Network Working Group
Internet Draft

Intended status: Informational

Expires: October 2015

Young Lee
Dhruv Dhody
Huawei

Sergio Belotti
Alcatel-Lucent

Khuzema Pithewan
Infinera

Daniele Ceccarelli
Ericsson

April 8, 2015

Requirements for Abstraction and Control of Transport Networks

draft-lee-teas-actn-requirements-00.txt

Abstract

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

Status of this Memo

This Internet-Draft is submitted to IETF in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF), its areas, and its working groups. Note that other groups may also distribute working documents as Internet-Drafts.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

The list of current Internet-Drafts can be accessed at http://www.ietf.org/ietf/1id-abstracts.txt

The list of Internet-Draft Shadow Directories can be accessed at http://www.ietf.org/shadow.html.

This Internet-Draft will expire on October 8, 2015.

Table of Contents

1. Introduction

This draft provides a set of requirements for ACTN identified in various use-cases of ACTN. [ACTN-frame] defines the base reference architecture and terminology. [ACTN-PS] provides problem statement and gap analysis.

Section 2 provides high-level ACTN requirements. Sections 3-5 provide the list of ACTN use-cases and the detailed requirement analysis of these use-cases.

2. High-level ACTN requirements

1. Requirement 1: Single Virtualized Network Topology

Ability to build virtual network operation infrastructure based on multi-layer, multi-domain topology abstracted from multiple physical network controllers (e.g., GMPLS, OpenFlow, PCE, NMS, etc.)

Reference: [KLEE], [LOPEZ], [DHODY], [CHENG].

2. Requirement 2: Policy Enforcement

Ability to provide service requirement/policy (Between Customer and Network) and mechanism to enforce service level agreement.

- Endpoint selection policy, routing policy, time-related policy, etc.

Reference: [KLEE], [LOPEZ], [SHIN], [DHODY], [FANG].

3. Requirement 3: VN Query

Ability to request/respond VN Query (Can you give me VN(s)?)

- Request Input:

  - VN end-points (CE end)

- VN Topology Service-specific Multi-Cost Objective Function

- VN Topology diversity (e.g., VN1 and VN2 must be disjoint)

- VN Topology type: path, graph

- Response includes VN topology

- Exact

- Potential

Reference: [KUMAKI], [FANG], [CHENG].

4. Requirement 4: VN Instantiate

Ability to request/confirm VN Instantiation

- VN instance ID

- VN end-points

- VN constraints requirement

- Latency only, B/W guarantee, Latency and B/W guarantee together

- VN diversity

- Node/Link disjoint from other VNs

- VN level diversity (e.g., VN1 and VN2 must be disjoint)

- VN type

- Path (tunnel), Node/Links (graph)

- VN instance ID per service (unique id to identify VNs)

Reference: [KUMAKI], [FANG], [CHENG].

5. Requirement 5: Dynamic VN Control

Dynamic/On-demand VN Modification/Confirmation with feedback loop to the customer

- Traffic monitoring and control policies sent to the network
- Network states based traffic optimization policies
- Utilization Monitoring (Frequency of report)
- Abstraction of Resource Topology reflecting these service-related parameters

Reference: [XU], [DHODY], [CHENG].

6. Requirement 6: VN Lifecycle M&O

VN lifecycle management/operation

- Instantiate
- Delete
- Modify
- Update (VN level OAM Monitoring) under policy agreement

Reference: [FANG], [KUMAKI], [LOPEZ].

7. Requirement 7: VN Service Operation

Ability to setup and manage end-2-end service on the VN involving multi-domain, multi-layer, meeting constraints based on SLAs.

Reference: [LOPEZ], [KUMAKI], [CHENG], [DHODY], [FANG], [KLEE].

8. Requirement 8: Multi-destination Coordination

Coordination of multi-destination service requirement/policy to support dynamic applications such as VM migration, disaster recovery, load balancing, etc.

- Service-policy primitives and its parameters

Reference: [FANG], [LOPEZ], [SHIN].

