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Framework for Abstraction and Control of Transport Networks

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Status of this Memo

This Internet-Draft will expire on June 15, 2015.

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

  - 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

  - 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

  - 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

  - 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

  - 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 selectio
                                           | |     policy (for VM migration, DR
                                           | 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. securi
                                          | |     function, etc.)
                                          | |   - Location profile for each VN
                                          | v
                                +---------+---------+
                                |  Multi-domain     |   Dynamically select the
                                |Service Controller|   network destination to
                                +-----+---+---+-----+   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
               /              |     |              |    |              |
              / \\\\      ////     / \\\\      ////      \\\\      ////
        +---+/      ------        /      ------    \         ------ \
        |DC2|                    /                  \                \\+----+
        +----+                  /                    \                 \DC6|
          {VNF a}             +/--+                   \ +----+         +----+
                              |DC3|                    \|DC4|            {VNF a
                              +----+                    +----+
                               {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

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Appendix A

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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.