THE PROGRAMMABLE CLOUD NETWORK

A PRIMER ON SDN AND NFV

STRATEGIC WHITE PAPER

The evolution to Network Functions Virtualization (NFV) and Software Defined Networking (SDN) is starting and will continue over time due to the financial and operational benefits that result. Alcatel-Lucent is at the forefront of the transformation to SDN and NFV, contributing to industry groups and developing solutions that have the potential to create a revolution in programmable cloud networking. This paper explores the key concepts behind SDN and NFV, the state of the industry today, and the unique approach Alcatel-Lucent is taking in each area to enable the programmable cloud network.

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INTRODUCTION

Network Functions Virtualization (NFV) and Software Defined Networking (SDN) are considered by many to be the two forces that will shape the future of telecommunications networks:

- NFV involves porting network or telecommunications applications that today typically run on dedicated and specialized hardware platforms to a virtualized cloud infrastructure.
- SDN involves increasing the network's ability to dynamically adapt to the needs of applications and services; that is, to make the network more programmable.

The two concepts are closely linked because the programmability of SDN will greatly enhance the performance and flexibility of NFV applications by allowing dynamic placement of resources and performing the choreographed networking to connect them.

The evolution to NFV and SDN is starting and will continue over time based on the relative economic benefits that result and the ability to transform today's provisioned networks, operations support systems (OSS) and business support systems (BSS) into dynamically adaptive networks and systems.

Alcatel-Lucent is playing a leading role in the evolution to SDN and NFV. We are active contributors in leading industry fora, including the Open Networking Foundation (ONF), OpenStack and the Internet Engineering Task Force (IETF) for SDN. We are also at the forefront of NFV, having been appointed as a board member of the European Telecommunications Standards Institute (ETSI) NFV Industry Specification Group (ISG) in recognition of our pioneering virtual telco (vTelco) vision.

In addition, we are actively developing differentiated solutions such as the CloudBand™ solution portfolio, which includes the CloudBand Management System and CloudBand Node, a novel data center SDN solution developed by our venture, Nuage Networks, and a companion WAN SDN solution. Combined, these assets have the potential to create a revolution around programmable cloud networking.

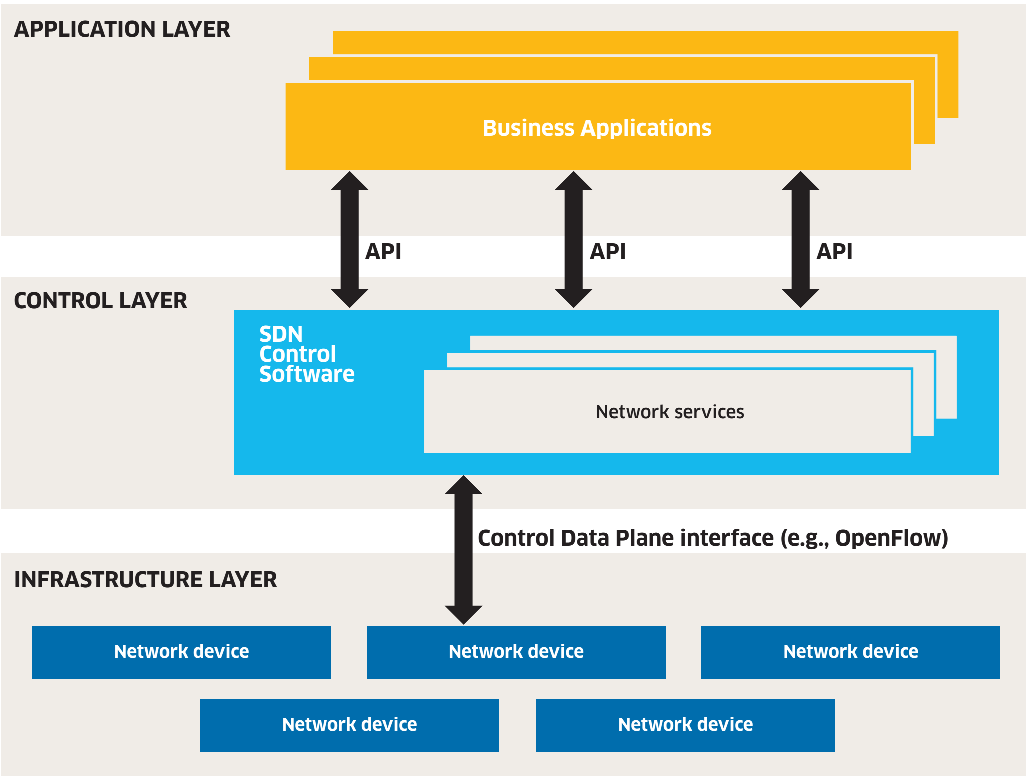
Before we explore the Alcatel-Lucent approach to the programmable cloud network, it is worthwhile to take a closer look at SDN, NFV and the current state of these technologies in the industry today.

