Carrier Ethernet and SDN

Part 2

Practical Considerations

September 2014

Table of Contents

1 Introduction and Overview ... 3
1.1 Introduction ... 3
1.2 Document Purpose and Scope of this Paper ... 3
1.3 Executive Summary ... 3
2 How does Carrier Ethernet Fit with SDN? ... 4
2.1 CE Control Layer Capabilities ... 5
2.2 CE Data Plane Capabilities ... 7
2.3 Dynamic Attributes of MEF Services for SDN ... 8
3 How does SDN for Carrier Ethernet fit with OSS? ... 8
3.1 Impact of SDN on OSS ... 8
3.2 The Relevance of OSS for SDN ... 8
3.3 Complementary Benefits of SDN and the OSS ... 9
3.4 The Carrier Ethernet Service Model for SDN and OSS ... 9
3.5 Leveraging Carrier Ethernet and SDN to gain operational efficiency ... 10
4 Scenarios and Applications ... 10
4.1 EVPL Service Creation ... 10
4.2 Enterprise to Cloud Connectivity ... 11
4.3 Subscriber Initiated Service Upgrades ... 12
4.4 Service OAM Performance Testing ... 12
4.5 Carrier Ethernet Network Optimization ... 13
5 Summary and Conclusions ... 14
6 About the MEF ... 15
7 Glossary and Terms ... 15
8 Acknowledgements ... 15

1 Introduction and Overview

1.1 Introduction

The wide area network (WAN) is in the midst of a paradigm shift. Demand for bandwidth continues to grow with no apparent end in sight. Simultaneously, expectations for how bandwidth is delivered are evolving. Carrier Ethernet services are driving the service revenue growth for carrier's retail and wholesale business services. However, this growth is predominantly based on the flexible, cost effective nature of Carrier Ethernet when compared with more traditional WAN services. As the market continues to evolve, this growth will continue, however the cost per bit and more importantly the cost per connection will decline. To maintain margins and drive greater value from Carrier Ethernet services carriers must consider migrating to an even more dynamic and responsive Carrier Ethernet service enabled by the implementation of software defined networking (SDN) and Network Functions Virtualization (NFV).

In the first of this two part paper entitled *"Carrier Ethernet and SDN Part 1: An Industry Perspective,"* the benefits of SDN for Carrier Ethernet were discussed together with the impact of developing Carrier Ethernet services to gain the automated and simplified management and responsiveness that SDN can provide.

1.2 Document Purpose and Scope of this Paper

This paper, "Carrier Ethernet and SDN Part 2 – Practical Considerations", discusses the architectural models of Carrier Ethernet and SDN, the practical considerations of SDN and Carrier Ethernet for operational support systems (OSSs). It also addresses the mechanisms Carrier Ethernet offers SDN and describes several application scenarios for the combined use of Carrier Ethernet and SDN, including discussions of services and management. This document also summarizes the applicable industry specifications available that support the application of SDN on Carrier Ethernet services and networks.

1.3 Executive Summary

This paper examines Carrier Ethernet and how Carrier Ethernet applies in a world where Software-Defined Networking (SDN) is emerging. The paper first describes high level characteristics of SDN including programmability, virtualization and abstractions. Next, it reviews many of the specific control and data plane mechanisms Carrier Ethernet offers in an SDN implementation. Then there is a discussion of the relationship between SDN and the operations and business support systems (OSS/BSS). Finally, the paper offers sample scenarios in which SDN leverages the Carrier Ethernet control and data plane to simplify and automate network management.

2 How does Carrier Ethernet Fit with SDN?

Since the MEF formed in 2001, its specifications have helped Carrier Ethernet become the dominant WAN connectivity service around the world. These specifications, along with ongoing MEF work, now form the basis for the next phase of network evolution: the emergence of SDN and Network Functions Virtualization (NFV). Today these two trends are increasing service automation, improving service agility and giving end-to-end visibility and control to service providers worldwide.

In Sections 2.1, 2.2 and 2.3, we review the MEF control and data plane specifications and mechanisms that are used by SDN to create, deliver and monitor services. However, SDN requires more than just the MEF specifications to be effective. SDN encompasses an architecture and ecosystem that, in concert, facilitate the rapid creation, delivery, and monitoring of services. The MEF control plane and data plane specifications are valuable for service delivery and enable SDN within the context of other network developments.

