Welcome to this overview about Software-Defined Networking, or SDN, and Network Virtualization.

This training course will not only provide the technical background to SDN, but will also show the value of SDN by looking at some specific use cases based on the Nuage Networks solution.

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SDN introduction.

The goals of this module are to introduce and demystify Software-Defined Networking (or SDN).

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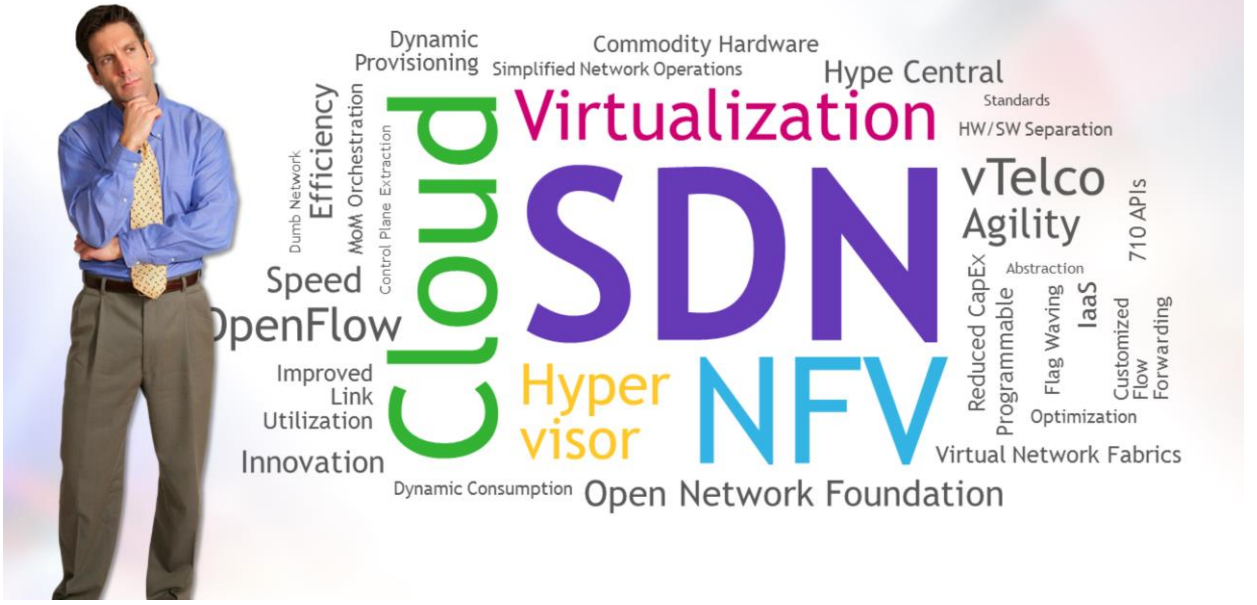
HYPE AND CONFUSION



Over the past couple of years, SDN has grown to be one of the hottest topics in the telecommunications industry. Ultimately, SDN is an industry vision that has become all things to all people and yet for many observers the term remains shrouded in hype and confusion. You will have heard many other terms and acronyms in the area of Cloud such as Virtualization, Hypervisor, or NFV – that may be equally vague, one main objective of this tutorial is to provide a framework for a discussion that will explain many of these terms and how they relate to one another in the SDN context.

Let's begin in this module with the demystification of SDN. In order to do so, we need to look at the basic problems that SDN, or implementations thereof, are trying to solve.

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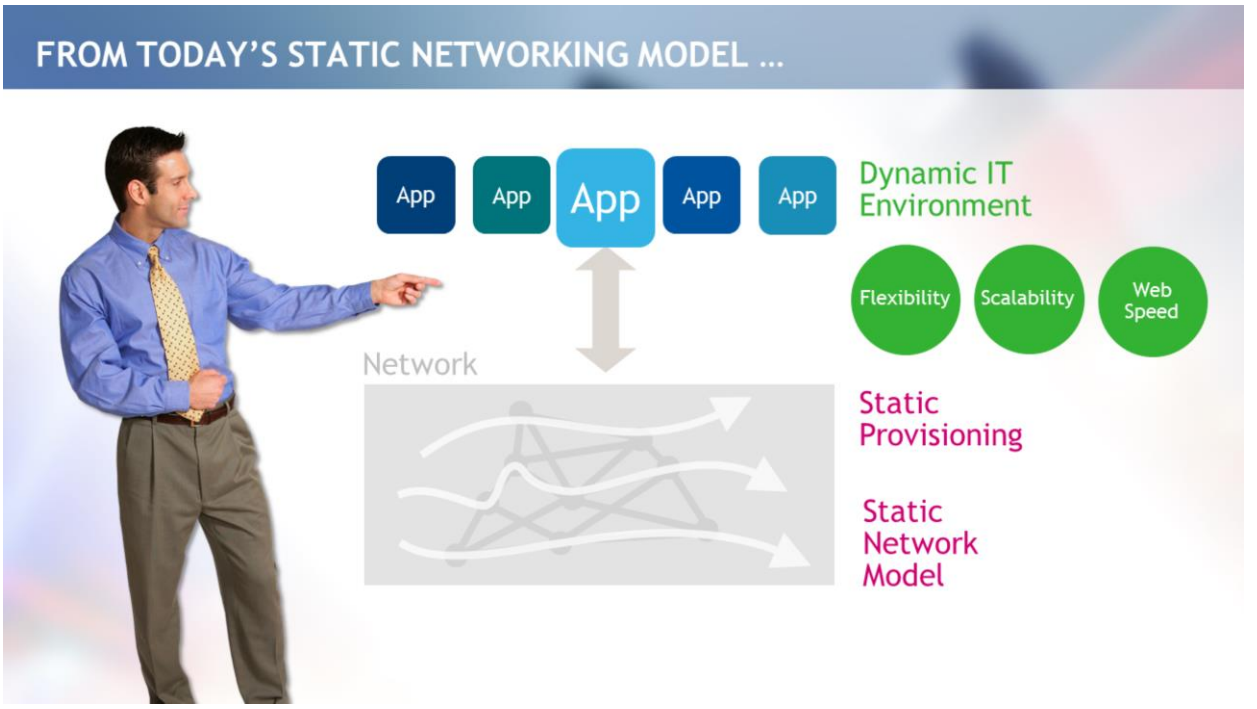

Let's take a step back to consider how web or cloud based applications are currently being deployed and contrast that with how data center networks are being operated today.

The advent of mobility and cloud services means that applications are now being implemented and deployed at web speed, with scalability, and flexibility. Imagine an online ticketing service that announces the availability of 50,000 much sought after concert tickets. The compute and storage capacity supporting the ticketing service should scale up to meet this new user demand. Once the offer is over, the capacity should elastically scale down again. Otherwise, additional costs would be incurred with a huge excess of capacity.

This is all possible as applications now run on Virtual Machines in data centers in dynamic IT compute environments.

However, today's network connectivity is not like that at all. It is not adapted to support the dynamic connections that these applications require. Today's networks are cumbersome to operate; they rely on static provisioning on a device-by-device basis, which means that it can take days or weeks for network services to be established. Which takes us to the crux of the matter: Why should cloud applications that come up in seconds have to wait days or weeks for the required network service to be established?

Clearly, there is a serious misalignment between a dynamic cloud applications environment and a static networking environment.

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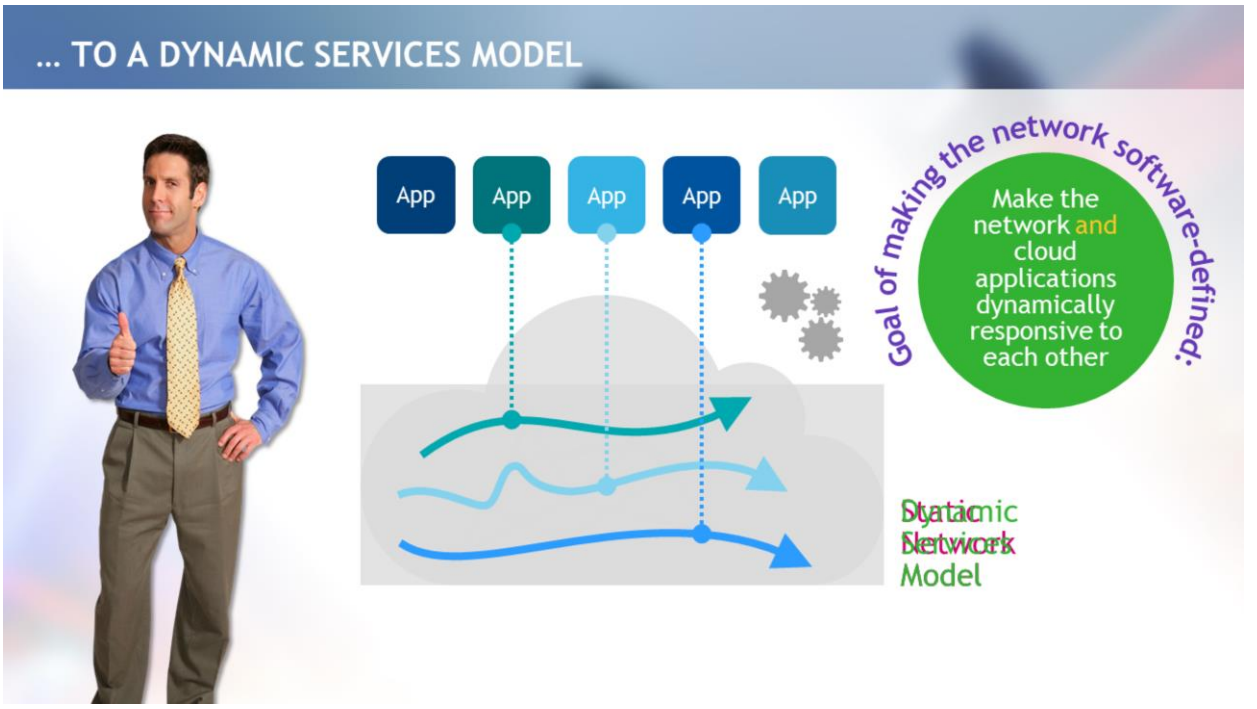

An awareness of this misalignment leads to the realization that the fundamental nature of today's networks needs to change.

Service Providers and enterprises are increasingly acknowledging this - they know they need to keep pace with the networking needs of cloud applications and they know they need to evolve their networks from today's static networking model to a dynamic Services Model.

This knowledge represents the heart of what SDN is all about.

While there are many different perspectives on the scope, emphasis and building blocks of SDN across the industry, the overarching goal of making the network "software-defined" is "To make the network and cloud applications dynamically responsive to each other".

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The pressure on the current networking model in data centers is now acute.

Explosive growth in the number of cloud applications has resulted in a massive increase in the volume and complexity of equipment inside today's data centers. This, in turn, is giving rise to a sharp increase in the number of network connections required.

But the physical view of the increase in racks is only the tip of the iceberg: due to the advent of server virtualization, a single network cable now represents multiple network connections. Later we will explore the huge impact server virtualization is having on networking.

As network connections are not automated, these two developments are putting enormous pressure on the network.

SDN, however, is set to revolutionize networking and will transform it to become an application-driven services model.

But before we explore the principles of SDN and its use cases, it is important to understand the key network challenges by looking at some basic details of how applications work in data centers and the significance of server virtualization.

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Impact of applications

To begin to appreciate why network complexity has grown in the data center, it is worth exploring the drivers behind the growth. In this module, we will examine how applications are designed and work, we will also look at the topology of a data center and finally we will show how applications are applying enormous pressure on data center networks.