9. Requirement 9: Multi-domain & Multi-layer Coordination

Ability to Coordinate multi-domain and multi-layer path computation and setup operation (network)

- Computes E2E path across multi-domain (based on abstract topology from each domain)

- Determines the domain sequence

- Request path signaling to each domain controller

- Find alternative path if any of the domain controllers cannot find its domain path

Reference: [CHENG], [DHODY], [KLEE], [LOPEZ], [SHIN].

10. Requirement 10: E2E Path Restoration

Ability to perform E2E Path Restoration Operation

- Intra-domain recovery

- Cross-domain recovery

Reference: [CHENG], [KLEE], [DHODY], [LOPEZ], [SHIN].

11. Requirement 11: Dynamicity of network control operations

The ACTN interfaces should support dynamicity nature of network control operations. This includes but not limited to the following:

- Real-time VN control (e.g., a fast recovery/reroute upon network failure).
- Fast convergence of abstracted topologies upon changes due to failure or reconfiguration across the network domain view, the multi-domain network view and the customer view.
- Large-scale VN operation (e.g., ability to query tens of thousands of nodes and connectivity) for time-sensitive applications.

Reference: [SHIN], [XU], [KUMAKI].

3. ACTN Use-Cases

Listed below is a set of high-level requirements identified by each of the ACTN use-cases:

- [CHENG] (ACTN Use-cases for Packet Transport Networks in Mobile Backhaul Networks)

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

- [DHODY] (Packet Optical Integration (POI) Use Cases for Abstraction and Control of Transport Networks (ACTN))

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

- [FANG] (ACTN Use Case for Multi-domain Data Center Interconnect)

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

o 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

- [KLEE] (ACTN Use-case for On-demand E2E Connectivity Services in Multiple Vendor Domain Transport Networks)

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

o Coordination of signal flow for E2E connections.

o 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).

- [KUMAKI] (ACTN : Use case for Multi Tenant VNO)

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

- [LOPEZ] (ACTN Use-case for Virtual Network Operation for Multiple Domains in a Single Operator Network)

  - o 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.
  - o End-to-end connection lifecycle management
  - o Invocation of path provisioning request to each domain (including optimization requests)
  - o Invocation of path protection/reroute to the affected domain(s)
  - o End-to-end network monitoring and fault management. This could imply potential KPIs and alarm correlation capabilities.
  - o End-to-end accounting and generation of detailed records for resource usage
  - o End-to-end policy enforcement

- [SHIN] (ACTN Use-case for Mobile Virtual Network Operation for Multiple Domains in a Single Operator Network)

  - o 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.

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

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

- [XU] (Use Cases and Requirements of Dynamic Service Control based on Performance Monitoring in ACTN Architecture)

- 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.

3.1. Two categories of requirements

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	Service-specific Requirements	Network-related Requirements	ACTN Work Scope
[CHENG]	- E2E service provisioning - Performance monitoring - Resource utilization abstraction	- Multi-layer (L2/L2.5) coordination - VNO for multi-domain transport networks	- Dynamic multi-layer coordination based on utilization is in scope of ACTN - YANG for utilization abstraction
[DHODY]	- Service awareness/ coordination between P/O.	- POI Performance monitoring - Protection/ Restoration synergy	- Performance related data model may be in scope of ACTN - Customer's VN survivability policy enforcement for protection/restoration is unique to ACTN.
[FANG]	- Dynamic VM migration (service), Global load balancing (utilization efficiency), Disaster recovery - Service-aware network query	- On-demand virtual circuit request - Network Path Connection request	- Multi-destination service selection policy enforcement and its related primitives/information are unique to ACTN.

