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# Network Function Virtualization (NFV): A Technology Enabler for 5G Networks

**National University of Science & Technology (NUST)**

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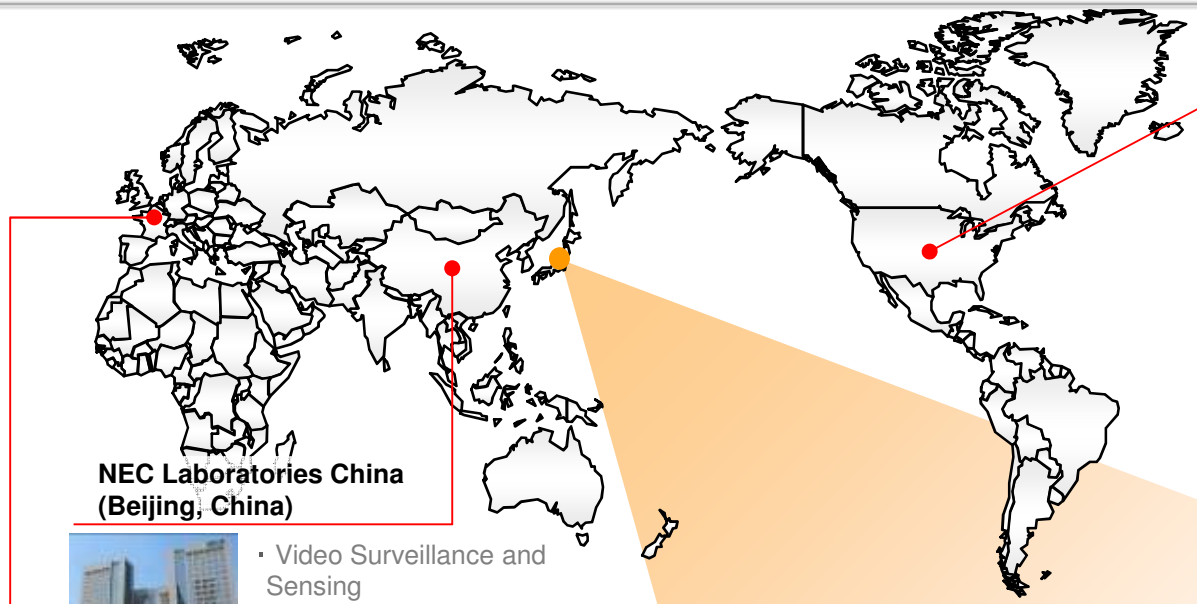
MCN Mobile Cloud Networking

# Agenda

- Introduction to NEC Research Labs
- Mobile network traffic trends and forecasts
- Issues in existing mobile network architecture/infrastructure
- Network Function Virtualization (NFV) overview
- NFV Management and Orchestration (MANO) framework
- RAVA Method – A Case Study
- Open research topics and open source projects

# INTRODUCTION TO NEC RESEARCH LABORATORIES

# NEC's Global R&D



**(Princeton, Silicon Valley, U.S.A.)**
**NEC Laboratories America**

- Media Analytics, Machine Learning
- System Management and Verification
- Energy Management
- IT System Architecture
- Broadband and Mobile Networking
- Quantum IT

**NEC Laboratories China**
**(Beijing, China)**

- Video Surveillance and Sensing
- Data Mining
- Cloud ICT
- Wireless Access

**Tsukuba,Ibaraki**

Smart Energy Research Labs.
Green Platform Research Labs.

- Energy Component
- Functional Material
- Low Power Device

**Ikoma,Nara**

C&C Innovation Initiative
Information and Media Processing Labs.

- User Interface
- Information and Media Processing

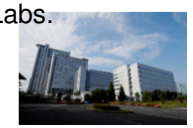
**NEC Laboratories Europe**
**(Heidelberg , Germany / S.Ruislip, U.K.)**

- **Future Networks (5G)**
- **NFV/SDN and NW Management**
- **Data Analytics**
- **Security and Privacy**
- **M2M & Internet of Things**
- **Smart Transport/ITS**
- **Smart Energy**
- **Standardization**

**Tamagawa,Kanagawa**

C&C Innovation Initiative
Knowledge Discovery Research Labs.
Cloud System Research Labs.
Information and Media Processing Labs.
Smart Energy Research Labs.
Green Platform Research Labs.