These developments are designed to automate service provisioning, delivery and maintenance. MEF defined specifications along with the emerging SDN environment are increasing service agility and velocity. These tools enable service providers to more rapidly provision services and enable a wider range of new services. They offer new tools to increase end-to-end service visibility and control. For example, in an SDN environment, MEF defined Service Operations, Administration and Management (SOAM) specifications that offer Performance and Fault Management information can simultaneously be correlated, filtered and displayed from multiple vendors' equipment that support standardized SDN APIs. These new methods of operation are being enabled by emerging trends within the industry.

Programmability and Openness

Network elements (NE) should expose their features and functions to enable programmability from external 3rd party software. The behavior of NEs is typically controlled through a vendor NMS or specific CLI. In order to achieve programmability and openness, NEs must conform to a standardized service information model. Access to the NE results from the adoption of Southbound APIs i.e. SNMP, NETCON or OpenFlow and also through open Northbound APIs with for example, REST.

Virtualization

Network features and functions will become increasingly virtualized and able to run in standard x86 servers. These VNFs (virtualized network functions) can be dynamically instantiated and terminated as network service requirements change. This virtualization of functions will enable rapid reassignment of resources within the network in response to changing business requirements.

Abstractions

MEF Carrier Ethernet service attributes are defined independently from the particular technology implementation. This was done to enable Carrier Ethernet service delivery over any network infrastructure. Coincidentally, these definitions are also ideal for creating the abstractions needed in an SDN environment . These abstractions ensure that SDN commands or NFV applications designed to help manage network complexity, i.e. protection, grooming, traffic engineering or resource management, can be interpreted correctly by any NE.

Examples of MEF defined control plane and data plane capabilities and associated parameters for Carrier Ethernet are depicted in Figure 1 below. With SDN, control plane functions can be separated from data plane capabilities or augmented and managed from centralized redundant servers located anywhere on the network.

Figure 1 illustrates possible placement of Carrier Ethernet functionality described in various MEF specifications into SDN Control or Infrastructure Layers. Some functions, e.g., UNI attributes, are implemented in the Infrastructure Layer because that is where the physical UNI resides. However, the control and management of those functions can be implemented in the Control Layer. Other functions may need to be implemented in the Infrastructure layer due to their high performance requirements that could not tolerate processing delay in the Control Layer server software or the interactive communications delay between the Infrastructure and Control Layers. For example, SOAM-PM PDUs or a Bandwidth Profile (BWP) traffic management algorithm need to be performed in "real-time" in the Infrastructure Layer. However, their control and management functions can be performed in the Control Layer.