	- Service Policy Enforcement		- Service-aware network query and its data model can be extended by ACTN.
[KLEE]		- 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.)	- Multi-domain service policy coordination to network primitives is in scope of ACTN
[KUMAKI]	- On-demand VN creation - Multi-service level for VN - VN survivability /diversity/confidentiality		- All of the service-specific lists in the left column is unique to ACTN.
[LOPEZ]	- E2E accounting and resource usage data	- E2E connection management, path provisioning - E2E network	- Escalation of performance and fault management

	- E2E service policy enforcement	monitoring and fault management	data to CNC and the policy enforcement for this area is unique to ACTN.
-------	----------	----------	----------
[SHIN]	- Current network resource abstraction Endpoint/DC dynamic selection (for VM migration)	- LB for recovery - Multi-layer routing and optimization coordination	- Multi-layer routing and optimization are related to VN's dynamic endpoint selection policy.
-------	----------	----------	----------
[XU]	- Dynamic service control policy enforcement - Dynamic service control	- Traffic monitoring - SLA monitoring	- 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.

4. Mapping of requirements into generalized scenarios

The subsequent sections provide the mapping of requirements into a number of generalized scenarios.

- Coordination of Multi-destination Service Requirement/Policy (Section 4.1)
- Application Service Policy-aware Network Operation (section 4.2)
- Dynamic Service Control Policy Enforcement for Performance/Fault Management (Section 4.3)

- E2E VN Survivability and Multi-Layer (Packet-Optical) Coordination for Protection/Restoration (Section 2.4)