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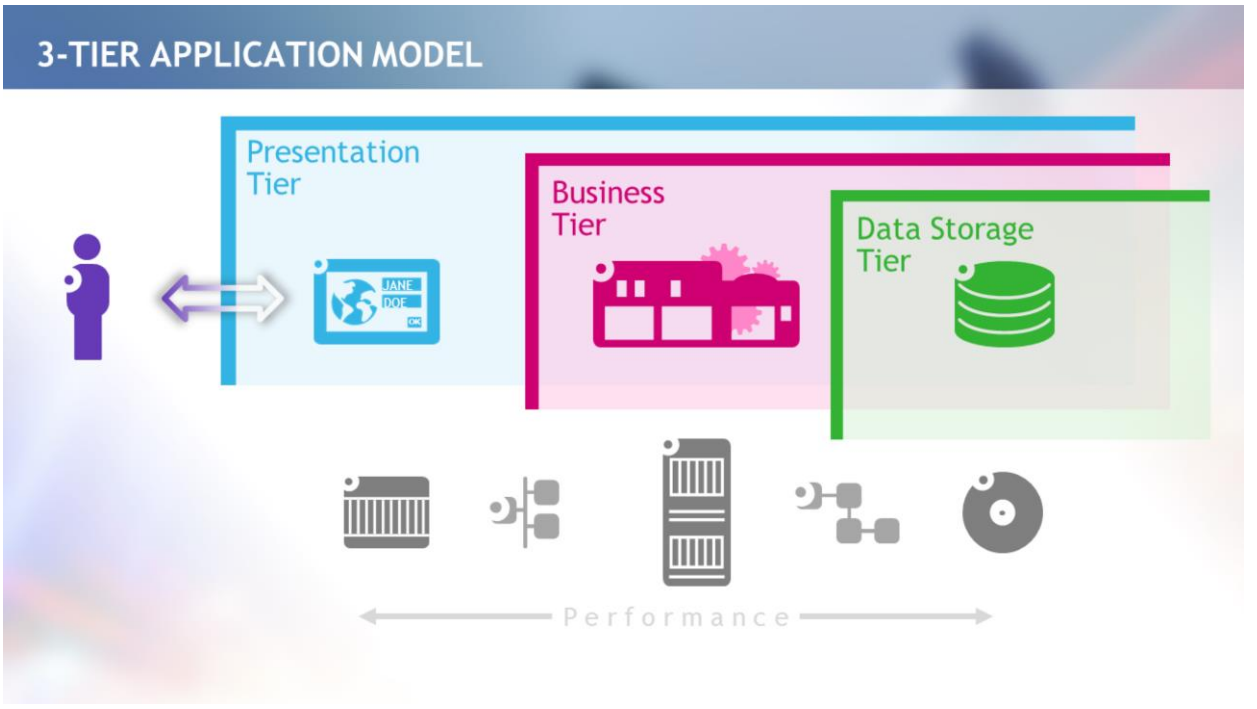

The most common approach for the design of all web and cloud based applications is a three-tier architecture.

At the top level, the presentation tier is the interface where users interact with the application. For example, if user input is required, data entry fields are made available at this layer.

Behind the presentation tier is the business tier. This is the application's engine and is responsible for manipulating data and making the application do whatever it is designed to do.

The final tier is the data storage tier, which is where data is stored and retrieved in support of the business tier.

For an application to run, compute space is required for the presentation and business logic tiers and data storage space is required for the data tier.

The real significance for our discussion is that each tier of the application is isolated from the other tiers by network connections.

One benefit of this type of model is the flexibility with which compute and storage can be added. Another advantage is the enhanced security provided to protect confidential data.

A major challenge, however, is that the perceived performance of the application depends on how quickly the isolated layers communicate with one another. This is why careful consideration must be given to how network connectivity is implemented.

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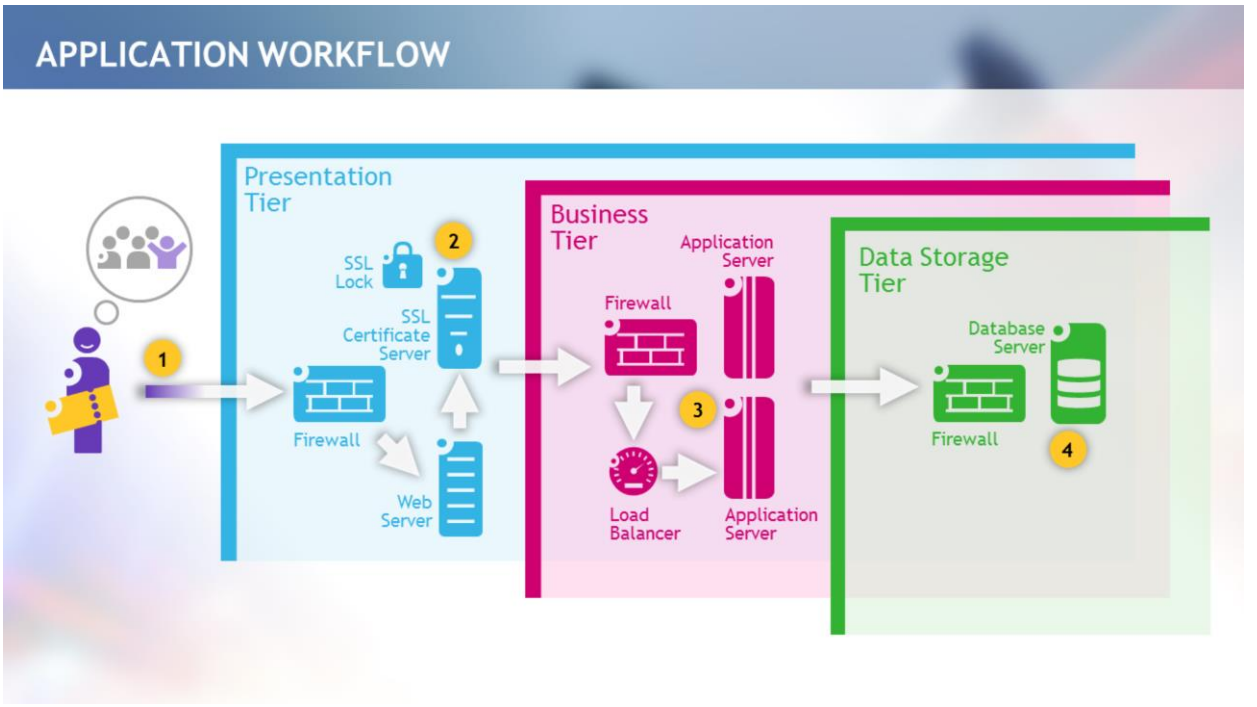

To help appreciate why there are so many connections and so much complexity within the data center, it is worth considering the physical connections typically made to enable a cloud application.

Let's consider our previous example in which a user wants to purchase an online ticket from a secure web site.

First of all the user clicks on the link to the web server.

The web server is protected by a firewall to block malicious attacks.

The user then provides login and password that are checked by the SSL certificate server.

Once the user is authenticated and authorized, a secured SSL connection is established between the web server and the user so that confidential information can be transferred securely.

At this point, the user can access the application server, which presents the business logic related to booking and purchasing tickets. The application server may sit behind a load balancer, which distributes traffic load between multiple application servers.

The application server then accesses the database to store user information and record the sales transaction.

Even in this simplified view, we can appreciate the volume of connections with hundreds of applications segregated by the 3-tier model, serving multiple customers, who are also known as multi-tenants in this context. The physical hardware supporting these connections are servers, storage devices and network elements all interconnected typically using Ethernet VLAN technology; and remember: all of these connections need to be configured and provisioned.

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DATA CENTER NETWORK ARCHITECTURE

Let's describe the physical topology in a data center and identify its networking equipment.

Servers are generally stacked within racks in data centers.

Typically, servers have a 10-Gigabit Ethernet connection to a Top-of-Rack Switch. For resiliency purposes, each server has two physical connections to two Top-of-Rack Switches.

The Top-of-Rack switches have a resilient connection to the End-of-Rack switches. The End-of-Rack switch connects to two data center edge routers. These routers are the gateway between the data center and the Wide Area Network.

It is important to note that these switches and routers are typically manually configured. There is limited automation in data center networking configuration today, it is fundamentally static in nature. So when you consider the volume and scalability of cloud-based applications in an environment which requires extensive human interaction on all the related equipment, you should begin to appreciate the extent of the data center network challenge.

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SUMMARY

Let's quickly sum up the main points in this section:

- Cloud and web applications are designed in a 3-tier architecture for security and scalability
- Many connections are needed to interconnect all servers of a given application
- Data centers supporting large numbers of multi-tenant applications create a complex networking environment to configure and operate
- And finally a lack of automation of the network connections inside the data center is a serious limitation

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Impact of virtualization.

In this module, we will examine the basic concepts of server virtualization as well as the impact virtualization has on data center networks, we will conclude with the reasons why the current networking model needs to evolve.

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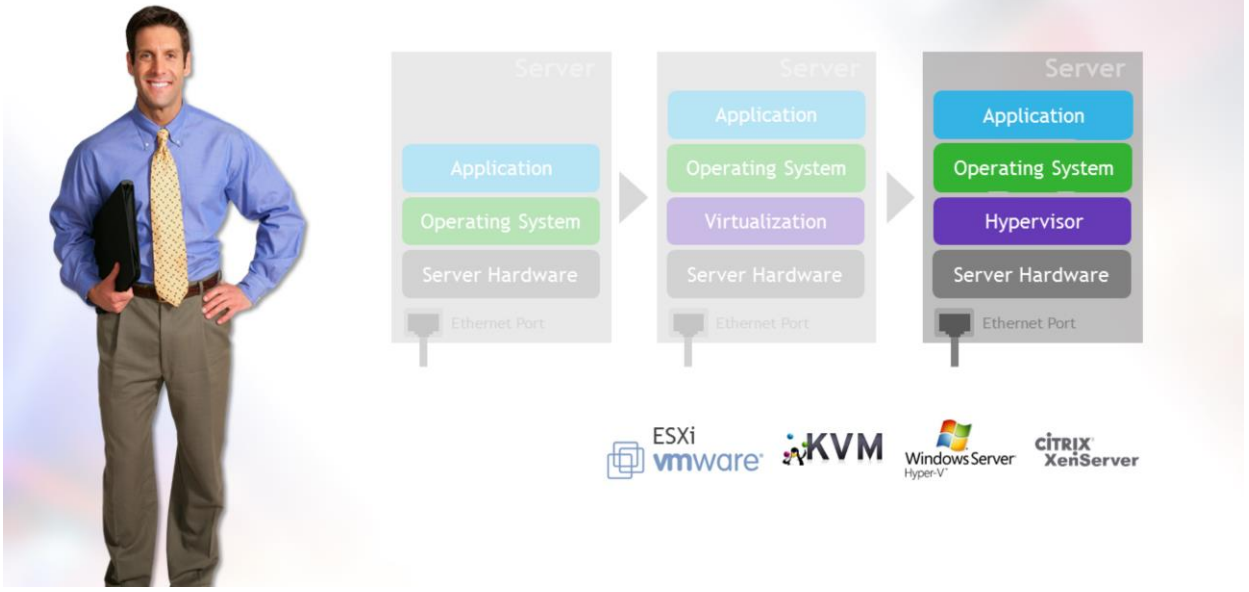
SERVER VIRTUALIZATION



Historically, a single server was only able to support one operating system such as either Linux or Windows, but not both. It was possible to add more applications to the server, but they had to run in the same operating system environment. The operating system ran directly on server hardware and was connected to the network via an Ethernet port.

With the evolution of virtualization, all this has changed.

Virtualization allows the separation of operating system and application from the server hardware on which they run.

This separation is enabled by the introduction of what is known as the virtualization layer.

The separation of operating system from server hardware means that multiple types and instances of operating system with associated applications may reside on a single server hardware platform.

The key advantage of the move to server virtualization is that the underlying hardware resources of the server are more efficiently used by allowing them to be shared by multiple applications and users.

The virtualization layer is based on a software component known as a Hypervisor.