- Knowledge Discovery
- ICT System
- Information and Media Processing
- Communication, Processing and Sensor / Actuation Platforms
- Energy Management
- R&D Marketing



**Sagamihara, Kanagawa**

Smart Energy Research Labs.

- Energy Component

# NEC Laboratories Europe - Overview

- **~100 leading researchers from all over Europe and world-wide in Heidelberg**, and London/S.Ruislip (NEC E HQ)
- **Close links with leading European research institutes & universities**
- **Collaboration with major industry in Europe**, eg. network operators, ICT vendors, automotive, utilities….
- **Collaborating with NEC E's Competence Centers** to transfer R&D output into regional business

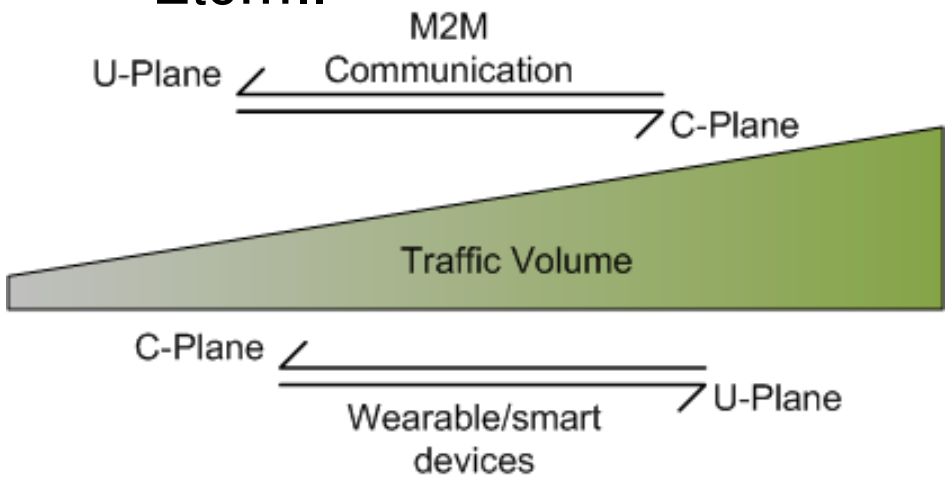
- Research **areas** in NLE
  - 5G and Future Internet, incl. NFV/SDN
  - Cloud platform, management & services
  - Security, Privacy & Performance
  - Internet of Things (M2M) platform & services
  - ITS and Green Telematics
  - Smart Energy

# MOBILE NETWORK TRAFFIC TRENDS & FORECASTS

# Internet-of-Everything (IoE)

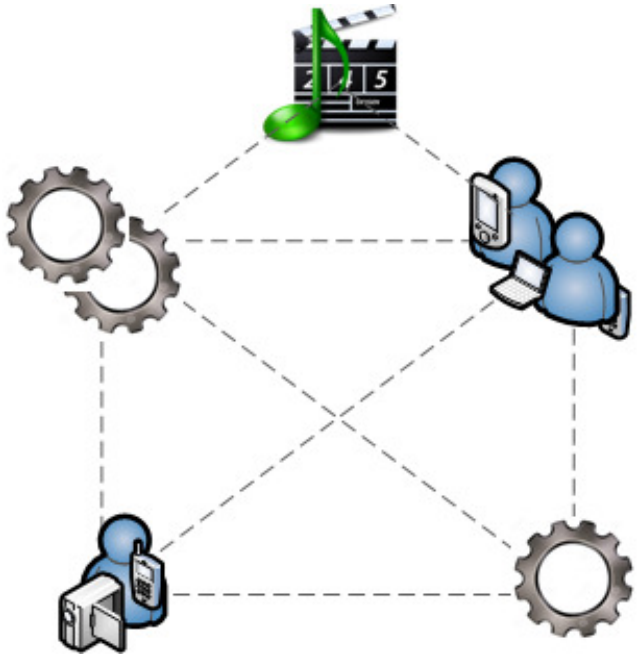
## M2M communication

- Home/office security automation
- Smart metering/grid
- Facility monitoring and maintenance
- Healthcare
- Industry
- Automotive and transport
- Etc…..

