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        ACTN Use-case for Virtual Network Operation for Multiple Domains
                      in a Single Operator Network

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Abstract

   This document provides a use-case that addresses the need for
   facilitating the application of virtual network abstractions to
   network operation. These abstractions shall create a virtualized
   environment supporting operators in viewing and controlling
   different domains as a single virtualized network. Each domain can
   be created due to the applied technology, administrative zones, or
   vendor-specific technology islands).Such an approach will facilitate
   the deployment of NFV (Network Function Virtualization) mechanisms,
   and accelerate rapid service deployment of new services, including
   more dynamic and elastic services, and improve overall network
   operations and scaling of existing services.

   This use-case considers the application of these abstractions within
   the network of a single operator.

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1. Introduction

   Network operators build and operate their network using multiple
   domains in different dimensions. Domains may be defined by a
   collection of links and nodes (each of a different technology),
   administrative zones under the concern of a particular business
   entity, or vendor-specific "islands" where specific control
   mechanisms have to be applied. Establishing end-to-end connections
   spanning several of these domains is a perpetual problem for
   operators, which need to address both interoperability and
   operational concerns at the control and data planes. The
   introduction of new services often requiring connections that
   traverse multiple domains needs significant planning, the creation

of umbrella Network Management Systems (NMSs) or even several manual
operations to interface different administrative zones, vendor
equipment and technology. This problem becomes more relevant as the
consolidation of virtualization technologies like Network Functions
Virtualization (NFV) calls for a more elastic behavior of the
transport network, able to support their requirements on dynamic
infrastructure reconfiguration [NFV-UC].

This document provides a use-case that addresses the aforementioned
need within a single operator network.

This use-case is a part of the overarching work, called Abstraction
and Control of Transport Networks (ACTN). The goal of ACTN is to
facilitate virtual network operation by:

   . The creation of a virtualized environment allowing operators to
     view and work with the abstraction of the underlying multi-
     admin, multi-vendor, multi-technology networks and

   . The operation and control/management of these multiple networks
     as a single virtualized network.

This will accelerate rapid service deployment of new services,
including more dynamic and elastic services, and improve overall
network operations and scaling of existing services.

Related documents are the ACTN-framework [ACTN-Frame] and the
problem statement [ACTN-PS].

2. Operational Issues in Multi-domain Networks

As an illustrative example, let's consider a multi-domain network
consisting of four administration zones: three Data Center Network
zones, A, B and C; and one core Transport Network (TN) zone to which
Data Center Network zones A, B and C are inter-connected. These
zones are under a single operator's administration, but there are
organizational boundaries amongst them (being under the concern of
different business units or technical departments, for example).

