

Introduction to Network Function Virtualization (NFV)

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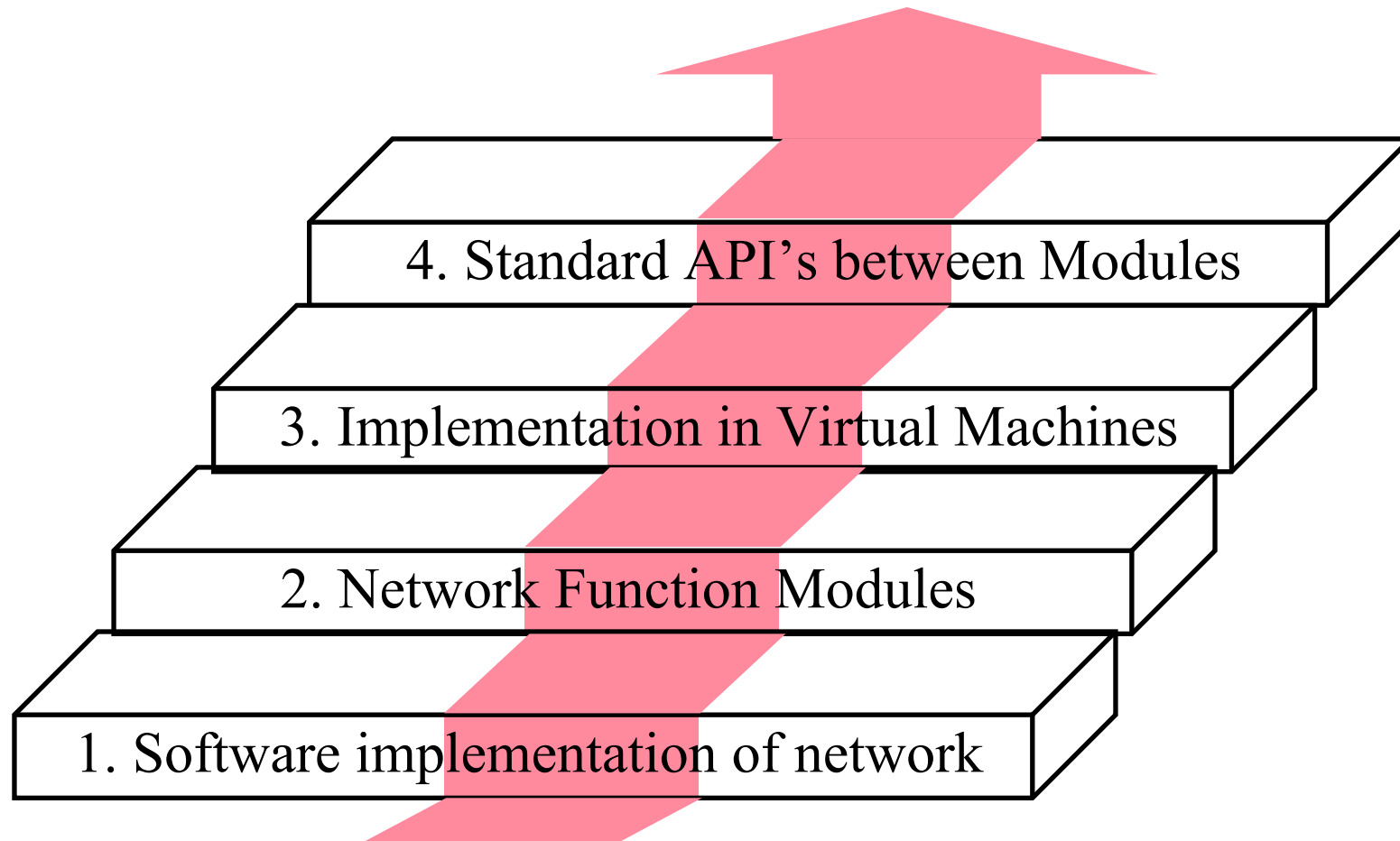
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1. What is NFV?
2. NFV and SDN Relationship
3. ETSI NFV ISG Specifications
4. Concepts, Architecture, Requirements, Use cases
5. Proof-of-Concepts and Timeline

