An Industry Initiative for Third Generation Network and Services

November 2016

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1. Executive Summary

A significant transformation is taking place in data communication networks that will accelerate the ability of network operators to deliver self-service, cloud-connected and on-demand services over interconnected networks. These next generation networks will enable agile, assured and orchestrated network services for the digital economy and the hyper-connected world, with user-directed control over network resources and cloud connectivity. Optimized for real-time, QoS-enabled, secured traffic and integration of value-added network functions-as-a-service (NFaaS), these new network services will be delivered over automated, virtualized, and interconnected networks globally managed by Lifecycle Service Orchestration (LSO), Software Defined Networks (SDN), and Network Function Virtualization (NFV).

This paper describes an industry vision for the evolution and transformation of network connectivity services and the networks used to deliver them. The MEF refers to this vision as the “Third Network” where the Third Network combines the on-demand agility and ubiquity of the Internet with the performance and security assurances of today’s business grade networks (i.e.: Carrier Ethernet 2.0 and MPLS). This new third generation network will also enable services between, not only physical service endpoints used today such as Ethernet ports (UNIs), but also between virtual service endpoints located on blade servers in the cloud in order to connect to Virtual Machines (VMs) or Virtual Network Functions (VNFs).

The industry vision of the Third Network is based on network-as-a-service (NaaS) principles which make the network appear to the user as the user’s own virtual network with bump-in-the-wire value-add services. This enables IT administrators to in a dynamic and on-demand way create, modify and delete services via customer web portals or software applications. This is similar in concept to cloud-based services, such as infrastructure-as-a-service (IaaS), where users can dynamically create, modify or delete compute and storage resources. *The industry will achieve this vision by building upon the various cloud-centric technological advances that are occurring in the marketplace today such as SDN, NFV and open APIs. These advances can be used to create a new global business network fabric that combines the agility of the cloud with a new layer of intelligence that overlays the interconnected islands of connectivity networks (e.g. CE 2.0 and MPLS) provided by different operators.* Additionally, next generation OSS and BSS systems are evolving into a solution which is called Lifecycle Service Orchestration (LSO) systems. The Lifecycle Service Orchestration will be used for service ordering, fulfillment, performance, usage, analytics and security, both within an operator domain and across multi-operator networks. This approach overcomes existing OSS/BSS constraints by defining service abstractions that hide the complexity of underlying technologies and network layers from the applications and users of the services.

In summary, the vision of the Third Network is based on network-as-a-service principles, and enables *agile* networks to deliver *assured* connectivity services *orchestrated* across network domains between physical and virtual service endpoints.

2. Key Third Network Business Drivers

2.1 Cloud Connected

The rapid growth of cloud services has created a market need for reliable and elastic connectivity between cloud provider (CP) data centers on the one hand and between these CP data centers and cloud consumer (CC) locations on the other. Initially this connectivity was provided over the public Internet; However, requirements for improved security, predictable and guaranteed performance, and control of data governance and regulatory compliance are difficult or impossible to realize over the public Internet. Carrier Ethernet services provide a high-quality alternative to the Internet for cloud service interconnection by enabling strict control of access and conforming to defined service level specifications (SLS).

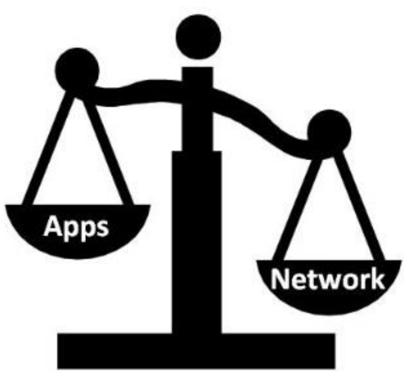
2.2 On-Demand Services

Technology advances in the orchestration of compute and storage resources have enabled cloud service providers to rapidly instantiate cloud computing services that can be consumed for short durations. With the continued rapid growth of cloud services as a new revenue source for communications service providers, network connectivity services must also evolve to align with cloud services' short service activation times and variable service durations. Additionally, on-demand network connectivity services enable faster time to revenue balanced by the duration of the service. The new cloud-centric reality puts pressure on network connectivity service ordering and activation times which can no longer take days or weeks but need to be measured in minutes. The matching of the speed of innovation of cloud compute and storage services with the agility and speed of enabling business grade connectivity solves the time to market velocity of new high value cloud-centric multi-domain services.

2.3 Expectation for Quality

In many markets, consumers and businesses have choices in their selection of a service provider. The user's quality of experience has become a far more decisive factor in the selection or rejection of a service provider. With the growth of cloud-computing, enterprise applications increasingly 'live' on the WAN as traffic moves from user to data center or cloud whether the user is connected at home, in the office or on the road. Users expect their apps in the remote cloud to perform as well as they do when running locally on their LAN. Therefore, the quality of the network connectivity service must align with the needs of the applications and their users.

2.3.1 Value Perception



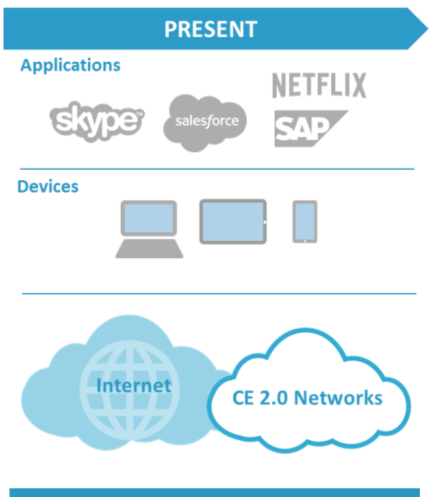
As applications become the focus of businesses and consumers in terms of delivering value, the network becomes practically invisible until it negatively impacts the application experience. Today, many apps are networked, especially those that run on tablets and smartphones. Without a network connection, these apps either operate with limited functionality or do not operate at all. Network connections are often perceived as "dumb, fat pipes", e.g., broadband connection to the Internet purchased in bandwidth tiers. This lower perceived value of network connectivity, when compared to applications, can result in an inequitable distribution of revenues between network connectivity service providers and over-the-top (OTT) application service providers.

2.4 Evolution of Telecom Networks and Services

Telecommunications circuit switched networks are deterministic because the entire circuit bandwidth is dedicated to the user or application. These networks were optimized for TDM voice applications that transmit and receive at a constant bit rate but are inefficient for packet-centric applications that send and receive information in bursts.

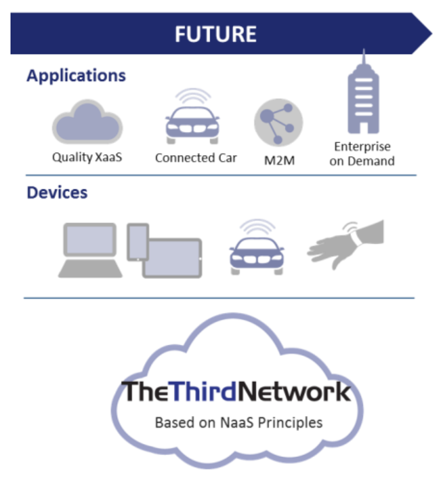
Not all applications require 'platinum TDM-quality' service performance. Offering a higher class of service for an application that doesn't require it wastes valuable network resources resulting in higher network operations cost and a higher service cost for the subscriber.

Usage of packet-based applications has long dominated legacy, circuit-based applications. Sharing of network resources is the norm with most applications using a common network infrastructure. However, this shared environment introduces the possibility of resources conflict that may cause service degradation. Real-time media communications using voice over IP (VoIP) and video, for example, are decoupled from what was formerly an application-specific infrastructure of telephones (devices) and the PSTN (network). Now, real-time media communications are an 'app' that runs on computers, tablets, smartphones and IP phones that connect over a general-purpose packet-based network and often the 'best effort' Internet.



When using the Internet one may experience service impairments or degradation, such as echo or voice distortion, on a real-time media call due to dropped or delayed delivery of voice/video packets. To achieve a more deterministic experience, one uses private or virtual private network services that provide quality assurances. However, when using such services, one must sacrifice some flexibility in terms of activation times and purchasing models. The service provider selling the network service requires a long-term lease to commit to the required service performance.

As we move to an even more dynamically connected cloud-centric future, many devices, e.g., connected cars, smartwatches, smartphones, tablets, phablets, and sensors, will connect and communicate to further enhance our lives. The underlying network must transform to facilitate cloud service delivery with agility in a way that connects people and devices in real-time, on-demand, with an assured quality of experience.



The transformation has begun where industry-based open APIs will enable LSO systems to control and operate existing networks of today, with the SDN and NFV of the future thereby realizing more programmatic control and automation of the underlying network resources.