Some hypervisors on the market today are:

- ESXi by VMware
- KVM by Linux distribution
- Hyper-V by Microsoft
- XEN by Citrix.

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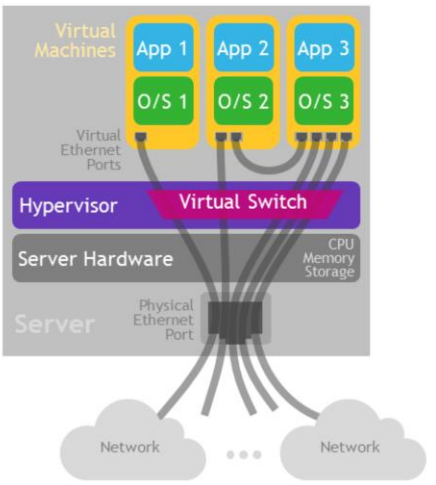
VIRTUAL MACHINES AND VIRTUAL CONNECTIONS



As just explained, the hypervisor allows multiple sets of operating systems and applications to share the underlying physical server hardware.

Each operating system with associated applications runs in what is known as a Virtual Machine.

A Virtual Machine is a virtual container for an operating system and applications which is created, managed, and deleted by the hypervisor. A key function of the hypervisor is to ensure isolated environments in which all Virtual Machines are clearly segregated from one another.

The hypervisor also allocates hardware resources to each Virtual Machine. The allocation of hardware resources may differ from Virtual Machine to Virtual Machine depending on the needs of the applications involved.

For communication purposes, each Virtual Machine is configured with one or multiple virtual Ethernet interfaces; in our example one Virtual Machine has 4 of these interfaces.

A virtual Ethernet interface allows the Virtual Machine to connect with other Virtual Machines or with networks via a networking component inside the hypervisor known as a virtual switch.

So when considering the server's single physical port, remember there are many virtual connections running over it.

It is equally important to bear in mind that this is a dynamic environment in which Virtual Machines can also be moved, copied, and reassigned to different physical servers in order to optimize hardware resources.

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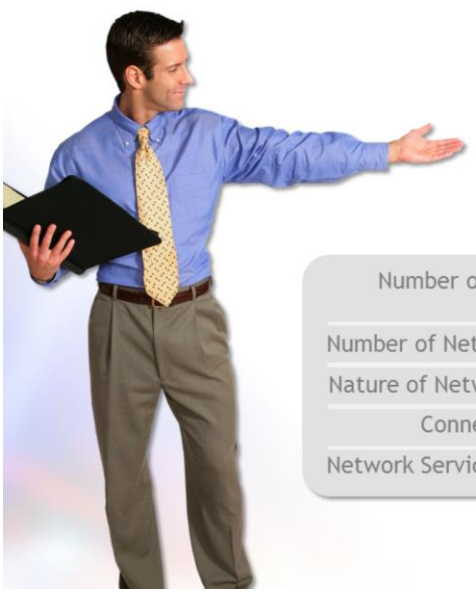
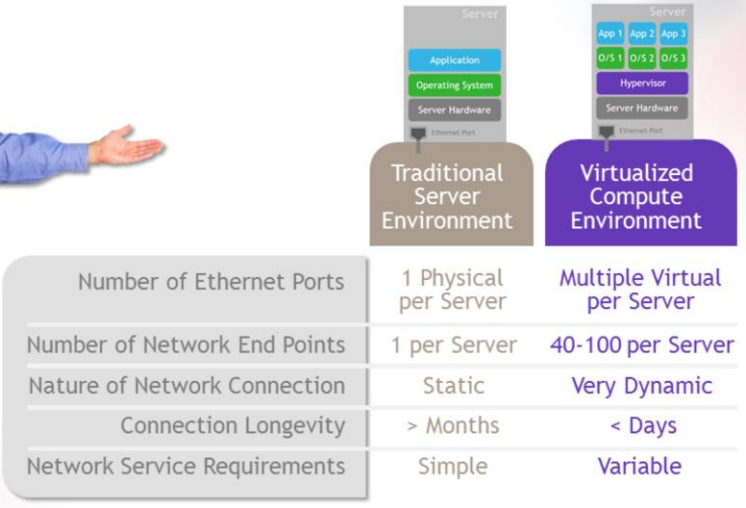
IMPACT ON DATA CENTER NETWORK





	Traditional Server Environment	Virtualized Compute Environment
Number of Ethernet Ports	1 Physical per Server	Multiple Virtual per Server
Number of Network End Points	1 per Server	40-100 per Server
Nature of Network Connection	Static	Very Dynamic
Connection Longevity	> Months	< Days
Network Service Requirements	Simple	Variable

Let's now look at the impact of virtualization on the data center network.

In the traditional server environment a network connection used to be a single physical connection at the Ethernet port; now, however, a single physical network connection has expanded to include multiple virtual connections, each one terminating on a Virtual Machine and representing a network endpoint.

In the past, there was one network endpoint per server; nowadays there are typically 40 to 100 network endpoints per server with that number growing with every new generation of CPU.

The nature of these endpoints has changed too, from static to dynamic connections that are only required for the time that the Virtual Machine exists. Instead of lasting for months, connections can be as short-lived as days or even a few hours.

Finally, the introduction of cloud services leads to a need for more sophisticated network services. The configuration of the network has changed from being a simple switched type of connectivity to a more variable route-based connectivity, potentially consisting of chains of components, such as Firewall and load balancing, in customer or application-specific network services.

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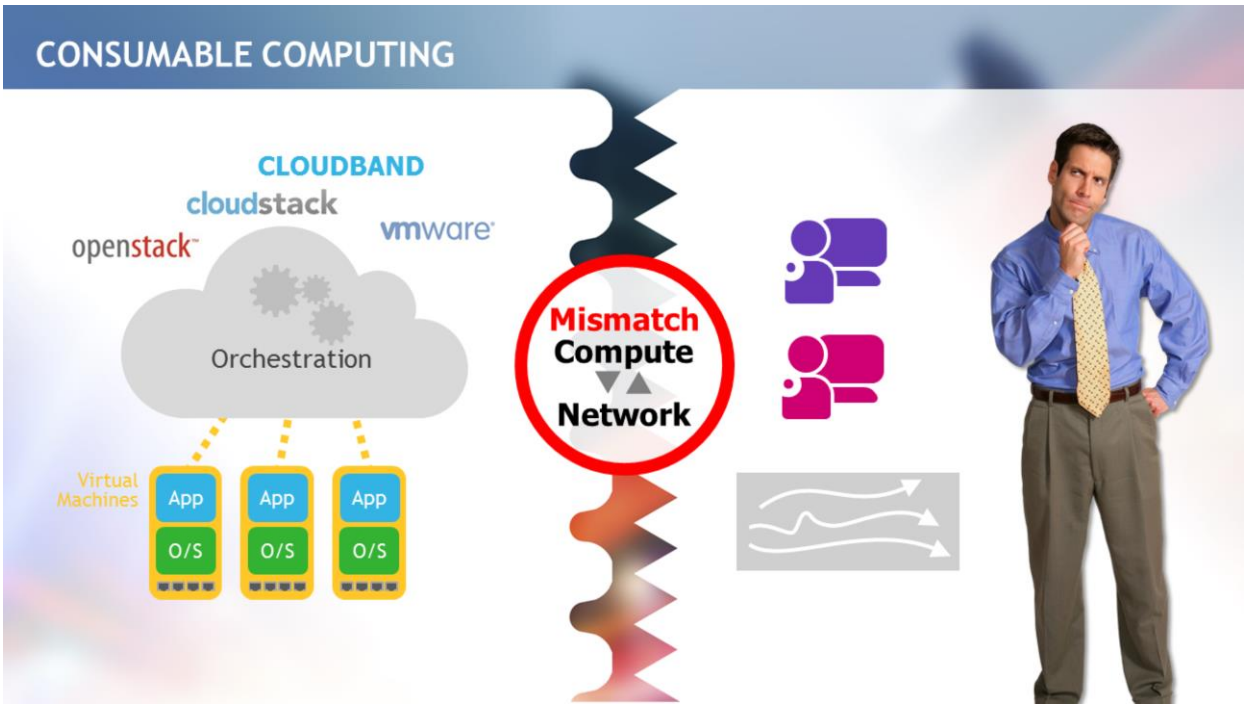

Following the development of hypervisors and virtualization, another important development in cloud computing is the emergence of cloud orchestration software.

This software manages multiple Virtual Machines and their deployment by keeping track of the resources that have been consumed and by whom. It is one of the key IT tools that has greatly simplified the procurement of Virtual Machines as it typically includes an end user portal for self-configuration.

The result of these developments in the industry is that compute and storage have become very easily consumable.

However, networking components have not embraced this dynamic change. They have not kept pace with the virtualization of computing and as a result, networking is not nearly as easy to consume as are compute and storage.

The introduction of Software-Defined Networking, however, is set to revolutionize networking and to bridge the gap by making networking resources as dynamically consumable as are compute and storage resources today.

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SUMMARY

Let's sum up the main points in this section:

- Server virtualization allows multiple operating systems and applications to run on a single physical server for better resources utilization
- The resulting number of network connections per server has significantly increased
- Compute and storage resources have evolved to become highly automated and consumable, whereas the network has not
- And finally we have concluded that the purpose of SDN is to bridge this gap.

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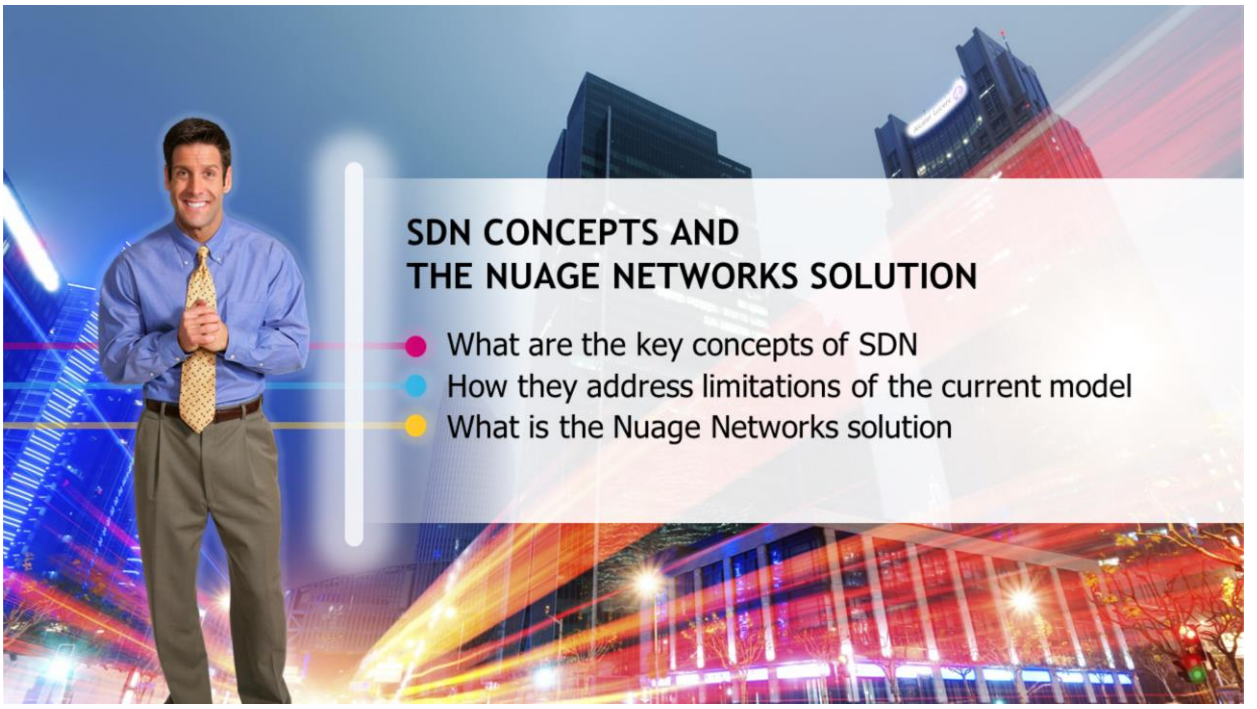

SDN concepts and the Nuage Networks solution.

