-------+

         | GMPLS            /      |              /    \
         | trigger         /       |             /      \
      --------      __----      +-----+  __     +-----+    \
     (        )    (    )_   | PNC |__       | PCE |     \
      -       -   ( Phys )    +-----+        +-----+    -----
     (  GMPLS   )  (Netw)        |            /        (     )
     (  Physical  ) ----         |           /       ( Phys. )
     (  Network )              -----     -----         ( Net )
       -      -              (     )   (     )          -----
     (        )             ( Phys. ) ( Phys  )
       --------             ( Net )   ( Net )
                             -----     -----
```
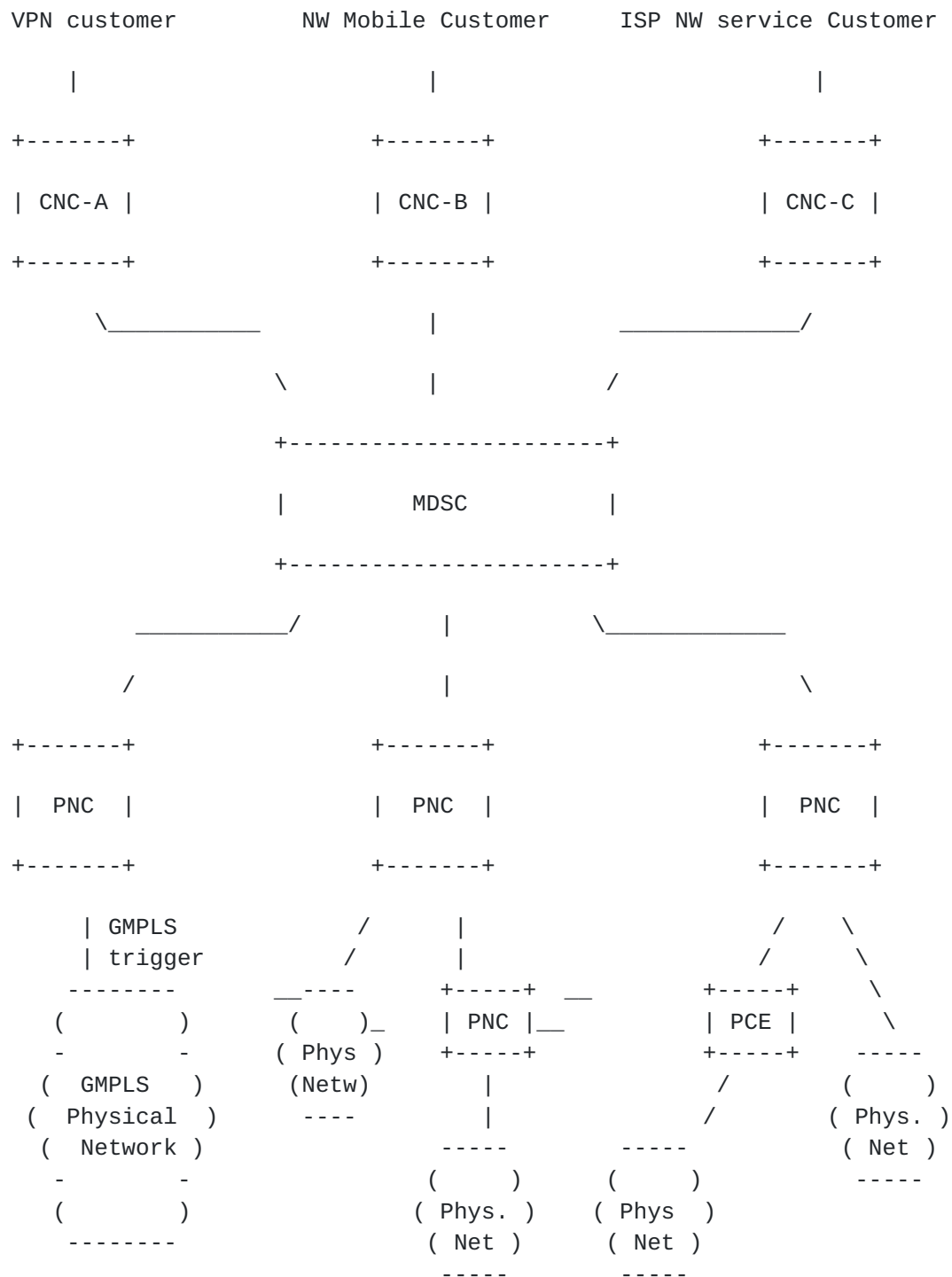
                    Figure 3: ACTN Control Hierarchy

3.1. Customer Network Controller

A Virtual Network Service is instantiated by the Customer Network
Controller via the CMI (CNC-MDSC Interface). As the Customer Network
Controller directly interfaces the application stratum, it
understands multiple application requirements and their service
needs. It is assumed that the Customer Network Controller and the
VNC have a common knowledge on the end-point interfaces based on
their business negotiation prior to service instantiation. End-point
interfaces refer to customer-network physical interfaces that
connect customer premise equipment to network provider equipment.
Figure 8 in Appendix shows an example physical network topology that
supports multiple customers. In this example, customer A has three
end-points A.1, A.2 and A.3. The interfaces between customers and
transport networks are assumed to be 40G OTU links.

In addition to abstract networks, ACTN allows to provide the CNC
with services. Example of services include connectivity between one
of the customer's end points with a given set of resources in a data
center from the service provider.

3.2. Multi Domain Service Coordinator

The MSDC (Multi Domain Service Coordinator) sits between the CNC
(the one issuing connectivity requests) and the PNCs (Physical
Network Controllersr - the ones managing the physical network
resources). The MSDC can be collocated with the PNC, especially in
those cases where the service provider and the network provider are
the same entity.

The internal system architecture and building blocks of the MDSC are
out of the scope of ACTN. Some examples can be found in the
Application Based Network Operations (ABNO) architecture [ABNO] and
the ONF SDN architecture [ONF-ARCH].

The MDSC is the only building block of the architecture that is able
to implement all the four ACTN main functionalities, i.e. multi
domain coordination function, virtualization/abstraction function,
customer mapping function and virtual service coordination.
A hierarchy of MSDCs can be foreseen for scalability and
administrative choices.