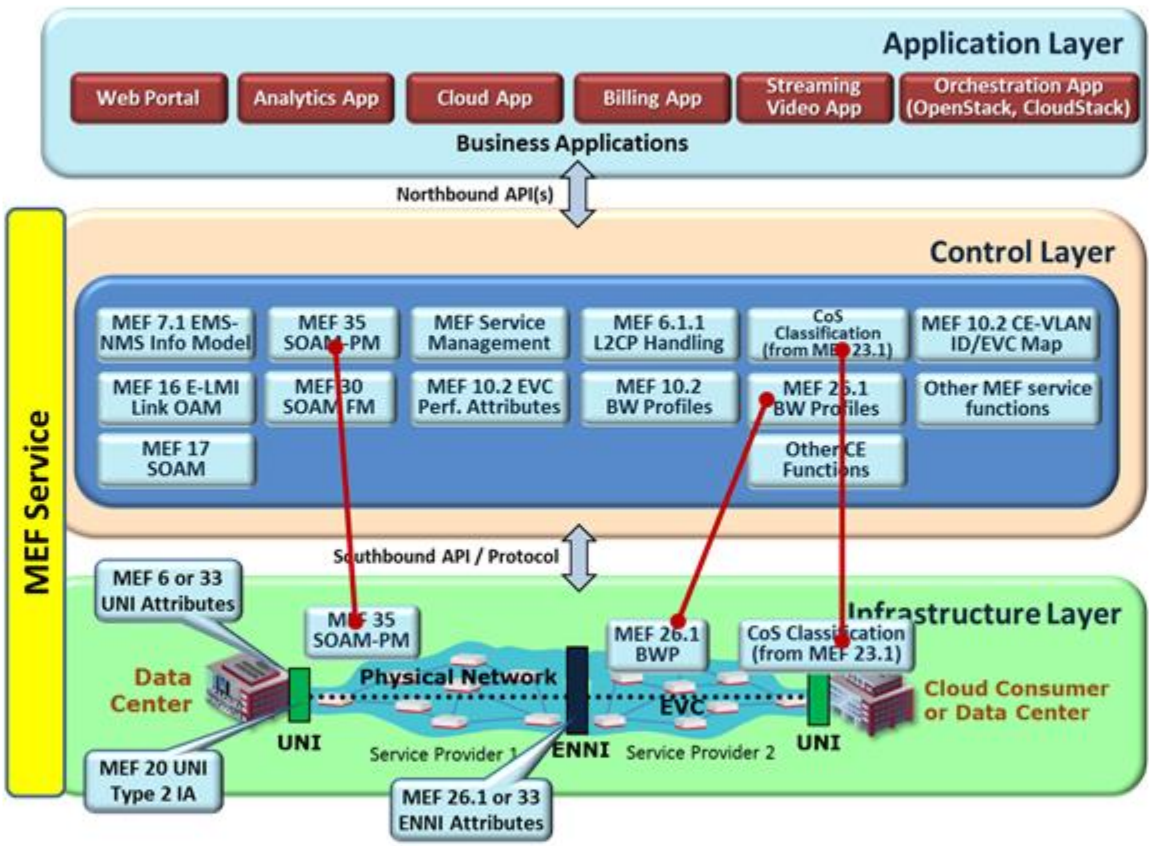


Figure 1: An example of mapping MEF specifications to Control and Infrastructure Layers

2.1 CE Control Layer Capabilities

The MEF has worked for more than a decade to define the service abstractions that enable the creation, delivery and management of Ethernet services. These definitions, information models and specifications are the mechanisms by which SDN can orchestrate and control Ethernet services. The following control layer capabilities were defined by the MEF and can be used for SDN based management of Carrier Ethernet services. They are distributed at UNI, VUNI and ENNI external interfaces, and EVC and OVC.

At UNI, the following capabilities can be configured or enabled/disabled using SDN depending on the application requirements:

- Bundling
- All to One Bundling
- Bandwidth Profile at the UNI
- Maximum number of EVCs
- CE-VLAN ID for Untagged and Priority Tagged Service Frames
- CE-VLAN ID/EVC Map
- Link OAM
- UNI MEG
- E-LMI
- Layer 2 Control Protocol Address Set
- Counters associated with Performance Management
- Synchronous mode

For an EVC, the following capabilities may be configured or enabled/disabled through SDN:

- EVC Type
- EVC Class of Service Level Performance Objectives (CPOs)
- EVC Bandwidth Profile, Source MAC Address Limit, Service OAM capabilities such as Test MEG and Subscriber MEG MIP, Maximum Number of UNIs, CE-VLAN ID Preservation, CE-VLAN CoS Preservation, Unicast Service Delivery, Multicast Service Frame Delivery, Broadcast Service Frame Delivery
- Counters associated with Performance Management

When an EVC crosses multiple operators' networks, the following capabilities could be configured or enabled/disabled at the ENNI using SDN:

- S-VLAN ID-OVC End Point Mapping
- ENNI LAG
  CoS Preservation
- ENNI MEP or MIP
- Max number of OVCs
- Max number of OVC end-points per OVC
- L2CP handling

When an EVC crosses multiple operators, some of the EVC segment (OVC) capabilities could be managed by SDN. These include:

- OVC Class of Service Level Performance Objectives (CPOs)
- OVC Bandwidth Profile , OVC MTU, CE-VLAN ID Preservation, unicast frame delivery, multicast frame delivery, broadcast frame delivery, color forwarding
- S-VLAN ID Preservation
- CoS Preservation
- CoS Mapping

For VUNI, the following capabilities could be considered part of the control layer and be configured through SDN:

- Bandwidth Profile
- Maximum number of OVC End Points

2.2 CE Data Plane Capabilities

The control layer mechanisms mentioned above are designed to maintain behaviors in the data layer. Listed below are some of the data layer capabilities that could be manipulated through the control layer via SDN commands. These data layer features are distributed and located at UNI, VUNI and ENNI external interfaces as well as at the EVC and OVC.