3. The Industry Vision

In the telecommunications market, communications service providers often sell WAN connectivity services based on technology: wavelength, Ethernet, MPLS, IP, etc. This requires subscribers to understand a myriad of technologies to determine which technology is best suited to meet their applications' requirements. Additionally, telecom network management and operations are closely tied to specific technology implementations with little to no technology abstraction and orchestration when compared to cloud services. Telecom network management systems (NMS) often interact directly with the equipment using equipment-specific SNMP, TL1 or CLI device management interfaces instead of a common, standardized, technology-abstracted API. This approach requires the service provider's management system software to change if the equipment, technology or equipment-specific management interfaces change. These changes are costly, take a long time to develop and deploy, and require extensive lab testing. The management problem is compounded in multi-operator networks because of service management, e.g., service ordering, service provisioning, etc., which is labor intensive with limited automation. This lack of automation results in long lead times (in the order of weeks) for service ordering and activation.

Now contrast the telecommunications market with the cloud services market. For many years, cloud services have provided technology abstraction using open source or de-facto standard APIs to automate service management and orchestration among compute, storage and data center (DC) networking technologies. With this technology abstraction, subscribers need not be aware of the underlying technology. For example, they don't need to know if the storage being used is connected via Fibre Channel or iSCSI. Subscribers merely indicate the amount of storage they want to order. Furthermore, management and business applications operate without requiring any modification, even when underlying technologies change. This abstraction enables a level of operations agility and automation that supports on-demand ordering and activation of services. WAN connectivity services need to advance and align with these cloud services models.

In order to address this transformation to an on-demand, cloud-centric world, the industry envisions that network connectivity services must evolve to provide:

- Agile, on-demand, self-service connectivity between physical and virtual service endpoints
- Assured performance and security, backed by an end-to-end SLA, connectivity and point services
- Service orchestration using standardized APIs across single or multi-operator network domains
- Operational agility via service, resource, and technology abstractions and model driven orchestration

Today, WAN connectivity services are typically ordered and provisioned manually between two or more physical service endpoints. For example, in Carrier Ethernet services these are referred to as User-to-Network Interfaces (UNI) and External Network-Network Interfaces (ENNI). However, with the increasing use of cloud-computing and other cloud-based services, the connectivity services purchased by a 'virtual tenant' for a virtual tenant network may not terminate on a physical port (e.g., top of Rack Switch) but instead at a virtual switch inside a compute platform such as a blade server or inside a network element running virtual network functions.

In today's environment, when a user wants to connect to their virtual machine (VM) in the cloud, the VM connects to a virtual switch in the blade server which subsequently, connects to a physical LAN within the data center. This DC LAN in turn connects to a WAN service via a physical service endpoint, e.g., a MEF UNI. With the concatenation of a virtual network to DC LAN to WAN, the service performance is not measured and monitored consistently between the actual endpoints of the end-to-end connection. Instead, service performance may be measured solely up to the physical service endpoint of the WAN resulting in a partial measurement covering only a segment of the connection. Furthermore, it is Important to have end-to-end visibility for complete connectivity fault detection and isolation which otherwise would require extensive manual co-ordination with different network operators.

3.1 Three Attributes of a Third Network

The industry vision is to enable *agile* networks that deliver *assured* connectivity services *orchestrated* across multiple network operator domains between physical or virtual service endpoints. These three attributes are described below.

3.1.1 Agile

Agile refers to the service providers' ability to rapidly introduce new, on-demand services leveraging new technologies together with the necessary transformation of the operational environment. Service agility is achieved via proper product, service, and resource abstractions leveraging open APIs and service orchestration. SDN and NFV enable significant network agility for the new Third Network, but require the service providers' operational environment to be at least as agile in order to achieve accelerated time-to-market for new service introduction. Service and network provisioning must move away from hard-coded paradigms to re-usable building blocks that will be more dynamic and model driven. The very rapid speed at which a high-quality connection is enabled between the user and the cloud service is a critical enabler for a Third Network Operator to be agile.

3.1.2 Assured

Assured refers to subscribers' expectations that network-as-a-service will provide consistent performance and security assurances to meet the needs of their applications. This needs to be applied across the spectrum of services from physical to virtual services. Given the dynamic, on-demand nature of a Third Network, subscribers self-provision their services and the related workflows are completely automated with little to no involvement on the part of the Operator. The ability for subscribers to gain visibility into how well their service is working and analytics-based insights into how well their applications are performing form the basis of an assured service.

3.1.3 Orchestrated

Orchestrated refers to dynamic and automated service management of the entire lifecycle of connectivity services that may encompass network domains within a single Operator's network or across multiple Operator networks. This includes service fulfillment, control, performance, assurance, usage, analytics, policy, and security. Since no service provider has a network footprint in all locations, such automation must include that for peering between service providers for automated ordering, provisioning, and management of access or transit connectivity services that reach off-net subscriber physical or virtual locations required for a given virtual tenant network.

Service orchestration is achieved programmatically through APIs that provide abstraction from the particular technology used to deliver the service. Any new service orchestration model needs to support co-existence of existing network implementations and newer SDN and NFV implementations.

3.2 The Evolution to the Third Network

All network connectivity services - for example, Carrier Ethernet, IP VPNs, MPLS VPNs, and Optical Transport services - have two fundamental service components: The service endpoints between which network connectivity is provided and the service attributes that determine the service characteristics.

Figure 1. Physical Service Endpoints

When a network connectivity service is ordered, at least two interconnected service endpoints must be specified. The service endpoints have traditionally been physical endpoints, e.g., an Ethernet interface, an OTN OTU2 interface, OC-48 SONET or STM-16 SDH interface, or a T1 or E1 interface.

Figure 2. Physical and Virtual Service Endpoints

In contrast, Third Network virtual service endpoints can be on a device such as a smartphone, or a virtual switch running on a blade server, which in turn would connect to a Virtual Machine (VM) or Virtual Network Function (VNF).

Today, most WAN connectivity services today, the service attributes are static and cannot be changed on-demand by subscribers via customer portals or software applications. Any such changes typically require a service modification which may take days or weeks to activate, supposing that the network is even functionally capable of supporting the change request.

Today, subscribers have become accustomed to on-demand services in the cloud and on-demand Internet network connectivity via Wi-Fi or cellular networks. This subscriber expectation is especially prevalent when using private and virtual private network business connectivity services. For example, a subscriber may want to increase or decrease the service bandwidth-on-demand, add or remove a service endpoint or even create or terminate a service via a customer web portal just as they do with their cloud services.

The Third Network vision, based on network-as-a-service principles, will enable network connectivity services to be delivered to physical or virtual service endpoints with a set of dynamic service attributes. These dynamic service attributes enable network connectivity services to better align with on-demand cloud service capabilities. For example, many real-time applications measure network performance. In the future, these applications could automatically communicate their requirements via an API on how they want voice, video or data conferencing treated in terms of bandwidth, packet loss, jitter and delay requirements. No longer will there be a need for a tenant being forced to statically provision Classes of Service (CoS) at a given site for a given application. Instead, the Third Network will be inherently elastic so that when an application dynamically enables additional features for a given session, the Third Network will automatically adapt to the application's needs, having eliminated static provisioning models which are very common in today's business networks. For example, a Unified Communications application session might be initiated only for voice communication and then dynamically evolve on demand into a multiparty conference, with high definition video and application/white-board sharing, these being supported by the appropriate Classes of Service created dynamically in the network response to triggers in real-time by the application.

Additionally, the Third Network will use Lifecycle Service Orchestration (LSO) APIs to provide the technology, service and resource abstraction between the subscriber, service provider, network operators, and the network infrastructure. At the top level of the hierarchy illustrated in Figure 3, subscriber interfaces with a self-service web portal (or software application communicating directly) to instantiate a network-as-a-service which in turn triggers the instantiation of the supporting network connectivity in the relevant network operator domains. The subscriber need only communicate the essential information required to order the service, e.g., service endpoint locations, service bandwidth and service SLAs in addition to billing information. The customer ordering experience should be similar to how they order cloud services, i.e., placing an order from a product catalog after which fixed and recurring costs are totaled and then the order is submitted.

The web portal communicates the order information to the service provider via standardized APIs. In the example in Figure 3, a service provider (network operator 1 - left blue cloud) peers with another network operator (right gray cloud), e.g., an access provider, to reach the off-net Subscriber Site 2. This peering arrangement is required to deliver the end-to-end network-as-a-service. Open APIs communicate the more detailed service attributes used across each network operator, e.g., user and operator service endpoints and operator virtual connection attributes. Each network operator must then orchestrate an operator virtual connection across the different network technology domains which are interconnected via internal network-network interfaces (INNIs).