3.3. Physical Network Controller

The physical network controller is the one in charge of configuring
the network elements, monitoring the physical topology of the
network and passing it, either raw or abstracted, to the MDSC.

The internal architecture of the PNC, his building blocks and the
way it controls its domain, are out of the scope of ACTN. Some
examples can be found in the Application Based Network Operations
(ABNO) architecture [ABNO] and the ONF SDN architecture [ONF-ARCH]

The PNC, in addition to being in charge of controlling the physical
network, is able to implement two of the four ACTN main
functionalities: multi domain coordination function and
virtualization/abstraction function
A hierarchy of PNCs can be foreseen for scalability and
administrative choices.

3.4. ACTN interfaces

To allow virtualization and multi domain coordination, the network
has to provide open, programmable interfaces, in which customer
applications can create, replace and modify virtual network
resources and services in an interactive, flexible and dynamic
fashion while having no impact on other customers. Direct customer
control of transport network elements and virtualized services is
not perceived as a viable proposition for transport network
providers due to security and policy concerns among other reasons.
In addition, as discussed in the previous section, the network
control plane for transport networks has been separated from data
plane and as such it is not viable for the customer to directly
interface with transport network elements.

While the current network control plane is well suited for control
of physical network resources via dynamic provisioning, path
computation, etc., a multi service domain controller needs to be
built on top of physical network controller to support network
virtualization. On a high-level, virtual network control refers to a
mediation layer that performs several functions:

Figure 4 depicts a high-level control and interface architecture for
ACTN. A number of key ACTN interfaces exist for deployment and
operation of ACTN-based networks. These are highlighted in Figure 4
(ACTN Interfaces) below:

```
                   .--------------
                  -------------   |
                 | Application |--
                  -------------
                      Figure 1                    ^

                      | I/F A             --------
                       v                 (         )
                 --------------          -         -
                | Customer     |        (  Customer  )
                |  Network     |-------->(    Network   )
                |   Controller |        (             )
                 --------------          -           -
                      ^                 (           )
                      | I/F B           --------
                       v                 ^     ^
                 --------------          :     :
                | MultiDomain  |         :     .
                |  Service     |         :      .
                |   Coordinator|        --------   . I/F E
                 --------------        (       )  .
                    ^                   -      -  .
                    | I/F C           (  Physical  )  .
                     v               (    Network   )  .
                 ---------------     (             )   --------
                |             |<----> -            -   (        )
                 -------------    |   (           )   -        -
                | Physical     |--       --------    (  Physical  )
                |  Network     |<--------------------->(    Network   )
                |   Controller |        I/F D        (             )
                 --------------                        -         -
                                                      (           )
                                                       --------
```
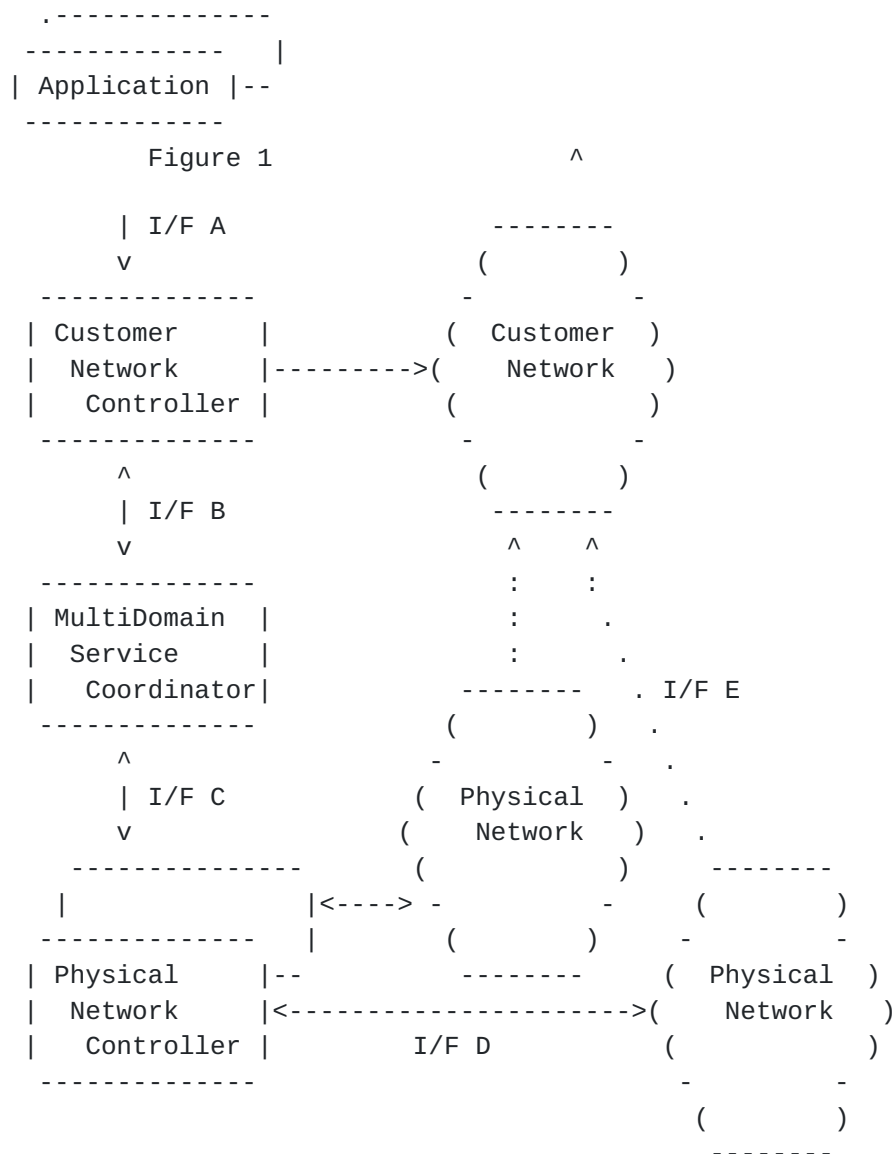
                    Figure 4: ACTN Interfaces

   The interfaces and functions are described below:

     - Interface A: A north-bound interface (NBI) that will
        communicate the service request or application demand. A
        request will include specific service properties, including:
        services, topology, bandwidth and constraint information.