SDN: WHAT IS IT?

SDN is a network vision with many different definitions. The ONF pioneered the early work, but has a relatively narrow definition of SDN with the following essential characteristics:

- **Separation of control and data planes** so that hardware forwarding plane elements can be controlled by a control plane residing on a separate general-purpose compute-based element.
- **A logically centralized control plane** to allow simple switching elements to share a common control element that is more intelligent and more complex than individual isolated control elements.
- **Network virtualization and slicing** to allow the network to elastically scale and adapt, and be shared by multiple entities, each of which has a unique network view.
- **Network application programming interfaces (APIs)** to allow programming of network resources by applications and services.

Figure 1. The ONF has defined a basic SDN architecture



The ONF defined a new protocol called OpenFlow to enable the separation and interworking of the control and data planes. However, few players in the industry are adhering to the ONF's narrow definition of SDN. There is also general agreement that SDN should be less about separation of the control and data planes and more about the programmability of networks. It is accepted that some form of centralization of control is appropriate, but opinions diverge widely about the scope of SDN and the protocols to be used.

Therefore, in addition to ONF, related standards are being developed in the IETF, which is working on data center networking and network virtualization, and in the OpenStack community, which is developing a set of APIs that are becoming the de-facto standard for cloud resource management for compute, storage and data center networking management.

In the telecom network applications and network functions virtualization space, the development of a common industry view is led by the newly formed NFV Industry Specification Group in ETSI.

THE STATE OF THE INDUSTRY

There are disparate views in the industry as to the scope of SDN. There is also a lot of hype and misinformation in the industry and the media concerning whether SDN and NFV represent an evolution or a revolution.

Alcatel-Lucent and other large equipment vendors see SDN as an evolution of the current architecture and believe that the value proposition of SDN can often be achieved through enhancements to existing protocols and solutions to achieve revolutionary results. New entrants, including venture capital-backed startups, tend to advocate a revolution in the current architecture driven by SDN, and are more focused on completely new solutions and protocols. Operators are still trying to decide how best to benefit from SDN.

Recent events have brought significantly increased industry attention and credibility to SDN. For example:

- Google's announcement of the implementation of its data center network based on SDN principles in general and OpenFlow in particular, followed by similar announcements by NTT, NEC and Dell.
- VMware's acquisition of SDN pioneer Nicira for 1.3 billion United States dollars, Brocade's acquisition of Vyatta, Juniper's acquisition of Contrail for 173 million United States dollars, F5's acquisition of LineRate, and Cisco's multiple acquisitions and investments in this space, including Cloupia for 125 million United States dollars, Cariden for 141 million United States dollars, and Insieme, a spin-out with a 750 million dollar buy-back option.
- Large service providers such as Verizon, Deutsche Telecom and AT&T being vocal, if not specific, about their SDN intentions.
- Ericsson and Huawei providing details about their SDN implementations and roadmaps as a focal point of their Mobile World Congress announcements.

In the following sections, we outline the approach that Alcatel-Lucent is taking in SDN, and the rationale behind it.

THE REALITY OF SDN

Cloud service providers typically run data centers comprised of hundreds of switches, thousands of virtual switches (vSwitches), firewalls and load balancers to interconnect the blade servers and racks. Each of these elements typically requires provisioning from a separate system, as well as separate overlay networks and systems to interconnect to the storage resources and the WAN. In this context, the separation of the control and data planes and use of the related OpenFlow protocol to centralize and unify control of this infrastructure is attractive and is a prime motivation for SDN in the data center.

However, there is an additional issue: the need to simultaneously support thousands of customers, each of which needs its own virtual private network (VPN) to connect virtual processing and storage components. Each VPN must be isolated from other tenants' resources, yet be able to dynamically scale and adapt to the customer's changing demands at different times of the day or month, for example.