The Service Provider (network operator with the business relationship with the subscriber) may use an Ethernet access network to reach Subscriber Site 1. This access network interconnects via an INNI to an MPLS core network. The core network provides an operator service endpoint which is used to peer with another network operator (right gray cloud) to reach Subscriber Site 2.

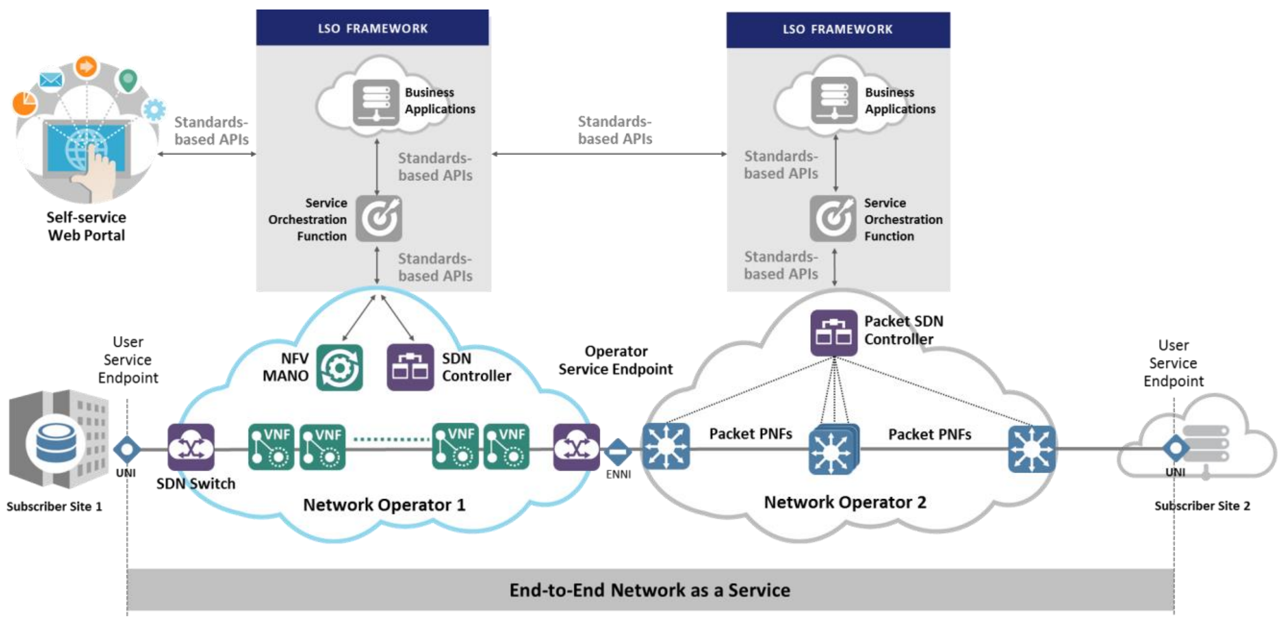


Figure 3. Third Network "Big Picture" View

The network operator on the right (gray cloud) may use an Ethernet access network to reach Subscriber Site 2 and a Packet network to connect to the peering operator service endpoint. The Service Provider must then orchestrate the service between the user service endpoints at each subscriber site. This functionality will be performed by the service provider with the business relationship with the subscriber. The service provider could be one of the network operators or a 3rd-party who doesn't own or operator the physical network infrastructure.

Service providers can also orchestrate and bundle network-as-a-service with other network-based services, e.g., firewall, intrusion prevention, and cloud services. In Figure 4 a customer wants to connect to a cloud service from all of its sites and wants its service provider to not only provide the connectivity between all its sites (including connections to all its clouds services), but also provide all the security and routing/NAT aspects in connecting their sites to the cloud. As more and more enterprises move to the cloud, their management of all the security and networking complexity becomes very cumbersome and operationally expensive. Since most enterprises already have business relationships with their local service providers, it is a natural evolution for these enterprises to want and trust their local providers to provide more value-added services than just bandwidth.

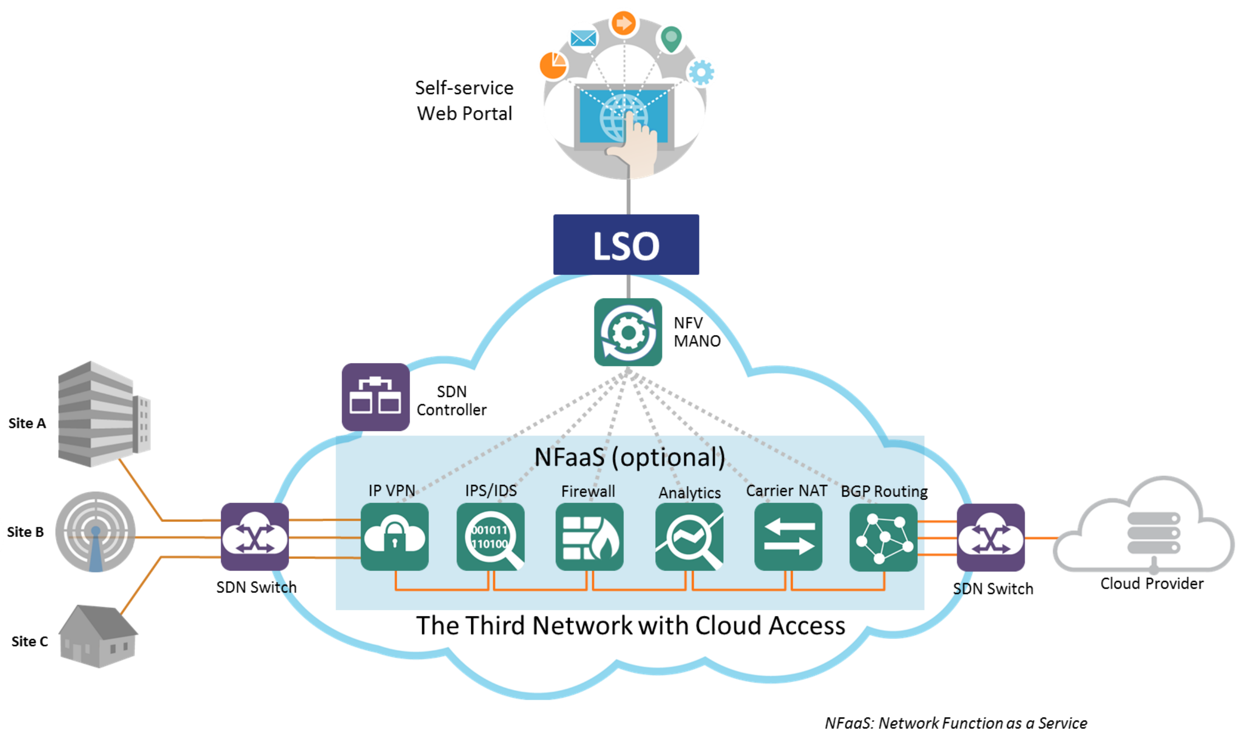


Figure 4. Third Generation Network with Cloud Access

Ultimately, the Third Network delivers a network-as-a-service, which in turn provides *agile* connectivity on-demand among any group of service endpoints - much like making a telephone call where one dials a number and the network establishes the connection - with *assured* service quality that is *orchestrated* across different network domains.

4. Framework for a Third Generation Network

A key element in the framework for a Third Network is Lifecycle Service Orchestration (LSO) which is the intelligent coordination of all the 'moving parts' required to create an agile, assured and orchestrated network. LSO provides agility, assurance, and orchestration by understanding the desired global connectivity services, and where each functional area, from product definition through service orchestration, assurance, and billing need to be further streamlined and automated.

For example, Figure 5 describes an operational thread for product ordering and activation orchestration within the LSO ecosystem for a connectivity service both within the provider domain and also addressing the partner domain portion of the service. As can be seen from the figure, the Service Provider (SP) has to query its partner Operators at the Business Application (BUS) layer when enabling an E2E service across multiple network domains. Pricing and resource availability, for example, are just part of a Serviceability enquiry. Once a partner Operator's proposal is accepted, there are still a number of additional steps to the fulfillment step, such as ordering, provisioning the network resources, performance testing, and activation testing. LSO enables automation of what are currently significantly time-consuming processes, especially between service providers.