The goals of this module are to present the key concepts of SDN and show how they address the limitations of the current model. We will conclude by taking a look at the Nuage Networks solution.

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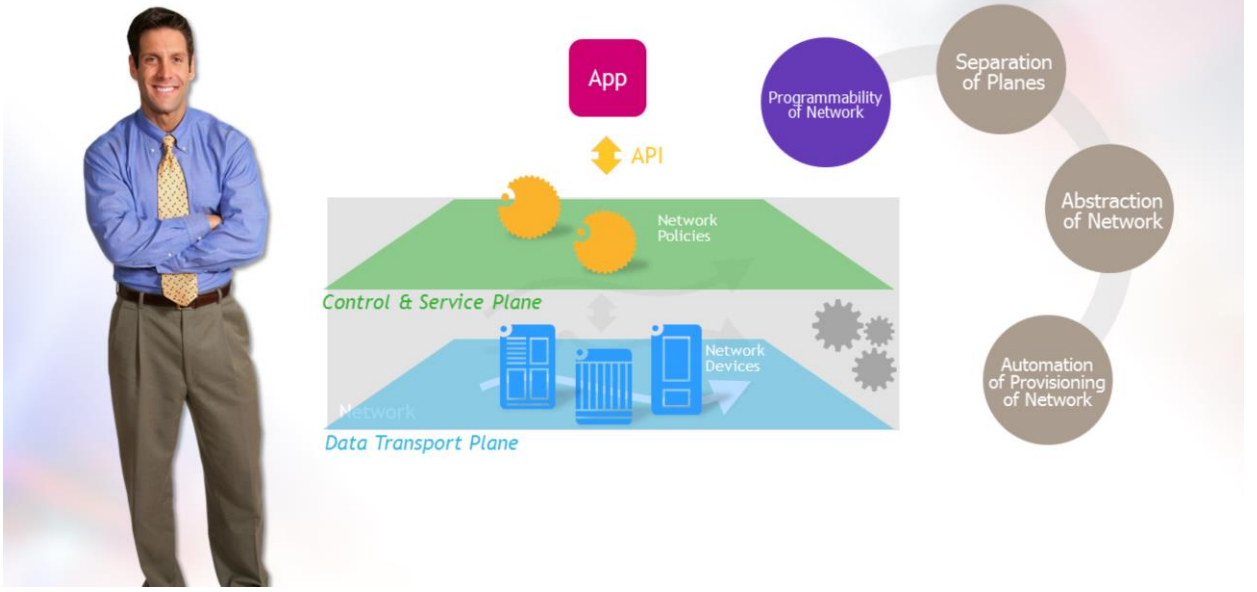
KEY CONCEPTS OF SDN



The overriding concept in Software-Defined Networking is the programmability of the network. In order for this goal to be achieved, the following 3 concepts are key:

Firstly, the decoupling of the data plane from the control and service plane for a centralized control and service logic.

Next, the abstraction of the network, which means a simplified representation of the network can be presented to applications via APIs.

And lastly, the automation of the provisioning of network elements.

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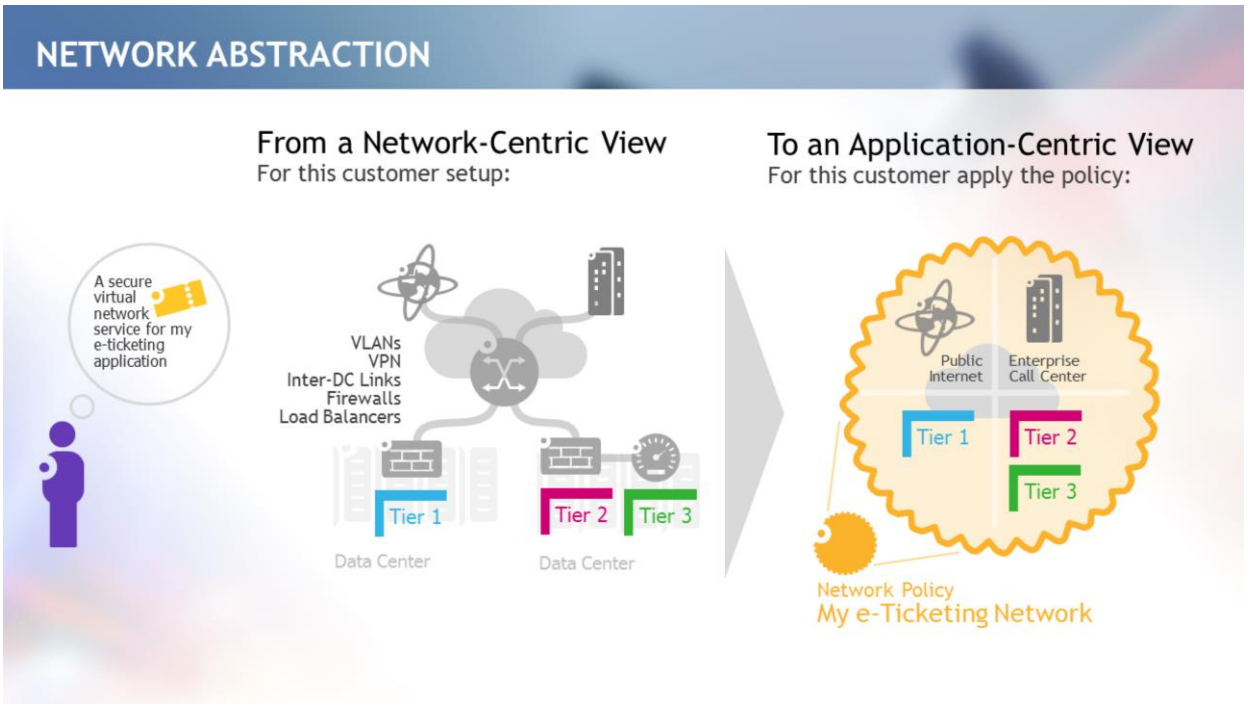

Let's go back to the online ticket sales example.

A key requirement for the Enterprise running this application is that it needs a secure virtual network service established between 2 different data center locations and the Enterprise call center.

This means the Service Provider must do the following:

Set up VLANs in both data centers, set up a VPN to the Enterprise call center, provision high-bandwidth inter-data center links, instantiate Firewalls as well as provide load-balancing services.

In traditional cloud deployments, these network configuration operations are complex as they require IT Network integration work and lots of manual low-level provisioning on network elements.

SDN hides these configuration details in what is known as a Network Policy, which is a simplified representation or abstraction of the network service required for a given application. In our ticket sales example, we could call it the "My e-ticketing Network" policy.

The application does not need to know about the underlying complexity of the network and what low-level commands are required. Abstraction offers a simplified language to empower applications to easily program their network connectivity.

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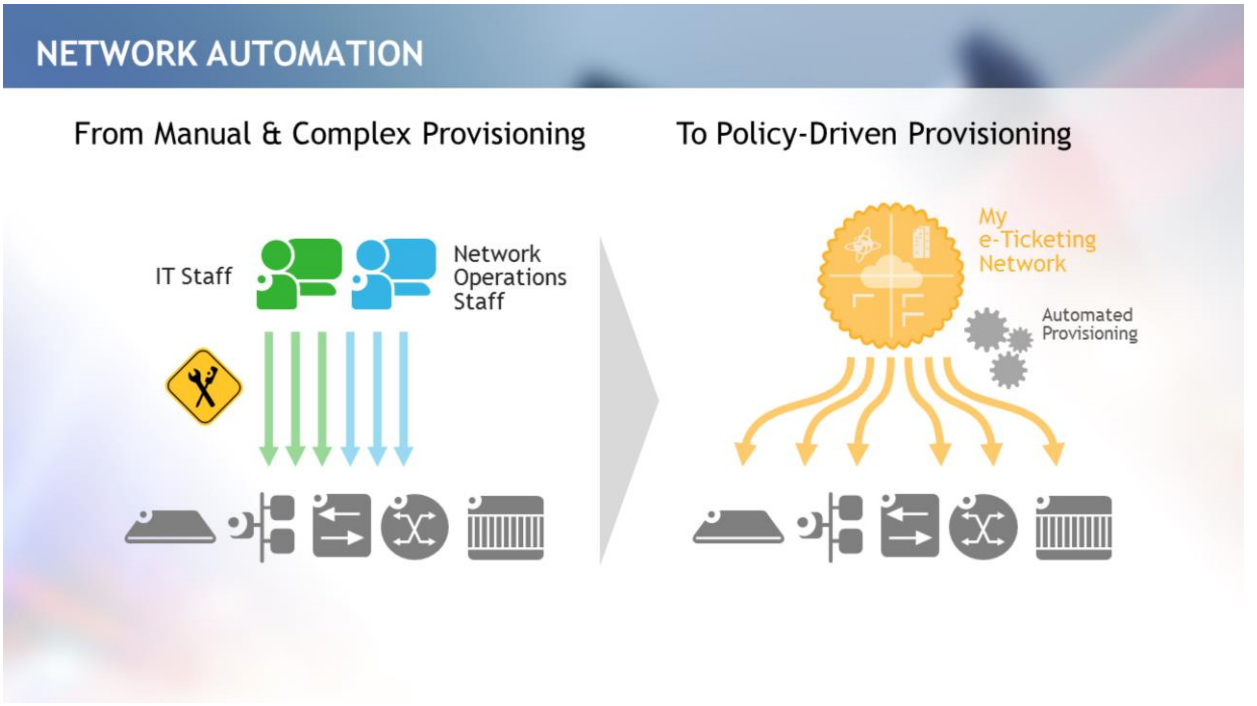

Today's provisioning model is manual and labor-intensive. Whenever a new application comes up, IT and network operations staff needs to configure all the different elements in an intensive process with lots of low level provisioning and that needs to be repeated for each request.

The SDN concept, however, changes all this by employing an automated policy-driven provisioning model.

When a new virtual machine running the application is turned up, the network is triggered to dynamically provision itself according to the configuration details defined in the “My e-Ticketing Network” policy. This means all configuration tasks are instantiated automatically on the relevant network elements.

The same service can be easily repeated for each new similar request, effectively simplifying, accelerating, and reducing the cost of thousands of changes per day.

Thus, a laborious and expensive provisioning model is replaced by a dynamic, policy-driven, fully-automated network provisioning model.