This so-called multi-tenancy requirement cannot be adequately met with traditional techniques, such as manually provisioned Ethernet virtual LANs (VLANs), due to the limited scalability of such solutions. Conversely, Layer 3-based approaches that allocate private subnets to each tenant allow better scaling, but do not allow easy migration of processes due to the attendant change in IP address that would typically occur.

Consequently, new solutions are required. A more holistic approach to data center SDN can provide the right foundational elements, specifically:

- Management of cloud resources to support end-to-end applications needs, including compute, storage and network in a distributed and fully automated environment.

- Complete automation of networking connectivity, both in the data center and to the WAN by dynamically creating and reconfiguring virtual private Layer 2 and Layer 3 networks with web scale.
- APIs that enable cloud consumers to construct and manage their own virtual networks of resources through technology-agnostic network abstractions.

These foundational elements are the basis of the approach Alcatel-Lucent is taking for data center SDN, as described in the following section. In addition, the role of SDN outside data centers is being evaluated to allow more direct and dynamic policy-based control of the all-IP network infrastructure, including the optical, access and customer premises equipment (CPE) domains.

The increased virtualization of the telco network will result in a much more dynamic environment where applications and services can be instantiated, scaled and moved on the fly. Increased use of analytics will enable operators to surgically and dynamically optimize the network and allow enterprises, content providers and end users to request specific network services on demand. As a consequence of these trends, the IP and transport infrastructure must be able to adapt much more rapidly to changing connectivity needs than it does today. Meeting that requirement is the essence of SDN.

ALCATEL-LUCENT AND SDN

Given the many different definitions of SDN that exist, it is first important to specify what is meant by SDN in the context of the Alcatel-Lucent vision. Alcatel-Lucent has defined SDN as follows.

A **software defined network** (or function) is one that allows **automatic and dynamic programming of network services by applications**, allowing modification and consumption of network resources on demand. This is enabled by:

- **Abstraction of network functions** to provide simple, application-level programming of the network control planes.
- **Modification of the forwarding path** of the network (through the abstracted control plane) by changing forwarding entries to optimize a) the network path or allocated capacity, or b) specific flow or packet forwarding rules, including modifying the flow marking, queuing, priority, bandwidth allocation and policing.

Alcatel-Lucent believes that a primary value of SDN will come from automating the data center network and the associated WAN delivery network with the following attributes:

- Support of true multi-tenant data center networks with inter-tenant and inter-process security.
- Seamless and dynamic linking of the data center virtual LANs and IP subnets with VPNs in the WAN.
- Full, web scale virtual machine (VM) mobility within and across data centers.
- Enablement of third parties to request network resources and affect network behavior.
- The ability to continuously optimize cloud network deployments by monitoring network, compute and storage utilization and applying sophisticated multidimensional analytics and policies to provide the requisite service level agreements (SLAs).

To this end, we have launched a unique set of SDN products for data center networking, led by our venture, Nuage Networks[1]. In addition, we are investing in the CloudBand Cloud Management System, which provides an open, analytics-driven solution for compute and storage resource optimization. In short, CloudBand enables the creation of a fully distributed cloud, including seamless application on-boarding and lifecycle management, and the creation of cloud and network specification policies that allow the Nuage Networks solution to provide the required network automation. It also offers efficient, automated and easy-to-deploy cloud nodes that allow for plug-and-play creation of distributed cloud environments.

Outside the data center environment, we are currently investigating solutions for use cases that require rapid adaptation of the network. The idea is to support dynamic network slicing that will allow operators to resell network capacity to different services and service providers, including web services providers, enterprise services providers, strategic industries and consumers. This will be the subject of a forthcoming white paper.

We now consider further the topic of NFV, which builds on these solution elements to create a more efficient and scalable set of telecommunications applications and services.

NFV: WHAT IS IT?

Network Functions Virtualization aims to improve the scalability, adaptability and economics of network applications by using standard IT virtualization technology to consolidate the many different network equipment hardware platforms that are optimized for a single application onto industry-standard high-volume servers, switches and storage.

Using cloud orchestration platforms, these virtualized applications can then be instantiated in, or moved to, various locations in the network as required by dynamically changing demand, without incurring the time or cost required to install new dedicated equipment. In addition, NFV fosters innovation by allowing unproven services to be deployed quickly using a fast fail model, incurring very little financial risk, while providing opportunities for new sources of revenue.