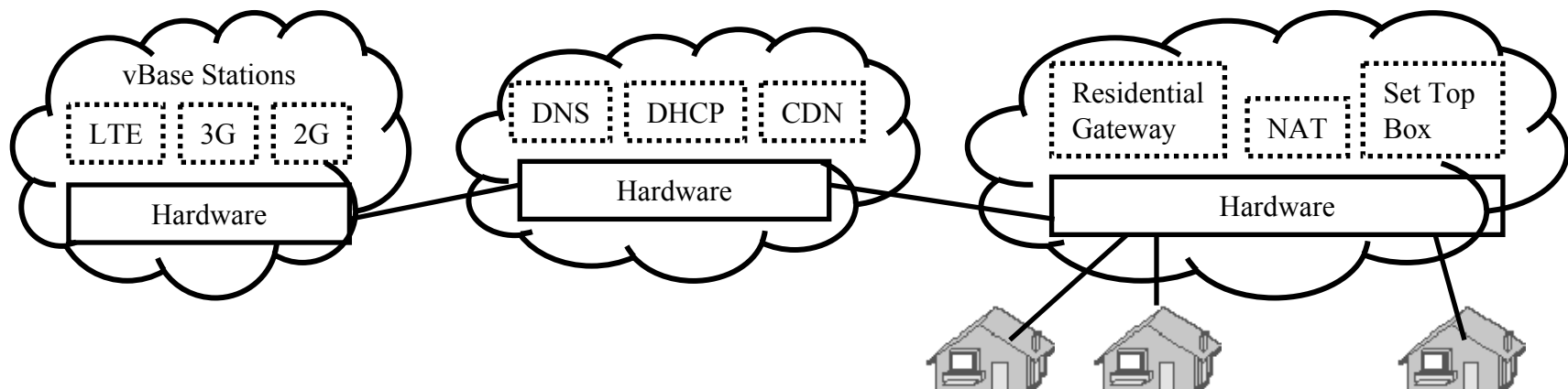
Note: This module is a part of a series of modules on OpenFlow, SDN and NFV in this course.

Four Innovations of NFV



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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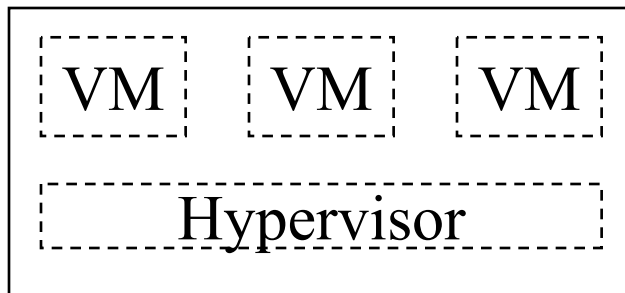
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NFV (Cont)

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

Why We need NFV?

1. **Virtualization**: Use network resource without worrying about where it is physically located, how much it is, how it is organized, etc.
2. **Orchestration**: Manage thousands of devices
3. **Programmable**: Should be able to change behavior on the fly.
4. **Dynamic Scaling**: Should be able to change size, quantity
5. **Automation**
6. **Visibility**: Monitor resources, connectivity
7. **Performance**: Optimize network device utilization
8. **Multi-tenancy**
9. **Service Integration**
10. **Openness**: Full choice of Modular plug-ins

Note: These are exactly the same reasons why we need SDN.

NFV and SDN Relationship

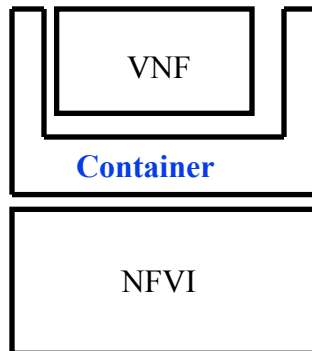
- ❑ Concept of NFV originated from SDN
 - ⇒ First ETSI white paper showed overlapping Venn diagram
 - ⇒ It was removed in the second version of the white paper
- ❑ NFV and SDN are complementary.
One does not strictly depend upon the other.
You can do SDN only, NFV only, or SDN and NFV.
- ❑ Both have similar goals but approaches are very different.
- ❑ Management/virtualization of large networks becomes easier with SDN
- ❑ SDN needs new interfaces, control modules, applications.
NFV requires moving network applications from dedicated hardware to virtual containers on commercial-off-the-shelf (COTS) hardware.
- ❑ NFV is present. SDN is the future.
- ❑ Multiple flavors of SDN resulting in a debate. Not much debate about NFV.

