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/
Overview

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 ⇒ **Software based Devices**
   Routers, Firewalls, Broadband Remote Access Server (BRAS)
   ⇒ A.k.a. *white box* implementation

2. **Function Modules** (Both data plane and control plane)
   ⇒ DHCP (Dynamic Host control Protocol), NAT (Network Address Translation), Rate Limiting,

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NFV (Cont)

3. Virtual Machine implementation
   ⇒ Virtual appliances
   ⇒ All advantages of virtualization (quick provisioning, scalability, mobility, Reduced CapEx, Reduced OpEx, …)

   VM  VM  VM
   Hypervisor

   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


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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,
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

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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)


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MANO (Cont)

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

Customer/Provider Inputs

Order

Order Management

Provisioning and Activation

BSS Functions

Order Management

Billing and Reporting

OSS Functions

Provisioning and Activation

Accounting and Monitoring

Orchestration

Customer/Provider Outputs

Bills

Reports

Analytics

Data

Services

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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

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.

NFV Releases

Release 1: Feasibility
Virtual Net Fn
MANO
Proof of Concepts

Release 2: Interoperability
Detailed Interfaces

Release 3: Enhancements
Policy
Licensing
Cloud-Native support

Release 4
Lightweight Virtualization
Automation
Life-cycle management

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

References

- ETSI Specifications, see the public download directory at https://docbox.etsi.org/ISG/NFV/Open/Publications_pdf/Specs-Reports
<table>
<thead>
<tr>
<th>Acronyms</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>API</td>
<td>Application Programming Interface</td>
</tr>
<tr>
<td>BRAS</td>
<td>Broadband Remote Access Server</td>
</tr>
<tr>
<td>BSS</td>
<td>Business Support Systems</td>
</tr>
<tr>
<td>CapEx</td>
<td>Capital Expenditure</td>
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<td>CDN</td>
<td>Content Distribution Network</td>
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<td>CGNAT</td>
<td>Carrier-Grade Network Address Translator</td>
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<td>CGSN</td>
<td>Combined GPRS Support Node</td>
</tr>
<tr>
<td>COTS</td>
<td>Commercial-off-the-shelf</td>
</tr>
<tr>
<td>DDIO</td>
<td>Data Direct I/O Technology</td>
</tr>
<tr>
<td>DHCP</td>
<td>Dynamic Host control Protocol</td>
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<tr>
<td>DPI</td>
<td>Deep Packet Inspection</td>
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<td>EMS</td>
<td>Element Management System</td>
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<td>ETSI</td>
<td>European Telecom Standards Institute</td>
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<td>GGSN</td>
<td>Gateway GPRS Support Node</td>
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<td>GPRS</td>
<td>General Packet Radio Service</td>
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<td>HLR</td>
<td>Home Location Register</td>
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<tr>
<td>IaaS</td>
<td>Infrastructure as a Service</td>
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</tbody>
</table>
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 Expenses
- 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
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