

Introduction to Network Function Virtualization (NFV)

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These slides and audio/video recordings of this class lecture are at:

<http://www.cse.wustl.edu/~jain/cse570-19/>

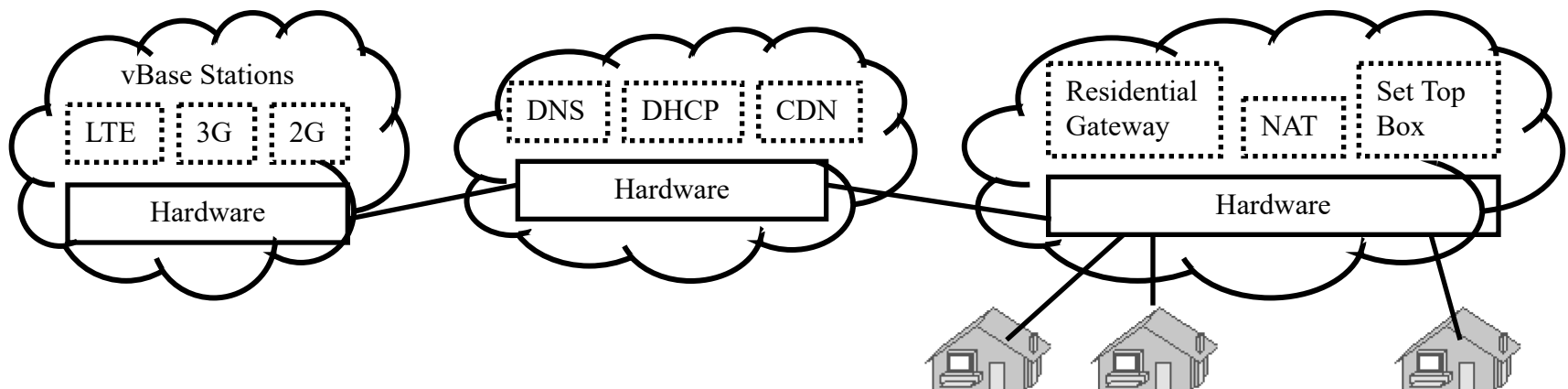


1. What is NFV?
2. NFV and SDN Relationship
3. ETSI NFV ISG Specifications
4. Concepts, Architecture, Requirements, Use cases
5. Proof-of-Concepts and Timeline

Note: This module is the 3rd in a series of modules on OpenFlow, SDN and NFV in this course.

Network Function Virtualization (NFV)

1. Fast standard hardware \Rightarrow **Software based Devices**
Routers, Firewalls, Broadband Remote Access Server (BRAS)
 \Rightarrow A.k.a. *white box* implementation
2. **Function Modules** (Both data plane and control plane)
 \Rightarrow DHCP (Dynamic Host control Protocol), NAT (Network Address Translation), Rate Limiting,



Ref: ETSI, "NFV – Update White Paper V3," Oct 2014, http://portal.etsi.org/NFV/NFV_White_Paper3.pdf (Must read)

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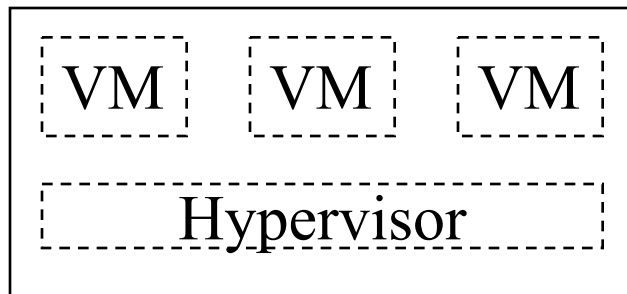
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NFV (Cont)

3. Virtual Machine implementation

⇒ Virtual appliances

⇒ All advantages of virtualization (quick provisioning, scalability, mobility, Reduced CapEx, Reduced OpEx, ...)



Partitioning

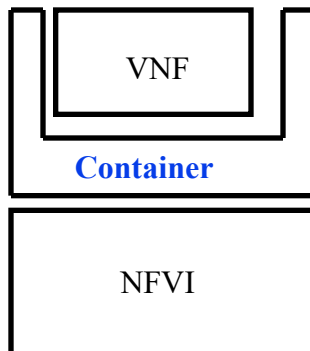
4. **Standard APIs:** New ISG (Industry Specification Group) in ETSI (European Telecom Standards Institute) set up in November 2012

