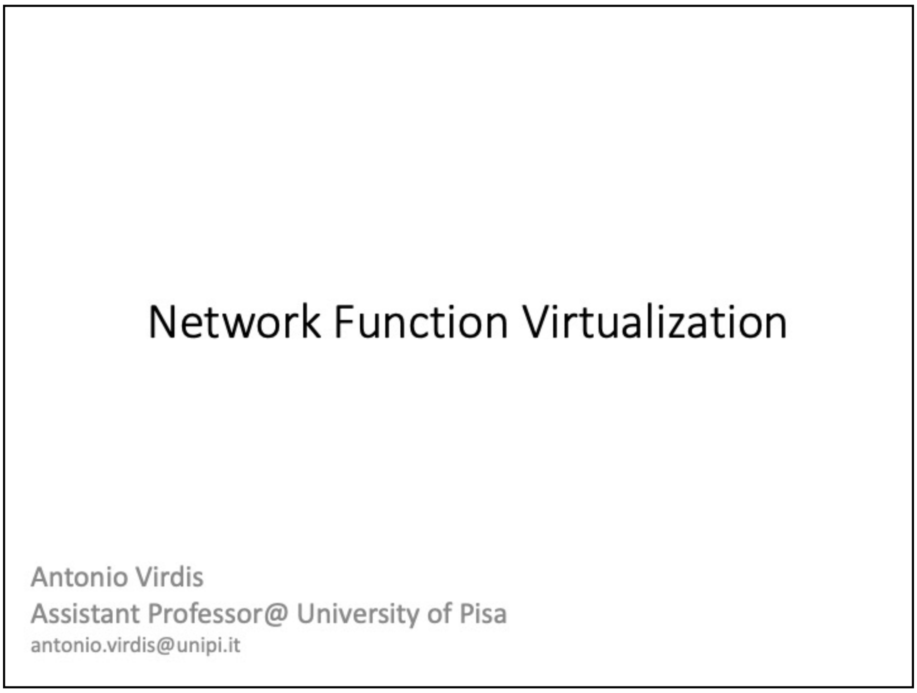

Network Function Virtualization

Antonio Virdis
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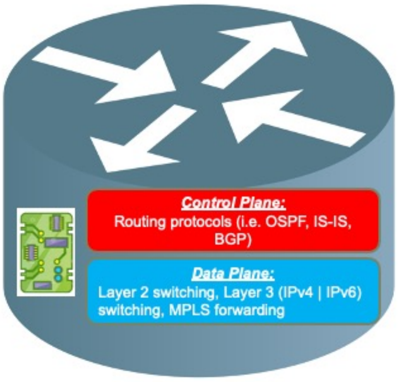
Traditional Network Equipment

- A limited set of functionalities (just a little more than routing/forwarding) implemented in hardware

- Network is designed around the hardware and not viceversa

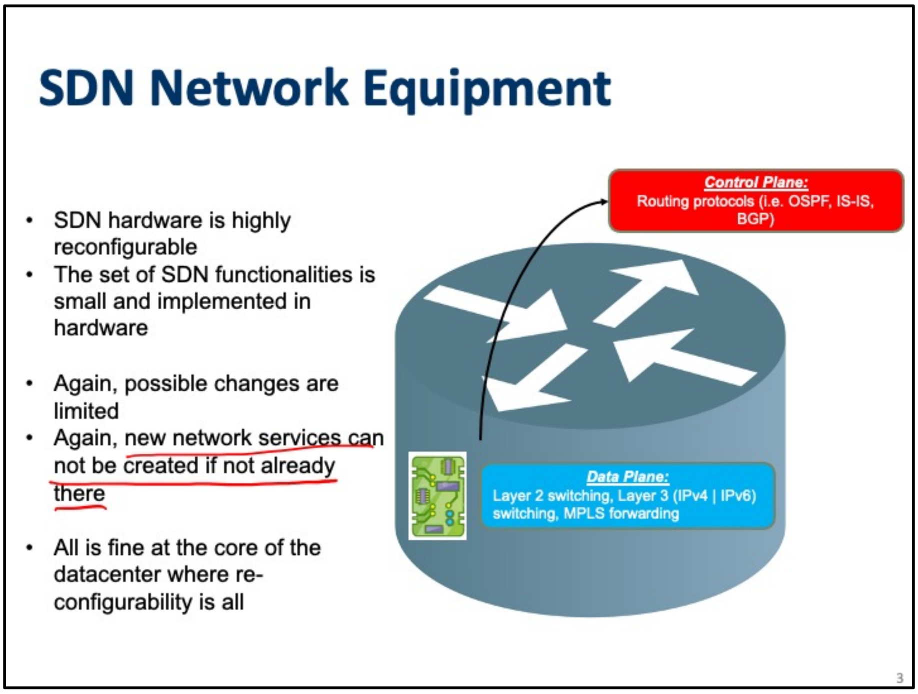
- Possible changes are limited
- New network services can not be created

- All is fine for the core of ISP networks



Control Plane:
Routing protocols (i.e. OSPF, IS-IS, BGP)