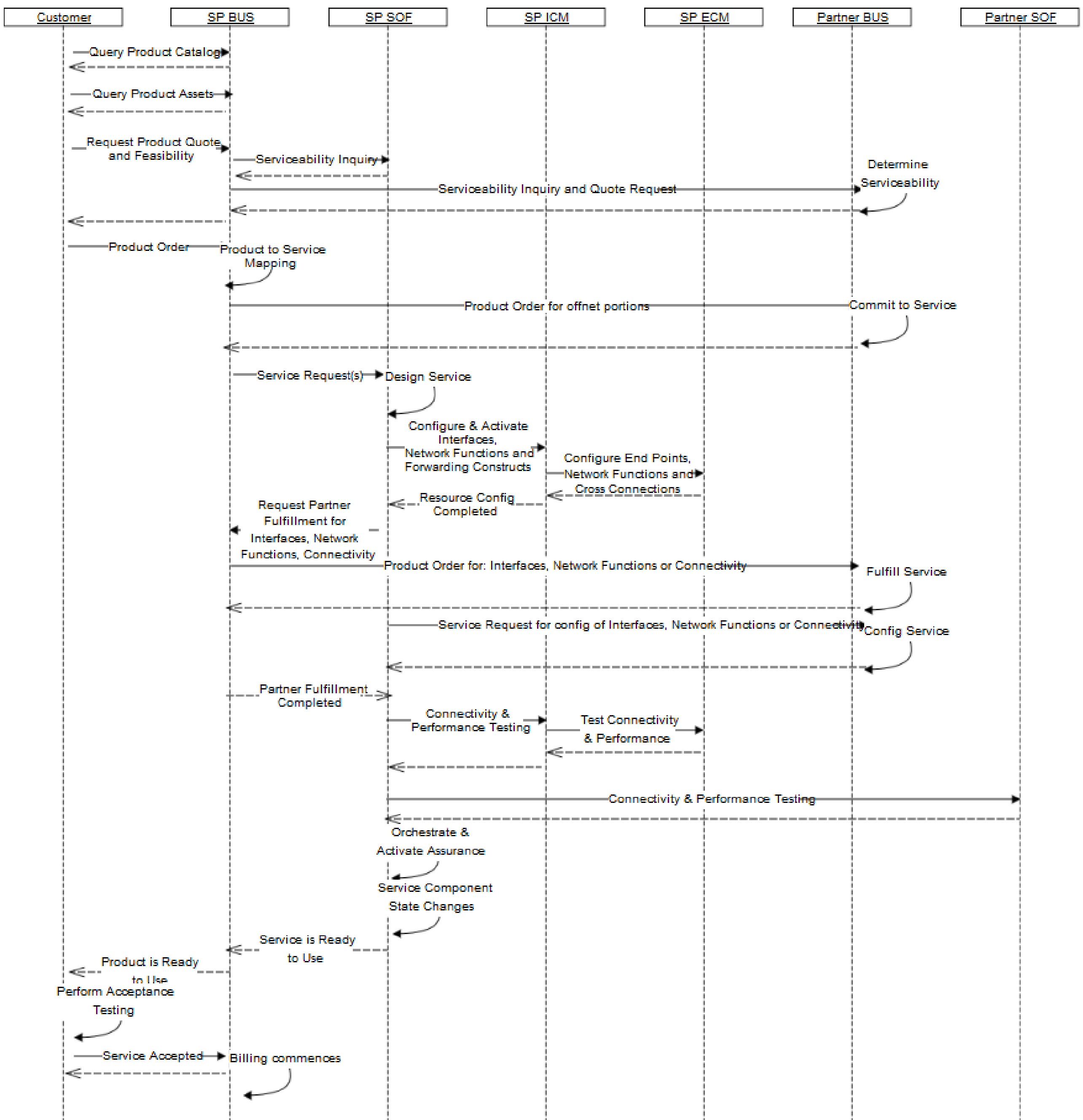


Figure 5. Product Ordering and Service Activation Orchestration

As a further example, the pre-ordering and ordering phases of the service lifecycle are focused on automating the inter-provider business interactions and interfaces for the buyer-seller process, including the product catalog, order, service location, and service qualification questionnaire. Just the basic use case of figuring out which federated partner has the right resources for a given set of requirements is a very complex task. Each of these phases is based on the product offer defined by the selling Operator. Since the product offer is fully defined in the product catalog, a model-driven approach is used to execute the subsequent stages of the service lifecycle, including pre-order, order, and service orchestration. By using a model-driven approach along with abstractions representing products, services, and resources, LSO ensures an agile approach to streamlining and automating the entire service lifecycle in a sustainable fashion.

As shown in Figure 6, connectivity services in the Third Network will be orchestrated across all internal and external network domains belong to one or more network operators. These networks may be operated by communications service providers, data center operators, enterprises, wireless network operators, virtual network operators, or content providers. LSO spans all network domains that require coordinated end-to-end management and control to deliver connectivity services. Within each provider domain, the network infrastructure may be implemented with traditional WAN technologies, as well as SDN and/or NFV. LSO capabilities allow the Third Network not only to dramatically decrease the time to establish and modify the characteristics of the connectivity service, but also to assure the overall service quality and security for these services.

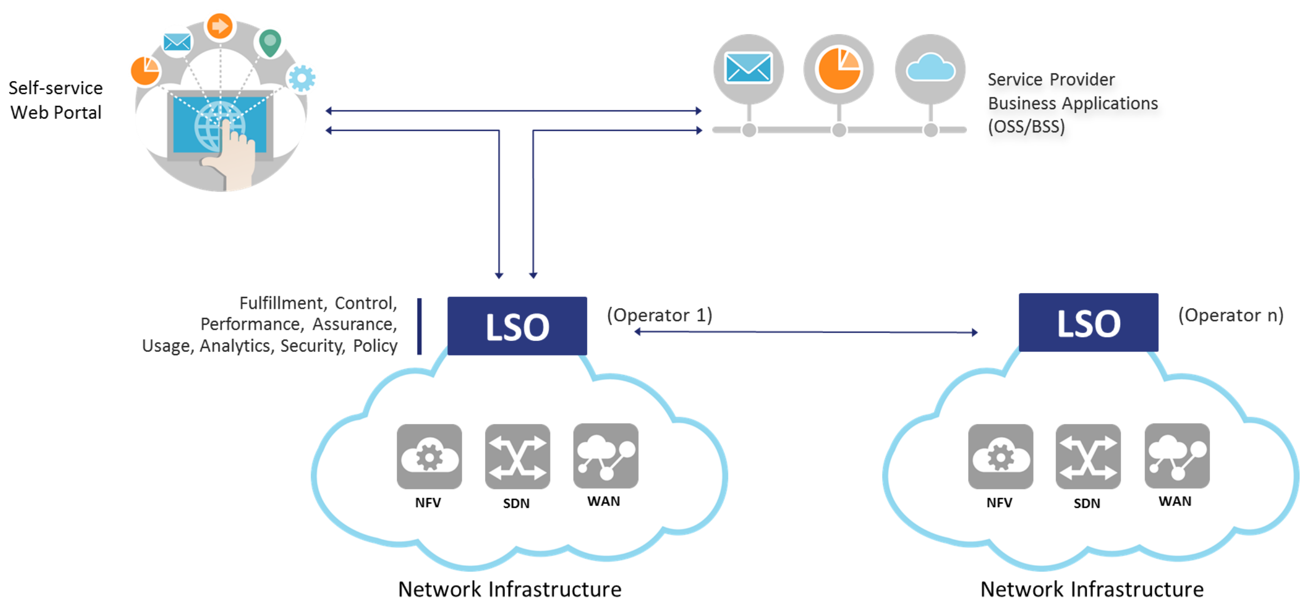


Figure 6. Connectivity Services in the Third Network

Since most operators have invested billions of dollars into today's existing networking equipment, implementing a greenfield SDN and NFV based infrastructure is not practical from the operators' point of view. It is very common for many service providers to have many brownfield deployments where both optical and transport domains must coexist with an SDN and NFV environment. Many providers are managing this evolution by inserting SDN controllers into their existing WAN networks, the implication of which is that LSO becomes the glue between the legacy and SDN/NFV environments. This allows LSO to communicate with legacy networks without having to support the plethora of various vendor proprietary EMS APIs and protocols that would weigh on LSO implementations. In this case, the SDN controller acts as an abstraction layer communicating northbound to the LSO framework with a common set of APIs and southbound to the various flavors of communication protocols and APIs required by each vendor's network elements.

Furthermore, a very common model is to aggregate data to a more centralized area, such as data centers, where traffic can be further processed for higher layer functions such as routing, security, etc. LSO allows a tenant IT administrator to request services, with the fulfillment being organized and orchestrated end-to-end even when traffic has to be transported across today's traditional transport and packet networks into a more centralized location for higher layer processing. This is illustrated in Figure 7, below.