Mobile Network Functions

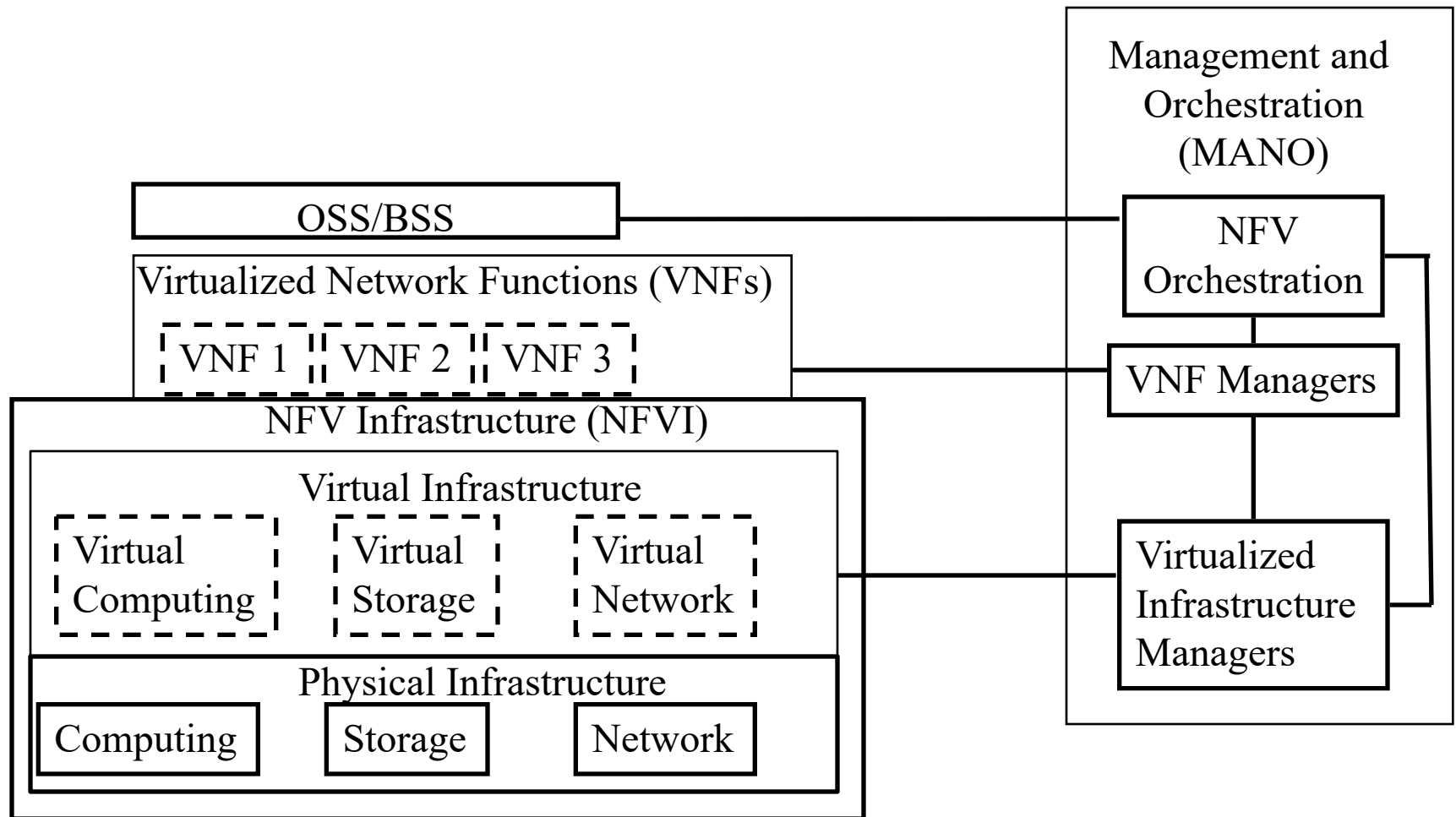
- ❑ Switches, e.g., Open vSwitch
- ❑ Routers, e.g., Click
- ❑ Home Location Register (HLR),
- ❑ Serving GPRS Support Node (SGSN),
- ❑ Gateway GPRS Support Node (GGSN),
- ❑ Combined GPRS Support Node (CGSN),
- ❑ Radio Network Controller (RNC),
- ❑ Serving Gateway (SGW),
- ❑ Packet Data Network Gateway (PGW),
- ❑ Residential Gateway (RGW),
- ❑ Broadband Remote Access Server (BRAS),
- ❑ Carrier Grade Network Address Translator (CGNAT),
- ❑ Deep Packet Inspection (DPI),
- ❑ Provider Edge (PE) Router,
- ❑ Mobility Management Entity (MME),
- ❑ Element Management System (EMS)

VNF

- ❑ **NFV Infrastructure (NFVI):** Hardware and software required to deploy, manage and execute VNFs
- ❑ **Network Function (NF):** Functional building block with a well defined interfaces and well defined functional behavior
- ❑ **Virtualized Network Function (VNF):** Software implementation of NF that can be deployed in a virtualized infrastructure
- ❑ **Container:** VNF is independent of NFVI but needs a container software on NFVI to be able to run on different hardwares



NFV Architecture



Ref: ETSI, "Architectural Framework," 2015,

http://www.etsi.org/deliver/etsi_gs/NFV/001_099/002/01.02.01_60/gs_NFV002v010201p.pdf

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NFV Proof of Concepts (PoCs)

ETSI has formed and NFV ISG PoC Forum.