Data Plane:
Layer 2 switching, Layer 3 (IPv4 | IPv6) switching, MPLS forwarding

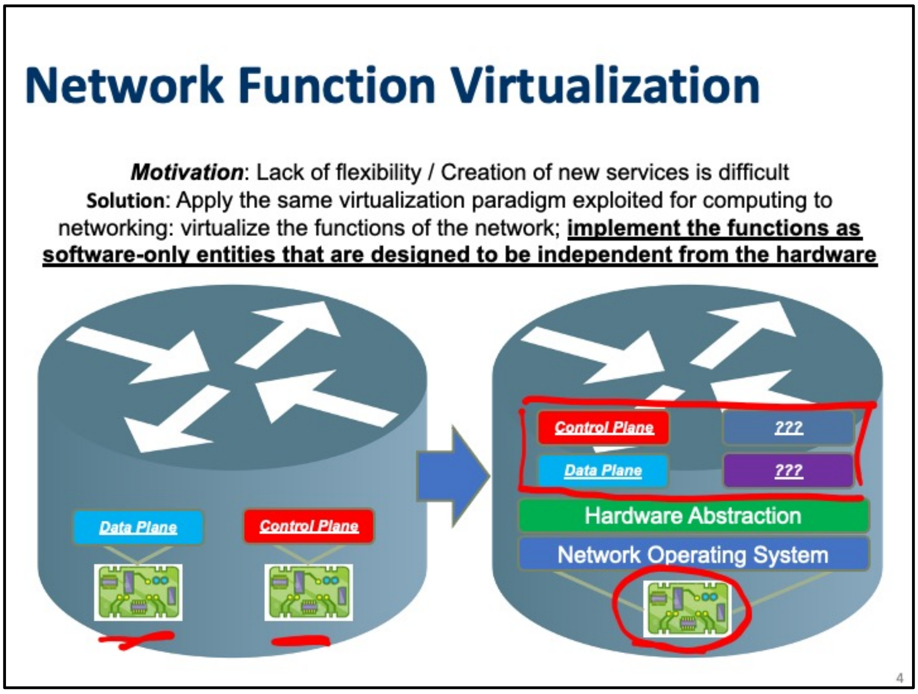


SDN Network Equipment

- SDN hardware is highly reconfigurable
- The set of SDN functionalities is small and implemented in hardware
- Again, possible changes are limited
- Again, new network services can not be created if not already there
- All is fine at the core of the datacenter where re-configurability is all

Control Plane:
Routing protocols (i.e. OSPF, IS-IS, BGP)

Data Plane:
Layer 2 switching, Layer 3 (IPv4 | IPv6) switching, MPLS forwarding

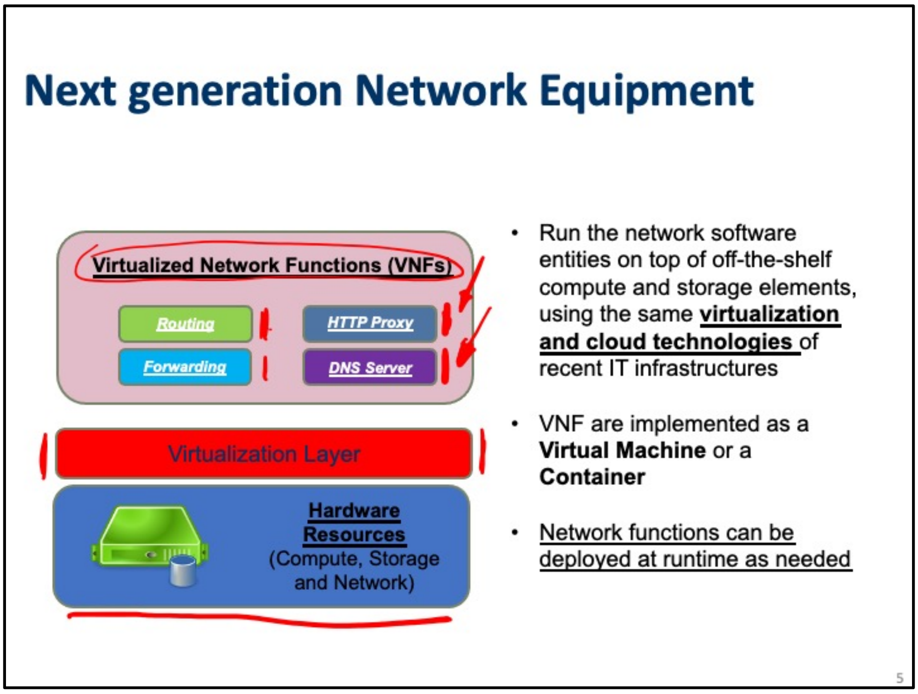


Network Function Virtualization

Motivation: Lack of flexibility / Creation of new services is difficult

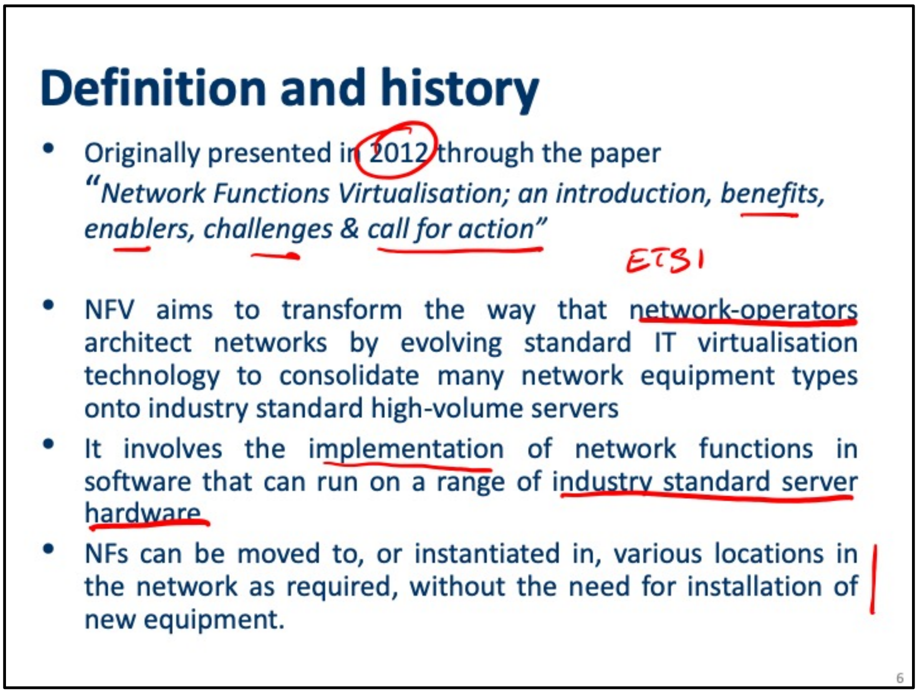
Solution: Apply the same virtualization paradigm exploited for computing to networking: virtualize the functions of the network; **implement the functions as software-only entities that are designed to be independent from the hardware**

Mobile network and cloud markets as main drivers



Next generation Network Equipment

- Run the network software entities on top of off-the-shelf compute and storage elements, using the same **virtualization and cloud technologies** of recent IT infrastructures
- VNF are implemented as a **Virtual Machine** or a **Container**
- Network functions can be deployed at runtime as needed



Definition and history

- Originally presented in 2012 through the paper *"Network Functions Virtualisation; an introduction, benefits, enablers, challenges & call for action"*

ETSI

- NFV aims to transform the way that network-operators architect networks by evolving standard IT virtualisation technology to consolidate many network equipment types onto industry standard high-volume servers
- It involves the implementation of network functions in software that can run on a range of industry standard server hardware
- NFs can be moved to, or instantiated in, various locations in the network as required, without the need for installation of new equipment

NFV was introduced in a presentation titled "Network Functions Virtualisation; an introduction, benefits, enablers, challenges and call for action" in 2012 at the SDN and OpenFlow World Congress [1].