4.1. Coordination of Multi-destination Service Requirement/Policy

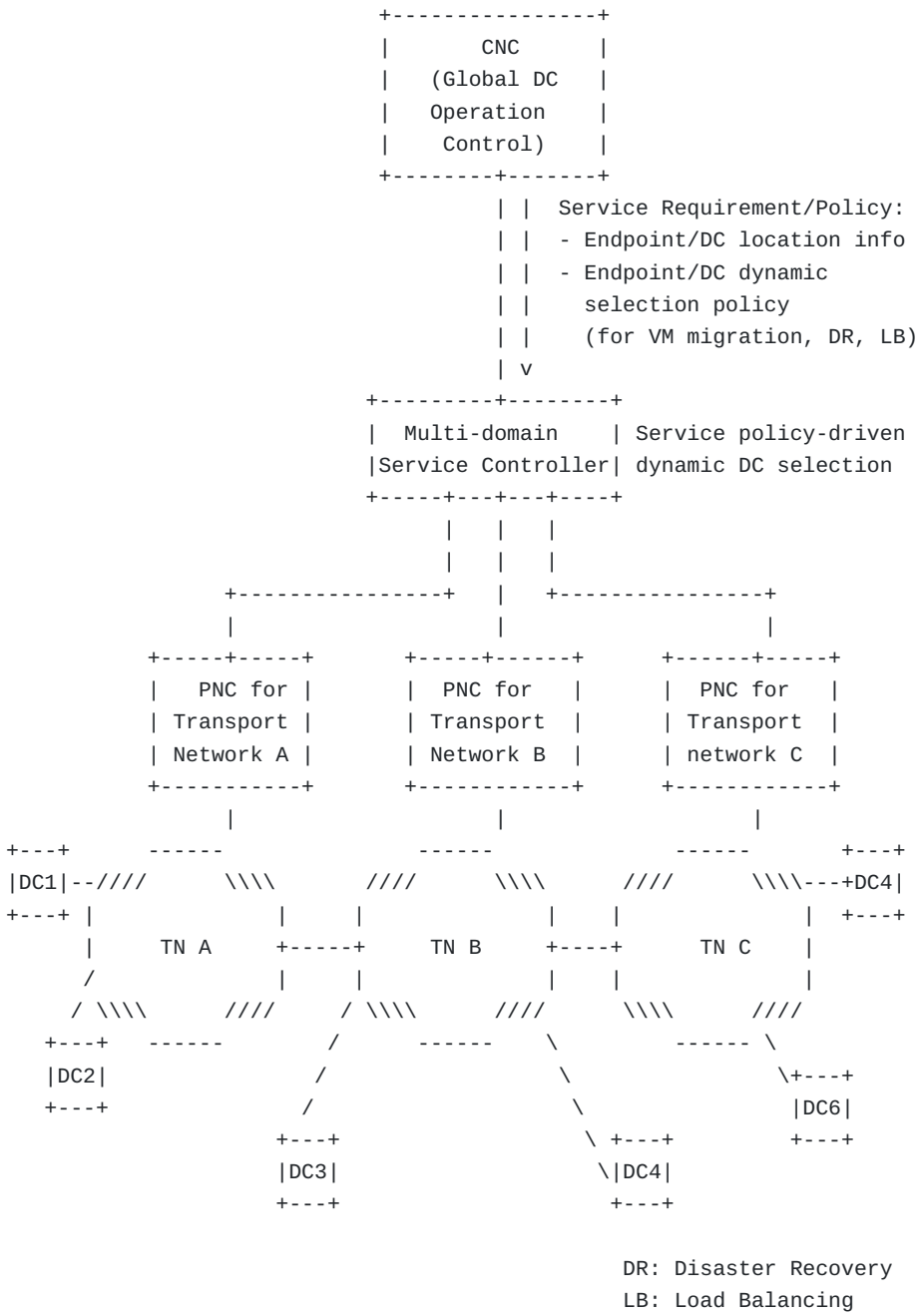

Figure 1: Service Policy-driven Data Center Selection

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

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

4.2. Application Service Policy-aware Network Operation

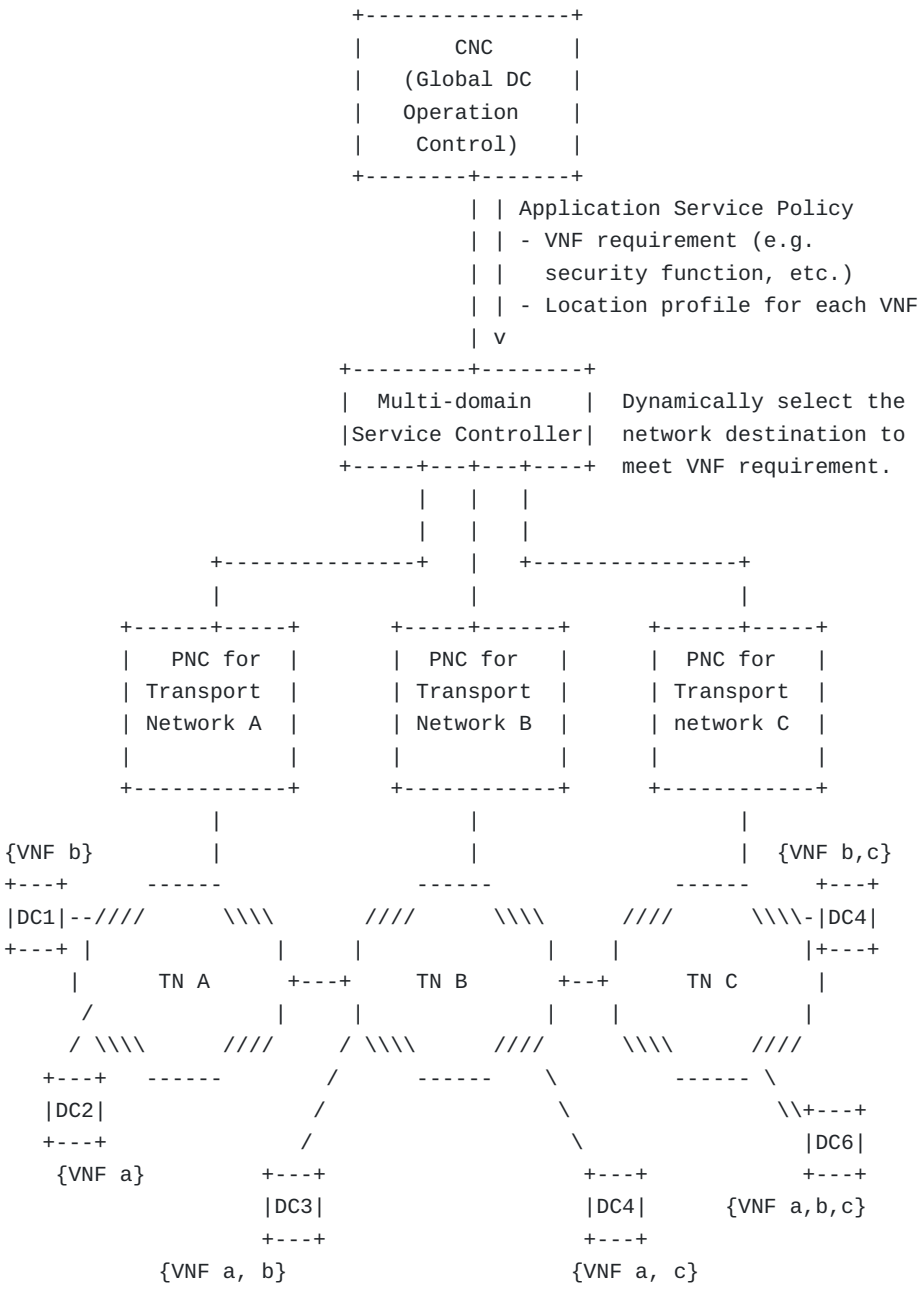