Following modules have been demoed:

1. Virtual Broadband Remote Access Server (BRAS) by British Telecom
2. Virtual IP Multimedia System (IMS) by Deutsche Telekom
3. Virtual Evolved Packet Core (vEPC) by Orange Silicon Valley
4. Carrier-Grade Network Address Translator (CGNAT) and Deep Packet Inspection (DPI), Home Gateway by Telefonica
5. Perimeta Session Border Controller (SBC) from Metaswitch
6. Deep packet inspection from Procera

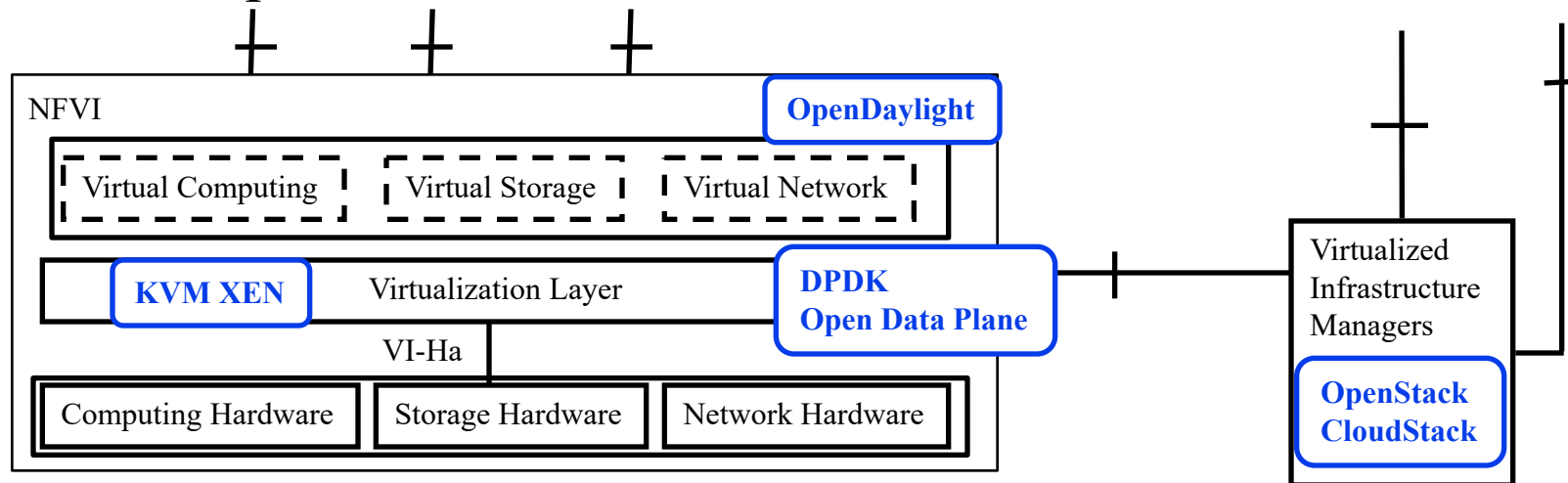
Most of these are based on Cloud technologies, e.g., OpenStack

Ref: M. Cohn, "NFV Group Flocks to Proof-of-Concept Demos," Aug 2013,

<http://www.sdncentral.com/technology/nfv-group-flocks-to-proof-of-concept-models/2013/08/>

OPNFV

- ❑ Open Source NFV implementation project under Linux Foundation (Similar to OpenDaylight)
- ❑ Founded September 2014
- ❑ Initial goal to integrate KVM, OpenStack, and OpenDaylight
- ❑ Integrated project will be run through software testing labs at service providers



Ref: K. Gray and T. Dadeau, "Network Function Virtualization," Morgan Kaufmann, July 2016, 270 pp., ISBN:0128021195