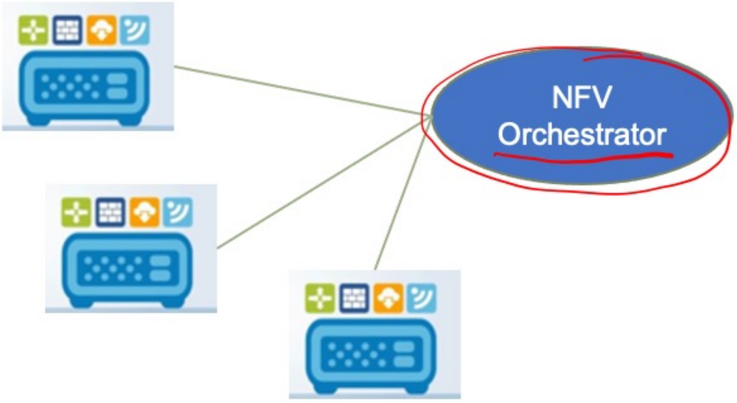
Shortly after it was introduced, the *European Telecommunications Standards Institute* (ETSI) took the lead on NFV.

ETSI has created an NFV framework that will lead to standard solutions from a plethora of network vendors. This framework defines an *NFV Infrastructure* (NFVI), where VNFs are created and managed by an *NFV Orchestrator* (NVFO) and VNF Manager.

Network Functions Virtualisation aims to transform the way that network operators architect networks by evolving standard IT virtualisation technology to consolidate many network equipment types onto industry standard high volume servers, switches and storage, which could be located in Data Centers, Network Nodes and in the end user premises. . . It involves the implementation of network functions in software that can run on a range of industry standard server hardware, and that can be moved to, or instantiated in, various locations in the network as required, without the need for installation of new equipment.

NFV Orchestrator

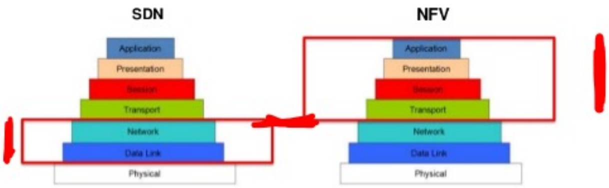
Softwarization allows to control all the components of each virtualized network equipment by a centralized entity, called **NFV Orchestrator**, *which controls the services to be instantiated on each device*



SDN vs NFV

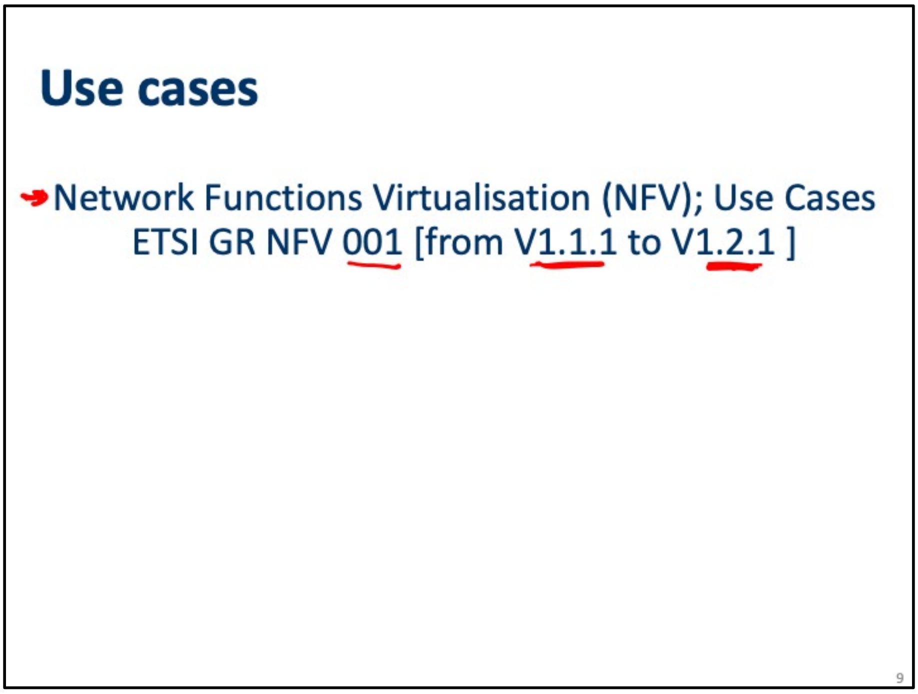
SDN and NFV are not in contrast and can coexist

- SDN, more focused on optimizing network infrastructure
- NFV, more focused on optimizing the network functions



- Optimize network infrastructure such as Ethernet switches, routers and wireless access points
- OSI Layer 2-3

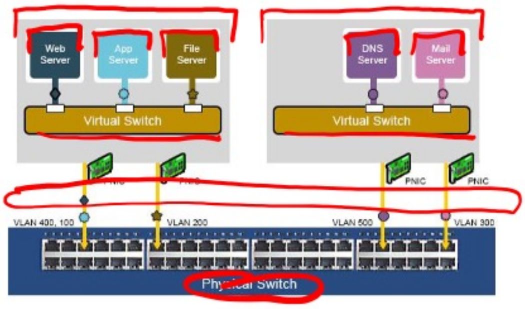
- Optimize deployment of network functions such as: load balancer, firewall, WAN optimization controller, deep packet inspection etc.
- OSI Layer 4-7



Use cases

- Network Functions Virtualisation (NFV); Use Cases ETSI GR NFV 001 [from V1.1.1 to V1.2.1]

Use Cases (i)



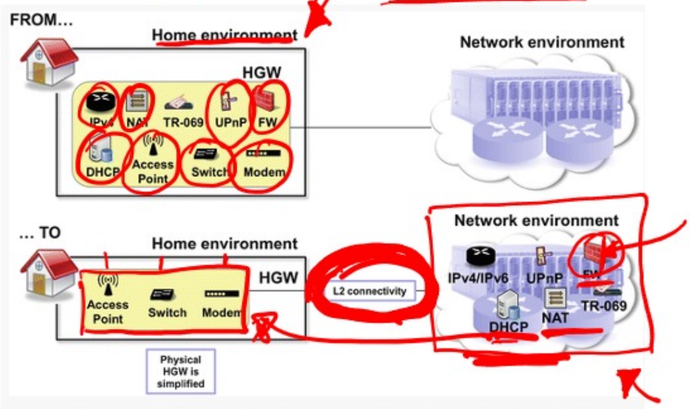
New networks and virtual network services can be instantiated as VMs are created or destroyed

Virtual Networks inside Cloud Computing platforms: *Network functions are virtualized by definitions as they are implemented on top of the cloud virtual infrastructure*

The cloud orchestrator (the software controlling the instantiation of VMs) is already a NFV orchestrator

Use Cases (ii)

OnPremises



Customer network equipment can be virtualized.