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)

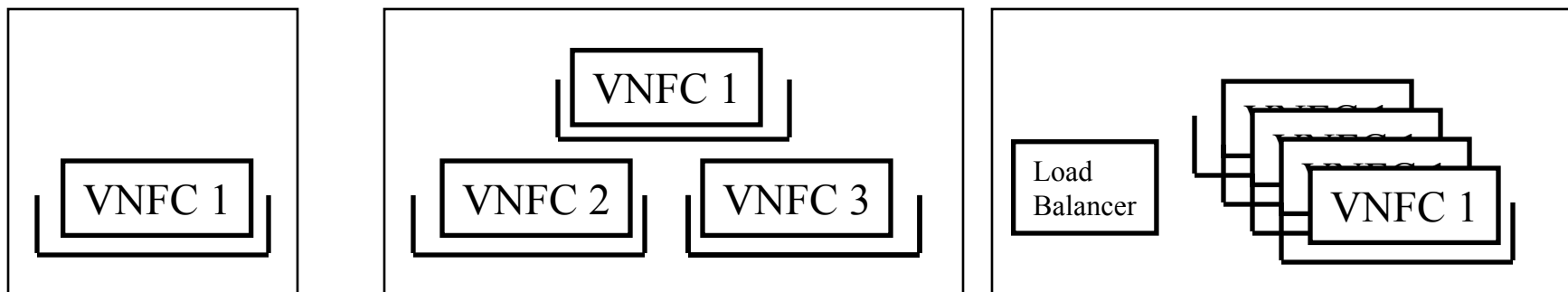
VNF

- ❑ **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 Concepts

- ❑ **Containers Types:** Related to Computation, Networking, Storage
- ❑ **VNF Components (VNFC):** A VNF may have one or more components
- ❑ **VNF Set:** Connectivity between VNFs is not specified, e.g., residential gateways
- ❑ **VNF Forwarding Graph:** Service chain when network connectivity order is important, e.g., firewall, NAT, load balancer



Ref: ETSI, “Architectural Framework,” 2015 , http://www.etsi.org/deliver/etsi_gs/NFV/001_099/002/01.02.01_60/gs_NFV002v010201p.pdf

Ref: ETSI, “NFV Terminology for Main Concepts in NFV,” 2015,

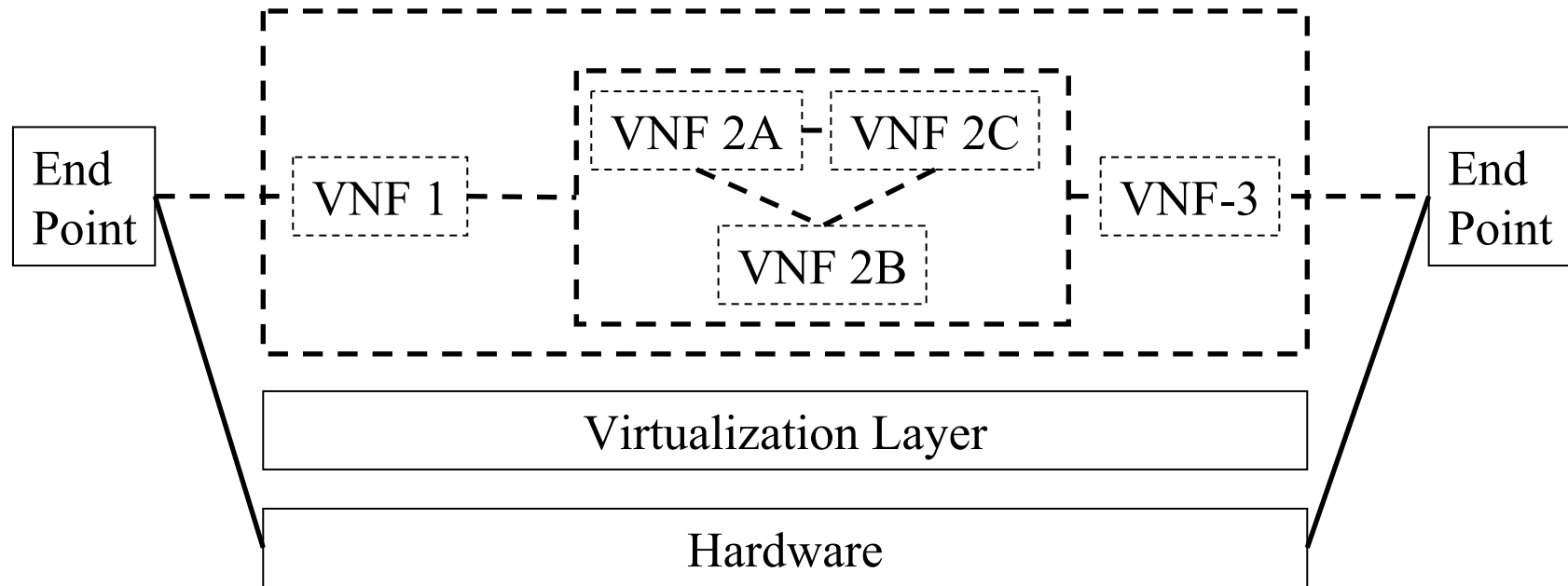
http://www.etsi.org/deliver/etsi_gs/NFV/001_099/003/01.02.01_60/gs_NFV003v010201p.pdf
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Network Forwarding Graph