Figure 2: Application Service Policy-aware Network Operation

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

4.3. Dynamic Service Control Policy Enforcement for Performance and Fault Management

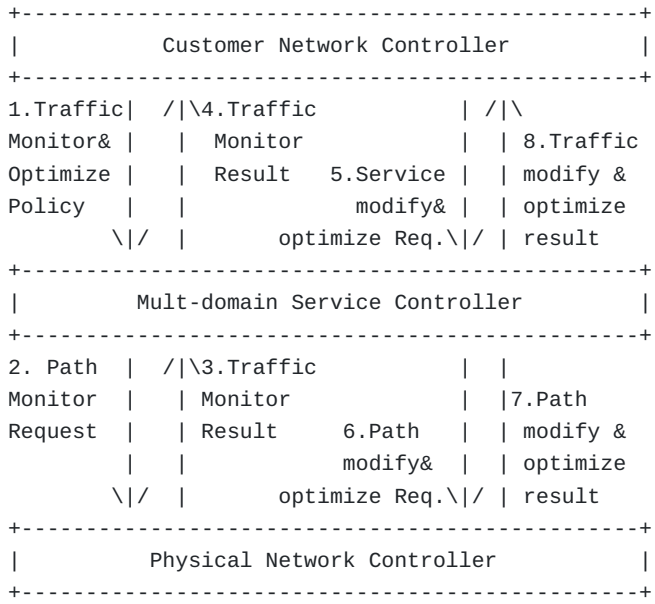

Figure 3: Dynamic Service Control for Performance and Fault Management

Figure 3 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.