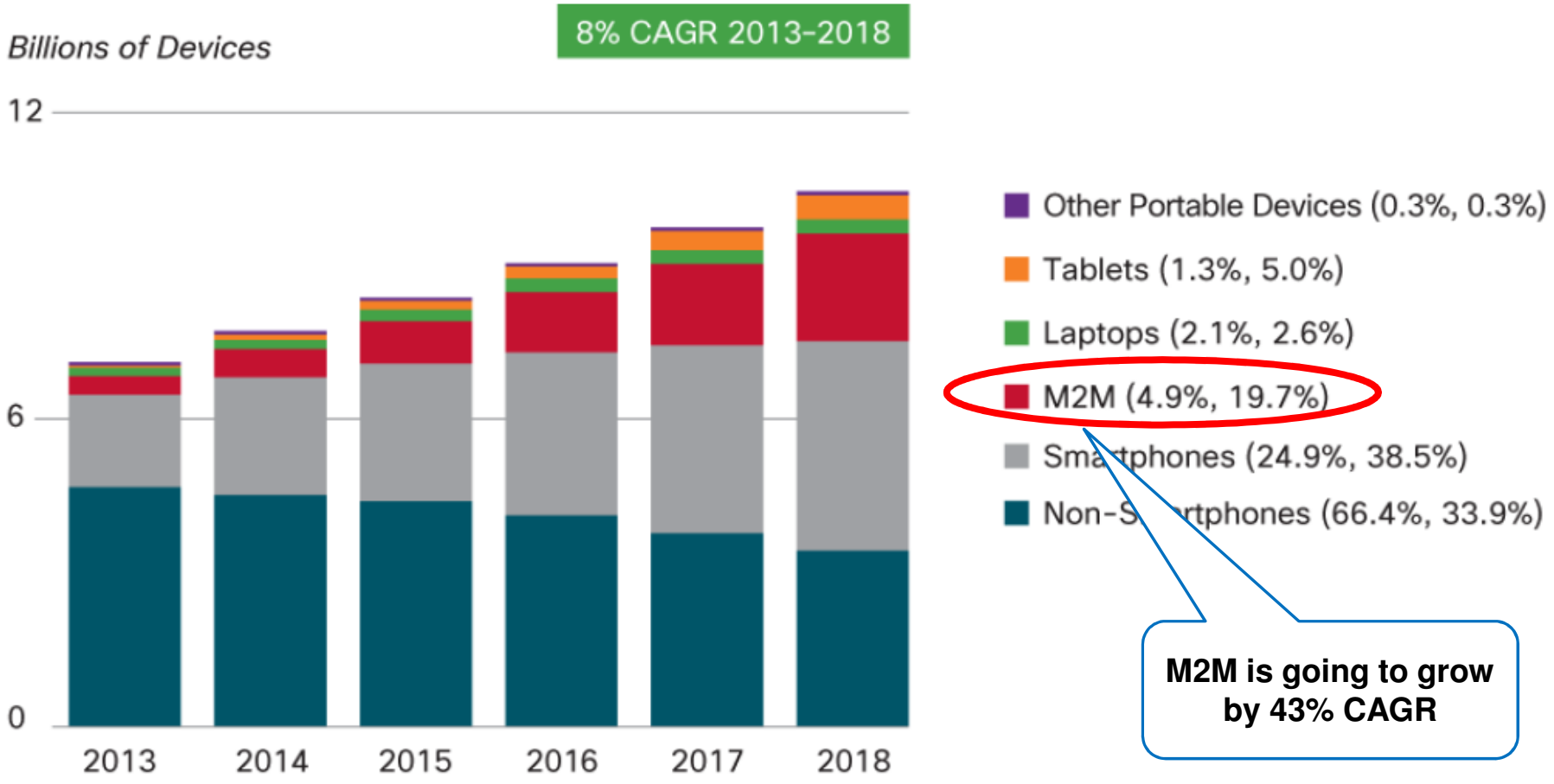



## Wearable devices/objects

- Smart phones
- Google glass
- Body Sensors
- Object sensors
- Etc …



# Expected proliferation of mobile devices and connections

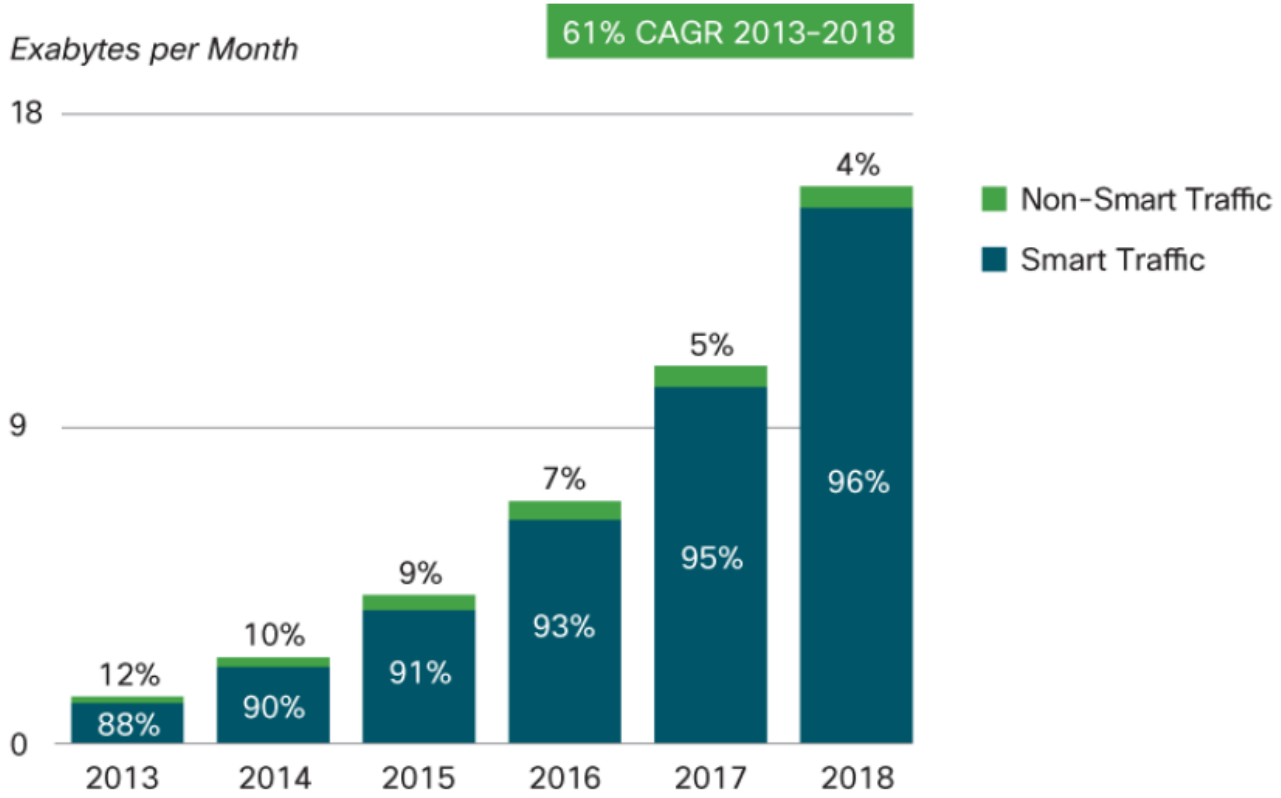



Figures in parentheses refer to device or connections share in 2013, 2018.

Source: Cisco VNI Mobile, 2014

# (SMART) Data Tsunami

- New services and applications will create an unprecedented amount of data
- A huge portion of the “things” will be smart, and the smartest “things” will generate the bulk of traffic.




Percentages refer to device or connections share.