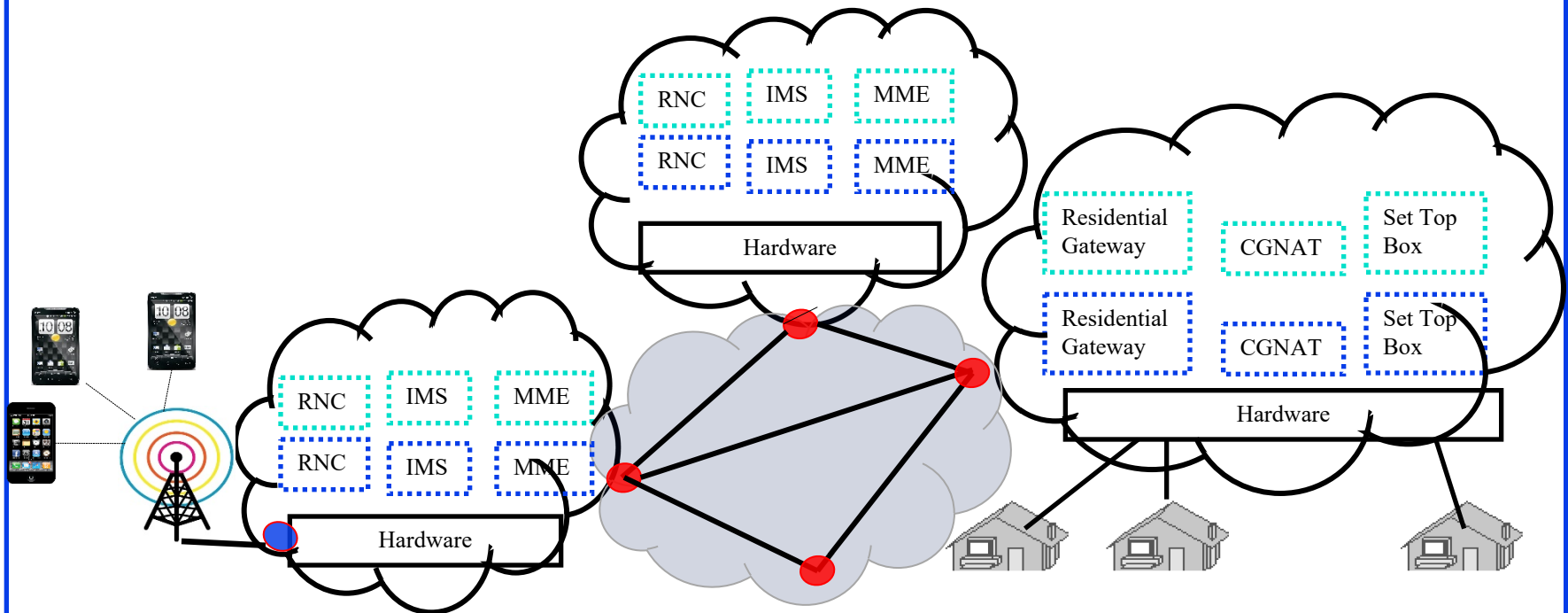
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Service Chaining in a Multi-Cloud Multi-Tenant Environment

- ❑ VNFs (Virtual network fns) belong to tenants. Multiple tenants.
- ❑ Each Cloud belongs to a different Cloud Service Provider (CSP)
- ❑ Internet infrastructure belongs to an NFVI service provider (NSP)
- ❑ Service chain = Workflow



Challenges in Service Chaining

❑ **Dynamic:**

- Forwarding changes with state of the servers, links, ...
- Independent of physical topology

❑ **Content sensitive:**

- Different for different types of videos, read-writes, ...