- An end-to-end service may include nested forwarding graphs



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 Concepts (Cont)

- ❑ **NFVI Point of Presence (PoP)**: Location of NFVI
- ❑ **NFVI-PoP Network**: Internal network
- ❑ **Transport Network**: Network connecting a PoP to other PoPs or external networks
- ❑ **VNF Manager**: VNF lifecycle management e.g., instantiation, update, scaling, query, monitoring, fault diagnosis, healing, termination
- ❑ **Virtualized Infrastructure Manager**: Management of computing, storage, network, software resources
- ❑ **Network Service**: A composition of network functions and defined by its functional and behavioral specification
- ❑ **NFV Service**: A network services using NFs with at least one VNF.

NFV Concepts (Cont)

- ❑ **User Service:** Services offered to end users/customers/subscribers.
- ❑ **Deployment Behavior:** NFVI resources that a VNF requires, e.g., Number of VMs, memory, disk, images, bandwidth, latency
- ❑ **Operational Behavior:** VNF instance topology and lifecycle operations, e.g., start, stop, pause, migration, ...
- ❑ **VNF Descriptor:** Deployment behavior + Operational behavior
- ❑ **NFV Orchestrator:** Automates the deployment, operation, management, coordination of VNFs and NFVI.
- ❑ **VNF Forwarding Graph:** Connection topology of various NFs of which at least one is a VNF

NFV Reference Points

Reference Point: Points for inter-module specification

1. Virtualization Layer-Hardware Resources (**VI-Ha**)
2. VNF – NFVI (**Vn-Nf**)
3. Orchestrator – VNF Manager (**Or-Vnfm**)
4. Virtualized Infrastructure Manager – VNF Manager (**Vi-Vnfm**)
5. Orchestrator – Virtualized Infrastructure Manager (**Or-Vi**)
6. NFVI-Virtualized Infrastructure Manager (**Nf-Vi**)
7. Operation Support System (OSS)/Business Support Systems (BSS) – NFV Management and Orchestration (**Os-Ma**)
8. VNF/ Element Management System (EMS) – VNF Manager (**Ve-Vnfm**)
9. Service, VNF and Infrastructure Description – NFV Management and Orchestration (**Se-Ma**): VNF Deployment template, VNF Forwarding Graph, service-related information, NFV infrastructure information

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 Framework Requirements

1. **General:** Partial or full Virtualization, Predictable performance
2. **Portability:** Decoupled from underlying infrastructure
3. **Performance:** as described and facilities to monitor
4. **Elasticity:** Scalable to meet SLAs. Movable to other servers.
5. **Resiliency:** Be able to recreate after failure.
Specified packet loss rate, calls drops, time to recover, etc.
6. **Security:** Role-based authorization, authentication
7. **Service Continuity:** Seamless or non-seamless continuity after failures or migration