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

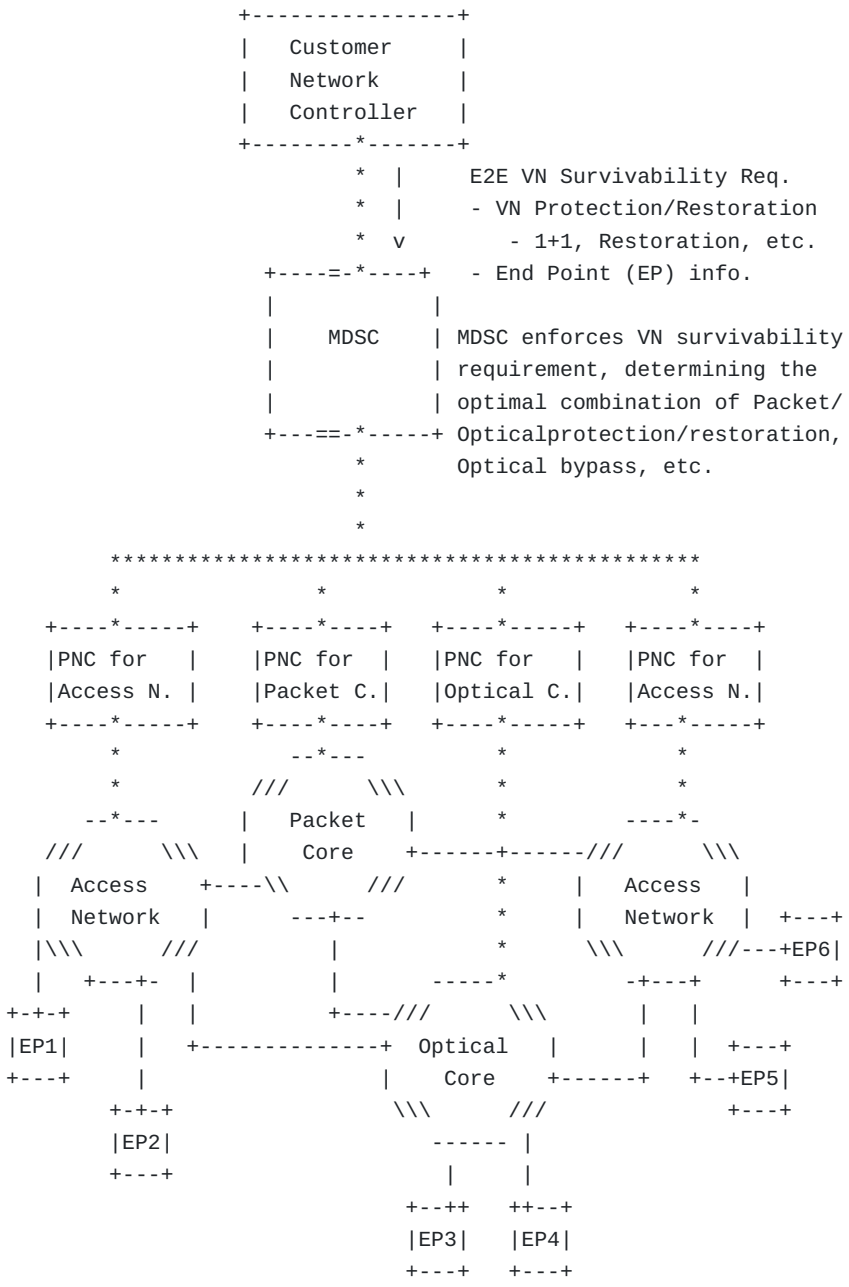

Figure 4: E2E VN Survivability and Multi-layer Coordination for Protection and Restoration

Figure 4 shows the need for E2E protection/restoration control coordination that involves CNC, MDSC and PNCs to meet the VN survivability requirement. VN survivability requirement and its policy need to be translated into multi-domain and multi-layer network protection and restoration scenarios across different controller types. After an E2E path is setup successfully, the MSDC has a unique role to enforce policy-based flexible VN survivability requirement by coordinating all PNC domains.

As seen in Figure 4, multi-layer (i.e., packet/optical) coordination is a subset of this E2E protection/restoration control operation. The MDSC has a role to play in determining an optimal protection/restoration level based on the customer's VN survivability requirement. For instance, the MDSC needs to interface the PNC for packet core as well as the PNC for optical core and enforce protection/restoration policy as part of the E2E protection/restoration. Neither the PNC for packet core nor the PNC for optical core is in a position to be aware of the E2E path and its protection/restoration situation. This role of the MSDC is unique for this reason. In some cases, the MDSC will have to determine and enforce optical bypass to find a feasible reroute path upon packet core network failure which cannot be resolved the packet core network itself.