❑ **Distributed Control:**

- Equipment belongs to infrastructure provider
- Data belongs to Tenants

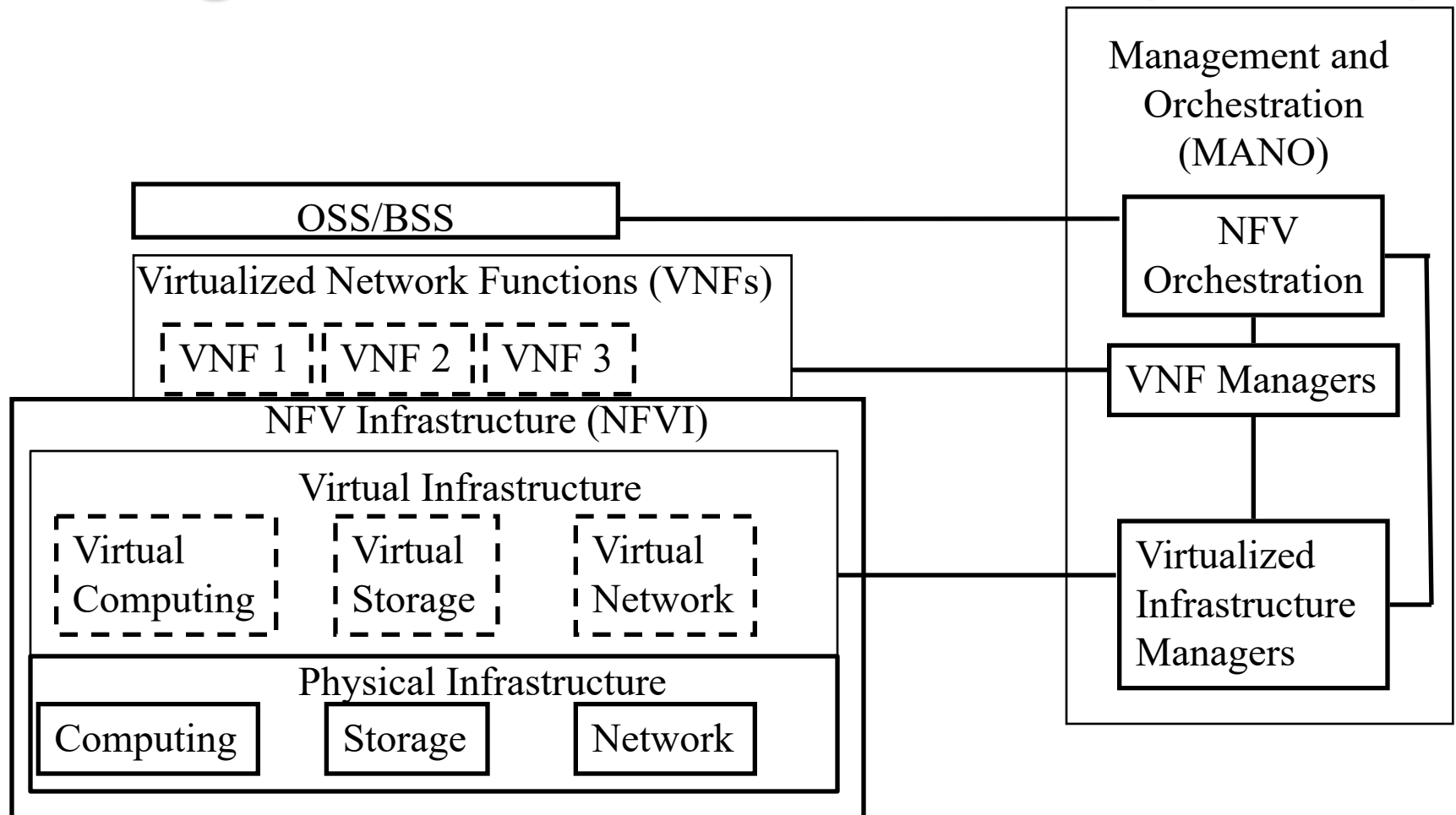
❑ **Massive Scale:**

- Billions of users with different user context

❑ **Stateful Services:**

- All packets of a flow should be sent to the same replica
 - ❑ Message level services (firewalls),
 - ❑ Packet level services (intrusion detection)

Management and Orchestration (MANO)



Ref: ETSI, "Architectural Framework," 2015,

http://www.etsi.org/deliver/etsi_gs/NFV/001_099/002/01.02.01_60/gs_NFV002v010201p.pdf