At UNI, the data layer capabilities are :

- Physical interface capabilities: rates, auto provisioning, synchronous mode, number of links, resiliency, service multiplexing, maximum frame size
- Counters for Performance Measurements
- Support of alarms and events including AIS, RDI, LOS

For an EVC, the data layer capabilities are: :

- EVC Type (i.e. point-to-point, multipoint-to-multipoint, rooted-multipoint)
- CoS
- Policing
- Counters and bins for Performance Measurements
- MEP , MIP and MEG Levels
- Support of CCM related alarms, AIS, RDI

At ENNI, the data layer capabilities are:

- Rates
- Number of links
- Resiliency
- Frame format
- MTU
- Maximum number of OVCs
- Maximum number of OVC end points per OVC
- Counters and bins for Performance Measurements
- Support of alarms and events including AIS, RDI, LOS

For OVC, the data layer capabilities are:

- OVC Type
- CoS
- OVC Policing
- OVC Performance Measurements
- Support of CCM related alarms, AIS, RDI, LOS

Some of capabilities for interfaces and connections are listed for both Control and Data Layers. These capabilities are configured by the Control Layer and performed by the Data Layer.

2.3 Dynamic Attributes of MEF Services for SDN

MEF is in the process of developing a new implementation agreement (IA) to define service attributes that can be modified on demand to support SDN applications.
These are listed in Table below.

Service Attribute	Elasticity
UNI Service Attributes	
CE-VLAN ID/EVC Map	Add/remove CE-VLAN ID when EVPL
EVC per UNI Service Attributes	
Class of Service Identifier	Modify CoS ID value to CoS Name mapping
Ingress BWP per CoS ID	
CIR	Adjust CIR within bounds (CIR LB..CIR UB)
EIR	Adjust EIR within bounds (0..EIR UB)

3 How does SDN for Carrier Ethernet fit with OSS?

3.1 Impact of SDN on OSS

SDN has a significant impact on the traditional OSS. Impacts include the delegation of functionality to SDN controllers, the dynamic behavior of services, the direct interactions with SDN by third parties, as well as the increasing virtualization of all aspects of functionality. These changes require that the OSS be extremely versatile in dealing with multiple levels of service abstraction and in gracefully delegating responsibilities.

3.2 The Relevance of OSS for SDN

Product offerings based on Carrier Ethernet services are usually composed of more than just the logical connectivity across the Service Provider’s infrastructure. Therefore, where physical devices and physical connectivity are required, the OSS provides essential coordination with other systems such as work force management and supply chain management that are often required to complete real-world fulfillment of network-based services.

A modern OSS unifies disparate Carrier Ethernet service implementations across existing legacy networks and SDN into a cohesive infrastructure, avoiding management of SDN-based implementations in isolation. Isolated management silos counter the benefits promised by SDN by increasing overall operational complexity, reducing flexibility and increasing costs. An OSS architecture that unifies CE service implementations is illustrated in Figure 2.

A modern multi-domain OSS provides agile and automated Service Fulfillment and Assurance operations based upon its highly configurable, data-driven service and network resource management capabilities. Among other things, the OSS’s purpose is to increase revenue through billable and on-demand services, reduce overall OpEx and support a better customer experience by optimizing and automating service development, service deployment and service fulfillment, as well as optimizing resource utilization and coordinating assurance reporting. SDN adoption enables an agile OSS to better achieve these objectives.

3.3 Complementary Benefits of SDN and the OSS

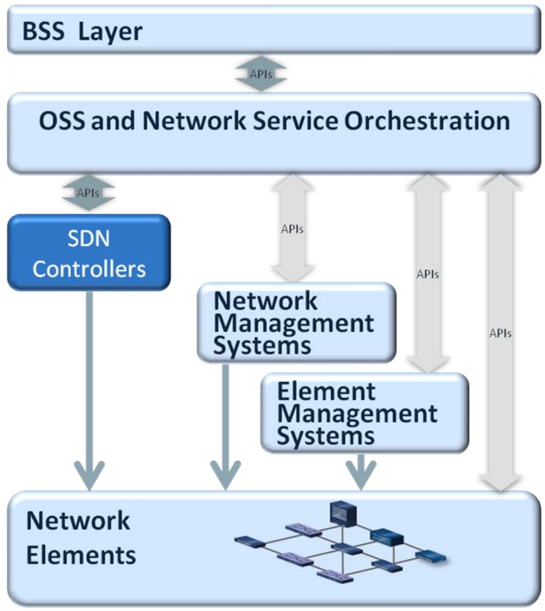


Figure 2: SDN in the BSS/OSS context

The goals of SDN and the OSS are aligned since SDN can assist with simplifying, standardizing and automating functions that the OSS performs. Examples of ways they complement each other include:

- SDN's programmability offers automation of service activation that can be directly leveraged by service fulfillment operations coordinated through the OSS
- SDN offers standard APIs that minimize system integration effort and offer mechanisms for consistent service deployment
- SDN provides abstraction of the network details that allows the OSS to delegate responsibilities on well-structured boundaries

3.4 The Carrier Ethernet Service Model for SDN and OSS

To capitalize on the benefits of SDN for Carrier Ethernet, it is critical that both the OSS and SDN controllers' information models be aligned to the common service model provided by MEF Carrier Ethernet definitions. The SDN controller should also be cleanly decoupled through well-defined APIs. This alignment simplifies service fulfillment by minimizing the transformations required to convert customer orders into network configurations, while preserving implementation flexibility.

Exposing a Carrier Ethernet service perspective from the OSS ensures upstream Business Support Systems (BSSs) are cleanly decoupled from the increasingly dynamic nature of the network infrastructure. Commercial abstractions are based on stable service abstractions, thereby insulating the commercial offers from service implementation details.

This Carrier Ethernet service abstraction within the OSS enables consistent representation of both legacy network infrastructure and evolving network implementations based on SDN and NFV concepts. For hybrid implementations, this provides a consistent end-to-end representation of the Network Service.

3.5 Leveraging Carrier Ethernet and SDN to gain operational efficiency

Combining MEF's Carrier Ethernet service abstractions and SDN functionality in a modern OSS enables Service Providers to gracefully adopt SDN while continuing to leverage legacy network assets. Therefore, Service Providers can benefit from SDN with minimal impact to existing products and services. SDN working harmoniously with a modern OSS enables increased operational efficiency and service agility and reduces potential back office complexity. These are key goals of all service providers as they evolve to support new dynamic high bandwidth data services.

4 Scenarios and Applications

The following scenarios using Carrier Ethernet service attributes are examined in this paper:

- EVPL Service Creation
- Enterprise to Cloud Connectivity
- Subscriber Initiated Service Upgrades
- Service OAM Performance Testing
- Carrier Ethernet Network Optimization

Carrier Ethernet is distinguished by 5 attributes of 1) Standardization of Services, 2) Scalability, 3) Reliability, 4) Service Management and 5) Quality of Service. These attributes represent the CE business management and service management features that could be operationalized through an SDN controller. To implement SDN, the service provider must have access to the CE functions resident within individual Network Elements (NE). CE features can then be provisioned using SDN according to service provider requirements. Listed below are representative scenarios in which CE functionality within the NE is controlled and orchestrated through an SDN controller.

4.1 EVPL Service Creation

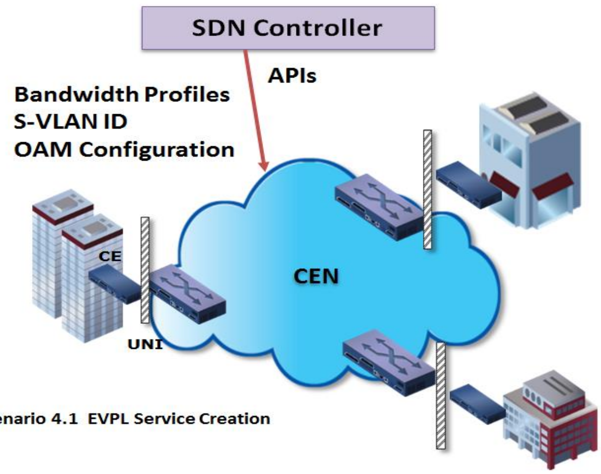
Scenario: A service provider in Nashville, TN wins a new customer, a furniture manufacturer with two locations in the region, for an Ethernet Virtual Private Line service. The SLA specifies a bandwidth profile with a committed information rate (CIR) of 200Mbps service, an Excess Information Rate (EIR) of 100Mbps along with Color Marking, a Frame Loss Ratio of 0.01% and a One-Way Delay measurement approximated by Round-Trip Delay (RTD) measurement of no more than 10ms. All of this should take place without affecting the customer VLAN IDs that transit the network. As part of new customer identification, order processing, and order fulfillment, a final step in the service delivery process could involve instructing an SDN controller to interact with network elements supporting CE services, over standard-based interface, to create the customer's service and SLA.