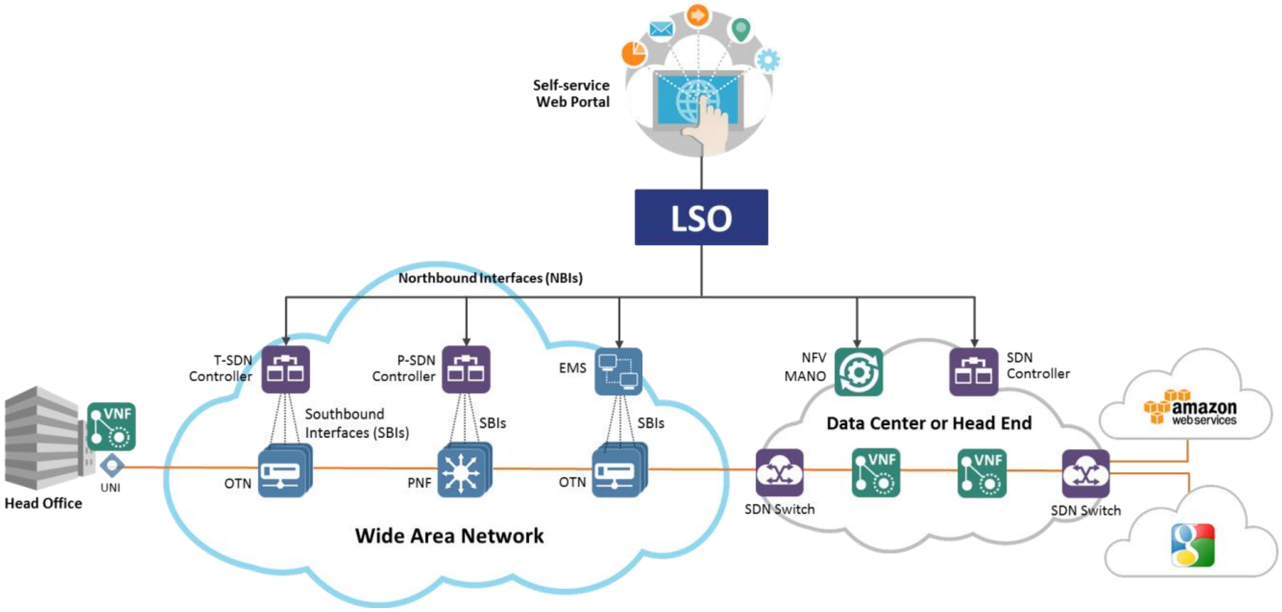


Figure 7. Third Network & Brownfield Deployments

In the more centralized data centers within the Operator's network, new SDN leaf-spine underlay fabrics are being built within an open environment in which any of the moving parts can be interchanged with a best-of-breed, vendor-independent approach. This new model allows an open environment where loosely coupled integration can occur using a set of open industry standard APIs. Disaggregation allows a provider to use a single platform to deliver a physical substrate for supporting any number of services. The value of this approach is that it allows for features such as an open software-based hyper-scale cloud platform with multi-service capabilities supporting any kind of deployment models (e.g. IaaS, NaaS, PaaS, SaaS, etc.). Automated load optimization within the highly scalable leaf-spine fabric always maintains a state of homeostasis while new SDN-based analytic applications enable new automated approaches for supporting of root-cause analysis, QoS, traffic engineering, etc. Together, all of this leads to lower operational expenses by eliminating human intervention from the daily operation of networks thereby allowing these networks to evolve into a self-healing, self-organizing autonomic systems. An additional benefit is that the physical network functions (PNFs) currently tightly coupled with monolithic OSS/BSS systems can be disaggregated into an open ecosystem system of functions, as elements in smaller manageable pieces that can be composed of the latest, lower cost, best-of-breed components.

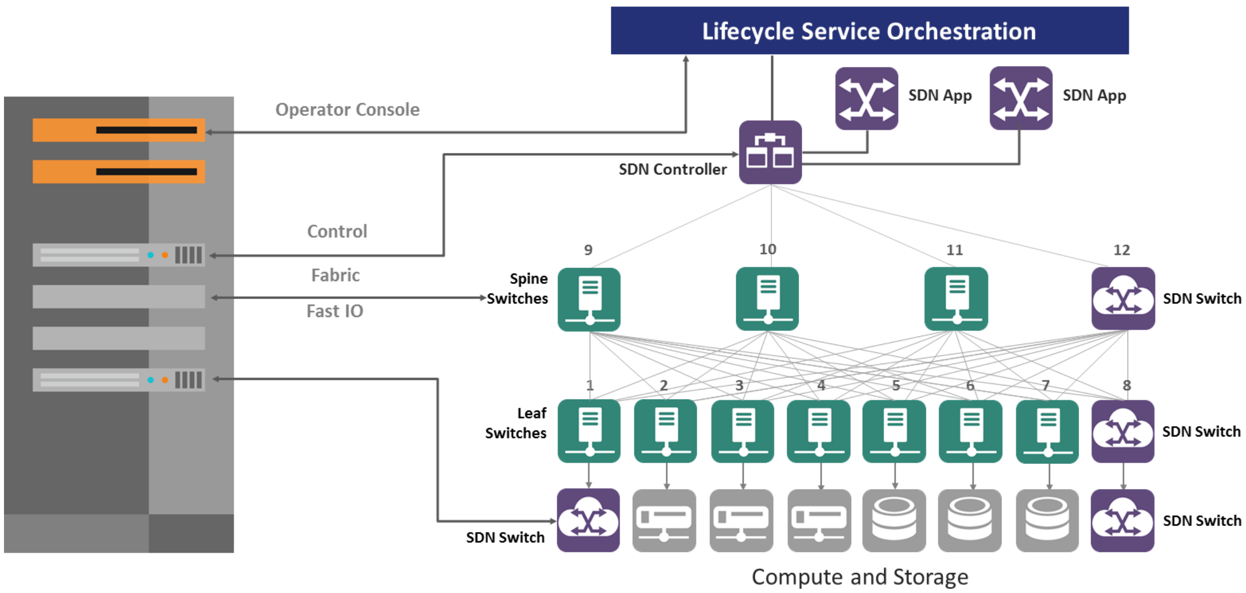


Figure 8. Disaggregation of Switching Fabric

With the physical underlay creating a stable foundation within the data center, the higher layers can be disaggregated into an overlay in which any number of VNFs can be accessed. The SDN controller negotiates the underlay with the NFV overlay to allow the Operator to convert its data centers into cloud-like fabrics where new network functions can be realized almost instantaneously. This, in turn, means availability of on-demand "bump-in-the-wire" network services provisioned by customers using the LSO framework.

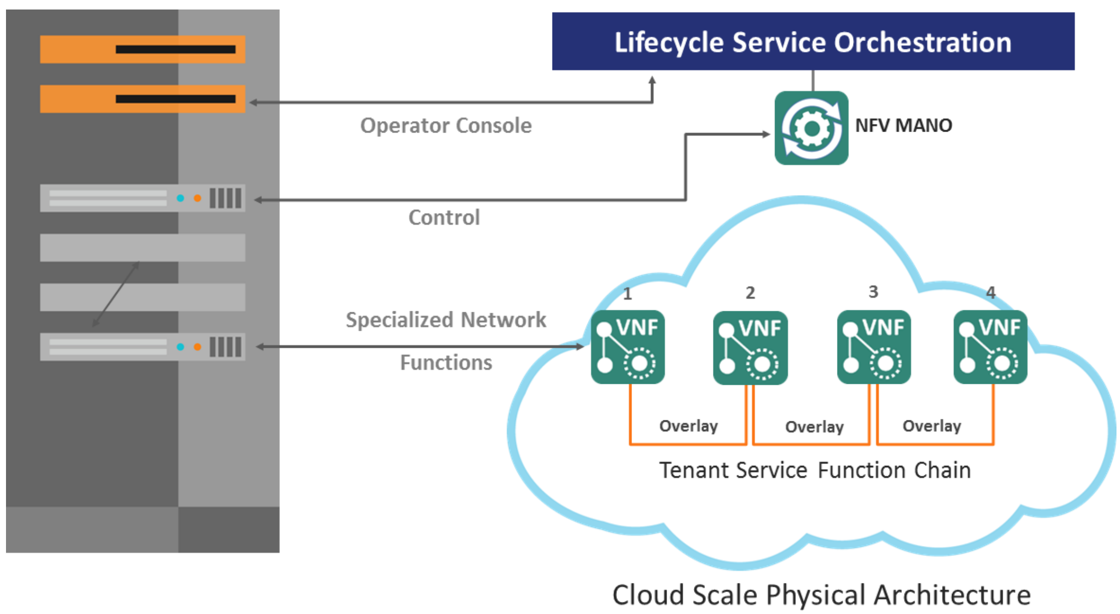


Figure 9. Disaggregation of Layer 3-7 Fabric

In concert, LSO, SDN, and NFV deliver resource abstraction, facilitating agile service operationalization as well as network agility, all of which contribute to the enablement of an on-demand network with intelligence that in turn delivers NaaS. The Third Network vision of agile, assured and orchestrated connectivity services requires that the service lifecycle will be automated, from product definition through to service orchestration, assurance, and billing. LSO orchestrates connectivity services in the Third Network across all internal and external network domains from one or more network operators, including all communications service providers, data center operators, enterprises, wireless network operators, virtual network operators, and administrative domains supplying or consuming components of the service. LSO spans all network domains to provide coordinated end-to-end management and control of connectivity services. LSO capabilities allow the Third Network not only to dramatically decrease the time to establish and modify the characteristics of connectivity services, but also assure the overall service quality and security guarantees for these services.