Figure 1 shows this multi-domain network example.

```
                                          +---------------------+
                                          |  +---+ DC Domain B   |
                                          |  |EP6|               |
                                          |  +---+               |
                                          |    |                 |
                                          |    |--------         |
                  +----------------+      |  ///        \\\      |
                  |  TN Domain     |      | //            \\     |
+----------------------+    ----    -|-- ||                |     |
| DC Domain A          |  | //-    -\\ | ||  Data Center B  |    |
|     ---------        |  | /        \ | |  \\            //     |
|  ///        \\\      |  | /          \ | |  \\\        ///      |
| //            \\     |  ||            || |    ---------         |
| |                |   |-|  | Transport || +---------------------+
| |  Data Center A |-|- ||   Network   || +---------------------+
| |                |   | | |            || |     ---------        |
|  \\            //    | | \          / | |  ///        \\\      |
|  \\\        ///      | |  \        /| | | //            \\     |
|   | --------- |      | |   \\-    -// | | ||                |   |
|   |           |      | |    ----    | | ||  Data Center C  |   |
| +---+     +---+      | |    |       -|-- ||                |   |
| |EP1|     |EP2|      | |    |          | |  \\            //    |
| +---+     +---+      | |  +---+        | |  \\\        ///      |
+----------------------+ |  |EP3|        | |   | --------- |      |
                        |  +---+        | |   |           |      |
                        |               | | +---+     +---+      |
                        +----------------+ | |EP4|     |EP5|      |
                                          | +---+     +---+      |
                                          |    DC Domain C       |
                                          +---------------------+
```
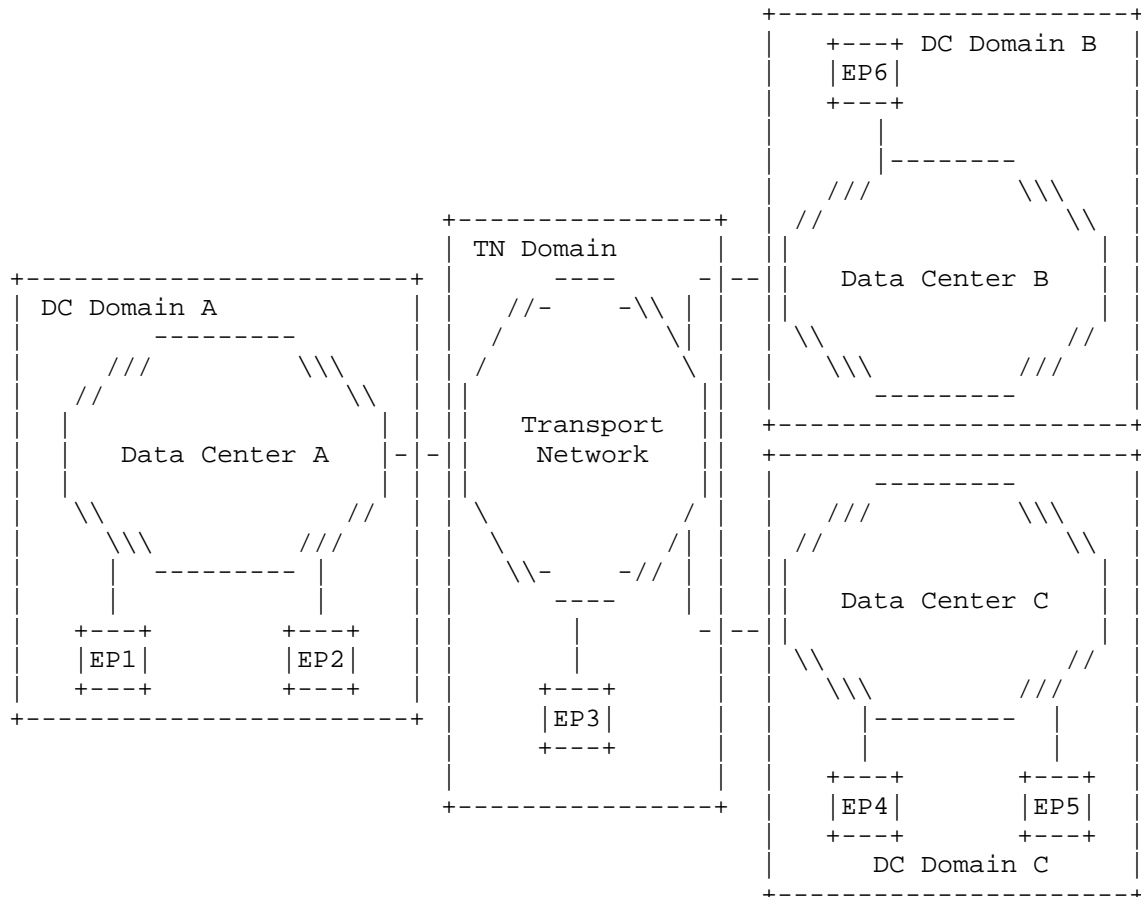
                   Figure 1. Multi-domain Network

   Although the figure depicts a single operator's network, there can
   be several partitions into sub-domains in which some connections may
   have to traverse several sub-domains to connect End Points (EPs).
   EPs are customer end-points such as enterprise gateway locations,
   some of which are directly homed on transport networks, while some

others are part of data center networks. EPs can also host physical
or virtual network functions (PNFs/VNFs) or virtual machines (VMs).
Connections between EPs in many cases have to traverse multiple
technology and/or administrative domains. For instance, in Figure 1
if EP1 were to be connected to EP4, then the data path for this
connection would have to traverse DC Domain A, TN Domain and DC
Domain C where the destination of this connection resides. Another
example of a multi-domain connection would be from EP3 in TN Domain
to EP 6 in DC Domain B.