CE Functions: The SDN controller would interact with the network elements to send and receive configuration data in standard formats. Whether these are OpenFlow, CLI, SNMP/SMI, NETCONF (YANG) or other mechanisms, the network elements must be able to respond to and forward control plane information for requirements defined in the customer SLA. There are a number of MEF defined CE features that require configuration on network elements for this service to be enabled. These include: 1) define the UNIs associated with the service, 2) defining the S-VLAN IDs, 3) creating the Bandwidth Profiles, 4) defining the OAM measurement tests as well as MEPs and MIPs and in some cases defining any intermediary ENNIs that may exist between the UNIs.

Result: In a traditional CE configuration, each of these parameters must be defined for each CE enabled network device in the EVC. This is done using a CLI, scripts or an EMS specific to the device. Depending on the level of automation in the network this task can be time consuming for service provider personnel and it will vary from one network element to another and from vendor to vendor.

In an SDN environment, the service provider can complete service fulfillment in much less time. This responsibility would now be delegated to the SDN controller which would use open APIs and a consistent level of network abstraction to interact with the network elements. The advantage is that the controller can program equipment from multiple vendors using one abstracted command from the operator. Eliminating the need to program each vendor's device separately significantly reduces service provisioning time and also reduces errors associated with the unique configurations required by each vendor's devices.

Using predefined business rules the operator would make a request for the resources indicating the participating ports, the C-VLAN ID and bandwidth profile from the SDN controller. The controller would send the low level commands to each network element in the EVC to create the service.



Scenario 4.1 EVPL Service Creation

4.2 Enterprise to Cloud Connectivity

Most enterprises are leveraging cloud now or will in the near future. When an enterprise moves infrastructure, platforms and/or software into the cloud, they need high performance between the enterprise, cloud and end-user. High performance and reliable connectivity are features of Carrier Ethernet specifications; therefore many enterprises demand Carrier Ethernet for cloud applications.

Scenario: A Fortune 500 pharmaceutical company has developed a sales tool used by their 300 person salesforce in Germany, France and the UK. The application is hosted by a major 3rd party cloud infrastructure provider but the application is managed by the Fortune 500 Company's software developers and IT department. These three countries have distinct laws regarding prescription sales and legal changes that require continual update to the hosted application.

Carrier Ethernet Functions: The Carrier Ethernet service that salespeople receive from the cloud on a VPN at a home office could be different than the service they receive when on the road or at a client site. In order to assure that proper security and QoS is enforced when corporate databases are accessed from client locations the CE VLANs, UNIs and even the servers they access could be different. Unique Bandwidth Profiles could be defined for these sessions and invoked upon access. Alternate security requirements could be required and all of this could be programmed and rapidly modified using the SDN management infrastructure.

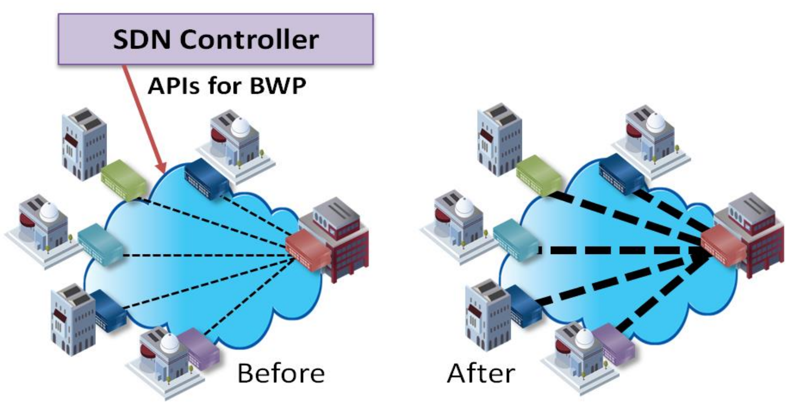
Results: This arrangement would guarantee that salespeople have the best quality for presenting mediarich content at customer sites while conforming to legal requirements when on their home VPNs. Using SDN to enforce these rules ensures that the company can change the rules and content quickly and universally for all 300 users. It protects the company from legal issues, helps ensure successful sales meetings and minimizes requirements for input from the IT department.

4.3 Subscriber Initiated Service Upgrades

Scenario: A hospital group with an EVP-LAN service running a CIR of 100Mbps to 6 locations in a metro area wants to upgrade their bandwidth to share expensive new radiology equipment purchased by one of the members. Since one multilayer CAT scan can be more than a terabit in size and multiple scans per patient are common, the group determines they need upgrades to 1Gbps on all EVCs in their network.