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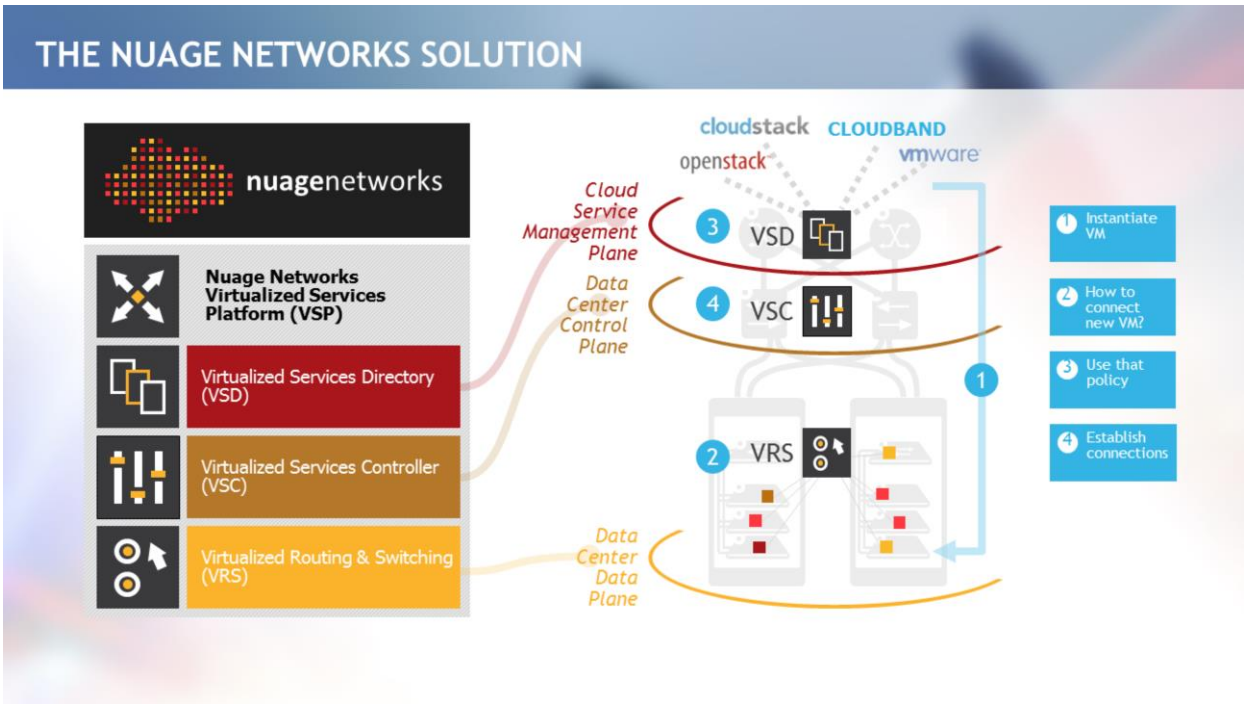

The Nuage Networks solution, known as the Virtual Services Platform, or VSP, unleashes the full power of SDN. The platform comprises three key software-based products:

Firstly, the Virtual Services Directory, or VSD, holds the per-tenant policies and network templates.

Secondly, the Virtual Services Controller, or VSC, is the SDN controller in the control plane which programs the network devices.

And thirdly, the Virtual Routing and Switching, or VRS agent, handles data forwarding in the data plane.

This solution is an open platform that leverages standard protocols to ease integration and interoperability with existing network environments. It supports any hypervisor, any data center switch, and any Cloud management system.

Let's see how the different components work together:

Firstly, in order to deploy an application, Cloud orchestration software, such as CloudBand, instantiates a new virtual machine in the data center.

Next, the VRS detects the new virtual machine and asks the VSC how the virtual machine is to be connected.

The VSD holds the necessary information for that customer in a Policy.

Finally, the VSC then establishes the appropriate connections automatically.

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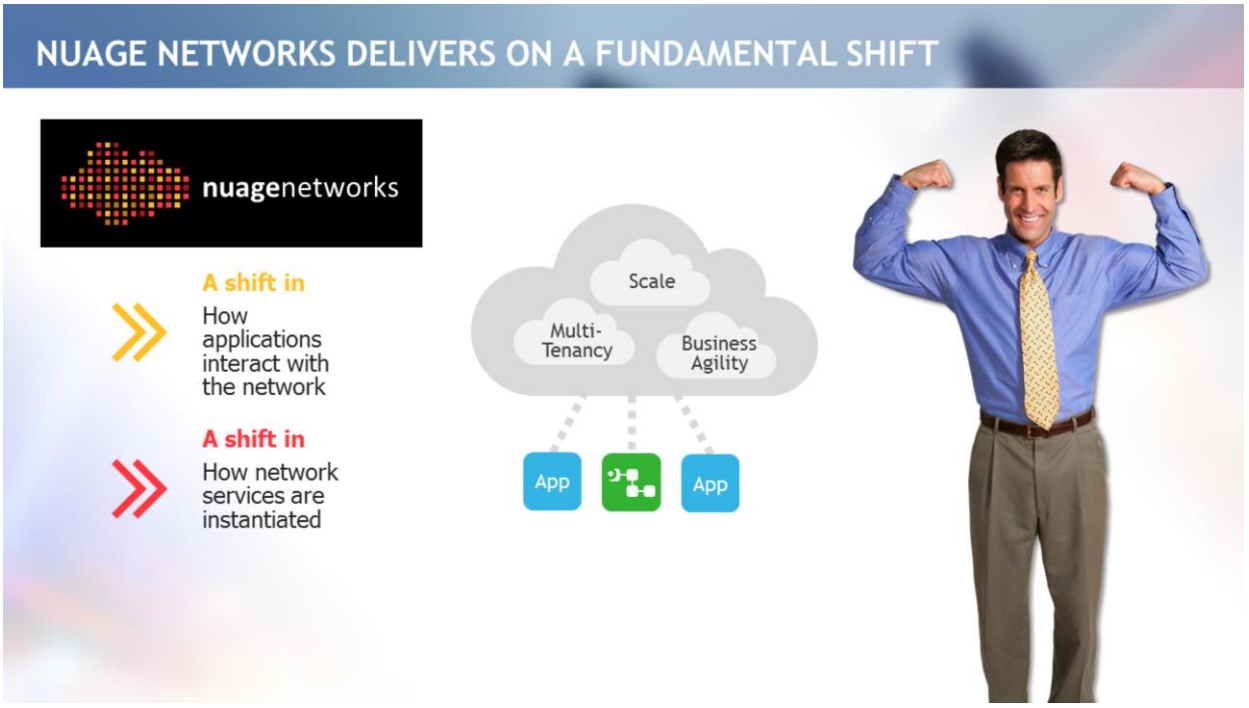

The Nuage Networks solution aligns the networking consumption model with the compute and storage consumption model. This represents a fundamental shift in two areas:

Firstly, a shift in how applications interact with the network: From a network-centric view to an application-centric programmable model.

And secondly, a shift in how network services are instantiated: From a static configuration-driven approach to a policy-driven auto-instantiation paradigm.

The Nuage Networks solution removes the restrictions of the network to enable Cloud Service Providers and Enterprises to scale out robust multi-tenant infrastructure within and across data centers and to gain business agility in a cloud era.

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SUMMARY

To sum up the main messages in this module:

- The key concepts of SDN include the abstraction of networks for easy programming and the automation of network provisioning via policy-based control
- The Nuage Networks solution known as the Virtual Services Platform is a software-based SDN solution that easily integrates into existing networks
- Crucially, it makes the network as consumable as the compute and storage consumption model.

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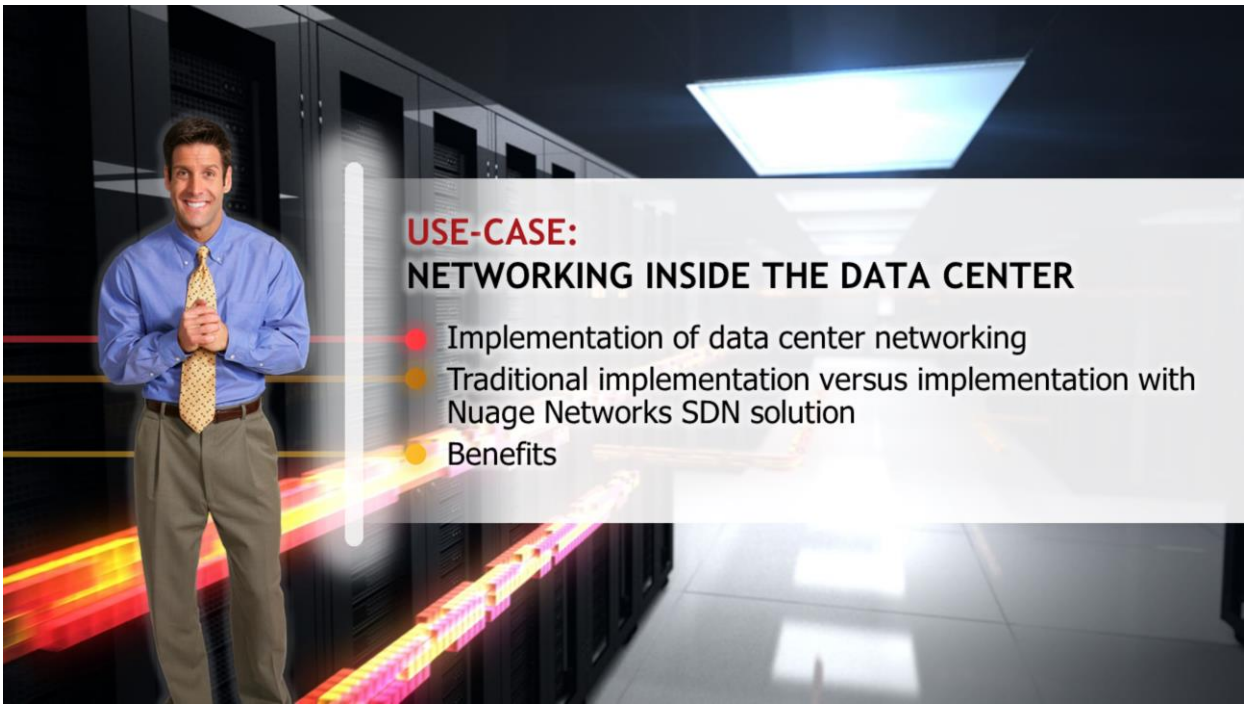

Use case: Networking inside a data center

In this module, we will contrast how networking is traditionally implemented in data centers with the Nuage Networks SDN solution and conclude by highlighting its benefits.

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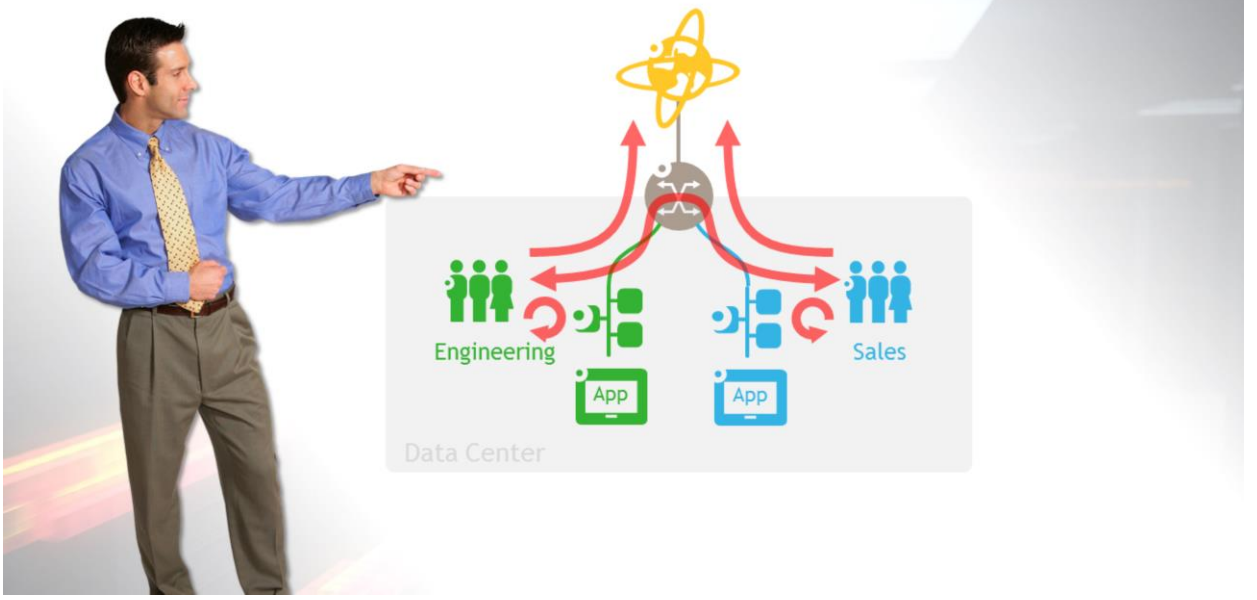
SCENARIO DESCRIPTION



A large company has 2 departments, Engineering and Sales, and wants to set up a networking environment in a data center.