This allows the deployment of new services in the customer's network as the customer requires (and pay) them. New services (unknown at the time of device installation) can be created and deployed anytime.

Use Cases (iii)

The core network of wireless operator is a complex infrastructure. Wireless protocols rapidly changes over time (e.g. UMTS -> LTE -> LTE Advanced -> 5G)

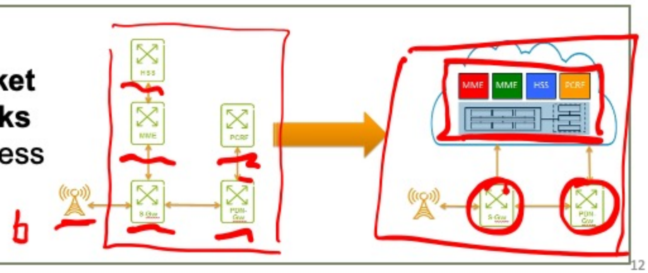
4G

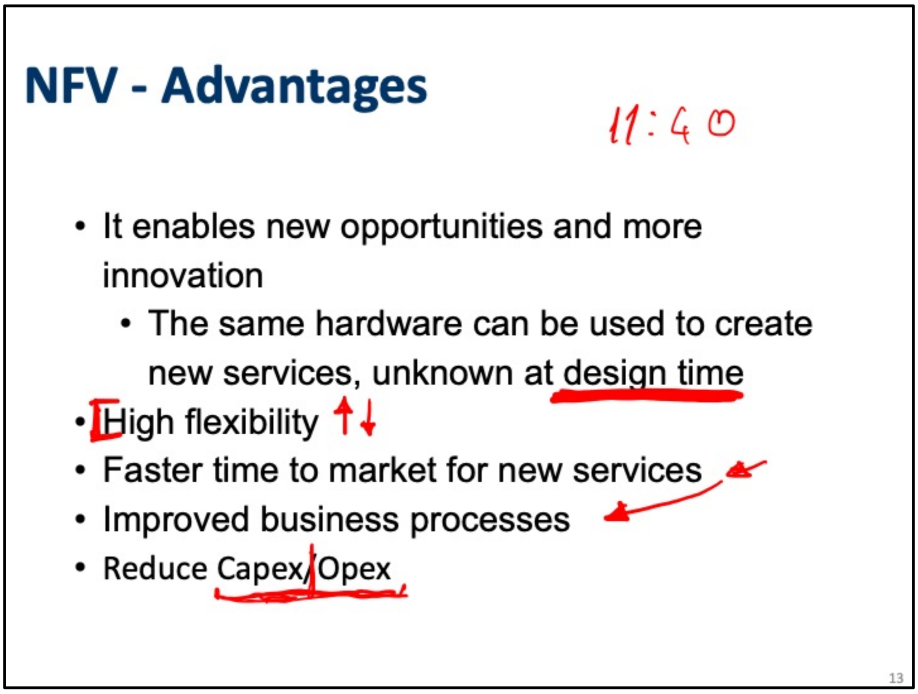
The virtualization of the core network can allow:

(i) Network reconfiguration and protocol update using the same hardware

(ii) Rapid deployment of virtualized network services to create Virtual Network Service Operators

Evolved Packet Core Networks (EPC) of Wireless Providers



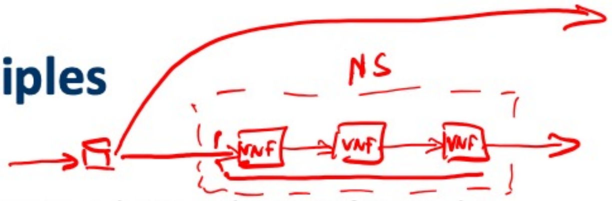


NFV - Advantages

11:40

- It enables new opportunities and more innovation
  - The same hardware can be used to create new services, unknown at design time
- High flexibility ↑↓
- Faster time to market for new services
- Improved business processes
- Reduce Capex/Opex

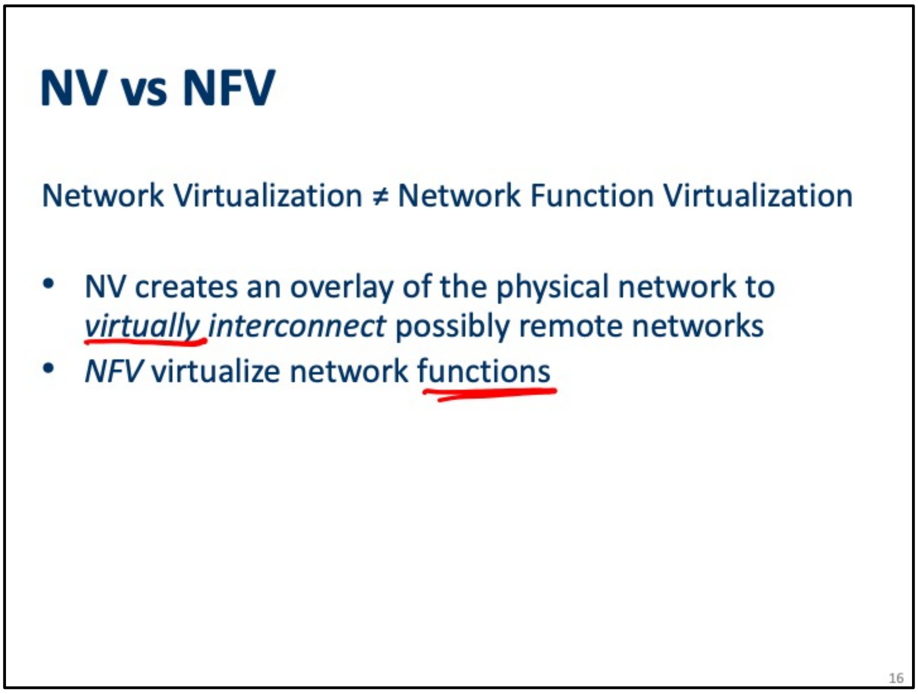
NFV - Principles



- **Service Chaining**: selecting the set of VNFs the traffic flow will traverse
- **Management and Orchestration (MANO)**: managing the whole lifecycle of VNF istances
- **Distributed Architecture**: a Network Service may be made up of one or more VNF components, each one possibly deployed on different hosts