CE Functions: In this case, everything about the customer's service stays the same except the Bandwidth Profile. Therefore, the customer might access their service via a customer portal, on which there could be fields for each aspect of their service. The Bandwidth Profile might include some of the following fields: Committed Information Rate, Excess Information Rate, Committed Burst Size, Excess Burst Size and Color Mode. If the service provider allows user modification then the customer would modify one or more of these parameters. In this case, the customer would increase the Committed Information Rate from 100Mbps to 1Gbps.

Results: This request would be passed from the portal to an SDN controller that maintains a complete map of the network and available resources. If the bandwidth was available the user would be able to save the request. After the SDN controller verified that the requested bandwidth was available and automatically checked that the request did not violate any other service provider rules, the request could be enabled. Commands formatted in the unique structure required by each network element would be automatically generated from the SDN controller to the devices, thereby enabling the service upgrade.



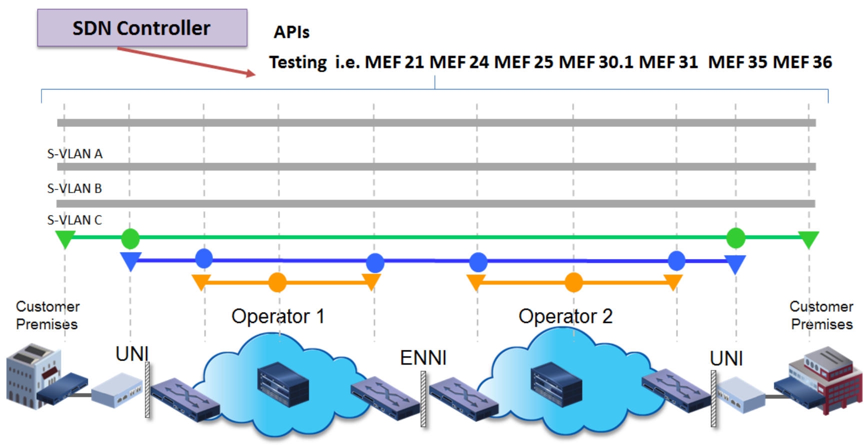
Scenario 4.3 Customer Initiated Service Upgrade

4.4 Service OAM Performance Testing

Scenario: A customer connected to 6 Gbps ports using 3 different S-VLAN IDs on a VP-LAN service says they are receiving slow or intermittent performance on some or all of their EVCs. Neither the customer nor the service provider know the EVC performance or the source of the performance issues. The issue could be in the service provider network or it could originate at the customer network before it reaches the service provider network.

CE Functions: The service provider may elect to initiate OAM testing using one or more MEF defined OAM tests. These tests generate protocol data units (PDUs) for each port, S-VLAN and bandwidth profile within the customer's service. These tests ensure that connections between each UNI-pair and their associated MEP and MIP in the entire EVP-LAN perform according to the SLA.

Results: In a traditional environment the service provider personnel must configure all the MEPs, MIPs, and SOAM test parameters for each UNI-pair within the service. However, an SDN controller could maintain state knowledge of each UNI-pair in the full service and also the precise format for instructing the network elements to begin testing each UNI-pair in the service. The definition of what test to use, the interval of the test and the frame sizes to test could be issued by the service provider and the details of invoking those tests would be handled by the SDN controller.



Scenario 4.4 OAM Performance Testing

4.5 Carrier Ethernet Network Optimization

A key attribute of an SDN architecture is the possibility of using a centralized controller that has a global view of the network and potentially of the utilization of its resources. In such a scenario, this controller could run traffic engineering applications that would use this information as input to software algorithms designed to enhance Carrier Ethernet networks and services.

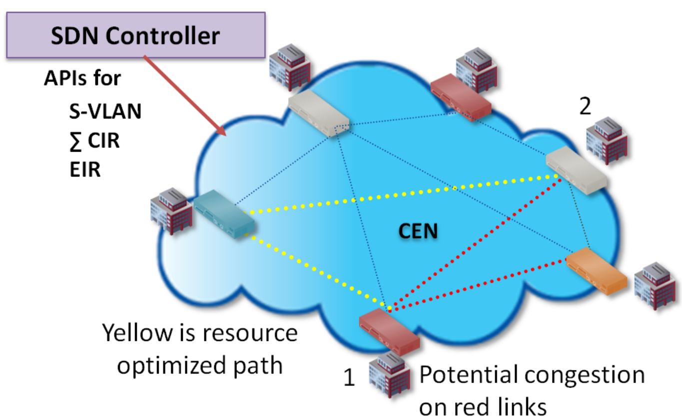
Scenario: A Tier 1 service provider wants to ensure their network EVCs are used at optimal performance. They could create a network optimization plan where the use of the centralized controller with a real-time (or near-real time) global view of the network could create a complete catalogue of the utilization of all the nodes and EVCs in their Carrier Ethernet Network. The traffic engineering application would know at any given moment where the Carrier Ethernet Network is congested or at high utilization and where capacity is under-utilized. When a new EVC is requested from the Carrier Ethernet Network, it would be presented to network controller's traffic engineering application that could be instructed to program it in the network using the nodes and EVCs with more capacity available and by doing so improve network assets utilization. As part of the validation process for the service provisioning, the traffic engineering application in the SDN controller can also check that during failure conditions the network will be able to protect or restore the EVCs according to predefined restoration criteria.