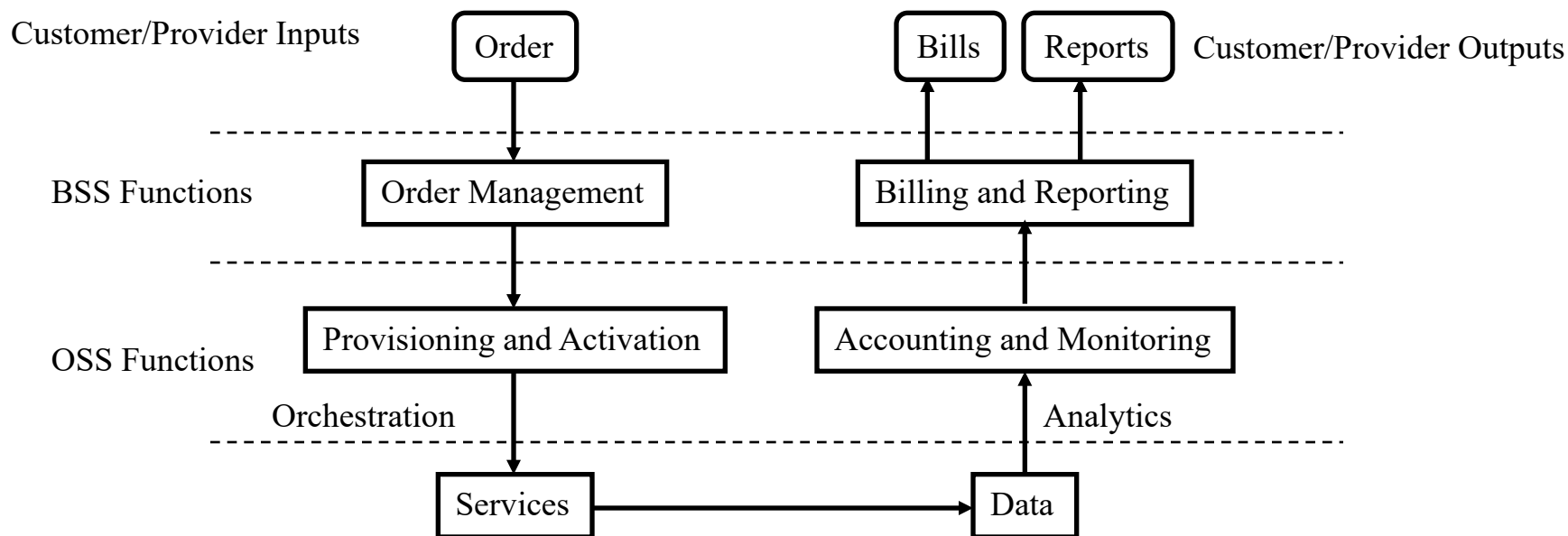
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MANO (Cont)

- ❑ Operation Support System (OSS)
- ❑ Business Support System (BSS)
- ❑ Element Management System, VNF Management, Infrastructure Management, Orchestration



Ref: Ken Gray and Thomas Nadeau, "Network Function Virtualization," Morgan Kaufmann, July 2016, 238 pp., ISBN: 978-0-12-802119-4, (Safari Book)

Open Source MANO Implementations

- ❑ Open-O: Linux Foundation project for open orchestration
- ❑ ECOMP: Linux Foundation project for Enhanced Control, Orchestration, Management, and Policy (Led by AT&T)
- ❑ **ONAP**: Open Network Automation Platform
Open-O and ECOMP merged at Linux Foundation
- ❑ **TACKER**: OpenStack project for NFV orchestration
- ❑ **Open Source MANO (OSM)**: ETSI effort started by Telefonica in 2015
- ❑ Most of these use TOSCA templates

Ref: <https://wiki.open-o.org/>, <https://about.att.com/content/dam/snrdocs/ecomp.pdf>, <https://www.onap.org/>,
<https://wiki.openstack.org/wiki/Tacker>, <http://www.etsi.org/technologies-clusters/technologies/nfv/open-source-mano>,
<https://openbaton.github.io/>