As for SDN, it is useful to define what comprises a virtual network function as foreseen by Alcatel-Lucent.

A **virtual network function** is a software instance of a network function **that leverages standard IT virtualization technology** to run on a **general-purpose computing, storage and network infrastructure**, rather than on vertically integrated hardware and software platforms dedicated to particular functions. The goal is to:

- **Enable improved economics** through consolidation of functions and automated operations.
- **Support the flexibility and agility necessary to adapt to dynamically changing usage demands** and rapidly evolving deployment needs.
- **Optimize performance by distributing functions** to locations in the network that can deliver the required quality of service (QoS) in terms of latency, bandwidth and other requirements.

[1] See http://www.nuagenetworks.net/press-releases/nuage-networks-introduces-2nd-generation-sdn-solution-for-datacenter-networks-accelerating-the-move-to-business-cloud-services/

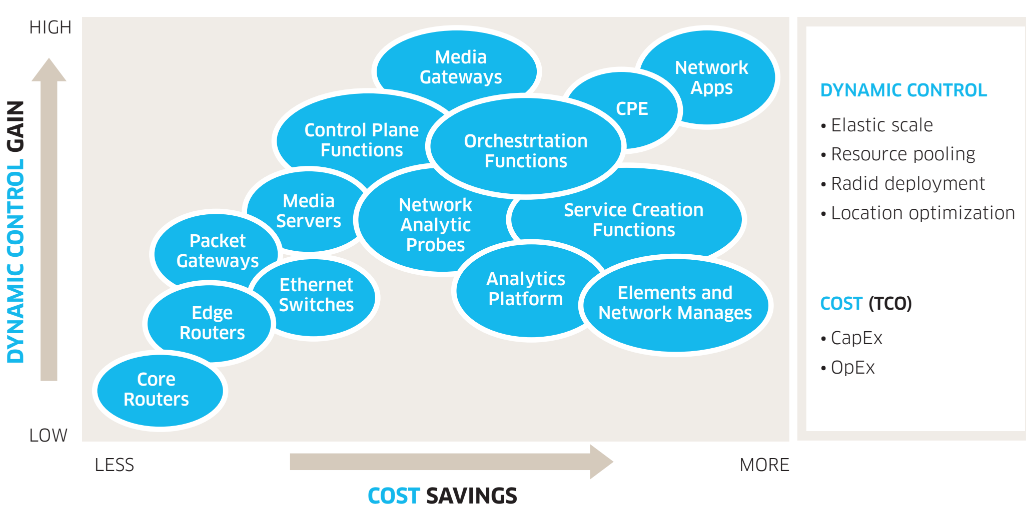
The NFV approach has the potential to provide significant benefits for network operators and their customers. Benefits include:

- Reduced capital and operating expenditures (CAPEX and OPEX) for operators through reduced equipment costs, space and power consumption.
- Reduced time-to-market to deploy new network services and critical security upgrades.
- The ability to flexibly scale up, scale down or evolve services.
- The ability to trial and deploy innovative new services with lower risk, and therefore with superior return on investment (ROI).
- The ability to customize network functions to meet the unique needs of specific customers.

NFV: SEPARATING THE REALITY FROM THE HYPE

The nature of the gain associated with NFV is two dimensional, as depicted by the two axes in Figure 2. On one hand, there are the performance gains associated with the increased automation, sharing and elasticity of cloud-based solutions, which we term dynamic control gain; on the other hand there are CAPEX and OPEX savings, which we term cost gain.

Figure 2. Virtualizing different network functions brings different benefits



Source: Alcatel-Lucent internal analysis

As shown in Figure 2, in a majority of cases, service providers will benefit from the virtualization of network functions, even some functions that perform real-time packet processing and whose current implementation uses dedicated hardware devices such as application-specific standard products (ASSPs) and application-specific integrated circuits (ASICs). Importantly, implementing the same functions on general-purpose processors (GPP) may increase CAPEX due to the higher number of server blades that would be required. However, the increase in CAPEX may be offset by OPEX savings and automation gains.

There are, however, notable exceptions. Our analysis shows it is unlikely that virtualization of high-performance routers or Ethernet switches will be cost effective because the data plane processing functionality of GPPs is typically only on the order of 1 to 2 Gb/s per core. This speed pales in comparison to the network processor unit (NPU) or ASIC-based packet processing throughput of 400 to 640 Gb/s available today.