     - Interface B: The CNC-MSDC Interface (CMI) is an interface
        between a Customer Network Controller and a Multi Service
        Domain Controller. It requests the creation of the network

resources, topology or services for the applications. The
Virtual Network Controller may also report potential network
topology availability if queried for current capability from
the Customer Network Controller.


- Interface C: The MDSC-PNC Interface (MPI) is an interface
  between a Multi Domain Service Coordinator and a Physical
  Network Controller. It communicates the creation request, if
  required, of new connectivity of bandwidth changes in the
  physical network, via the PNC. In multi-domain environments,
  the MDSC needs to establish multiple MPIs, one for each PNC, as
  there are multiple PNCs responsible for its domain control.


- Interface D: The provisioning interface for creating forwarding
  state in the physical network, requested via the Physical
  Network Controller.


- Interface E: A mapping of physical resources to overlay
  resources.


The interfaces within the ACTN scope are B and C.

## 4. ACTN Applicability

This section provides a high-level applicability of ACTN based on a
number of use-cases listed in the following:

+ draft-cheng-actn-ptn-requirements-00 (ACTN Use-cases for Packet
  Transport Networks in Mobile Backhaul Networks)

+ draft-dhody-actn-poi-use-case-03 (Packet Optical Integration (POI)
  Use Cases for Abstraction and Control of Transport Networks
  (ACTN))

+ draft-fang-actn-multidomain-dci-01 (ACTN Use Case for Multi-domain
  Data Center Interconnect)

+ draft-klee-actn-connectivity-multi-vendor-domains-03 (ACTN Use-
  case for On-demand E2E Connectivity Services in Multiple Vendor
  Domain Transport Networks)

+ draft-kumaki-actn-multitenant-vno-00 (ACTN : Use case for Multi
  Tenant VNO)

+ draft-lopez-actn-vno-multidomains-01 (ACTN Use-case for Virtual
  Network Operation for Multiple Domains in a Single Operator
  Network)

+ draft-shin-actn-mvno-multi-domain-00 (ACTN Use-case for Mobile
  Virtual Network Operation for Multiple Domains in a Single
  Operator Network)

+ draft-xu-actn-perf-dynamic-service-control-02 (Use Cases and
  Requirements of Dynamic Service Control based on Performance
  Monitoring in ACTN Architecture)

**4.1. ACTN Use cases Summary**

Listed below is a set of generalized requirements identified by each of
the aforementioned use-cases:

+ draft-cheng-actn-ptn-requirements-00

    - Faster End-to-End Enterprise Services Provisioning
    - Multi-layer coordination in L2/L3 Packet Transport Networks
    - Optimizing the network resources utilization (supporting
       various performances monitoring matrix, such as traffic flow
       statistics, packet delay, delay variation, throughput and
       packet-loss rate)
    - Virtual Networks Operations for multi-domain Packet Transport
       Networks

+ draft-dhody-actn-poi-use-case-03

    - Packet Optical Integration to support Traffic Planning,
       performance Monitoring, automated congestion management and
       Automatic Network Adjustments
    - Protection and Restoration Synergy in Packet Optical Multi-
       layer network.
    - Service Awareness and Coordination between Multiple Network
       Domains

+ draft-fang-actn-multidomain-dci-01

   + Multi-domain Data Center Interconnection to support VM
     Migration, Global Load Balancing, Disaster Recovery, On-demand
     Virtual Connection/Circuit Services

+ The interfaces between the Data Center Operation and each
  transport network domain should support standards-based
  abstraction with a common information/data model to support the
  following:
    - Network Query (Pull Model) from the Data Center
      Operation to each transport network domain to collect
      potential resource availability (e.g., BW availability,
      latency range, etc.) between a few data center
      locations.
    - Network Path Computation Request from the Data Center
      Operation to each transport network domain to estimate
      the path availability.
    - Network Virtual Connections/Circuits Request from the
      Data Center Operation to each transport domain to
      establish end-to-end virtual connections/circuits (with
      type, concurrency, duration, SLA.QoS parameters,
      protection.reroute policy options, policy constraints
      such as peering preference, etc.).
    - Network Virtual Connections/Circuits Modification
      Request

+ [draft-klee-actn-connectivity-multi-vendor-domains-02](draft-klee-actn-connectivity-multi-vendor-domains-02)

  - Two-stage path computation capability in a hierarchical
    control architecture (VNC-PNC) and  a hierarchical
    composition of integrated network views

  - Coordination of signal flow for E2E connections.

  - Abstraction of:

      - Inter-connection data between domains

      - Customer Endpoint data

      - The multiple levels/granularities of the abstraction of
        network resource (which is subject to policy and service
        need).

      - Any physical network constraints (such as SRLG, link
        distance, etc.) should be reflected in abstraction.

      - Domain preference and local policy (such as preferred
        peering point(s), preferred route, etc.), Domain network
        capability (e.g., support of push/pull model).

+ [draft-kumaki-actn-multitenant-vno-00](draft-kumaki-actn-multitenant-vno-00)

        - On-demand Virtual Network Service Creation
        - Domain Control Plane/Routing Layer Separation
        - Independent service Operation for Virtual Services from
           control of other domains
        - Multiple service level support for each VN (e.g., bandwidth
           and latency for each VN service).
        - VN diversity/survivability should be met in physical network
           mapping.
        - VN confidentiality and sharing constraint should be supported.

    + [draft-lopez-actn-vno-multidomains-01](draft-lopez-actn-vno-multidomains-01)

        - Creation of a global abstraction of network topology: The VNO
           Coordinator assembles each domain level abstraction of
           network topology into a global abstraction of the end-to-
           endnetwork.
        - End-to-end connection lifecycle management
        - Invocation of path provisioning request to each domain
           (including optimization requests)
        - Invocation of path protection/reroute to the affected
           domain(s)
        - End-to-end network monitoring and fault management. This could
           imply potential KPIs and alarm correlation capabilities.