Each department is configured with its own segregated network and messages are freely broadcast within the network of each department.

Communication between departments, however, requires discipline and rules must apply. The Engineering department can only communicate with the sales department through Web traffic.

Both departments are allowed to access the public Internet and all other communications should be blocked.

Traffic segregation is achieved by placing each department onto separate Virtual LAN segments; VLANs are an important aspect of data center networks.

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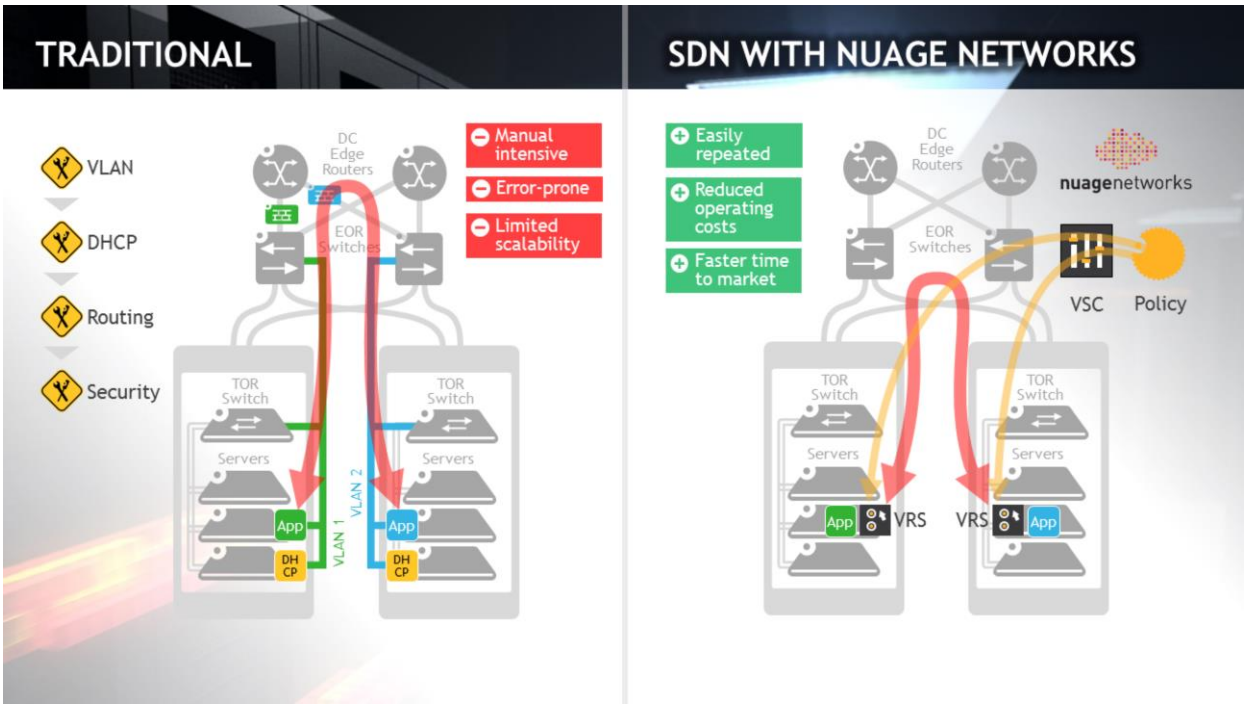

To deploy this scenario with traditional networking technologies, operations staff need to do the following:

Provision each VLAN in the virtual switch on the hypervisor.

Provision the VLANs in the data center network at the Top of Rack and End of Rack switches.

Set up the DHCP server on each network to allow IP address allocation to Virtual machines and users.

Define and configure the IP subnets in the router to connect the router to each network.

The staff must then create IP filtering rules inside the router to allow proper traffic to be forwarded between the Engineering and Sales departments and the Internet.

As you can see, a high degree of manual intervention is required as operations staff needs to configure lots of functions on various network components.

As well as being error-prone, manual operations take an unacceptably long time for customers waiting for applications to come online. These operations issues become vast and overwhelming when you consider the sheer volume and scalability of cloud-based applications and the related numbers of connections.

Let's see how it works with the Nuage Networks SDN solution.

A prerequisite for the scenario is the Enterprise administrator builds a set of policies applicable to both departments within that Enterprise. This is a straightforward 5-click operation through the Nuage Networks portal.

When the engineering or sales application is instantiated, a Virtual Machine is created by the hypervisor. This automatically triggers a request by the Nuage Networks VRS to the Nuage Networks VSC, which is the SDN controller, to retrieve the networking configuration details from the Policy for the Enterprise.

The Nuage Networks VRS, which is a configurable element, implements the Routing and Switching functionalities that are required without the need to touch the existing data center switches and data center routers.

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In this way, connections are automatically established, fewer routing resources are needed and the bottleneck at the data center router level is avoided.

As you can see, operations are made simple by means of policies and automation. Tedious manual operations as well as human error are eliminated.

If these operations need to be repeated multiple times, the policy is simply instantiated as many times as required.

To conclude, with the fully automated Nuage Networks SDN solution, operating costs are greatly reduced and business response time to customer demands is significantly accelerated.

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SUMMARY

To sum up the main messages in this module:

- The traditional approach to data center networking is manual, intensive, and error prone
- The SDN approach automates all operations by means of networking policies
- And the Nuage Networks SDN solution automates networking connections, enabling scale and reducing errors

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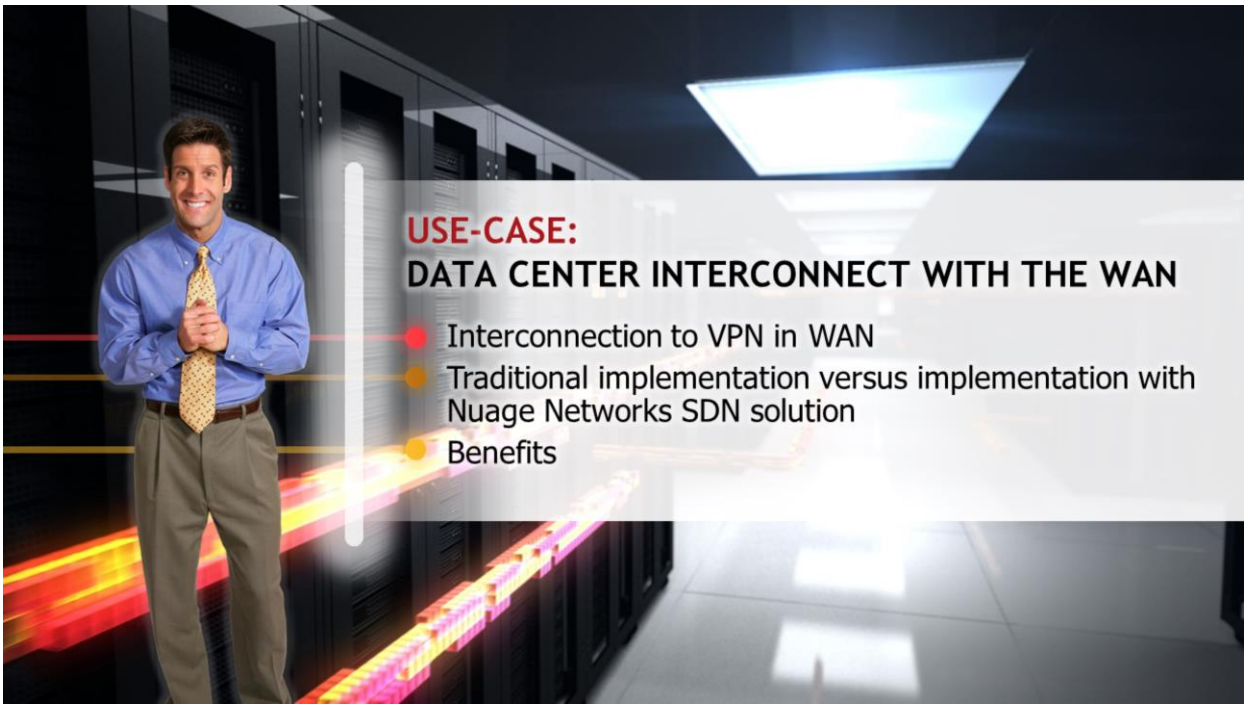

Use case: Data center interconnect with the Wide Area Network (WAN)

In this module, we will extend the data center networking use-case by looking at the interconnection to a Virtual Private Network (VPN) in the WAN.

Again, we will contrast how this scenario is traditionally implemented with the Nuage Networks SDN solution and conclude by highlighting its benefits.

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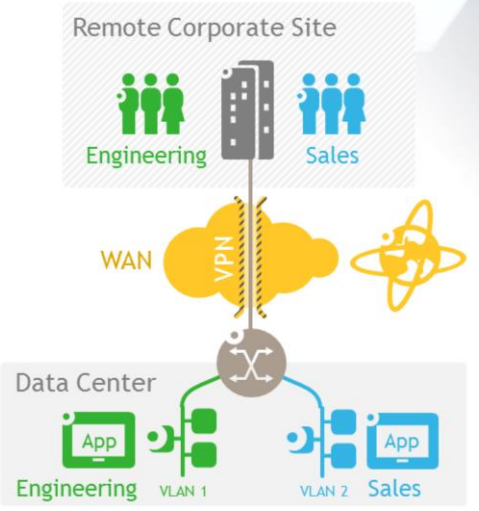
SCENARIO DESCRIPTION



Now let's build on what we explained in the previous scenario and focus our attention on the connection to the Wide Area Network.

This large Enterprise now has Sales and Engineering teams at a remote Corporate site which must connect to the same data center with a VPN connection through the Wide Area Network.

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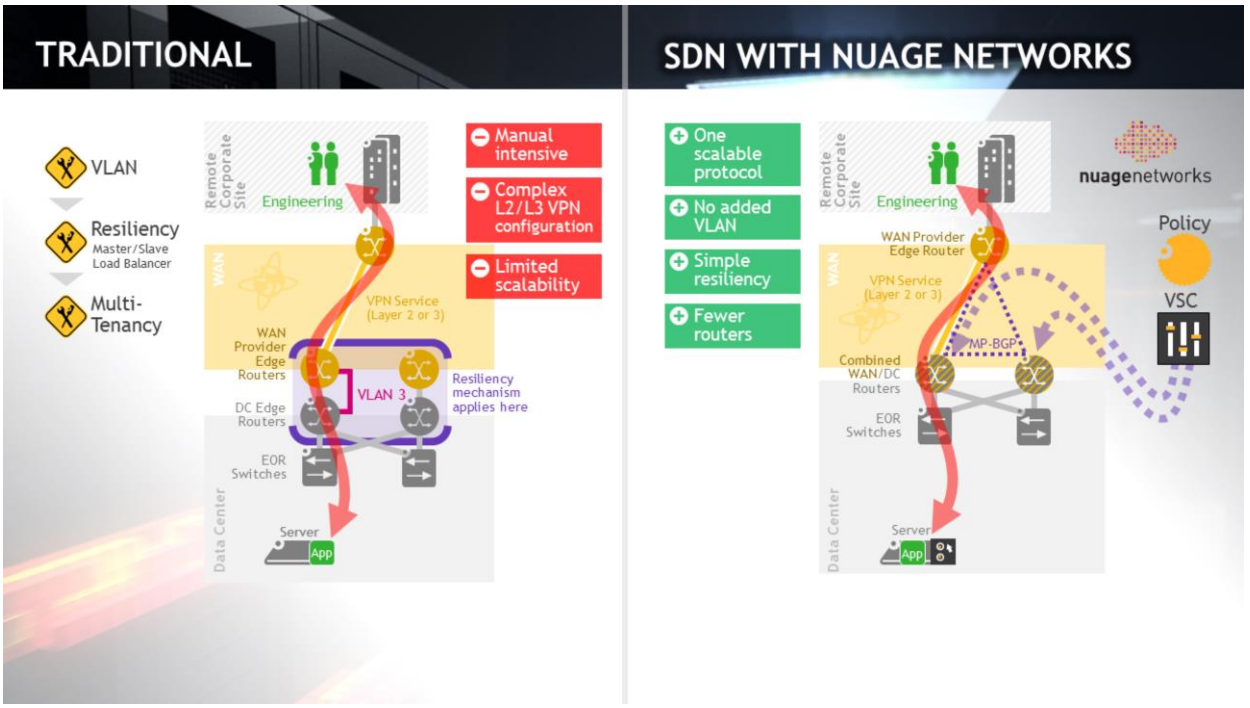

In this scenario, an interconnection must be implemented between the data center and the Wide Area Network running either a Layer 2 or Layer 3 VPN service.