NFV - Requirements

- Portability/interoperability
- Performance trade-off
- Migration and coexistence w.r.t. legacy equipment.
- Automation
- Security and resilience
- Network stability



NV vs NFV

Network Virtualization ≠ Network Function Virtualization

- NV creates an overlay of the physical network to *virtually interconnect* possibly remote networks
- *NFV* virtualize network functions

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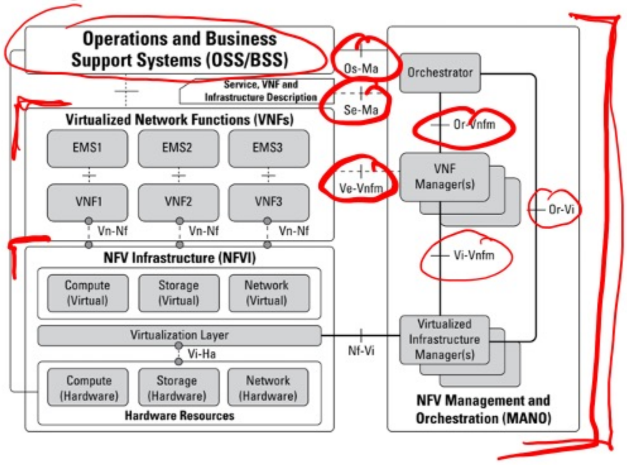
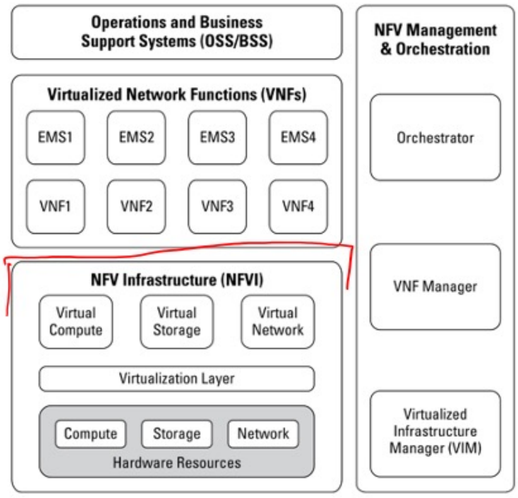
Network virtualization (NV) has existed for some time. It is not unusual to have trouble distinguishing NV from NFV, so we will attempt to clarify this here. NV creates an overlay of the physical network. Instead of connecting two different domains with physical wiring in a network, NV creates tunnels through the existing network. This saves time and effort for network administrators and technicians. NV is well-suited to providing connectivity between virtual machines. On the other hand, NFV virtualizes layer four through seven functions. Examples include firewalls, load balancers, *Intrusion Detection Systems* (IDS), *Intrusion Protection Systems* (IPS), and other

Standard Architecture

The ETSI NFV Industry Specification Group in its working group MANO has defined a high-level functional architectural framework for NFV

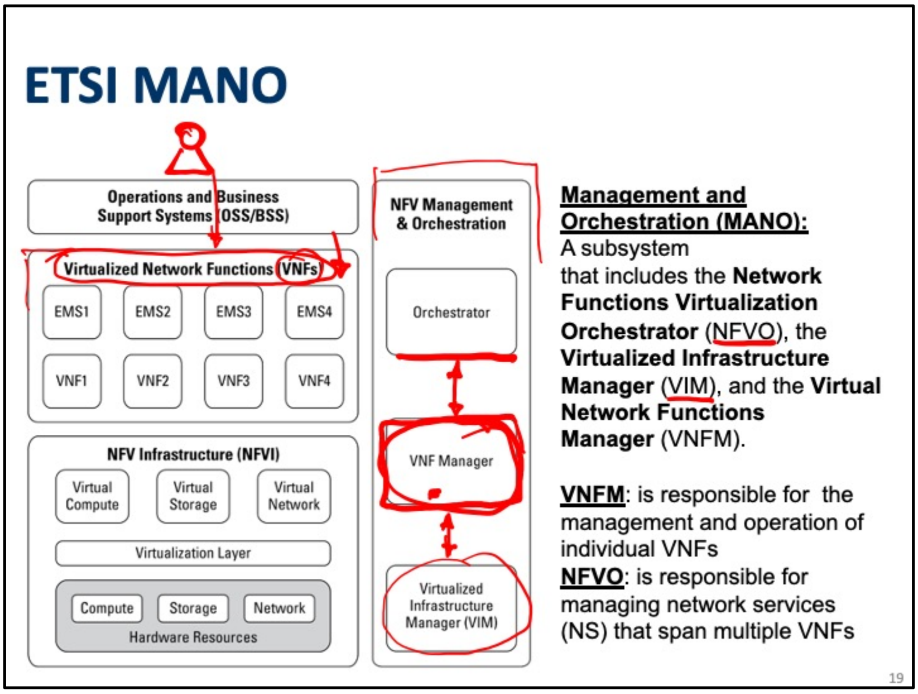


Components


Operations and Business Support Systems (OSS/BSS)
Virtualized Network Functions (VNFs)
EMS1
EMS2
EMS3
EMS4
VNF1
VNF2
VNF3
VNF4
NFV Infrastructure (NFVI)
Virtual Compute
Virtual Storage
Virtual Network
Virtualization Layer
Compute
Storage
Network
Hardware Resources
NFV Management & Orchestration
Orchestrator
VNF Manager
Virtualized Infrastructure Manager (VIM)

Network Functions Virtualization Infrastructure (NFVI):
A subsystem that consists of all the hardware and software components *on top of which VNFs are deployed*.