        - End-to-end accounting and generation of detailed records for
           resource usage
        - End-to-end policy enforcement

    + [draft-shin-actn-mvno-multi-domain-00](draft-shin-actn-mvno-multi-domain-00)

        - Resource abstraction: operational mechanisms in mobile
           backhaul network to give the current network usage
           information for dynamic and elastic applications be
           provisioned dynamically with QoS guarantee.

        - Load balancing or for recovery, the selection of core DC
           location from edge constitutes a data center selection
           problem.

        - Multi-layer routing and optimization, coordination between
           these two layers.

    + [draft-xu-actn-perf-dynamic-service-control-02](draft-xu-actn-perf-dynamic-service-control-02)

        - Dynamic Service Control Policy enforcement and Traffic/SLA
           Monitoring:

                    - Customer service performance monitoring strategy,
                       including the traffic monitoring object (the service
                       need to be monitored)
                    - monitoring parameters (e.g., transmitted and received
                       bytes per unit time),
                    - traffic monitoring cycle (e.g., 15 minutes, 24 hours),
                    - threshold of traffic monitoring (e.g., high and low
                       threshold), etc.

## 4.2. Work in Scope of ACTN

   This section provides a summary of use-cases in terms of two
   categories: (i) service-specific requirements; (ii) network-related
   requirements.

   Service-specific requirements listed below are uniquely applied to
   the work scope of ACTN. Service-specific requirements are related to
   virtual service coordination function defined in Section 3. These
   requirements are related to customer's VNs in terms of service
   policy associated with VNs such as service performance objectives,
   VN endpoint location information for certain required service-
   specific functions (e.g., security and others), VN survivability
   requirement, or dynamic service control policy, etc.

   Network-related requirements are related to virtual network
   operation function defined in Section 3. These requirements are
   related to multi-domain and multi-layer signaling, routing,
   protection/restoration and synergy, re-optimization/re-grooming,
   etc. These requirements are not inherently unique for the scope of
   ACTN but some of these requirements are in scope of ACTN, especially
   for coherent/seamless operation aspect of multiple controller
   hierarchy.

   The following table gives an overview of service-specific
   requirements and network-related requirements respectively for each
   ACTN use-case and identifies the work in scope of ACTN.

Use case-1: Cheng

Service-Specific requirements:

     - E2E service provisioning
     - Performance Monitoring, resource utilization, abstraction

Network-related requirements:

     - Multi-layer (L2/L2.5) coordination
     - VNO for multi-domain transport networks

ACTN work scope:

     - Dynamic multi-layer coordination based on utilization is in
       scope of ACTN
     - YANG for utilization abstraction

+----------------------------------------------------------------+

Use case-2: Dhody

Service-Specific requirements:

     - Service-awareness/coordination between Packet and Optical

Network-related requirements:

     - Packet/Optical performance monitoring
     - Protection/Restoration synergy

ACTN work scope:

     - Performance related data model may be in scope of ACTN
     - Customer's VN survivability  policy enforcement for
       protection/restoration is unique to ACTN.

+----------------------------------------------------------------+

Use case-3: Fang

Service-Specific requirements:

     - Dynamic VM migration (service), Global load balancing
       (utilization efficiency), Disaster recovery
     - Service-aware network query
     - Service Policy Enforcement

Network-related requirements:

        - On-demand virtual circuit request
        - Network Path Connection request

    ACTN work scope:

        - Multi-destination service selection policy enforcement and
          its related primitives/information are unique to ACTN.
        - Service-aware network query and its data model can be
          extended by ACTN.

    +------------------------------------------------------------------+

    Use case-4: Klee

    Network-related requirements:

        - Two stage path computation
        - E2E signaling coordination
        - Abstraction of inter-domain info
        - Enforcement of network policy (peering, domain preference)
        - Network capability exchange (pull/push, abstraction level,
          etc.)

    ACTN work scope:

        - Multi-domain service policy coordination to network
          primitives is in scope of ACTN

    +------------------------------------------------------------------+

    Use case-5: Kumaki

    Service-Specific requirements:

        - On-demand VN creation
        - Multi-service level for VN
        - VN survivability /diversity/confidentiality

    ACTN work scope:

        - All of the service-specific lists in the left column is
          unique to ACTN.

    +------------------------------------------------------------------+

    Use case-6: Lopez

    Service-Specific requirements:

          - E2E accounting and resource usage data
          - E2E service policy enforcement

    Network-related requirements:

          - E2E connection management, path provisioning
          - E2E network monitoring and fault management

    ACTN work scope:

          - Escalation of performance/fault management data to CNC and
            the policy enforcement for this area is unique to ACTN.

    +------------------------------------------------------------------+

    Use case-7: Shin

    Service-Specific requirements:

          - Current network resource abstraction
          - Endpoint/DC dynamic selection (for VM migration)

    Network-related requirements:

          - LB for recovery
          - Multi-layer routing and optimization coordination

    ACTN work scope:

          - Multi-layer routing and optimization are related to VN's
            dynamic endpoint selection policy.

    +------------------------------------------------------------------+

    Use case-8: Xu

    Service-Specific requirements:

          - Dynamic service control policy enforcement
          - Dynamic service control

    Network-related requirements:

                   - Traffic monitoring
                   - SLA monitoring

         ACTN work scope:

                   - Dynamic service control policy enforcement and its control
                     primitives are in scope of ACTN
                   - Data model to support traffic monitoring data is an
                     extension of YANG model ACTN can extend.