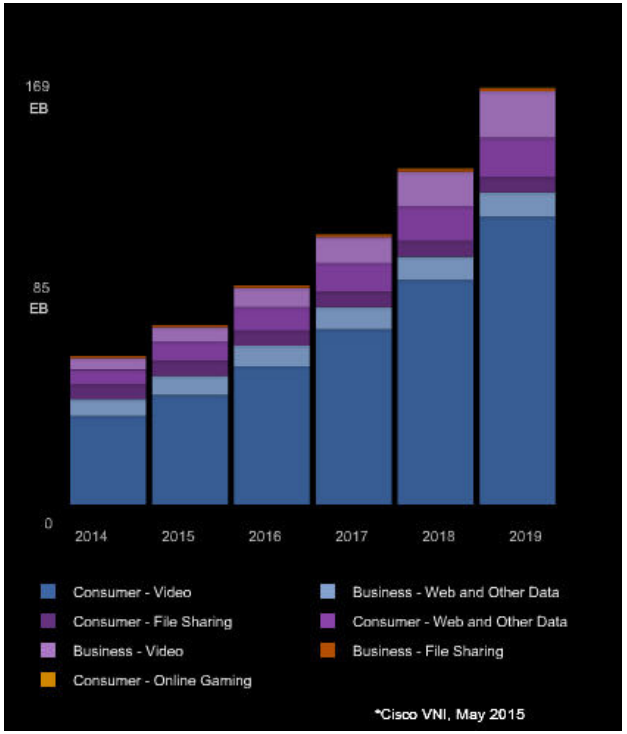
Source: Cisco VNI Mobile, 2014

# 2019 forecasts in comparison with 2014

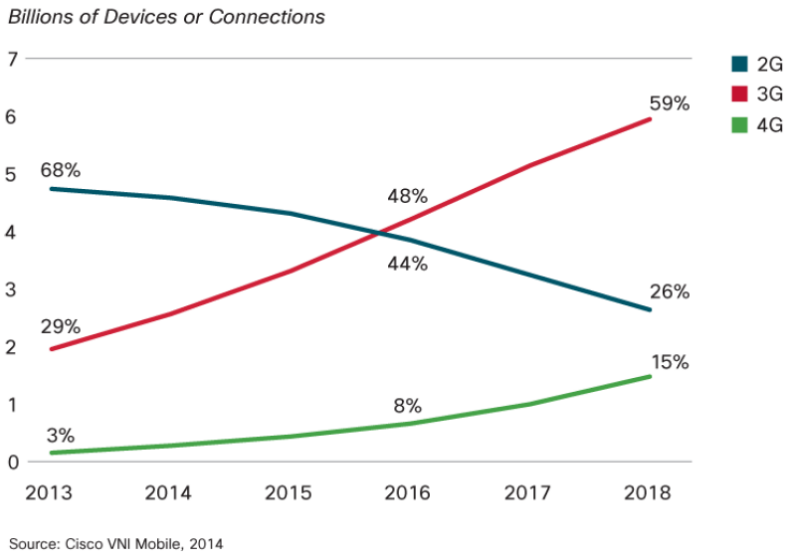
**3x** Total traffic

**5x** Size of Consumer – Online Gaming IP traffic

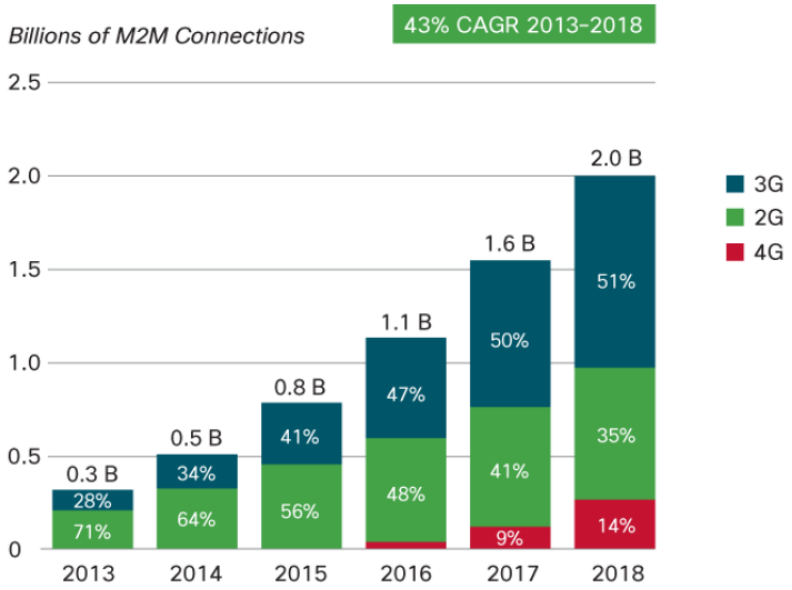
**37M** Global IP traffic in terms of DVDs/hour