One or more VNFs are instantiated to implement a **Network Service (NS)** to implement a specific network functionality.



ETSI MANO

Operations and Business Support Systems (OSS/BSS)

Virtualized Network Functions (VNFs)

EMS1 EMS2 EMS3 EMS4

VNF1 VNF2 VNF3 VNF4

NFV Infrastructure (NFVI)

Virtual Compute

Virtual Storage

Virtual Network

Virtualization Layer

Compute

Storage

Network

Hardware Resources

NFV Management & Orchestration

Orchestrator

VNF Manager

Virtualized Infrastructure Manager (VIM)

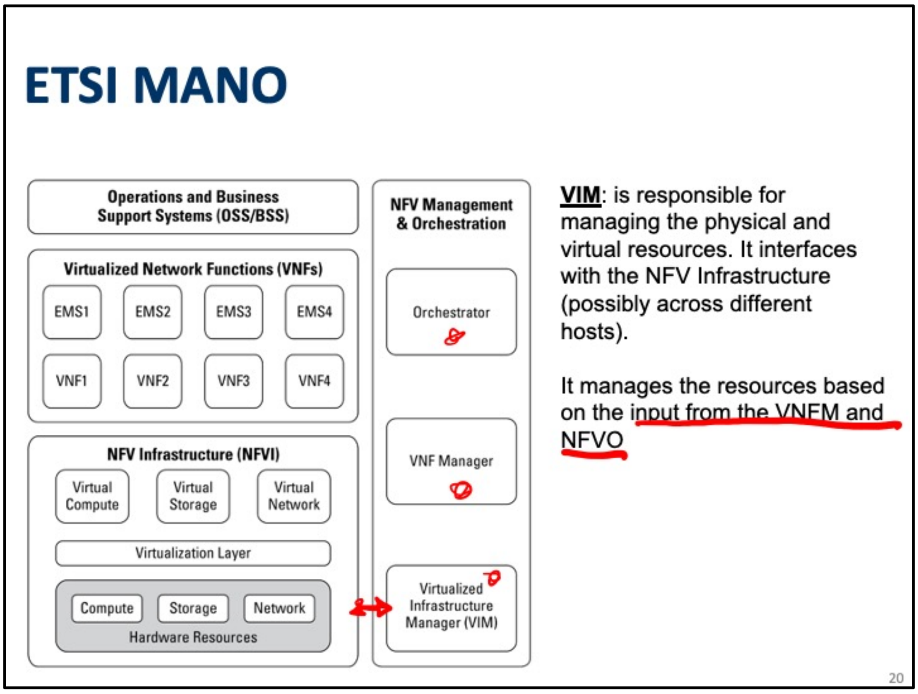
Management and Orchestration (MANO): A subsystem that includes the **Network Functions Virtualization Orchestrator** (NFVO), the **Virtualized Infrastructure Manager** (VIM), and the **Virtual Network Functions Manager** (VNFM).

VNFM: is responsible for the management and operation of individual VNFs

NFVO: is responsible for managing network services (NS) that span multiple VNFs

NFVO: This is used for on-boarding of new *Network Service* (NS), *VNF Forwarding Graph* (VNF-FG), and VNF Packages, NS lifecycle management (including instantiation, scale-out/in, performance measurements, event correlation, termination) global resource management, validation and authorization of NFVI resource requests, and policy management for NS instances.

VNF Manager**:** This provides lifecycle management of VNF instances, and overall coordination and adaptation for configuration and event reporting between NFVI, the *Element Management System* (EMS), and the *Network Management System* (NMS).



ETSI MANO

Operations and Business Support Systems (OSS/BSS)

Virtualized Network Functions (VNFs)

EMS1 EMS2 EMS3 EMS4

VNF1 VNF2 VNF3 VNF4

NFV Infrastructure (NFVI)

Virtual Compute | Virtual Storage | Virtual Network

Virtualization Layer

Compute | Storage | Network

Hardware Resources

NFV Management & Orchestration

Orchestrator

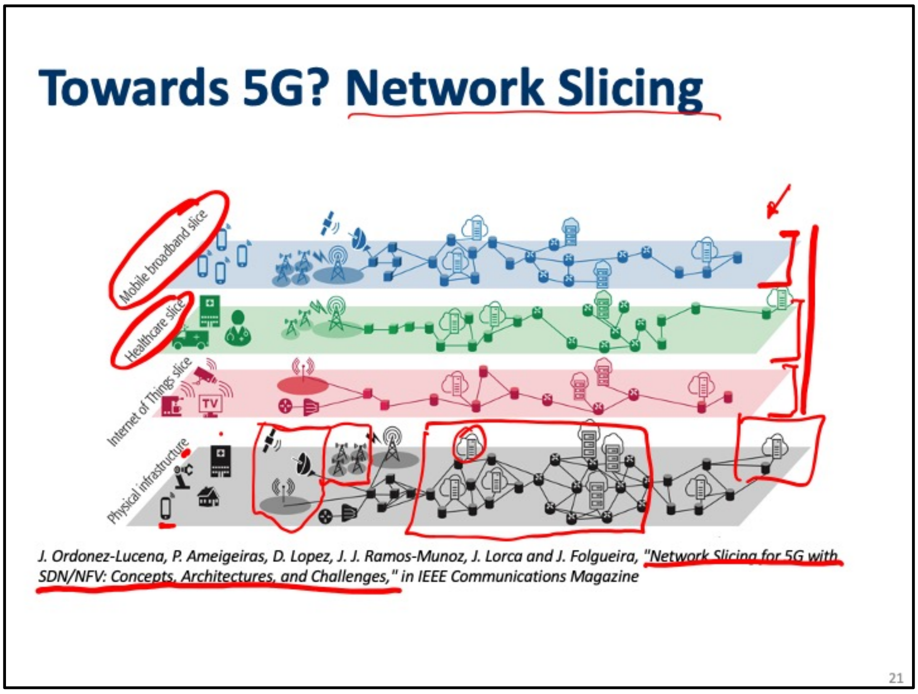
VNF Manager

Virtualized Infrastructure Manager (VIM)

VIM: is responsible for managing the physical and virtual resources. It interfaces with the NFV Infrastructure (possibly across different hosts).