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

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

5. ACTN interfaces requirements

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

- CMI: CNC-MDSC Interface (Section 5.1)
- MPI: MDSC-PNC Interface (Section 5.2)

5.1. CMI Interface Requirements

Requirement

1. Security/Policy Negotiation (Who are you?) (Between CNC and MDSC)

- Configured vs. Discovered
- Trust domain verification (External Entity vs. Internal Service Department)
- Push/Pull support (for policy)

2. VN Topology Query (Can you give me VN?) (From CNC to MDSC)

- VN end-points (CE end)
- VN Topology Service-specific Multi-Cost Objective Function
    - o Latency Map
    - o Available B/W Map
    - o Latency Map and Available B/W Map together
    - o Other types
- VN Topology diversity
    - o Node/Link disjoint from other VNs
    - o VN Topology level diversity (e.g., VN1 and VN2 must be disjoint)
- VN Topology type
    - o Path vector (tunnel)
    - o Node/Links (graph)

3. VN Topology Query Response (From MDSC to CNC: Here's the VN Topology that can be given to you if you accept)

- For VN Topology,
    - o This is what can be reserved for you
    - o This is what is available beyond what is given to you (potential)

4. VN Topology Abstraction Model (generic network model)
5. VN Topology Abstraction Model (Service-specific model that include customer endpoints)
6. Basic VN Instantiation Request/Confirmation (Between CNC and MDSC: I need VN for my service, please instantiate my VN)

- VN instance ID
- VN end-points
- VN service requirement
    - o Latency only
    - o B/W guarantee
    - o Latency and B/W guarantee together
- VN diversity
    - o Node/Link disjoint from other VNs
- VN level diversity (e.g., VN1 and VN2 must be disjoint)
- VN type
    - o Path vector (tunnel)
    - o Node/Links (graph)
- VN instance ID per service (unique id to identify VNs)
- If failed to instantiate the requested VN, say why

7. Dynamic/On-demand VN Instantiation/Modification and Confirmation with feedback loop (This is to be differentiated from Basic VN Instantiation)
- Performance/Fault Monitoring
- Utilization Monitoring (Frequency of report)
- Abstraction of Resource Topology reflecting these service-related parameters
- Dynamic Policy enforcement

8. VN lifecycle management/operation
- Create (same as VN instantiate Request)
- Delete
- Modify
- Update (VN level OAM Monitoring) under policy agreement

9. Coordination of multi-destination service requirement/policy to support dynamic applications such as VM migration, disaster recovery, load balancing, etc.
- Service-policy primitives and its parameters

5.2. MPI (MDSC-PNC Interface)

Requirement

1. Security/Policy negotiation (who are you?)

- Exchange of key, etc.
- Domain preference + local policy exchange
- Push/Pull support
- Preferred peering points
- Preferred route
- Reroute policy
- End-point mobility (for multi-destination)

2. Topology Query /Response (Pull Model from MDSC to PNC: Please give me your domain topology)

- TED Abstraction level negotiation
- Abstract topology (per policy)
    - o Node/Link metrics
    - o Node/Link Type (Border/Gateway, etc.)
    - o All TE metrics (SRLG, etc.)
    - o Topology Metrics (latency, B/W available, etc.)

3. Topology Update (Push Model from PNC to MDSC)

- Under policy agreement, topology changes to be pushed to MDSC from PNC

4. VN Path Computation Request (From MDSC to PNC: Please give me a path in your domain)

- VN Instance ID (Note: this is passed from CNC to MDSC)
- End-point information
- CE ends
- Border points (if applicable)
- All other PCE request info (PCEP)

5. VN Path Computation Reply (here's the path info per your request)

- Path level abstraction
- LSP DB
- LSP ID ??
- VN ID

6. Coordination of multi-domain Centralized Signaling (MSDC operation) Path Setup Operation

- MSDC computes E2E path across multi-domain (based on abstract topology from each PNC)
- MDSC determines the domain sequence
- MDSC request path signaling to each PNC (domain)
- MDSC finds alternative path if any of the PNCs cannot find its domain path
    - o PNC will crankback to MDSC if it cannot find its domain

path
o PNC will confirm to MDSC if it finds its domain path

7. Path Restoration Operation (after an E2E path is setup successfully, some domain had a failure that cannot be restored by the PNC domain)
- The problem PNC will send this notification with changed abstract topology (computed after resource changes due to failure/other factors)
- MDSC will find an alternate E2E path based on the changes reported from PNC. It will need to update the E2E abstract topology and the affected CN's VN topology in real-time (This refers to dynamic synchronization of topology from Physical topology to abstract topology to VN topology)
- MDSC will perform the path restoration signaling to the affected PNCs.