Ref: ETSI, "NFV Virtualization Requirements," 2015,

http://www.etsi.org/deliver/etsi_gs/NFV/001_099/004/01.01.01_60/gs_NFV004v010101p.pdf

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NFV Framework Requirements (Cont)

8. **Service Assurance:** Time stamp and forward copies of packets for Fault detection
9. **Energy Efficiency Requirements:** Should be possible to put a subset of VNF in a power conserving sleep state
10. **Transition:** Coexistence with Legacy and Interoperability among multi-vendor implementations
11. **Service Models:** Operators may use NFV infrastructure operated by other operators

NFV Use Cases

- ❑ **Home Environment:** Virtualization of the Home environment
- ❑ **CDNS:** Virtualization of Content Distribution Networks
- ❑ **Fixed Access Network:** Fixed Access NFV
- ❑ **NFVIaaS:** NFVI as a service like IaaS
- ❑ **VNFaaS:** VNFs as a service like SaaS
- ❑ **VNPaaS:** Virtual Network Platform as a Service like PaaS
- ❑ **VNF Forwarding Graph:** VNF forwarding graphs (Service Chains)
- ❑ **Mobile Core and IMS:** Virtualization of the Mobile Core Network and IP Multimedia System
- ❑ **Mobile Base Station:** Virtualization of Mobile Base Station

Ref: ETSI, "NFV Use Cases," http://www.etsi.org/deliver/etsi_gs/NFV/001_099/001/01.01.01_60/gs_NFV001v010101p.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,

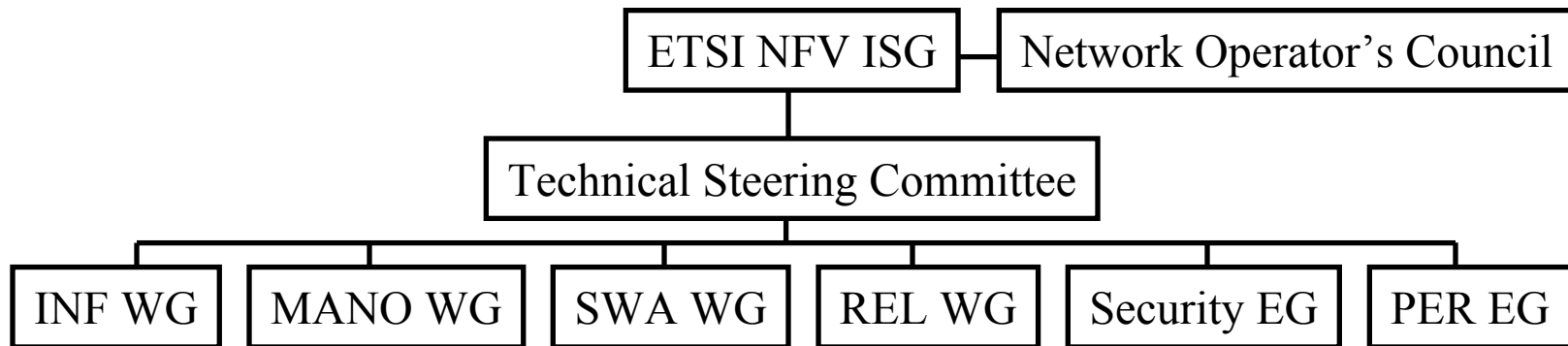
<http://www.sdncentral.com/technology/nfv-group-flocks-to-proof-of-concept-models/2013/08/>

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ETSI NFV ISG



- ❑ Industry Specification Group (ISG)'s goal is to define the requirements.
- ❑ Four Working Groups:
 - **INF**: Architecture for the virtualization Infrastructure
 - **MANO**: Management and orchestration
 - **SWA**: Software architecture
 - **REL**: Reliability and Availability, resilience and fault tolerance

Ref: M. Cohn, "NFV, An Insider's Perspective: Part 1: Goals, History, and Promise," Sep 2013,

<http://www.sdncentral.com/education/nfv-insiders-perspective-part-1-goals-history-promise/2013/09/>