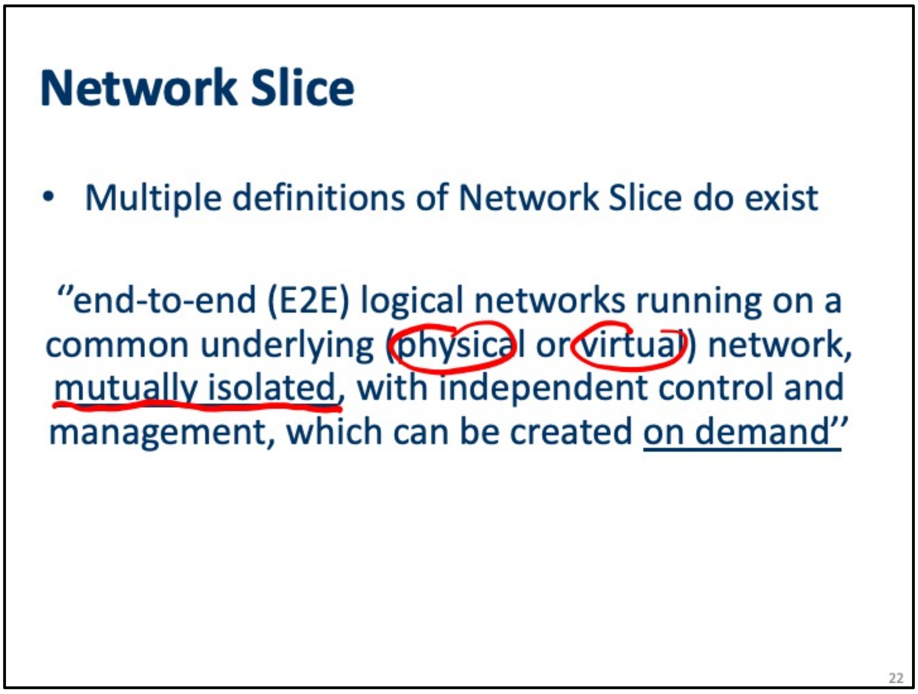
It manages the resources based on the input from the VNFM and NFVO

Virtualized Infrastructure Manager: This controls and manages the NFVI compute, storage, and network resources within one operator's infrastructure subdomain. It is responsible for the collection and forwarding of performance measurements and events.



Towards 5G? Network Slicing

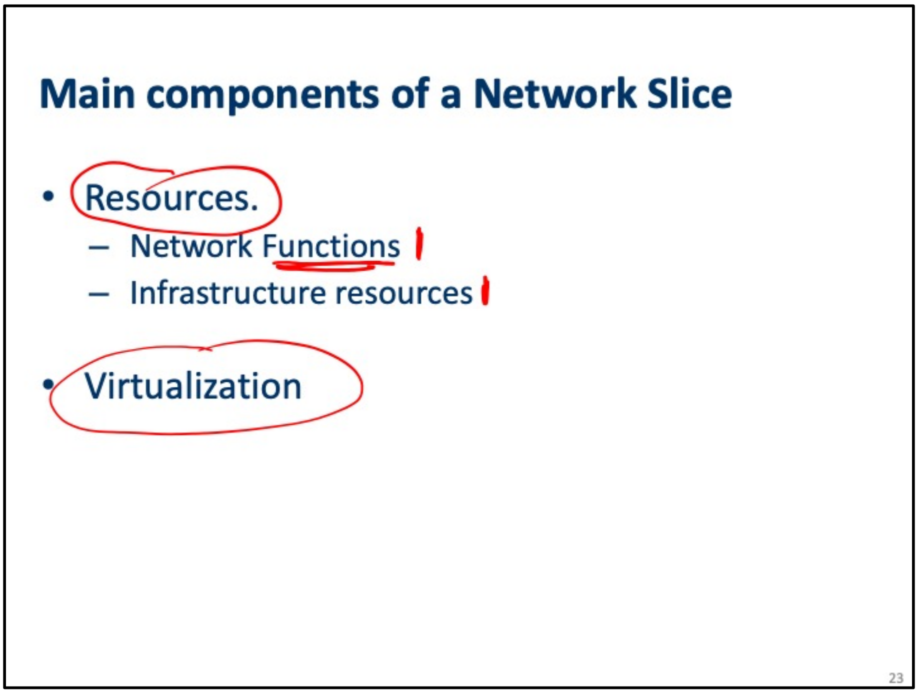
J. Ordonez-Lucena, P. Ameigeiras, D. Lopez, J. J. Ramos-Munoz, J. Lorca and J. Folgueira, "Network Slicing for 5G with SDN/NFV: Concepts, Architectures, and Challenges," in IEEE Communications Magazine



Network Slice

- Multiple definitions of Network Slice do exist

''end-to-end (E2E) logical networks running on a common underlying (physical or virtual) network, mutually isolated, with independent control and management, which can be created on demand''



Main components of a Network Slice

- Resources.
  - Network Functions
  - Infrastructure resources
- Virtualization

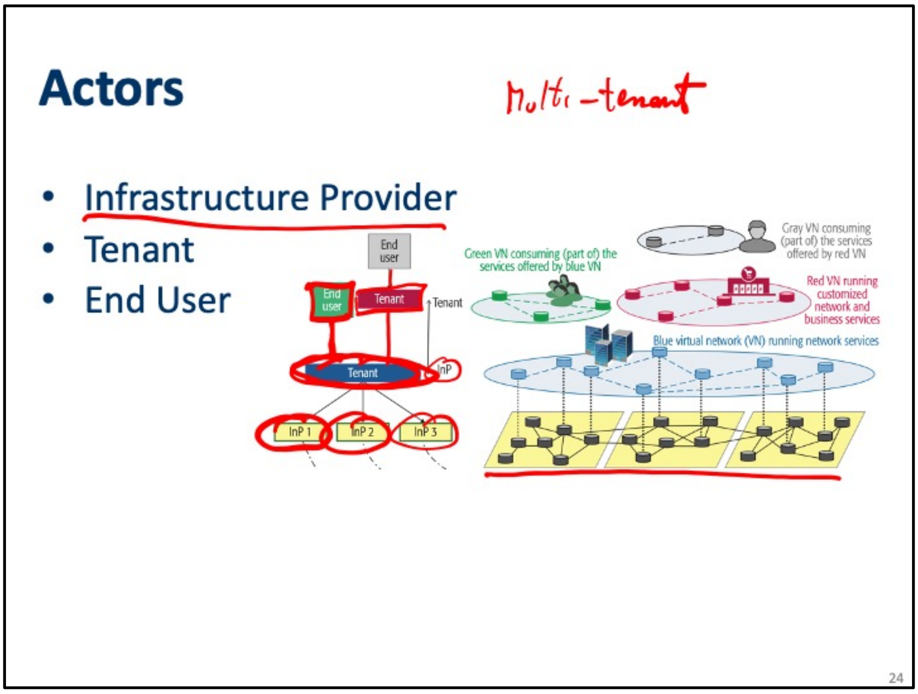
a **resource** is a manageable unit, defined by a set of attributes or capabilities that can be used to deliver a service.