To deploy this scenario with traditional networking technologies, operations staff needs to configure the interconnect between the data center and the WAN. This involves configuring a Virtual LAN, between the data center router and the WAN router as well as setting up a routing protocol to provide resiliency in case of failure.

These configurations must be done on both the data center router and the WAN router.

In this implementation, there are a few issues that need to be considered:

Firstly, different teams typically own data center network operations and WAN operations, making a manual process necessary that requires co-ordination between the teams.

Next, Layer 2 and Layer 3 VPN configurations are more complex because they use different resiliency mechanisms such as Master-Slave or Load-Balancing.

Finally, scalability is a major issue when using this approach as multiple tenants can be provisioned and each tenant requires a dedicated Virtual LAN as well as routing protocols.

Let's see how it works with the Nuage Networks SDN solution.

To address the needs of this environment, the Nuage Networks SDN solution leverages the multi-protocol border gateway protocol or MP-BGP, which is a multi-tenant protocol.

So when a new employee needs to be connected from the corporate site, the corresponding network policy is applied. The policy defines the services to be allowed and the type of resiliency to be used.

The Nuage Networks VSC then communicates with the edge routers using MP-BGP to make all the necessary connections.

This means employees can be quickly connected and only a single protocol instance is required regardless of whether an employee or a tenant needs to be instantiated.

Furthermore, MP-BGP is a scalable, policy-controlled protocol such that the WAN networking team and data center networking team only need to agree on routing rules for each enterprise tenant.

With that in place, connectivity between the data center and the WAN network gets instantiated

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automatically without the need to provision additional VLANs. Given that MP-BGP is common to Layer 2 and Layer 3 VPNs, we avoid the complexity of configuring different resilience mechanisms when providing Layer 2 or Layer 3 VPNs.

Moreover, it allows the operator to remove the Data Center edge router or the WAN Provider Edge router which reduces CAPEX.

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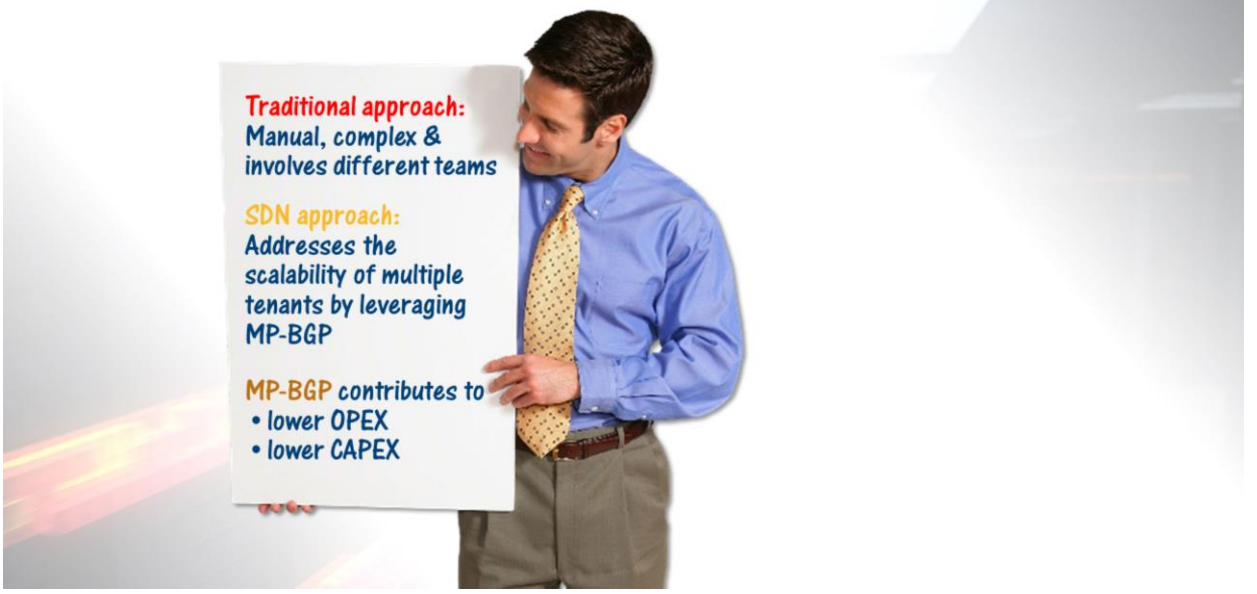
SUMMARY



Let´s sum up the main points in this module:

- The traditional approach to interconnecting the data center and the WAN is manual, complex and involves different teams
- The Nuage Networks SDN solution addresses the scalability of multiple tenants by leveraging the multi-protocol border gateway protocol
- MP-BGP contributes to lower OPEX and lower CAPEX

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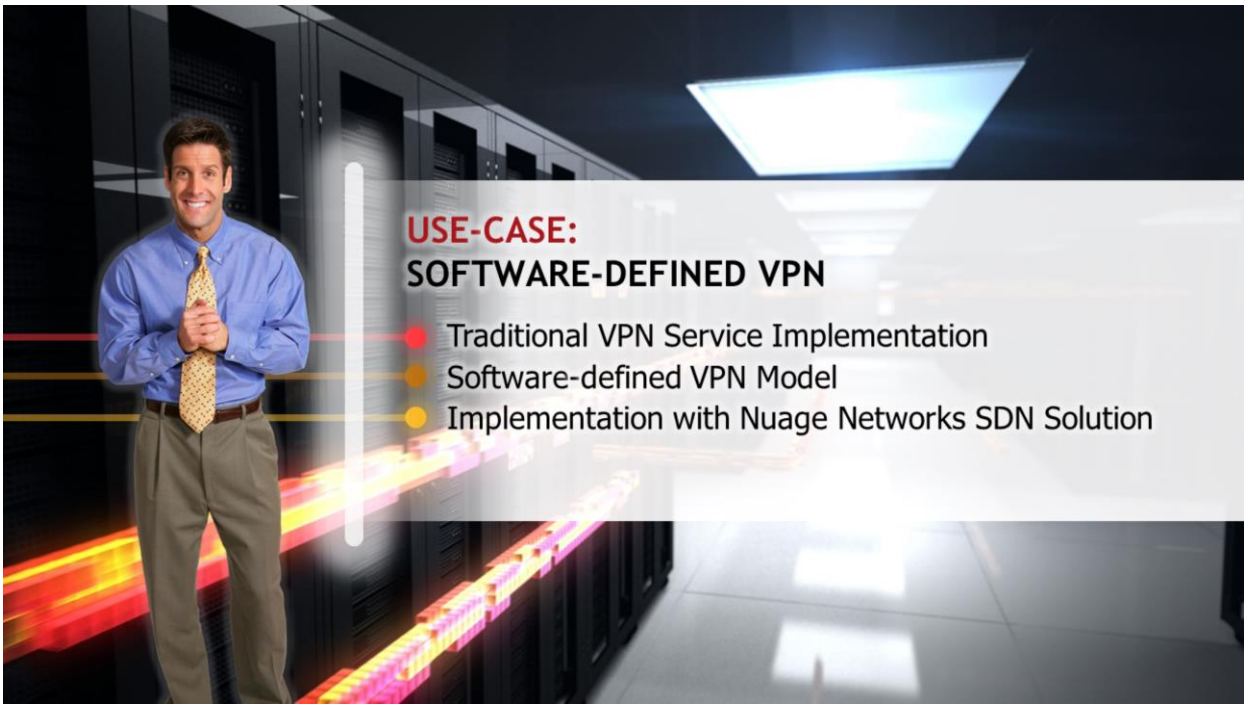

Use case: Software-Defined VPN

In this module, we will look at a traditional VPN service implementation, we will then introduce the Software-Defined VPN model and look at how this is implemented with the Nuage Networks SDN solution.

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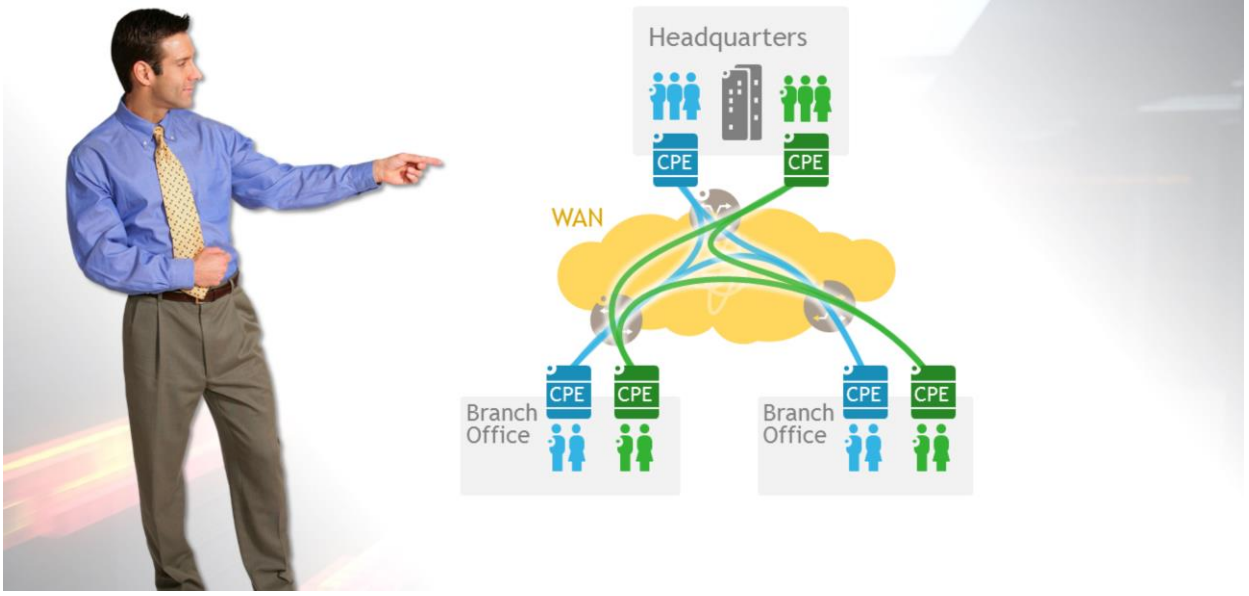
SCENARIO DESCRIPTION



Let's now consider an enterprise that has several remote locations with its Headquarters and 2 branch offices.

The enterprise needs to support 2 departments distributed across the 3 sites. Each department has its own VPN service across the WAN, and all 3 sites connect to the WAN through a router acting as the Customer Premises Equipment or CPE.