The industry is actively defining the necessary management architecture and framework for LSO, including fulfillment, control, performance, assurance, usage, security, analytics, and policy-based capabilities, as well as describing the essential reference points for management interoperability. This engineering approach, when adopted by the industry, will result in a consistent implementation that will accelerate the deployment and use of LSO-orchestrated connectivity services in the Third Network.

The interaction of LSO and the emergence of SDN/NFV in the Operator's network is depicted in Figure 10 below as a set of loosely coupled industry-defined open northbound interfaces (NBIs) where the SDN controller and NFV MANO abstract away the details of the underlying network infrastructure fabric. This allows the LSO to be more agile through decomposition into a set of micro-services organized by use-cases and operational threads such as service fulfillment, assurance, and problem management.

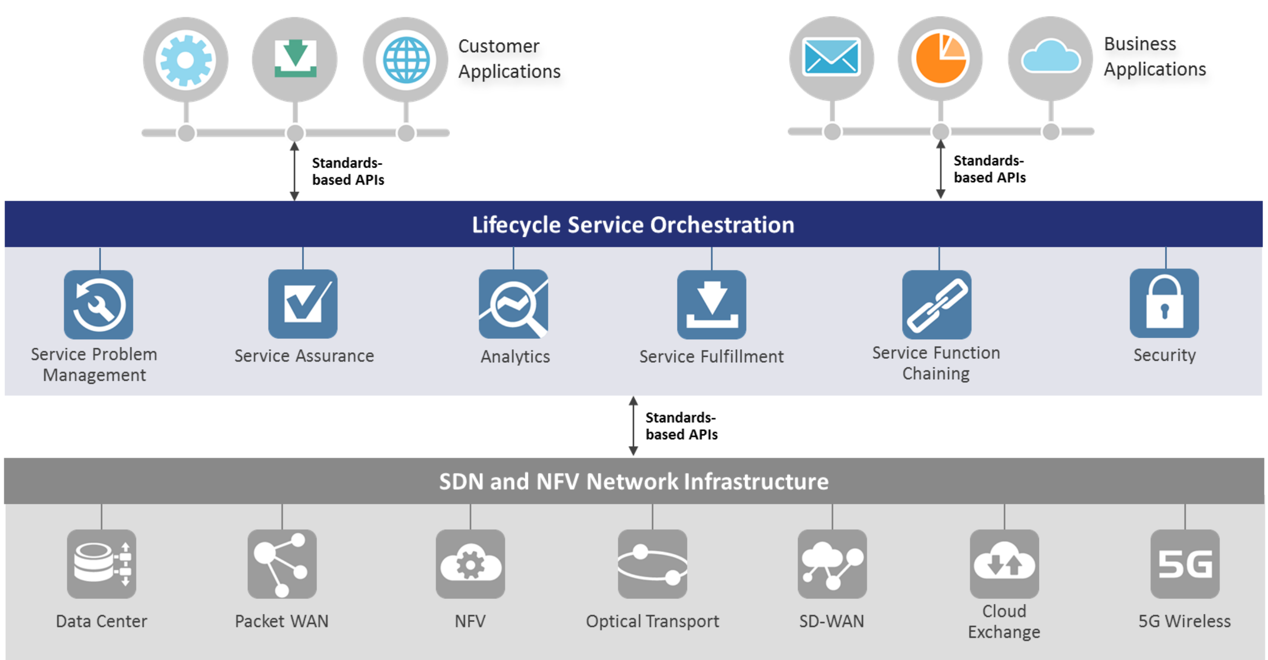


Figure 10. LSO Services and SDN/NFV Network Infrastructure

Figure 11 provides a view of the network connectivity between Third Network and cloud service providers. As service providers do not always have the capability to deliver services end-to-end or need to connect with cloud providers to deliver services, LSO provides the orchestration capability to deliver services in an agile, assured and orchestrated fashion. Third Network service providers can leverage both traditional and SDN/NFV technologies to automate end-to-end service delivery and provide cloud-connected and on-demand services over interconnected networks.

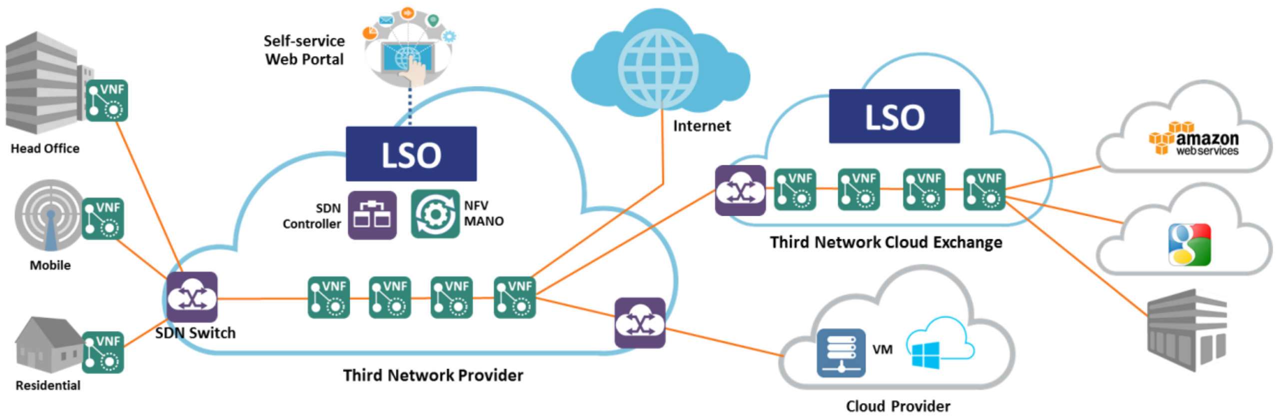


Figure 11. Third Network Provider Interaction with Provider Partners

5. Industry Collaboration

The industry supporters of this white paper MEF, CORD, Open-O, ODL, OPNFV, ONF, ON.Lab and TM Forum are working together to address a number of issues to ensure that services and related functions work reliably across multi-operator networks. Reliability has been a key factor in the success of the static business networks of today (e.g. MPLS and CE 2.0). Now, in order to realize the potential of a third-generation network that is agile and automated, the industry's strategy is to embrace and address the emergence of LSO, SDN, and NFV as the foundational layers for third generation networks. Areas that are being addressed by the industry in this context are:

5.1 Generalized Information Models

The industry is currently defining generalized Service Information Models to support network-as-a-service. These generalized models will encompass:

- Protocol independent and protocol specific data schema
- Physical or virtual service endpoints and support for Service Operations, Administration and Maintenance (SOAM) between them
- Dynamic service attributes for service endpoints and their virtual interconnections
- Abstraction of underlying transport network technologies
- Flexibility to allow vendor-specific and operator-specific extensions

5.2 Standardized Network-as-a-Service Definitions

The industry is currently defining network-as-a-service with the objective of eliminating variations in service definitions that add complexity versus value. For example, a multipoint connectivity NaaS should provide a common set of generalized service attributes independent of its implementation technology, e.g., Ethernet Provider Backbone Bridging, MPLS VPLS or IP.

5.3 Define Lifecycle Service Orchestration Functionality

The industry is currently defining complete Lifecycle Service Orchestration including service definition, contract, coverage, quotes, ordering, provisioning, assurance, reporting, modifications, and disconnect. This work has already commenced within the MEF and is being developed based on real-world operator processes and incorporating cloud-centric service lifecycle models where available. Lifecycle Service Orchestration is enabled by:

- Enhanced information models providing service, resource, and technology abstractions
- Enhanced service definitions to deliver network-as-a-service enabling additional user control and service differentiation
- APIs for applications such as OSSs, BSSs and self-service web portals to control network resources to dynamically order, modify, or delete a service

5.4 Standardized APIs

The goal of the industry is to function in a heterogeneous environment of networking technologies, architectures, and implementations. This approach will facilitate support for current WAN implementations based on PNFs as well as the evolution to VNFs managed by NFV resource orchestrators, software defined networks managed by SDN controllers and data center networks (physical or virtual) managed by cloud orchestrators. Further clarification of these API relationships is shown in Figure 12.