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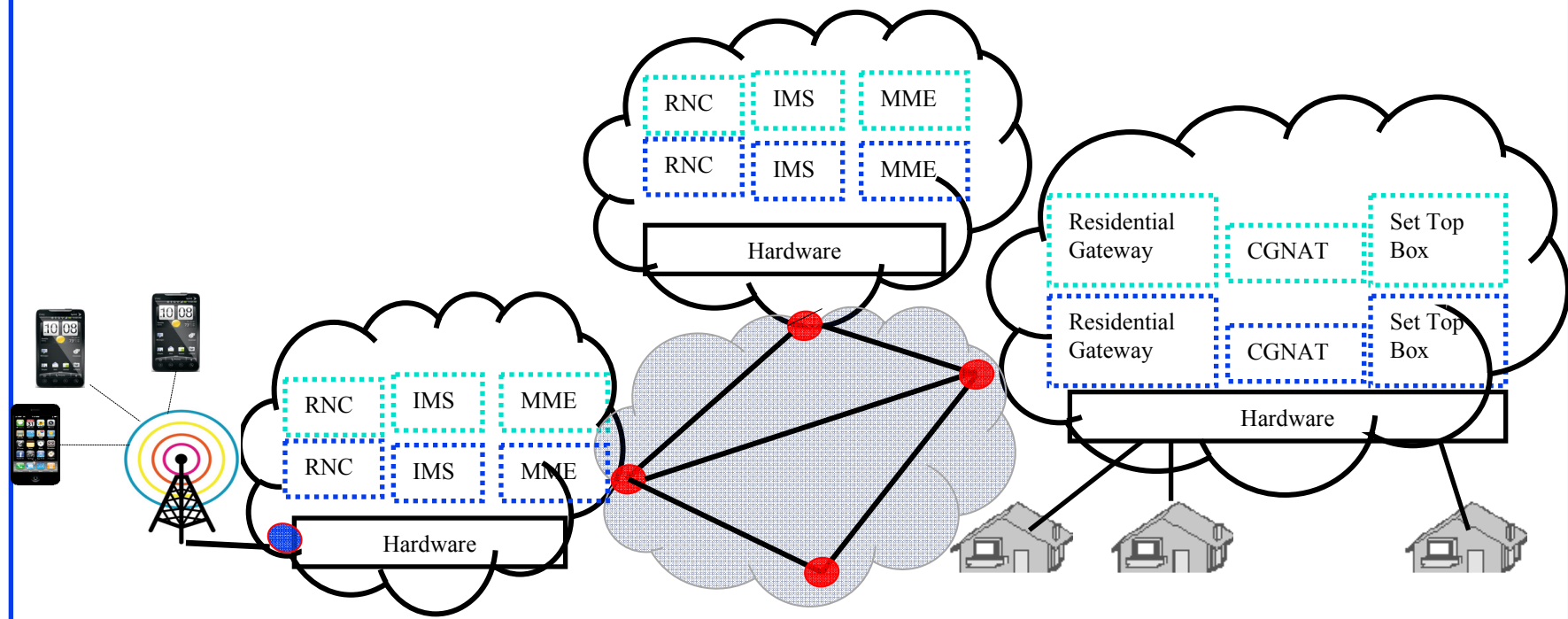
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ETSI NFV ISG (Cont)

- Two Expert Groups:
 - **Security** Expert Group: Security
 - **Performance and Portability** Expert Group: Scalability, efficiency, and performance VNFs relative to current dedicated hardware

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, ...
- ❑ **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)

Any Function Virtualization (FV)

- ❑ Network function virtualization of interest to Network service providers
- ❑ But the same concept can be used by any other industry, e.g., financial industry, banks, stock brokers, retailers, mobile games, ...
- ❑ Everyone can benefit from:
 - Functional decomposition of there industry
 - Virtualization of those functions
 - Service chaining those virtual functions (VFs)
⇒ A service provided by the next gen ISPs