There are also intra-domain connections; for instance, a connection
from EP4 to EP5 would only constitute an intra-domain connection
within DC Domain C. We can assume there are domain control entities
of various types (e.g., SDN-controller, NMS/EMS, Control Plane, or a
combination of these entities, etc.) responsible for domain-specific
network operations such as connection operation and management
(including creation/deletion of a connection, path computation and
protections, etc.), and other functions related to operations such
as configuration, monitor, fault management, etc. As different
technologies have emerged in different points of time, there is a
plethora of diverse domain control systems with their respective
interfaces and protocols. To maximize capital investments, operators
tend to keep the current legacy operation and management technology
and to continue to offer network services from the technology
deployed in their networks.

Due to these domain boundaries, facilitating connections that
traverse multi-domains is not readily achieved. Each domain control
establishing other domain control in a peer to peer level creates
permutation issues for the end-to-end control. Besides, these domain
controls are optimized for its local operation and in most cases not
suited for controlling the end-to-end connectivity services. For
instance, the discovery of the EPs that belong to other domains is
hard to achieve partly because of the lack of the common API and its
information model and control mechanisms thereof to disseminate the
relevant information. Some scenarios would require a path
computation service for each domain to carry out end-to-end path
computation, but considering current status of the network.

Moreover, the path computation for any end-to-end connection would
need abstraction of network resources and ways to find an optimal
path that meets the connection's service requirements. This would
require knowledge of the inter-domain peering relationships and the
local domain policy.

From a connection provisioning perspective, in order to facilitate a
fast and reliable end-to-end signaling, each domain operation and
management elements should ideally work with the same control
protocols that its neighboring domains. At least each domain should

support a stitching mode, so the end-to-end connection can be
created in a per domain basis.

From a network connectivity management perspective, it would require
a mechanism to disseminate any connectivity issues from the local
domain to the other domains whenever the local domain cannot resolve
a connectivity issue. This connectivity issue can happen during the
provisioning time or during the network operation, when there is a
failure on a connection that cannot be restored or protected.

3. Virtual Network Operations for Multi-domain Networks

Based on the issues discussed in the previous section in regard to
the operations for multi-domain networks, we propose the definition
of a virtual network operations (VNO) infrastructure that helps
operators to establish end-to-end connections spanning multiple
domains and its related operation and management issues.

The VNO Coordinator facilitates virtual network operation, the
creation of a virtualized environment allowing operators to view the
underlying multi-admin, multi-vendor, multi-technology networks and
their operation and management as a single, virtualized network.