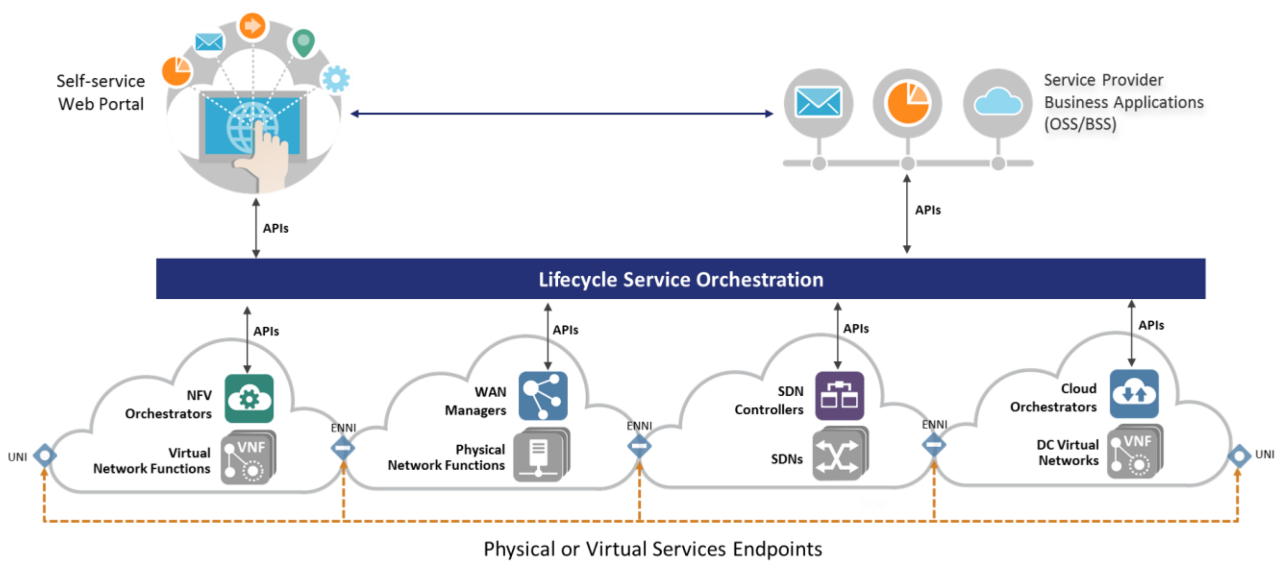


Figure 12. APIs to deliver services over existing WANs, DC networks, and SDN & NFV implementations

Open APIs based on the generalized information models will initiate state changes throughout the service lifecycle. The APIs will enable Lifecycle Service Orchestration within network operators' internal network technology domains and between network operator domains to automate the service lifecycle of the end-to-end network-as-a-service.

5.5 Orchestrated Services and Professionals Certification Programs

The industry will expand its certification programs to ensure conformance to open APIs and service definitions and ensure industry professionals have the level of expertise required to design and deploy network-as-a-service.

5.6 Industry Reference Implementation

Currently, all industry participants of this white paper are in the midst of collaborating to realize the vision of a Third Network service. This is being achieved by delivering a referenceable Network-as-a-Service (NaaS) implementations, including a demonstration of working code, that are agile in nature, and which will deliver assured connectivity services that are orchestrated across multiple network operator domains between physical and virtual service endpoints.

Collaboration

Today a large proportion of Application Programing Interfaces (APIs) are designed using a model-driven approach in which information models, operations, attributes, etc. are described using a protocol neutral language. The application development community has long utilized UML as the language for the model driven and UML has now been embraced by the networking industry as well. Using UML, tooling like Eclipse Papyrus from the open-source projects like Eclipse Papyrus can allow a modeler to express use cases in UML and automatically generate APIs of various protocol and encoding types with documentation. The automation of code generation means that even those without software development expertise can describe use cases and operational threads, model them in UML and then render them to API code in seconds. Once a use case is described in a model driven approach, iterations, modifications, and other aspects of APIs can be regenerated with a click of a button without any manual generation of code by developers. The TM Forum, ONF and MEF have begun a process of describing various NaaS use cases and creating common information models using XML to get to open, standards-based APIs.

Using a set of open, standards-based APIs enables orchestration of a set of technology domains in both the north-south and inter-provider east-west directions. Open North-South APIs allow orchestration of technology domains regardless of the particular vendor-specific or open source implementation of the technology domain. Open East-West APIs between providers enables automation of inter-provider workflows around ordering, serviceability, and other aspects of the service lifecycle. The MEF, ONF and TM Forum are moving rapidly to define open APIs in both the north-south and east-west directions. Instead of taking years to define open APIs, the TM Forum and ONF have already realized a rich set of APIs from which the MEF will utilize APIs to deliver orchestrated Third Network services.

While LSO is critical, having technology domains that support being orchestrated are just as important. The industry is also collaborating on this topic to demonstrate open orchestrated APIs in which the MEF's Open Initiatives describe reference implementations for a range of technology domains utilizing code from open source projects such as ON.Lab's Central Office Re-architected as a Datacenter (CORD), ODL, OPEN-O and OPNFV:

- ON.Lab's CORD (Central Office Re-architected as a Datacenter) combines NFV, SDN, and the elasticity of commodity clouds to bring data center economics and cloud agility to the Telco Central Office. CORD lets the operator manage its Central Offices using declarative modeling languages for agile, real-time configuration of new customer services. MEF is collaborating with ON.Lab on an Enterprise CORD version for the Carrier Ethernet market and for future Third Network services.

- ODL Open Source SDN Platform is an industry SDN controller for building programmable networks that are flexible and responsive to organizations' and users' needs. MEF is collaborating with ODL to deliver a set of open APIs at the North Bound Interface (NBI) to which MEF refers as the LSO Presto Reference Point in the MEF's LSO Reference Architecture and Framework (MEF 55).

- OPEN-O is seeking to offer network operators an incremental path to transform their networks, and OSS/BSS, through the adoption of SDN and NFV without scrapping the vast investments in existing equipment and technologies. MEF is collaborating with OPEN-O to realize a Lifecycle Service Orchestration solution in MEF's OpenLSO program.

- OPNFV is an open source project focused on accelerating NFV's evolution through an integrated, open platform. OPEN-O and OPNFV are collaborating to deliver a NFV solution offering which also includes a full Lifecycle Service Orchestration function for the deployment, provisioning and operation of an end to end NFV environment. Additionally, OPNFV is collaborating with ODL to provide solutions for delivering network virtualization.

- MEF is the driving force enabling agile, assured and orchestrated Third Network services for the digital economy and the hyper-connected world, with user-directed control over network resources and cloud connectivity. MEF is working with many open source projects and Standards Defining Organizations (SDOs) to deliver open APIs for LSO both within and between service providers. MEF has an Open Initiatives program that integrates many open and closed source solutions to create a set of open orchestrated Third Network service implementations starting with Carrier Ethernet and progressing towards IP Virtual Private Networks and L4 to L7 point solutions.

6. Summary

A significant transformation is taking place in data communications networks that will accelerate network operators' abilities to deliver self-service, on-demand services over interconnected, multi-operator networks. The next generation network industry vision embodies this transformation by combining the on-demand agility and ubiquity of the Internet with the performance and security assurances of today's business networks (Carrier Ethernet 2.0 and MPLS). To achieve this vision, the industry will create Lifecycle Service Orchestration with open APIs that hide and abstract the complexity of underlying technologies and network layers from the applications and users of the services.

In summary, the goal of the industry next generation network, based on network-as-a-service principles, is to enable *agile* networks that deliver *assured* connectivity services *orchestrated* across network domains between physical or virtual service endpoints.

7. About the MEF

The MEF is the driving force enabling agile, assured and orchestrated Third Network services for the digital economy and the hyper-connected world, with user-directed control over network resources and cloud connectivity. Optimized for real-time, QoS-enabled, secured traffic and integration of value-added network functions-as-a-service, Third Network services are delivered over automated, virtualized, and interconnected networks globally powered by LSO, SDN, and NFV.

The MEF leverages its global 200+ network operators and technology vendor community, builds upon the robust $80 billion Carrier Ethernet market, and provides a practical evolution to the Third Network with LSO, SDN, and NFV implementations that build upon a CE 2.0 foundation.