In addition, any networking equipment that is defined by a unique physical layer technology — non-Ethernet physical layer technology (PHY) such as digital subscriber line (DSL), passive optical network (PON), radio frequency (RF) radio access network (RAN) and coherent optical — which typically benefit from digital signal processing (DSP) components are not strong candidates for virtualization as typical GPPs do not perform these functions as well as a DSP.

Several other network functions are in a grey zone. For example, virtualization of products, such as mobile gateways, that are primarily focused on packet forwarding could result in cost savings in certain deployment scenarios, for example when the amount of traffic is relatively small, but not realize any savings for higher throughput applications with large amounts of video traffic. In the latter case, virtualization could only be justified by dynamic control gain benefits such as the ability to roll-out new services faster, or to elastically scale them to meet changing demand patterns.

WHO IS INTERESTED IN NFV?

Seven of the world's leading telecoms network operators have created a new group to promote virtualization of network functions. AT&T, BT, Deutsche Telekom, Orange/France Telecom, Telecom Italia, Telefonica and Verizon have since been joined by 70 other network operators, telecom equipment vendors, IT vendors and technology providers to create the ETSI Industry Specification Group (ISG) for Network Functions Virtualization (NFV) and lead the telecommunications industry on this transformation journey.

Alcatel-Lucent and Cisco are the only vendors who are on the NFV management team helping to drive the vision, strategy and implementation, together with the founding operators. We were awarded our leadership position in the NFV ISG due to our pioneering work over the last two years on the concept of the virtual telco (vTelco) and the subsequent development of the enabling CloudBand platform. We have recently been asked to chair the Security Definition and Architecture Group of the ETSI ISG as well — a further reflection of our leadership in this domain.

WHAT IS NEXT FOR NFV?

Alcatel-Lucent's current focus in the service provider space is to build strong strategic relationships with the NFV operators and to help them realize this future. A combined compute, storage and network connectivity cloud management and orchestration platform is necessary in every NFV implementation.

As a result, our CloudBand solution has allowed us to develop strong relationships with many Tier 1 operators globally and we are working with them to deploy proofs of concept, live trials, and to create NFV labs as they begin their NFV journey. Each operator is in the process of identifying the first applications or functions to virtualize and we are actively helping quantify the benefits in each case to ensure the right choices are made to achieve their specific goals.

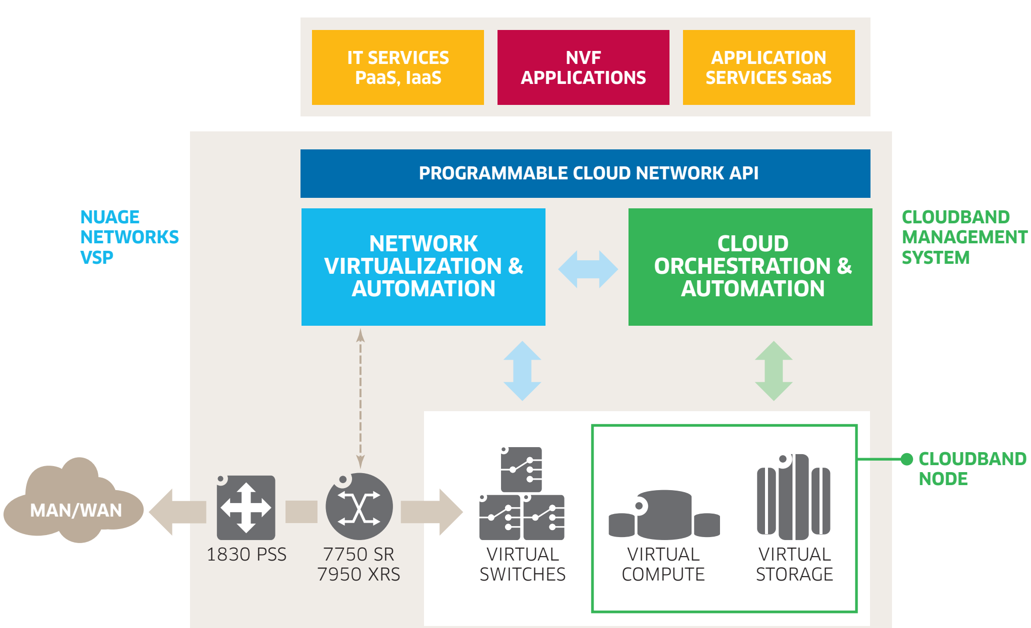
THE PROGRAMMABLE CLOUD NETWORK

The Alcatel-Lucent vision for the future of telecommunications networks is based on three pillars that combine to form the programmable cloud network, an evolution of the High Leverage Network (HLN) vision that reflects the new cloud network reality:

1. A collection of virtualized network elements implemented on general-purpose compute platforms and running over a highly efficient and reliable IP and transport infrastructure.
2. An end-to-end cloud management system providing:
   a. Automation, orchestration and optimization of compute and storage resources with pre-integrated cloud nodes.
   b. Service on-boarding using a Platform as a Service (PaaS) layer for NFV and other cloud applications.
   c. Carrier-grade reliability, security and analytics for full SLA support.
   d. Integration with our network connectivity solution (Nuage Networks) for optimal use of compute, storage and network resources.
3. A policy-driven SDN solution to enable dynamic programming of the underlying networking infrastructure for automated data center networking with seamless WAN interworking and across the telco network at large through seamless network choreography.

The essential architecture is shown in Figure 3. The key components of this vision are the CloudBand Cloud Management System and Nuage Networks' SDN-based networking solution. The resulting solution has the potential to create a revolution in cloud networking by providing an open, massively scalable, multi-tenant platform combining compute and storage orchestration with seamless network service choreography for a uniquely flexible and efficient cloud infrastructure. This solution is complemented by the virtualization roadmap for our portfolio (available upon request). Our IP multimedia subsystem (IMS) and Motive solutions are among the first of our products to be offered in a fully virtualized form.

Figure 3. Alcatel-Lucent combines SDN, cloud orchestration and NFV



CONCLUSION

SDN and NFV have the potential to profoundly transform our industry in the coming years, and Alcatel-Lucent is at the forefront of driving this change by bringing the data center out to the network and the network in to the data center.

The uniqueness of our approach can be summarized as follows: we view the cloud as a widely distributed multivendor infrastructure consisting of data centers of all sizes located throughout the network, with dynamically optimized VM placement and other resource allocation, based on the network status and the specific needs of the application and its users.

Efficient network management is critical to this distributed cloud environment. All of the other solutions on the market use an orchestration-based approach for compute, storage and networking. Consequently, they use a traditional configuration-based approach to the critical networking portion of service configuration.

In contrast, Alcatel-Lucent has decoupled the networking portion and has implemented a policy-based distributed service routing-type approach to data center networking. In our architecture, compute or storage resources are instantiated by the cloud management system, which results in automatic triggering of a request to a centralized policy server for networking services. These networking services are then automatically choreographed by associating the flow with new or existing Layer 2 and Layer 3+ forwarding labels and rules that allow the data center network to connect to the WAN routing and VPN infrastructure. This approach results in seamless connectivity from the VM all the way to the end user.

Alcatel-Lucent recognizes that to realize the benefits of NFV, an open, multivendor cloud platform that understands the specific needs of virtualized network functions is required. With this platform, service providers can automate distributed cloud management. They can also automate the full lifecycle of network functions, interfacing with an SDN component to address the networking needs of these functions.

With Alcatel-Lucent as their partner, network operators can deploy a comprehensive solution comprised of a leading cloud management solution for NFV and a novel automated approach to SDN.

ABBREVIATIONS

API	application programming interface
ASIC	application-specific integrated circuit
ASSP	Application-specific standard product
BSS	business support system
CAPEX	capital expenditure
CPE	customer premises equipment
DSP	digital signal processor
ETSI	European Telecommunications Standards Institute
GPP	General-purpose processors
HLN	High Leverage Network
IETF	Internet Engineering Task Force
IMS	IP multimedia subsystem
ISG	Industry Specification Group
NFV	Network Functions Virtualization
NPU	network processor unit
ONF	Open Networking Foundation
OPEX	operating expenditure
OSS	operations support system
PaaS	Platform as a Service
PHY	physical layer
PON	passive optical network
QoS	quality of service
RAN	radio access network
RF	radio frequency
ROI	return on investment
SDN	Software Defined Networking
SLA	service level agreement
VLAN	virtual LAN
VM	virtual machine
VPN	virtual private network
vSwitch	virtual switch
vTelco	virtual telco

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