The basic premise of VNO is to create a hierarchy of operations in
which to separate virtual network operations from physical network
operations. This helps operators build virtual network operations
infrastructure on top of physical network operations. Figure 2 shows
a hierarchical structure of operations.

```
                  +---------------------+
                  |   VNO Coordinator   |
                  +---------------------+
                            |
                            | VNO-I
              .-------------------------------------.
              |            |            |           |
        +----------+ +----------+ +----------+ +----------+
        |          | |          | |          | |          |
        |   DCN    | |   DCN    | |   DCN    | |          |
        | Domain A | | Domain B | | Domain C | | TN Domain|
        | Control  | | Control  | | Control  | | Control  |
        |          | |          | |          | |          |
        +----------+ +----------+ +----------+ +----------+
             |            |            |           |
          /----\       /----\       /----\      /----\
         //    \\     //    \\     //    \\    //    \\
        |  DC A  |   |  DC B  |   |  DC C  |   | Transport|
         \\    //     \\    //     \\    //    \\Network/
          \----/       \----/       \----/      \----/
```
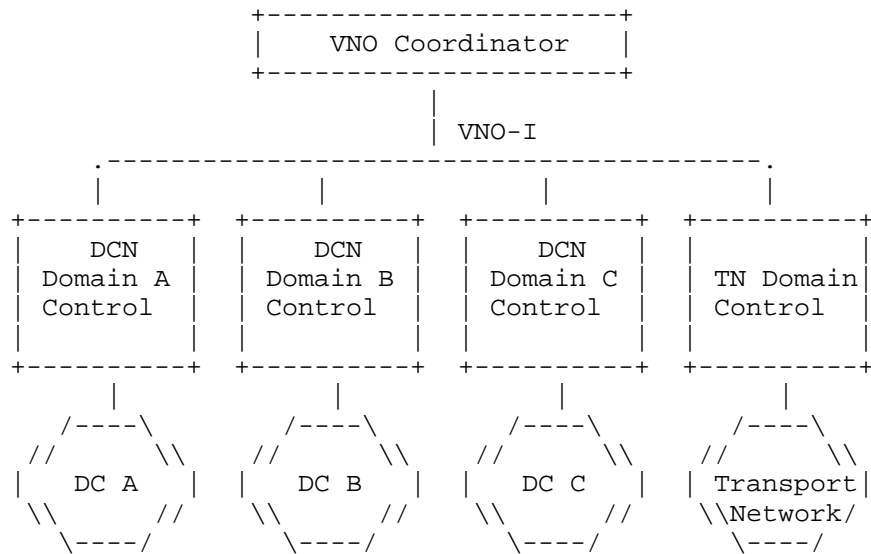
                   Figure 2. Operations Hierarchy

   Figure 2 shows operations hierarchy based on Figure 1. The two main
   ideas are:

   1. Domain control/management entities (e.g., DCN Domain Control A, B,
      C and TN Domain Control) are kept intact to continue its domain
      operations with its technology choice and policy, etc. As
      discussed before domain control/management entities can be a form
      of various types (e.g., SDN-controller, NMS/EMS, Control Plane, or
      a combination of these entities, etc.) that is responsible for
      domain-specific network operations.

   2. The VNO Coordinator establishes a standard-based API (which is
      termed as the Virtual Network Operations Interface (VNO-I) in
      Figure 2) with each of the domain control/management entities. The
      VNO coordination takes place via the VNO-I's.

3.1. Responsibilities of Domain Control/Management Entities

     . Creation of domain-level abstraction of network topology

        It is the responsibility of domain control/management entity to
        create an abstraction of its network topology. The level of
        abstraction varies from one domain to another, subject to local
        domain policy. All EPs and gateway nodes to other domains need

to be represented at a minimum. The level of internal nodes and
links may be abstracted according to its domain policy.

. Dissemination of abstraction of network topology to the VNO
  Coordinator (both Push and Pull models)

. VNO interface support (e.g., protocol, messages, etc.)

. Domain-level connection control/management that includes
  creation/deletion of a connection

. Domain-level path computation and optimization

. Domain-level protection and reroute

. Domain-lever policy enforcement

. Other functions related to operations such as monitor, fault
  management, accounting, etc.

3.2. Responsibilities of the VNO Coordinator

. 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-end
  network.

. VNO interface support (e.g., protocol, messages, etc.)

. 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

. OSS/BSS interface support for service management

3.3. Virtual Network Operations Interface (VNO-I)

   VNO-I should support the transfer of information detailed above to
   perform the identified functionality. It should be based on open
   standard-based API.

   [Editor's Note: the details of the supported functions of the VNO-I
   as well as the discussions pertaining to the info/data model
   requirements of the VNO-I will be supplied in the revision]

4. References

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            http://www.etsi.org/deliver/etsi_gs/NFV/001_099/001/01.01.
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