         +------------------------------------------------------------------+

The subsequent sections provide some illustration of the ACTN's unique
work scope identified by the above analysis:

- Coordination of Multi-destination Service Requirement/Policy (Section
  4.2.1)

- Application Service Policy-aware Network Operation (section 4.2.2)

- Dynamic Service Control Policy Enforcement for Performance/Fault
  Management (Section 4.2.3)

- Multi-Layer (Packet-Optical) Coordination for Protection/Restoration
  (Section 4.2.4)

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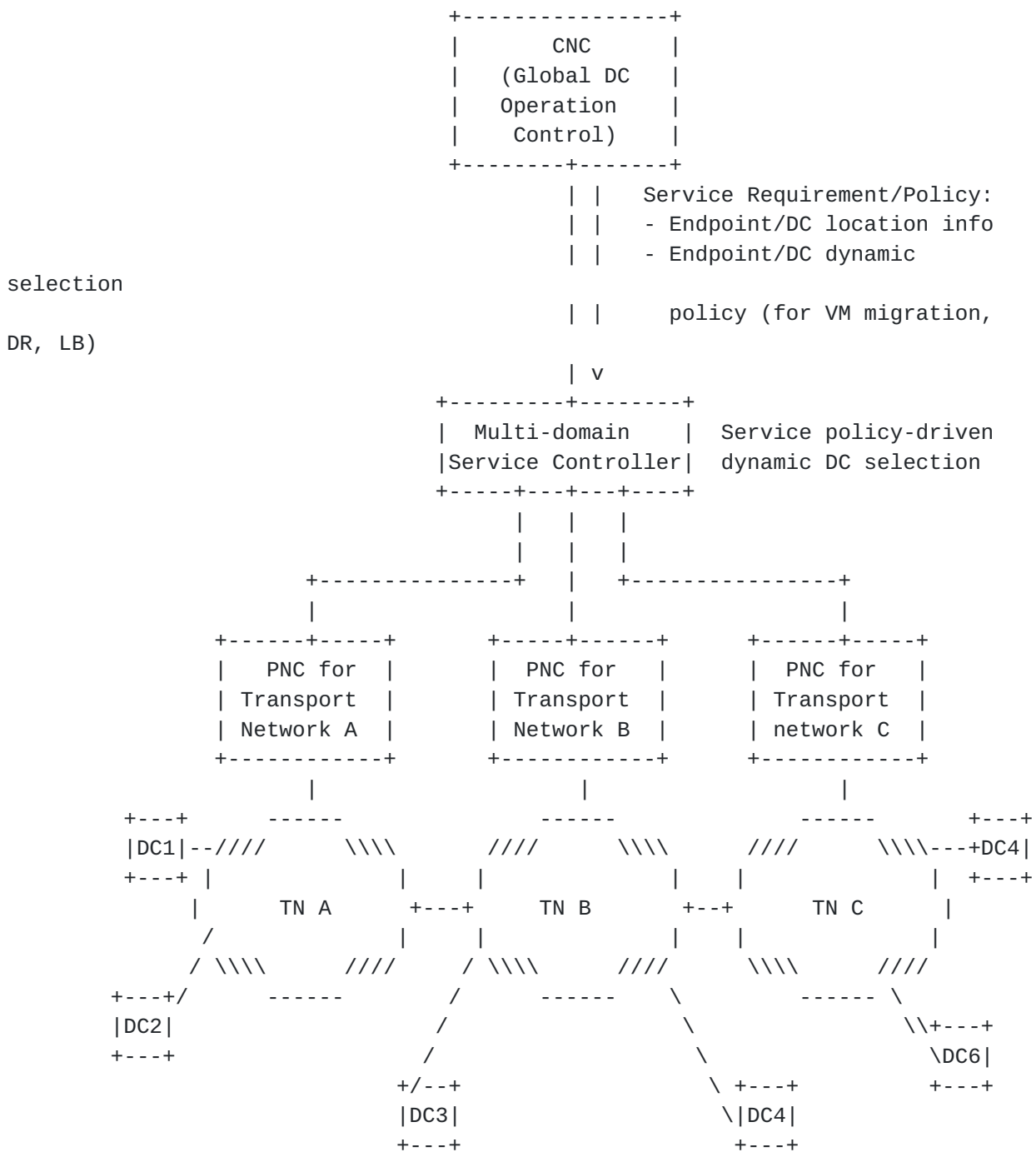
```
                            +----------------+
                            |      CNC       |
                            |   (Global DC   |
                            |    Operation   |
                            |     Control)   |
                            +--------+-------+
              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


                                       DR: Disaster Recovery
                                       LB: Load Balancing
```

            Figure 5: Service Policy-driven Data Center Selection

Figure 5 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 MSDC would then incorporate this information to meet the service objective of this application.

**[4.2.2](#)**. **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 Controller|   network destination to
meet
                                +-----+---+---+----+   VNF requirement.
                                      |   |   |
                                      |   |   |
                         +--------------+   |   +----------------+
                         |                  |                    |
                  +------+-----+     +-----+------+     +------+-----+
                  |   PNC for  |     |  PNC for   |     |   PNC for  |
                  | Transport  |     | Transport  |     | Transport  |
                  | Network A  |     | Network B  |     | network C  |
                  |            |     |            |     |            |
                  +-----------+      +-----------+      +-----------+
        {VNF b}         |                  |                    |
          +---+      ------             ------             ------      +---+
          |DC1|--////       \\\\      ////      \\\\     ////       \\\\---+DC4|
          +---+ |            |   |             |   |            |   | +---+
                |    TN A     +---+    TN B     +--+    TN C        |  {VNF
b,c}