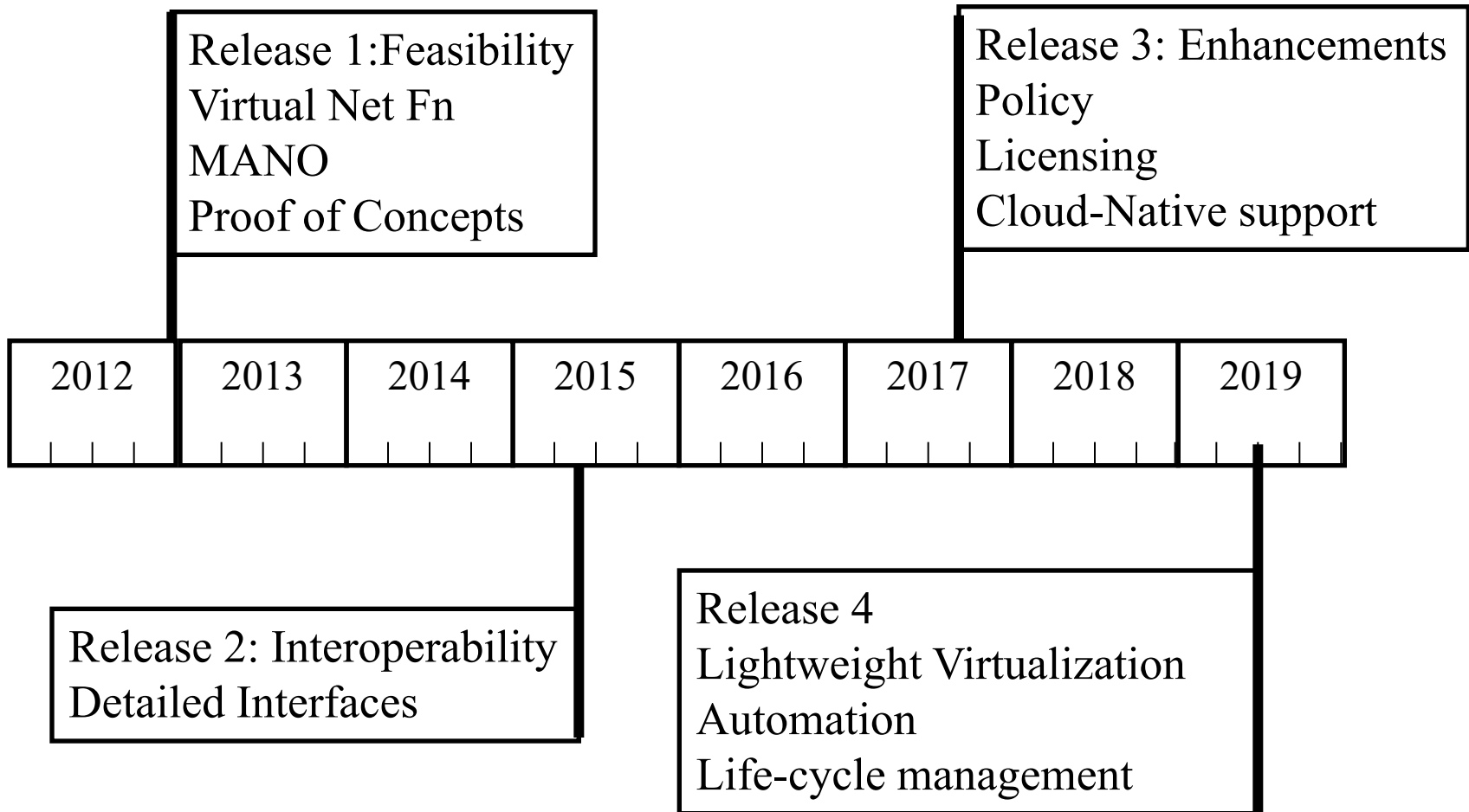
TOSCA

- ❑ Topology and Orchestration Specification for Cloud Applications
- ❑ TOSCA template for an application describes the resources required to run the application on a cloud
- ❑ Resources can be compute, network, storage, databases, etc.
- ❑ TOSCA template includes a graph modeling the relationships between various components and operations on them
- ❑ Orchestration engines can use the TOSCA template to create an instance of the application. Resources required are also created in correct order. For example, a database will be created before the program that needs it, etc.

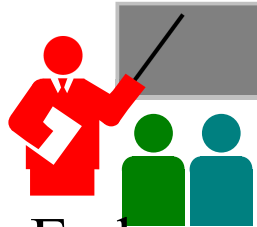
Ref: OASIS, "TOSCA Simple Profile in YAML Version 1.1," Jan 2018, 282 pp.,

<http://docs.oasis-open.org/tosca/TOSCA-Simple-Profile-YAML/v1.1/os/TOSCA-Simple-Profile-YAML-v1.1-os.pdf>

NFV Releases



Summary



1. NFV aims to reduce OpEx by automation and scalability provided by implementing network functions as virtual appliances
2. NFV allows all benefits of virtualization and cloud computing including orchestration, scaling, automation, hardware independence, pay-per-use, fault-tolerance, ...
3. NFV and SDN are independent and complementary. You can do either or both.
4. NFV requires standardization of reference points and interfaces to be able to mix and match VNFs from different sources
5. NFV can be done now. Several of virtual functions have already been demonstrated by carriers.

Reading List

- ❑ Ken Gray and Thomas Nadeau, “Network Function Virtualization,” Morgan Kaufmann, July 2016, 238 pp., ISBN: 978-0-12-802119-4, (Safari Book) – **Recommended Reading**
- ❑ Jim Doherty, "SDN and NFV Simplified: A Visual Guide to Understanding Software Defined Networks and Network Function Virtualization," Addison-Wesley Professional, March 2, 2016, 320 pp., ISBN:978-0-13-430739-8 (Safari Book).
- ❑ Ying Zhang, "Network Function Virtualization," Wiley-IEEE Press, January 2018, 192 pp., ISBN:978-1-119-39060-2 (Safari Book).
- ❑ Rajendra Chayapathi, Syed Farrukh Hassan, Paresh Shah, "Network Functions Virtualization (NFV) with a Touch of SDN," Addison-Wesley Professional, November 2016, 368 pp., ISBN:978-0-13-446431-2 (Safari Book).
- ❑ Russ White, Jeff Tantsura, "Navigating Network Complexity: Next-generation Routing with SDN, Service Virtualization, and Service Chaining," Addison-Wesley Professional, November 2015, 320 pp., ISBN:0-13-398792-2 (Safari Book).