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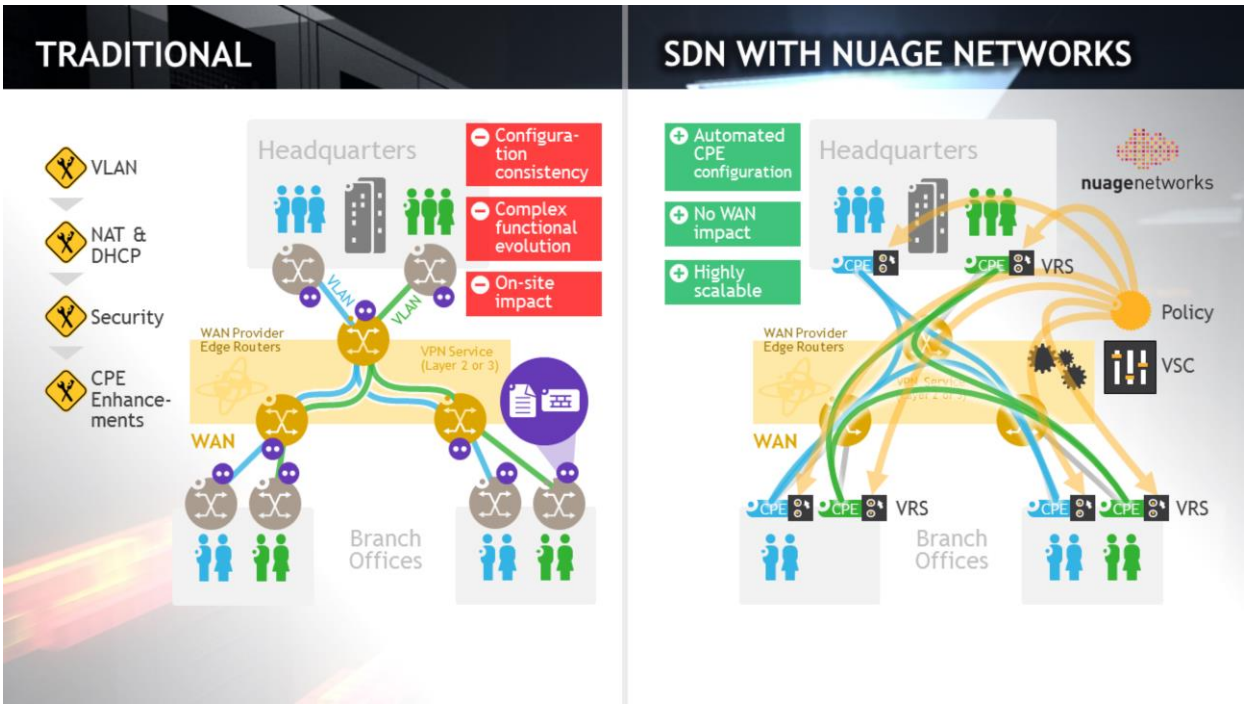

To deploy this scenario with traditional networking technologies, operations staff needs to do the following:

Connect each of the CPE devices to the WAN-Provider Edge router, or PE, in a peer-to-peer configuration through a dedicated link running 2 VLANs, one for each tenant.

Set up NAT and a DHCP server in the WAN to take care of IP addressing between the 2 domains.

Next, configure security policies on the CPEs and PE routers according to the rules defined by the customer.

Now the VPN tunnels can be established.

In this implementation, there are a couple of issues that need to be considered: One of these is that typically CPEs and PEs are configured by different management systems. This makes it difficult to ensure consistency with respect to connectivity, IP addressing, security policies, and Quality of Service.

Another issue is that Customer Premises Equipment is typically dedicated to either a Layer 2 VPN or a Layer 3 VPN. When a customer needs to move from a Layer 2 VPN to a Layer 3 VPN or add more advanced functionalities, the CPE needs to be either replaced or additional Customer Premises Equipment must be installed on-site at a high operational cost.

The Software-Defined VPN model simplifies the whole process. With regard to connectivity, rather than having to configure the VPN service on both the WAN Provider Edge router and Customer Premises Equipment, SD-VPN only requires configuration at the CPE level. This is possible because it is based on two things:

- firstly, a VPN overlay connectivity approach,
- and secondly, an Open CPE model.

Let's see how it works with the Nuage Networks SDN solution.

An instance of the Nuage Networks VRS agent runs in each CPE. The VRS agent allows all CPEs in the customer domain to be controlled by a centralized Nuage Networks VSC in the Service Provider domain.

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A network policy previously defined for this customer, which includes Layer 2 or Layer 3 connectivity with security and Quality of Service, must then be applied to the VPN service. As soon as a CPE boots up, the network policy is downloaded from the VSC to the VRS in order to program the CPE.

The benefits of the Nuage Networks solution in this interconnect case are:

- The installation and provisioning of CPEs become automated.
- The WAN network no longer needs to be provisioned with VPNs per-customer which eliminates complexity.
- No additional DHCP servers or NAT policies need to be assigned since they are programmed into the CPE.

And finally the Nuage Networks solution is scalable to thousands or even millions of CPEs

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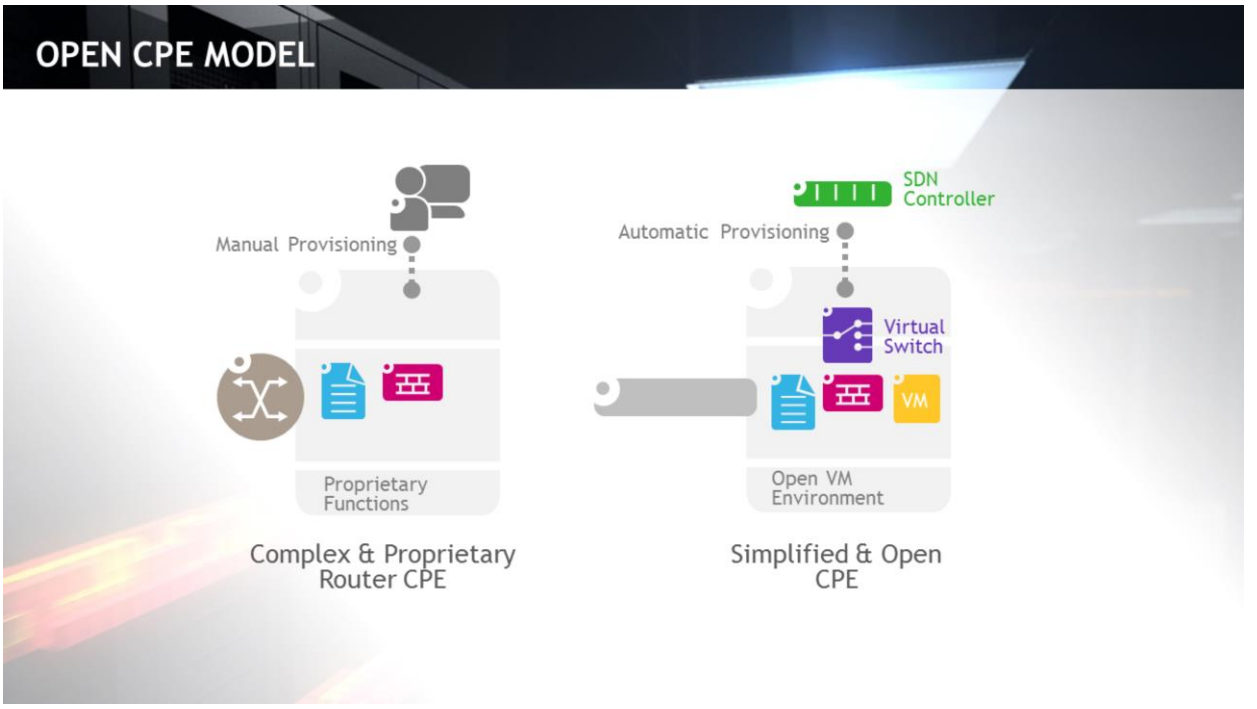

The programmability of the CPE is made possible because the Nuage Networks solution leverages an open CPE model that is controlled by software.

The traditional CPE model is based on proprietary Enterprise routers with functions that are complex to implement as well as limited in their ability to evolve.

The new Open CPE model is based on an open server implementation that is capable of supporting Virtual Machines.

With the Nuage Networks solution, the VRS agent is instantiated on the server and integrates all Layer 2, Layer 3, Quality of Service, security policies and forwarding rules. The VSC, which is the SDN controller, has full programming control of the VRS.

Virtual Machine-based software applications can also be installed directly on the CPE such that service providers can deploy their own applications depending on the customer's requirements. This simplifies the enhancement of services inside the customer´s LAN environment.

The new Open CPE model allows for a "unified CPE" approach which reduces the number of CPE types that the network Service Provider needs to maintain.

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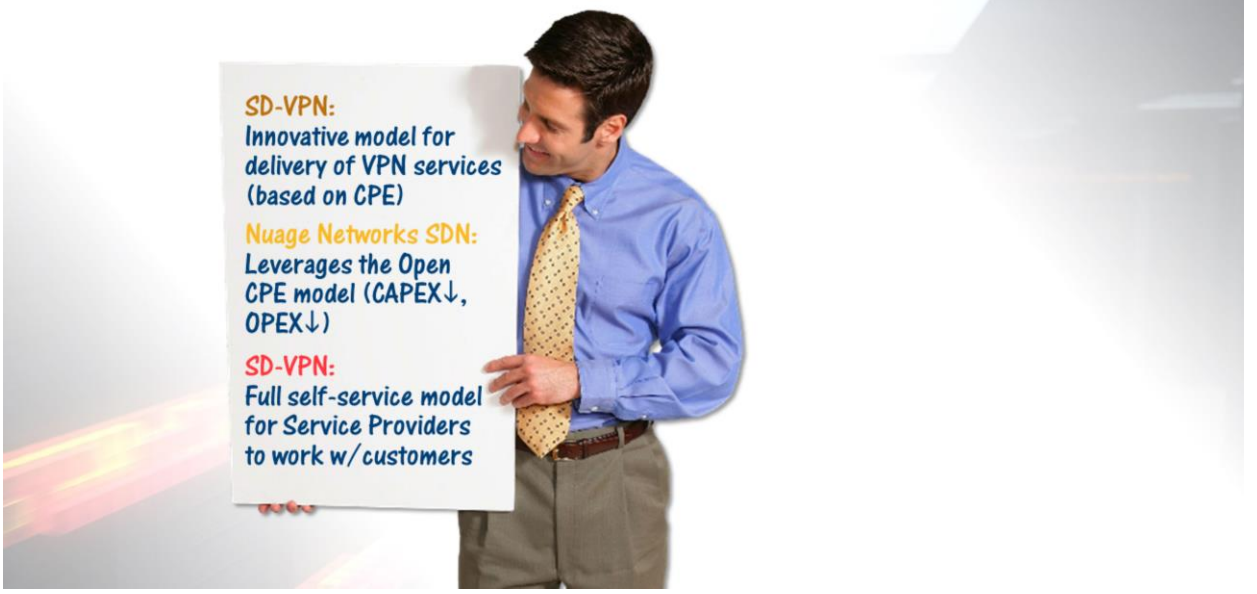
SUMMARY



Let´s sum up the main points in this module:

- SD-VPN is an innovative model for the delivery of VPN services based on the programmability of the CPE
- The Nuage Networks SDN solution leverages an Open CPE model to reduce CAPEX and OPEX
- And SD-VPN provides a full self-service model for Service Providers to work with their customers.

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In conclusion:

- Over the past few years, server virtualization has triggered a revolutionary shift in computing. The ability to turn up applications and move workloads instantaneously has made compute and storage infrastructure readily consumable when required by applications.
- With enterprises rapidly shifting to a cloud-based model, the network that forms the connectivity between users and applications is under enormous pressure and must evolve not only in the datacenter, but in the wide area network as well.
- Software-Defined Networking (SDN) enables this process of change to take place: it allows networking infrastructure to be abstracted and programmable, creating dynamic, on-demand services to meet the individual needs of cloud applications.
- Nuage Networks, an Alcatel-Lucent venture, enables network virtualization, making datacenter and networks consumable, programmable and scalable.

You have now completed the overview about SDN and Network Virtualization.

Finally, please note that this tutorial, as well as additional SDN and Nuage Networks documentation can be downloaded from the Resources tab in the upper right corner of this window.

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