               /             |   |            /  |   |               |
              / \\\\      ////    / \\\\      ////     \\\\        ////
          +---+/       ------        /       ------    \        ------ \
          |DC2|                     /                 \                \\+---+
          +---+                    /                   \                \DC6|
            {VNF a}          +/--+                \ +---+            +---+
                             |DC3|                 \|DC4|             {VNF
a,b,c}
                             +---+                   +---+
                             {VNF a, b}             {VNF a, c}
            Figure 6: Application Service Policy-aware Network Operation
```
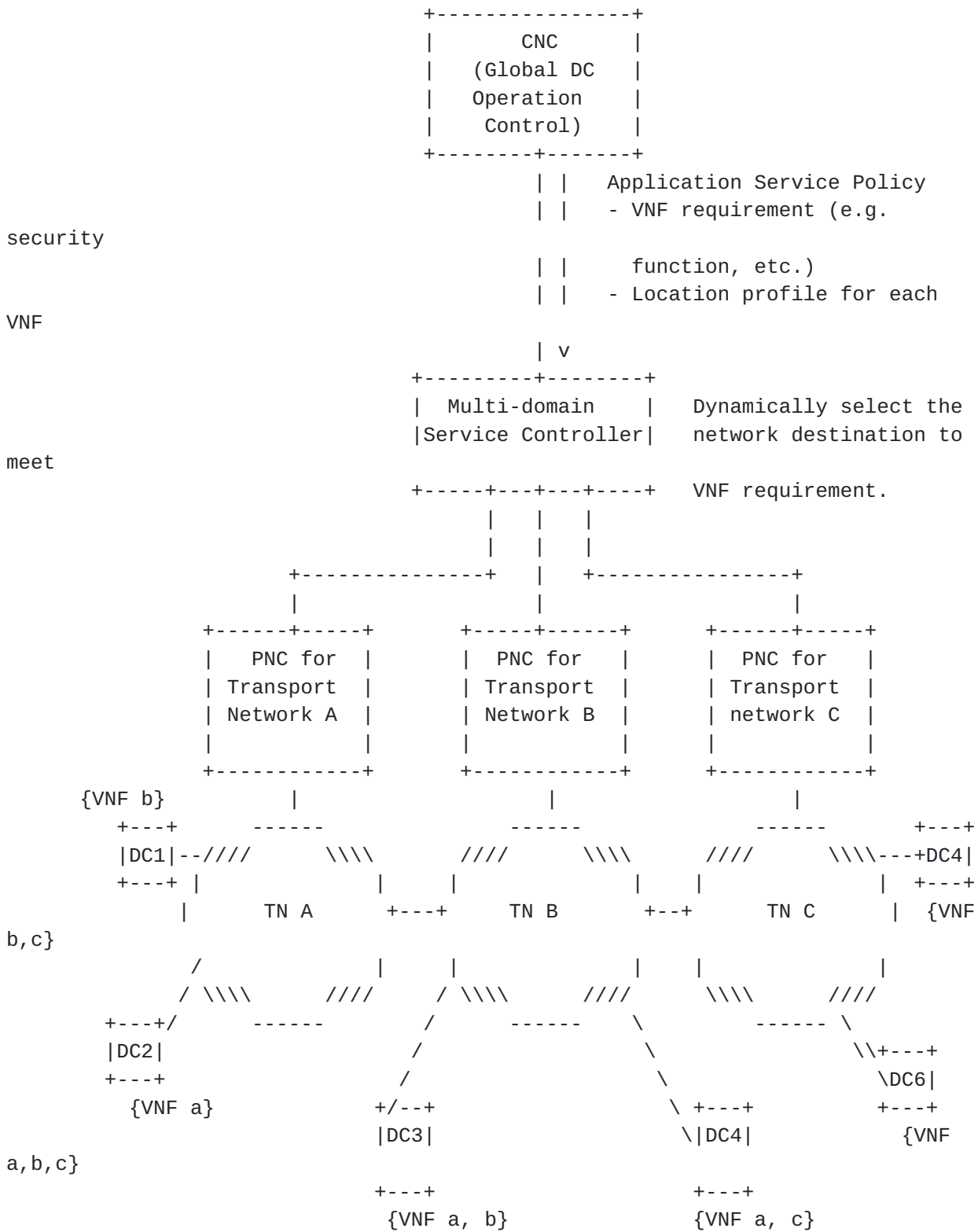
This scenario is similar to the previous case in that the VN service
policy for the application can be met by a set of multiple

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.


4.2.3. **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
       +--------------------------------------------------+
       |           Mult-domain Service Controller         |
       +--------------------------------------------------+
       2. Path  |  /|\3.Traffic           |  |
       Monitor  |   | Monitor             |  |7.Path
       Request  |   | Result      6.Path  |  | modify &
                |   |              modify& |  | optimize
              \|/  |        optimize Req.\|/ | result
       +--------------------------------------------------+
       |             Physical Network Controller          |
       +--------------------------------------------------+
```
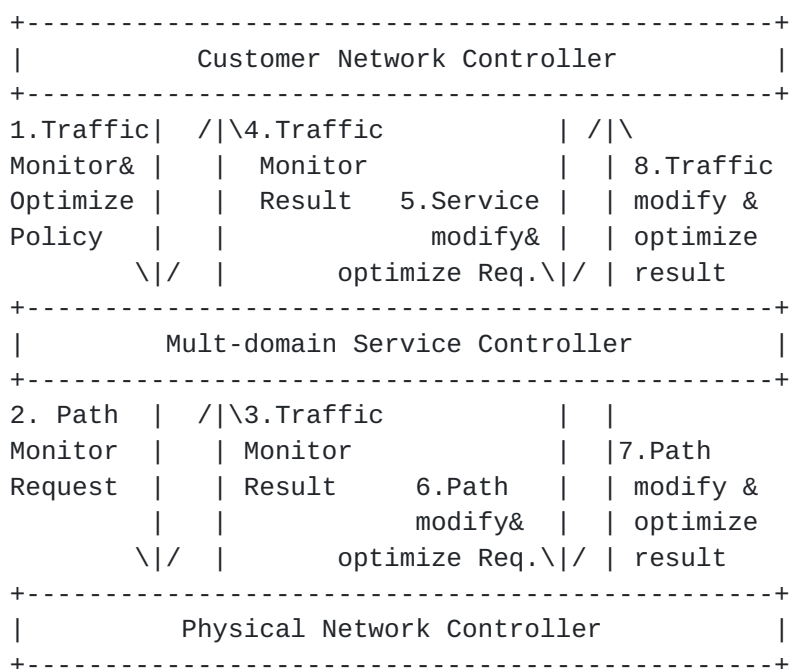
        Figure 7: Dynamic Service Control for Performance and Fault
                               Management


   Figure 7 shows the flow of dynamic service control policy
   enforcement for performance and fault management initiated by
   customer per their 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.

**4.2.4. Multi-Layer (Packet-Optical) Coordination for
       Protection/Restoration (TBD)**

**5. ACTN interfaces requirements**

   This section provides ACTN interface requirements for the two
   interfaces that are within the ACTN scope.

     . CMI: CNC-MDSC Interface
     . MPI: MDSC-PNC Interface

   TO BE FILLED

**6. Security Considerations**

   TBD

**7. IANA Considerations**

   TBD

**8. References**

   8.1. Informative References

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             pce-abno-architecture, work in progress.