The MEF has established a technical and implementation framework that includes architecture, information models, service definitions, operational processes, open source community, and certification programs. MEF work is conducted internally and – under the guidance of the MEF UNITE program – in collaboration with global standards organizations and open source projects.

MEF16 (www.MEF16.com) is the MEF's global networking event that brings together the ecosystem of players enabling the transition to Third Network services and showcase demonstrations of leading-edge service and technology innovations for the hyper-connected world.

8. About Open Networking Foundation (ONF)

Launched in 2011 by Deutsche Telekom, Facebook, Google, Microsoft, Verizon, and Yahoo!, the Open Networking Foundation (ONF) is a growing nonprofit organization with more than 130 members whose mission is to accelerate the adoption of open SDN. ONF promotes open SDN and OpenFlow technologies and standards while fostering a vibrant market of products, services, applications, customers, and users. For further details, visit the ONF website at: http://www.opennetworking.org.

9. About OpenDaylight (ODL)

The OpenDaylight Project is a collaborative open source project that aims to accelerate adoption of Software-Defined Networking (SDN) and Network Functions Virtualization (NFV) for a more transparent approach that fosters new innovation and reduces risk. Founded by industry leaders and open to all, the OpenDaylight community is developing a common, open SDN framework consisting of code and blueprints. Get involved: www.opendaylight.org.

OpenDaylight is a Collaborative Project at The Linux Foundation. Linux Foundation Collaborative Projects are independently funded software projects that harness the power of collaborative development to fuel innovation across industries and ecosystems. www.linuxfoundation.org

10. About ON.Lab

Open Networking Lab (ON.Lab) is a non-profit organization founded by SDN inventors and leaders from Stanford University and UC Berkeley to foster open source communities for developing tools and platforms to realize the full potential of SDN, NFV and cloud technologies. ON.Lab leads open source projects ONOS, CORD, and Mininet and provides architecture shepherding and core engineering to these projects. For further information on ON.Lab, visit http://onlab.us/.

11. About ONOS Project

ONOS is the open source SDN networking operating system for Service Provider networks architected for high performance, scale and availability. The ONOS ecosystem comprises ON.Lab, organizations that are funding and contributing to the ONOS initiative, and individual contributors. These organizations include AT&T, China Unicom, Comcast, Google, NTT Communications Corp., SK Telecom Co. Ltd., Verizon, Ciena Corporation, Cisco Systems, Inc., Ericsson, Fujitsu Ltd., Huawei Technologies Co. Ltd., Intel Corporation, NEC Corporation, Nokia, Radisys, and Samsung. See the full list of members, including ONOS' collaborators, and learn how you can get involved with ONOS at onosproject.org.

ONOS is an independently funded software project hosted by The Linux Foundation, the nonprofit advancing professional open source management for mass collaboration to fuel innovation across industries and ecosystems.

12. About CORD Project

CORD™ (Central Office Re-architected as a Datacenter) brings datacenter economics and cloud flexibility to the telco Central Office and to the entire access network. CORD is an open source service delivery platform that combines SDN, NFV, and elastic cloud services to network operators and service providers. It integrates ONOS, OpenStack, Docker, and XOS—all running on merchant silicon, white-box switches, commodity servers, and disaggregated access devices. The CORD reference implementation serves as a platform for multiple domains of use, with open source communities building innovative services for residential, mobile, and enterprise network customers. The CORD ecosystem comprises ON.Lab and organizations that are funding and contributing to the CORD initiative. These organizations include AT&T, China Unicom, Comcast, Google, NTT Communications Corp., SK Telecom Co. Ltd., Verizon, Ciena Corporation, Cisco Systems, Inc., Fujitsu Ltd., Intel Corporation, NEC Corporation, Nokia, Radisys and Samsung Electronics, Co. See the full list of members, including CORD's collaborators, and learn how you can get involved with CORD at opencord.org.

CORD is an independently funded software project hosted by The Linux Foundation, the nonprofit advancing professional open source management for mass collaboration to fuel innovation across industries and ecosystems.

13. About OPNFV

Open Platform for NFV is a carrier-grade, integrated, open source flexible platform intended to accelerate the introduction of new products and services using NFV. It brings together service providers, vendors and users to collaborate in an open forum on advancing the state-of-the-art in NFV. For more information, please visit: http://www.opnfv.org.

OPNFV is a Collaborative Project at The Linux Foundation. Linux Foundation Collaborative Projects are independently funded software projects that harness the power of collaborative development to fuel innovation across industries and ecosystems. www.linuxfoundation.org

14. About OPEN-O

This collaborative effort will bring the industry together to develop the first open source software framework and orchestrator to enable agile software-defined networking (SDN) and network function virtualization (NFV) operations.

Early support for OPEN-O comes from Brocade, China Mobile, China Telecom, DynaTrace, Ericsson, F5 Networks, GigaSpaces, Huawei, Infoblox, Intel, KT, Red Hat, Raisecom, Riverbed and ZTE. OPEN-O is inviting others interested in this technology to participate.

Next-generation networking technologies such as SDN, NFV and cloud computing are enabling autonomous, real-time telecom operations. However, many conventional operational support systems (OSS) are based on proprietary software, which leads to fragmented technologies and interoperability issues for carriers. As an open source orchestration framework, OPEN-O will integrate open networking technologies and enable carriers to quickly and cost-effectively implement SDN and NFV through open source code development. The project will also aim to accelerate multi-vendor integration, service innovation and improve agility across network operations.

15. About TM Forum

TM Forum is a non-profit global industry association which helps its members transform and succeed in the digital economy. The collective experience and interests of our member community comprised of tens-of-thousands of professionals within 900+ market-leading global enterprises, service providers and technology suppliers drives everything we do, from thought-provoking research and publications, to practical guidance, collaboration programs, tools and best practices, hands-on events, and training for business and IT leaders.

Through three key programs – Agile Business and IT, Open Digital Ecosystem, and Customer Centricity – we provide a unique platform for our members to connect and collaborate with individuals and groups from around the world to solve key challenges and rapidly innovate to deliver new services, improve business agility, partner for success, reduce cost and risk, and enhance customer value and loyalty. To learn more about the Forum and join our digital journey as a valued member and collaborator, please visit www.tmforum.org.

16. Glossary

Term	Description	Term	Description
Access Provider	A wide area network service provider that delivers connectivity between an ENNI and one or more UNIs	OTN	Optical Transport Network
API	Application Programming Interface	OTT	Over-the-Top
BSS	Business Support System	OTU	Optical Channel Transport Unit
BGP	Border Gateway Protocol	OVC	Operator Virtual Connection
CE 2.0	Carrier Ethernet 2.0 generation	PaaS	Platform-as-a-Service
CC	Cloud Consumer	Phablet	Smartphone with large screen
CLI	Command-line Interface	PNF	Physical Network Function
CoS	Class of Service	P-SDN	Packet-Software Defined Networking
CP	Cloud Provider	PSTN	Public Switched Telephone Network
DC	Data Center	QoS	Quality of Service
EMS	Element Management System	SaaS	Software-as-a-Service
ENNI	External Network-to-Network Interface	SDN	Software Defined Networking
EPL	Ethernet Private Line	SDO	Standards Development Organization
EVC	Ethernet Virtual Connection	SNMP	Simple Network Management Protocol
IaaS	Infrastructure-as-a-Service	Subscriber Service Endpoint	The demarcation point for the beginning or end of a NaaS
IDS	Intrusion Detection System	Service Provider	The seller of network services
INNI	Internal Network-to-Network Interface	SLA	Service Level Agreement
IPS	Intrusion Prevention System	SLS	Service Level Specification
iSCSI	Internet Small Computer Systems Interface	SONET	Synchronous Optical Networking
LAN	Local Area Network	STM	Synchronous Transport Module
LSO	Lifecycle Service Orchestration	Subscriber	The buyer of network services
MANO	Management and Orchestration	TDM	Time Division Multiplexing
MPLS	Multiprotocol Label Switching	TL1	Transaction Language 1
NaaS	Network-as-a-Service	T-SDN	Transport-Software Defined Networking
NAT	Network Address Translation	UNI	User-to-Network Interface
NBI	North Bound Interface	VNF	Virtual Network Function
NFaaS	Network Function-as-a-Service	VM	Virtual Machine
NFV	Network Functions Virtualization	VoIP	Voice over IP
OAM	Operations, Administration and Maintenance	VPN	Virtual Private Network
OC	Optical Carrier	VPLS	Virtual Private LAN Service
Operator Service Endpoint	The demarcation point between network operators	WAN	Wide Area Network
OSS	Operational Support System		