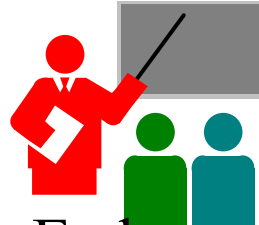
Enterprise App Market: Lower CapEx

Virtual IP
Multimedia
System

Available on the
App Store



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

- ❑ ETSI, "Architectural Framework," 2015 ,
http://www.etsi.org/deliver/etsi_gs/NFV/001_099/002/01.02.01_60/gs_NFV002v010201p.pdf
- ❑ ETSI, "Network Functions Virtualisation (NFV): Infrastructure Overview, " ETSI GS NFV-INF 001 V1.1.1, Jan 2015
- ❑ ETSI, "NFV - Update White Paper V3," Oct 2014,
http://portal.etsi.org/NFV/NFV_White_Paper3.pdf (Must read)
- ❑ 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, "NFV Use Cases,“
http://www.etsi.org/deliver/etsi_gs/NFV/001_099/001/01.01.01_60/gs_NFV001v010101p.pdf
- ❑ ETSI, "NFV Virtualization Requirements," 2015,
http://www.etsi.org/deliver/etsi_gs/NFV/001_099/004/01.01.01_60/gs_NFV004v010101p.pdf

Reading List (Cont)

- ❑ Intel, "Open simplified Networking Based on SDN and NFV," 2013, 7 pp., <http://www.intel.com/content/dam/www/public/us/en/documents/whitepapers/sdn-part-1-secured.pdf>
- ❑ J. DiGiglio, and D. Ricci, "High Performance, Open Standard Virtualization with NFV and SDN," http://www.windriver.com/whitepapers/ovp/ovp_whitepaper.pdf
- ❑ M. Cohn, "NFV Group Flocks to Proof-of-Concept Demos," Aug 2013, <http://www.sdncentral.com/technology/nfv-group-flocks-to-proof-ofconcept-models/2013/08/>
- ❑ M. Cohn, "NFV, An Insider's Perspective: Part 1: Goals, History, and Promise," Sep 2013, <http://www.sdncentral.com/education/nfv-insidersperspective-part-1-goals-history-promise/2013/09/>
- ❑ U Michel, "SDN and NFV: How things fit together," SDN and OpenFlow World Congress, Oct 2013, http://www.layer123.com/downloadnow&doc=62_DT-Michel-SDN_and_NFV
- ❑ B. Briscoe, et al., "NFV," IETF, March 2012, <http://www.ietf.org/proceedings/86/slides/slides-86-sdnrg-1.pdf>

ETSI NFV Documents

- ❑ NFV Virtual Network Functions Architecture, GS NFV-SWA 001
- ❑ NFV Use Cases, GS NFV 001
- ❑ NFV Architectural Framework, GS NFV 002
- ❑ NFV Terminology for Main Concepts in NFV, GS NFV 003
- ❑ NFV Virtualization Requirements, GS NFV 004

- ❑ NFV Infrastructure Overview, GS NFV-INF 001
- ❑ NFV Infrastructure (Compute Domain), GS NFV-INF 003
- ❑ NFV Infrastructure (Hypervisor Domain), GS NFV-INF 004
- ❑ NFV Infrastructure (Network Domain), GS NFV-INF 005
- ❑ NFV Infrastructure (Methodology to describe Interfaces and Abstractions), GS NFV-INF 007

- ❑ NFV Service Quality Metrics, GS NFV-INF 010

Ref: <http://www.etsi.org/technologies-clusters/technologies/nfv>

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ETSI NFV Documents (Cont)

- ❑ NFV Management and Orchestration, GS NFV-MAN 001
- ❑ NFV Performance & Portability Best Practises, GS NFV-PER 001
- ❑ NFV Proofs of Concept Framework, GS NFV-PER 002
- ❑ NFV Resiliency Requirements, GS NFV-REL 001
- ❑ NFV Reliability (Report on Scalable Architectures for Reliability Management)), GS NFV-REL 002

- ❑ NFV Security (Problem Statement), GS NFV-SEC 001
- ❑ NFV Security (Cataloguing security features in management software), GS NFV-SEC 002
- ❑ NFV Security (Security and Trust Guidance), GS NFV-SEC 003
- ❑ NFV Security Privacy and Regulation (Report on Lawful Interception Implications), GS NFV-SEC 004

Ref: <http://www.etsi.org/technologies-clusters/technologies/nfv>

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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
- ❑ NFVIaaS 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