Network Functions (NFs): Functional blocks that provide specific network capabilities to sup-port and realize the particular service(s) each use case demands. Generally implemented as software instances running on infrastructure resources, NFs can be physical (a combination of vendor-specific hardware and software, defin- ing a traditional purpose-built physical appliance) and/or virtualized (network function software is decoupled from the hardware it runs on).

Infrastructure Resources: Heterogeneous hard- ware and necessary software for hosting and con- necting NFs. They include computing hardware, storage capacity, networking resources (e.g., links and switching/routing devices enabling network connectivity), and physical assets for radio access. Suitable for use in network slicing, the aforemen- tioned resources and their attributes have to be abstracted and logically partitioned leveraging vir- tualization mechanisms, defining virtual resources that can be used in the same way as physical ones.

Virtualization is the abstraction of resources using appropriate techniques.

Just as server virtualization [2] makes virtual machines (VMs) independent of the underlying physical hardware, network virtualization [3] enables the creation of multiple isolated virtual networks that are completely decoupled from the underlying phys- ical network and can safely run on top of it.



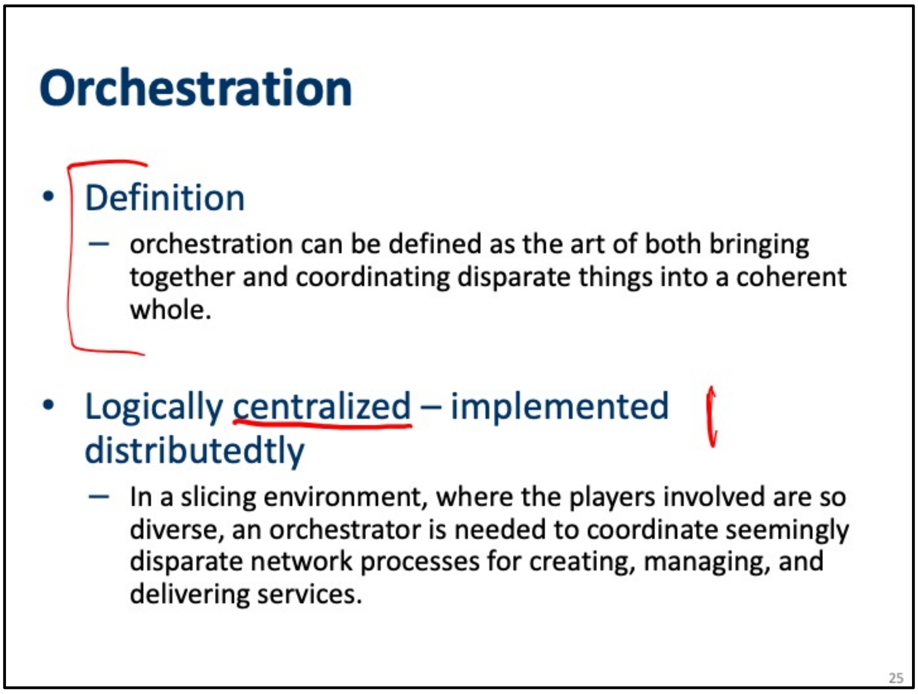
Actors

Multi-tenant

- Infrastructure Provider
- Tenant
- End User

End user
End user
Tenant
Tenant
Tenant
InP
InP 1
InP 2
InP 3
Green VN consuming (part of) the services offered by blue VN
Gray VN consuming (part of) the services offered by red VN
Red VN running customized network and business services
Blue virtual network (VN) running network services
24

- Infrastructure provider (InP): owns and manages a given physical network and its constituent resources. Such resources, in the form of WANs and/or data centers (DCs), are virtualized and then offered through programming interfaces to a single or multiple tenants.
- Tenant: leases virtual resources from one or more InPs in the form of a virtual network, where the tenant can realize, manage, and provide network services to its users. A network service is a composition of NFs, and it is defined in terms of the individual NFs and the mechanism used to connect them.
- End user: consumes (part of) the services supplied by the tenant, without providing them to other business actors.

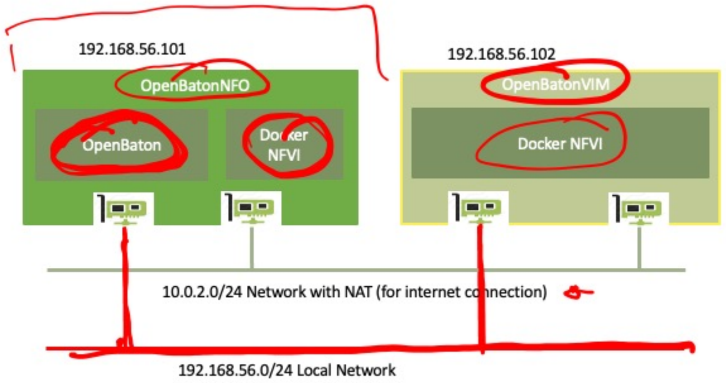


Orchestration

- Definition
  - orchestration can be defined as the art of both bringing together and coordinating disparate things into a coherent whole.
- Logically centralized – implemented distributedtly
  - In a slicing environment, where the players involved are so diverse, an orchestrator is needed to coordinate seemingly disparate network processes for creating, managing, and delivering services.

orchestration can be defined as the art of both bringing together and coordinating disparate things into a coherent whole. In a slicing environment, where the players involved are so diverse, an orchestrator is needed to coordinate seemingly disparate network processes for creating, managing, and delivering services.

Next Steps: lab session



192.168.56.101

OpenBatonNFO

OpenBaton

Docker NFVI

192.168.56.102

OpenBatonVIM

Docker NFVI

10.0.2.0/24 Network with NAT (for internet connection)

192.168.56.0/24 Local Network

User: osboxes / Password: osboxes.org