CE Functions: To improve EVC utilization and service performance as well as optimize network resources, the traffic engineering application could be programmed to use Carrier Ethernet delay and delay variation parameters in the Carrier Ethernet SOAM specifications. Selecting the EVC for a new EVC from EVC performance data collected via Carrier Ethernet OAM statistics for packet loss, delay and delay variation could be added to the capacity data known from the aggregate CIR in the Bandwidth Profile. Together, these Carrier Ethernet parameters provide new methods for service providers to optimize their network resource utilization.

Another network optimization technique could include using SDN to program future states of the network by working as a bandwidth calendaring tool to enable the service provider to offer scheduled off-peak services. Customers could use this capability to book or reserve bandwidth for a new or existing EVC in the Carrier Ethernet Network.

Results: Service providers could use Carrier Ethernet specifications to help optimize their network resources. They could direct traffic to under-utilized EVCs and reroute traffic from over-utilized EVCs. This could be done to maintain the maximum traffic throughput while enforcing all SLA performance requirements.

In addition, new services could be created such as pre-scheduling short-duration, high bandwidth services during low usage periods i.e. during the late night and early morning. In both of these examples, it is the combination of Carrier Ethernet parameters and SDN controllers that enable service providers to optimize their network resources.



Scenario 4.5 CE Network Optimization

5 Summary and Conclusions

It is clear that SDN has the potential to increase service agility, improve service automation and provide end-to-end service visibility and control. SDN is a network architecture evolution that will result in new standardized protocols, open APIs and service attributes MEF defined Carrier Ethernet specifications and abstractions will play a major role in this evolution as tools used by higher level management layers and SDN oriented OSS/BSS applications. As discussed in this paper many of the required definitions and attributes needed to enable SDN managed CE networks are available today. The virtualization of network functions and the programmability of hardware platforms will usher in a new era where networks can more rapidly meet the changing needs of subscribers and the business requirements of service providers.

Carrier Ethernet services and the specifications that enable them have taken a decade to become the dominant service worldwide. They achieved this position because they meet the needs of service providers and users. Similarly, SDN meets the need for lower operating costs, faster service provisioning times and more optimized network investments. SDN therefore enhances the capabilities of Carrier Ethernet with the speed of provisioning that allows for the creation of dynamic services enabling applications like cloud computing and cloud networking, significantly improves the value proposition for all stakeholders. The evolution to SDN is happening now. It is clear from existing industry developments that Carrier Ethernet and the specifications that enable it are key foundations for this next network transformation.

6 About the MEF

The MEF is a global industry alliance comprising more than 225 organizations including telecommunications service providers, cable MSOs, network equipment/software manufacturers, semiconductors vendors and testing organizations. The MEF's mission is to accelerate the worldwide adoption of Carrier-class Ethernet networks and services. The MEF develops Carrier Ethernet technical specifications and implementation guidelines to promote interoperability and deployment of Carrier Ethernet worldwide. The MEF's Certification Program has resulted in more than 800 products and services from more than 160 companies and more than 2300 certified professionals. For more information about the Forum, including a complete listing of all current MEF members, please visit http://www.MetroEthernetForum.org.

7 Glossary and Terms

A glossary of terms used in this document can be found online at www.metroethernetforum.org/glossary.

8 Acknowledgements

Editors: *Mannix O'Connor, MRV; Glenn Swanson, Oracle.* Project Leader: *Abel Tong, Cyan.* Contributors: *Anthony Peres, Alcatel-Lucent; Mehmet Toy, Comcast; Emerson Moura, Cisco; Mark Fishburn, MEF*