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Appendix A

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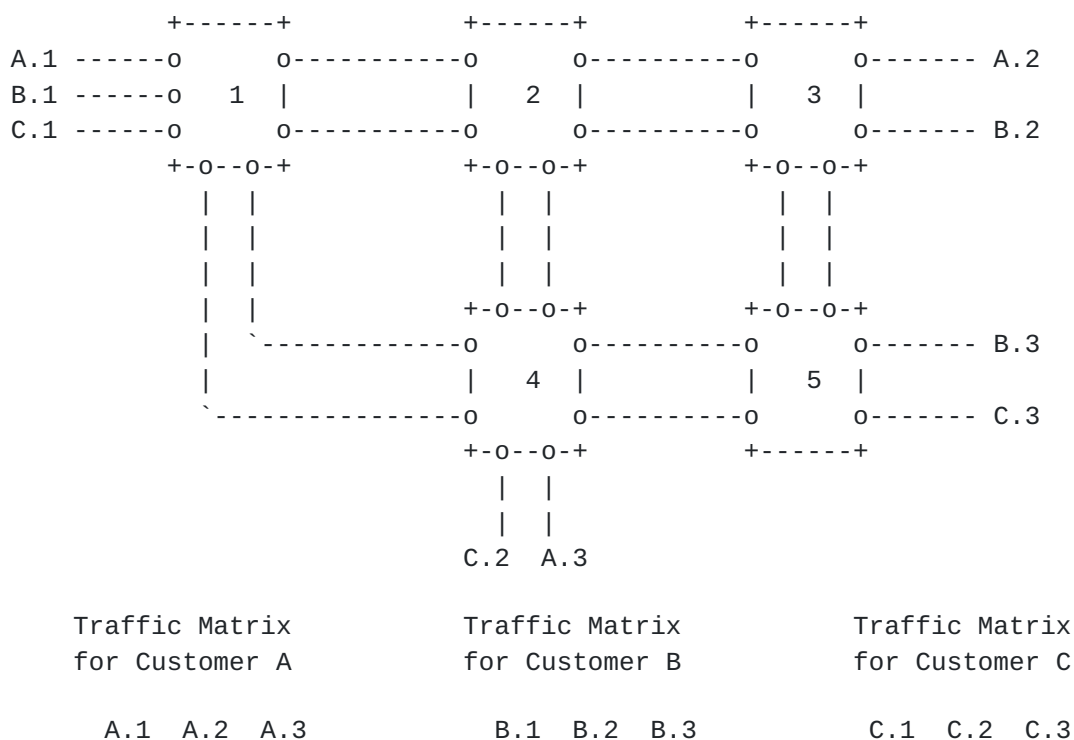    Email: diego@tid.es

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## 9. Appendix I: Abstracted Topology Illustration

   There are two levels of abstracted topology that needs to be
   maintained and supported for ACTN. Customer-specific Abstracted
   Topology refers to the abstracted view of network resources
   allocated (shared or dedicated) to the customer. The granularity of
   this abstraction varies depending on the nature of customer
   applications. Figure 8 illustrates this.

   Figure 8 shows how three independent customers A, B and C provide
   its respective traffic demand matrix to the VNC. The physical
   network topology shown in Figure 6 is the provider's network
   topology generated by the PNC topology creation engine such as the
   link state database (LSDB) and Traffic Engineering DB (TEDB) based
   on control plane discovery function. This topology is internal to
   PNC and not available to customers. What is available to them is an
   abstracted network topology (a virtual network topology) based on
   the negotiated level of abstraction. This is a part of VNS
   instantiation between a client control and VNC.

```
             +------+              +------+              +------+
   A.1 ------o      o------------o      o----------o      o------- A.2
   B.1 ------o   1  |            |   2  |          |   3  |
   C.1 ------o      o------------o      o----------o      o------- B.2
             +-o--o-+            +-o--o-+          +-o--o-+
               |  |                |  |              |  |
               |  |                |  |              |  |
               |  |                |  |              |  |
               |  |              +-o--o-+          +-o--o-+
               |  `------------o      o----------o      o------- B.3
               |              |   4  |          |   5  |
               `--------------o      o----------o      o------- C.3
                              +-o--o-+          +------+
                                |  |
                                |  |
                              C.2  A.3

        Traffic Matrix        Traffic Matrix          Traffic Matrix
        for Customer A        for Customer B          for Customer C

          A.1  A.2  A.3         B.1  B.2  B.3          C.1  C.2  C.3
```

```
         -------------------        -----------------        -----------------
         A.1  -    20G  20G         B.1  -   40G  40G        C.1 -     20G  20G
         A.2  20G   -   10G         B.2  40G  -   20G        C.2 20G    -   10G
         A.3  20G  10G   -          B.3  40G  20G  -         C.3 20G  10G   -
```
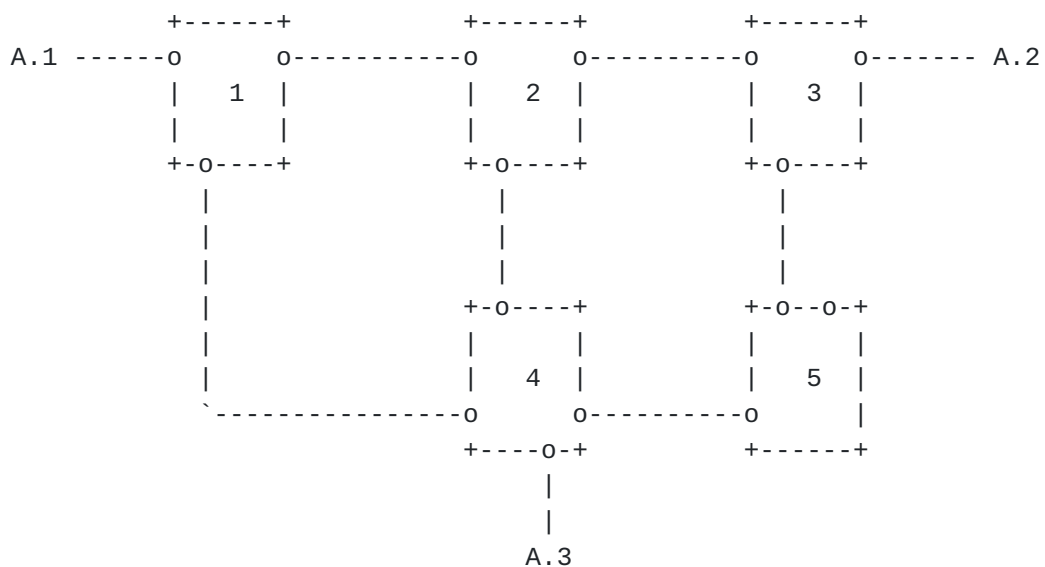
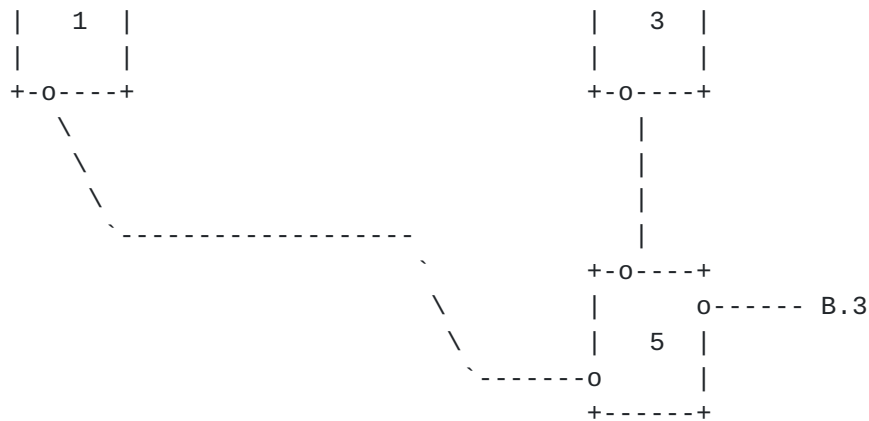Figure 8: Physical network topology shared with multiple customers

Figure 9 depicts illustrative examples of different level of
topology abstractions that can be provided by the VNC topology
abstraction engine based on the physical topology base maintained by
the PNC.  The level of topology abstraction is expressed in terms of
the number of virtual nodes (VNs) and virtual links (VLs). For
example, the abstracted topology for customer A shows there are 5
VNEs and 10 VLs. This is by far the most detailed topology
abstraction with a minimal link hiding compared to other abstracted
topologies in Figure 7.

         (a)  Abstracted Topology for Customer A (5 VNEs and 10 VLs)

```
              +------+                +------+                +------+