References

- ❑ ETSI, "Architectural Framework," 2015 ,
http://www.etsi.org/deliver/etsi_gs/NFV/001_099/002/01.02.01_60/gs_NFV002v010201p.pdf
- ❑ ETSI, "NFV - Update White Paper V3," Oct 2014,
http://portal.etsi.org/NFV/NFV_White_Paper3.pdf (Must read)
- ❑ ETSI, "White Paper on NFV priorities for 5G," Feb 2017, 15 pp.,
http://portal.etsi.org/NFV/NFV_White_Paper_5G.pdf
- ❑ ETSI, "NFV Terminology for Main Concepts in NFV," 2015,
http://www.etsi.org/deliver/etsi_gs/NFV/001_099/003/01.02.01_60/gs_NFV003v010201p.pdf
- ❑ ETSI Specifications, see the public download directory at
https://docbox.etsi.org/ISG/NFV/Open/Publications_pdf/Specs-Reports

Acronyms

- ❑ API Application Programming Interface
- ❑ BRAS Broadband Remote Access Server
- ❑ BSS Business Support Systems
- ❑ CapEx Capital Expenditure
- ❑ CDN Content Distribution Network
- ❑ CGNAT Carrier-Grade Network Address Translator
- ❑ CGSN Combined GPRS Support Node
- ❑ COTS Commercial-off-the-shelf
- ❑ DDIO Data Direct I/O Technology
- ❑ DHCP Dynamic Host control Protocol
- ❑ DPI Deep Packet Inspection
- ❑ EMS Element Management System
- ❑ ETSI European Telecom Standards Institute
- ❑ GGSN Gateway GPRS Support Node
- ❑ GPRS General Packet Radio Service
- ❑ HLR Home Location Register
- ❑ IaaS Infrastructure as a Service

Acronyms (Cont)

- ❑ IETF Internet Engineering Task Force
- ❑ IMS IP Multimedia System
- ❑ INF Architecture for the virtualization Infrastructure
- ❑ IP Internet Protocol
- ❑ ISG Industry Specification Group
- ❑ LSP Label Switched Path
- ❑ MANO Management and orchestration
- ❑ MME Mobility Management Entity
- ❑ NAT Network Address Translation
- ❑ NF Network Function
- ❑ NFV Network Function Virtualization
- ❑ NFVI Network Function Virtualization Infrastructure
- ❑ NFVlaaS NFVI as a Service
- ❑ NIC Network Interface Card
- ❑ OpEx Operational Expences
- ❑ OS Operating System

Acronyms (Cont)

- ❑ OSS Operation Support System
- ❑ PaaS Platform as a Service
- ❑ PE Provider Edge
- ❑ PGW Packet Data Network Gateway
- ❑ PoC Proof-of-Concept
- ❑ PoP Point of Presence
- ❑ PSTN Public Switched Telephone Network
- ❑ QoS Quality of Service
- ❑ REL Reliability, Availability, resilience and fault tolerance group
- ❑ RGW Residential Gateway
- ❑ RNC Radio Network Controller
- ❑ SaaS Software as a Service
- ❑ SBC Session Border Controller
- ❑ SDN Software Defined Networking
- ❑ SGSN Serving GPRS Support Node
- ❑ SGW Serving Gateway

Acronyms (Cont)

- ❑ SIP Session Initiation Protocol
- ❑ SLA Service Level Agreement
- ❑ SWA Software architecture
- ❑ TAS Telephony Application Server
- ❑ TMF TM Forum
- ❑ vEPC Virtual Evolved Packet Core
- ❑ VM Virtual Machine
- ❑ VNF Virtual Network Function
- ❑ VNFaaS VNF as a Service
- ❑ vSwitch Virtual Switch
- ❑ VT-d Virtualization Technology for Direct IO
- ❑ VT-x Virtualization Technology

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Related Modules



CSE567M: Computer Systems Analysis (Spring 2013),

https://www.youtube.com/playlist?list=PLjGG94etKypJEKjNAa1n_1X0bWWNyZcof

CSE473S: Introduction to Computer Networks (Fall 2011),

https://www.youtube.com/playlist?list=PLjGG94etKypJWOSPMh8Azcg5e_10TiDw



Wireless and Mobile Networking (Spring 2016),

https://www.youtube.com/playlist?list=PLjGG94etKypKeb0nzyN9tSs_HCd5c4wXF

CSE571S: Network Security (Fall 2011),

<https://www.youtube.com/playlist?list=PLjGG94etKypKvzfVtutHcPFJXumyyg93u>



Video Podcasts of Prof. Raj Jain's Lectures,

<https://www.youtube.com/channel/UCN4-5wzNP9-ruOzQMs-8NUw>