8. Coordination of Multi-destination service restoration operation (CNC have, for example, multiple endpoints where the source endpoint can send its data to either one of the endpoints)
- When PNC reports domain problem that cannot be resolved at MDSC level because of there is no network restoration path to a given destination.
- Then MDSC has Customers' profile in which to find the customer has "multi-destination" application.
- Under policy A, MDSC will be allowed to reroute the customer traffic to one of the pre-negotiated destinations and proceed with restoration of this particular customer's traffic.
- Under policy B, CNC may reroute on its VN topology level and push this to MDSC and MDSC maps this into its abstract topology and proceed with restoration of this customer's traffic.
- In either case, the MDSC will proceed its restoration operation (as explained in Req. 6) to the corresponding PNCs.

9. MDSC-PNC policy negotiation is also needed as to how restoration is done across MDSC and PNCs.

10. Generic Abstract Topology Update per changes due to new path setup/connection failure/degradation/restoration
11. Service-specific Abstract Topology Update per changes due to new path setup/connection failure/degradation/restoration
12. Abstraction model of technology-specific topology element

6. References

6.1. Informative References

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

[ACTN-PS] Y. Lee, D. King, M. Boucadair, R. Jing, L. Contreras Murillo, "Problem Statement for Abstraction and Control of Transport Networks", draft-leeking-actn-problem-statement, work in progress.

[CHENG] W. Cheng, et. al., "ACTN Use-cases for Packet Transport Networks in Mobile Backhaul Networks", draft-cheng-actn-ptn-requirements, work in progress.

[DHODY] D. Dhody, et. al., "Packet Optical Integration (POI) Use Cases for Abstraction and Control of Transport Networks (ACTN)", draft-dhody-actn-poi-use-case, work in progress.

[FANG] L. Fang, "ACTN Use Case for Multi-domain Data Center Interconnect", draft-fang-actn-multidomain-dci, work in progress.

[KLEE] K. Lee, H. Lee, R. Vilata, V. Lopez, "ACTN Use-case for On-demand E2E Connectivity Services in Multiple Vendor Domain Transport Networks", draft-klee-actn-connectivity-multi-vendor-domains, work in progress.

[KUMAKI] K. Kumaki, T. Miyasaka, "ACTN : Use case for Multi Tenant VNO ", draft-kumaki-actn-multitenant-vno, work in progress.

[LOPEZ] D. Lopez (Ed), "ACTN Use-case for Virtual Network Operation for Multiple Domains in a Single Operator Network", draft-lopez-actn-vno-multidomains, work in progress.

[SHIN] J. Shin, R. Hwang, J. Lee, "ACTN Use-case for Mobile Virtual Network Operation for Multiple Domains in a Single Operator Network", draft-shin-actn-mvno-multi-domain, work in progress.

[XU] Y. Xu, et. al., "Use Cases and Requirements of Dynamic Service Control based on Performance Monitoring in ACTN Architecture", draft-xu-actn-perf-dynamic-service-control, work in progress.

7. Contributors

Contributors' Addresses

Authors' Addresses

Young Lee
Huawei Technologies
5340 Legacy Drive
Plano, TX 75023, USA
Phone: (469)277-5838
Email: leeyoung@huawei.com

Dhruv Dhody
Huawei Technologies
Email: dhruv.ietf@gmail.com

Sergio Belotti
Alcatel Lucent
Via Trento, 30
Vimercate, Italy
Email: sergio.belotti@alcatel-lucent.com

Khuzema Pithewan
Infinera
Email: kpithewan@infinera.com

Daniele Ceccarelli
Ericsson
Torshamnsgatan,48
Stockholm, Sweden
Email: daniele.ceccarelli@ericsson.com