      A.1 ------o        o-----------o        o----------o        o------- A.2
              |   1  |                |  2   |                |  3   |
              |      |                |      |                |      |
              +-o----+                +-o----+                +-o----+
                |                       |                       |
                |                       |                       |
                |                       |                       |
                |                     +-o----+                +-o--o-+
                |                     |      |                |      |
                |                     |  4   |                |  5   |
                `---------------o        o----------o        |
                              +----o-+                +------+
                                |
                                |
                               A.3
```

         (b)  Abstracted Topology for Customer B (3 VNEs and 6 VLs)

```
              +------+                                +------+
      B.1 ------o        o----------------------------o        o------ B.2
```

```
       |   1  |                        |   3  |
       |      |                        |      |
       +-o----+                        +-o----+
          \                               |
           \                              |
            \                             |
             `-------------------         |
                                `      +-o----+
                 \              |            o------ B.3
                  \             |   5  |
                   `-------o    |
                                +------+
```

(c)  Abstracted Topology for Customer C (1 VNE and 3 VLs)

```
        +--------------------------------------------+
        |                                            |
        |                                            |
  C.1 ------o                                        |
        |                                            |
        |                                            |
        |                                            |
        |                                   o--------C.3
        |                                            |
        +-------------------o--------------------+
                 |
                 |
                 |
                 |
               C.2
```
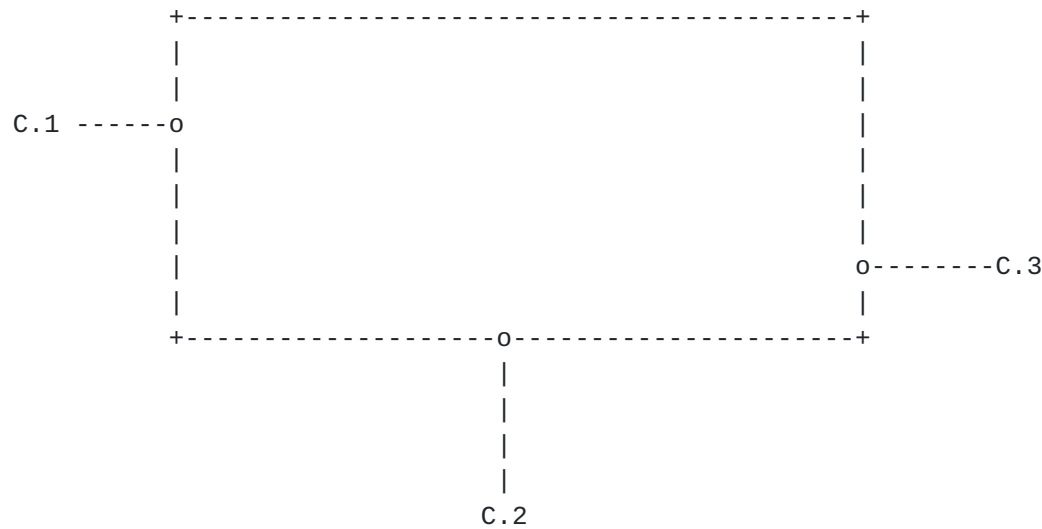
Figure 9: Topology Abstraction Examples for Customers


   As different customers have different control/application needs,
   abstracted topologies for customers B and C, respectively show a
   much higher degree of abstraction. The level of abstraction is

determined by the policy (e.g., the granularity level) placed for
the customer and/or the path computation results by the PCE operated
by the PNC. The more granular the abstraction topology is, the more
control is given to the Customer Network Controller. If the Customer
Network Controller has applications that require more granular
control of virtual network resources, then the abstracted topology
shown for customer A may be the right abstraction level for such
controller. For instance, if the customer is a third-party virtual
service broker/provider, then it would desire much more
sophisticated control of virtual network resources to support
different application needs. On the other hand, if the customer were
only to support simple tunnel services to its applications, then the
abstracted topology shown for customer C (one VNE and three VLs)
would suffice.