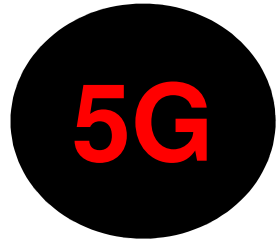


# IoE Connectivity over Mobile networks



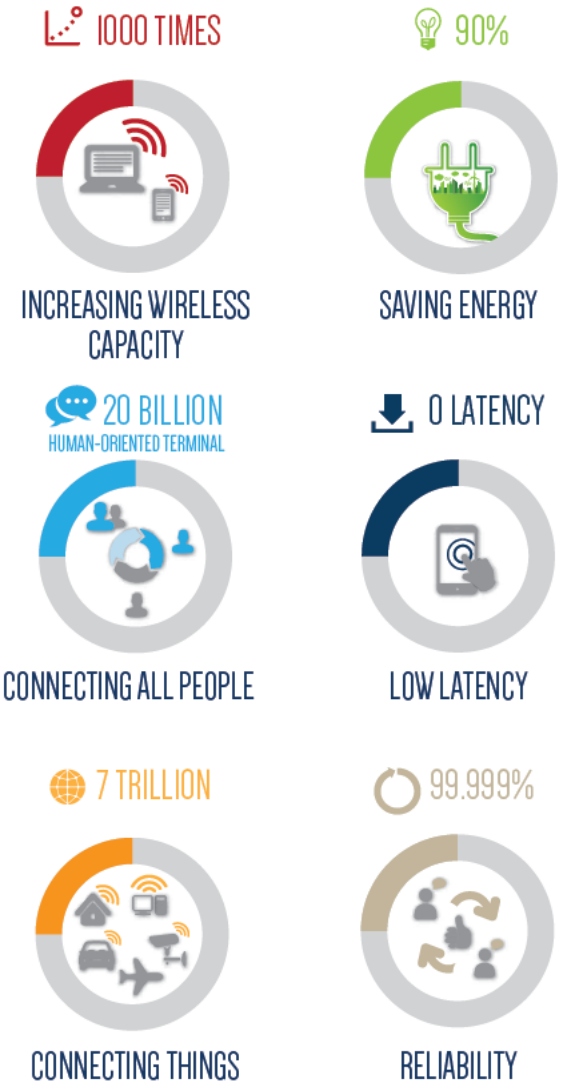

Source: Cisco VNI Mobile, 2014



# 5G Performance Expectations

- In terms of ICT infrastructure + services
  - Increased network capacity (~ 1000 folds)
  - 10 Gbps individual user experience
  - Extremely low latency (< 1msec)
  - (near) real-time processing of big data -> zero distance response
  - Intelligent forwarding and processing of data
  - Fine granular QoS handling and QoE centric
  - On-demand resource/service provisioning (i.e., Elasticity and Agility)
  - Reliable access
  - Seamless mobility
  - Secure
  - Context aware operations
  - Energy efficient
  - ……. And the wish list goes on
- Expected to be launched by 2020-21
  - EU's Horizon 2020 (H2020) initiative launched in July 2015
  - 5G-PPP – a €4B+ joint initiative between EC and European ICT industry.



# Will the existing network paradigms suffice ?

- "Smart objects" require "smart processing"
  - Context-aware, Intelligent and knowledge based analytics.
- The Big Data processing will rely on cloud service provided by powerful data center resources.
- For (near) real-time processing of Big Data requires fast, secure and reliable transport of data from IoT/M2M domains towards the DC is required.
- This will have an impact on existing communication network architectures and their data handling capabilities.
  - Ultra broadband and intelligent pipe network with "zero distance" connectivity.
- Existing mobile networks designed and geared towards handling of traditional voice/data services
  - 2G was about voice
  - 3G was about data
  - 4G is/was about multi-media/social-media
- The IoE will thus serve as a catalyst for developing 5G technologies.
  - 5G is all about "**Elasticity, Agility, Intelligence and context awareness**"

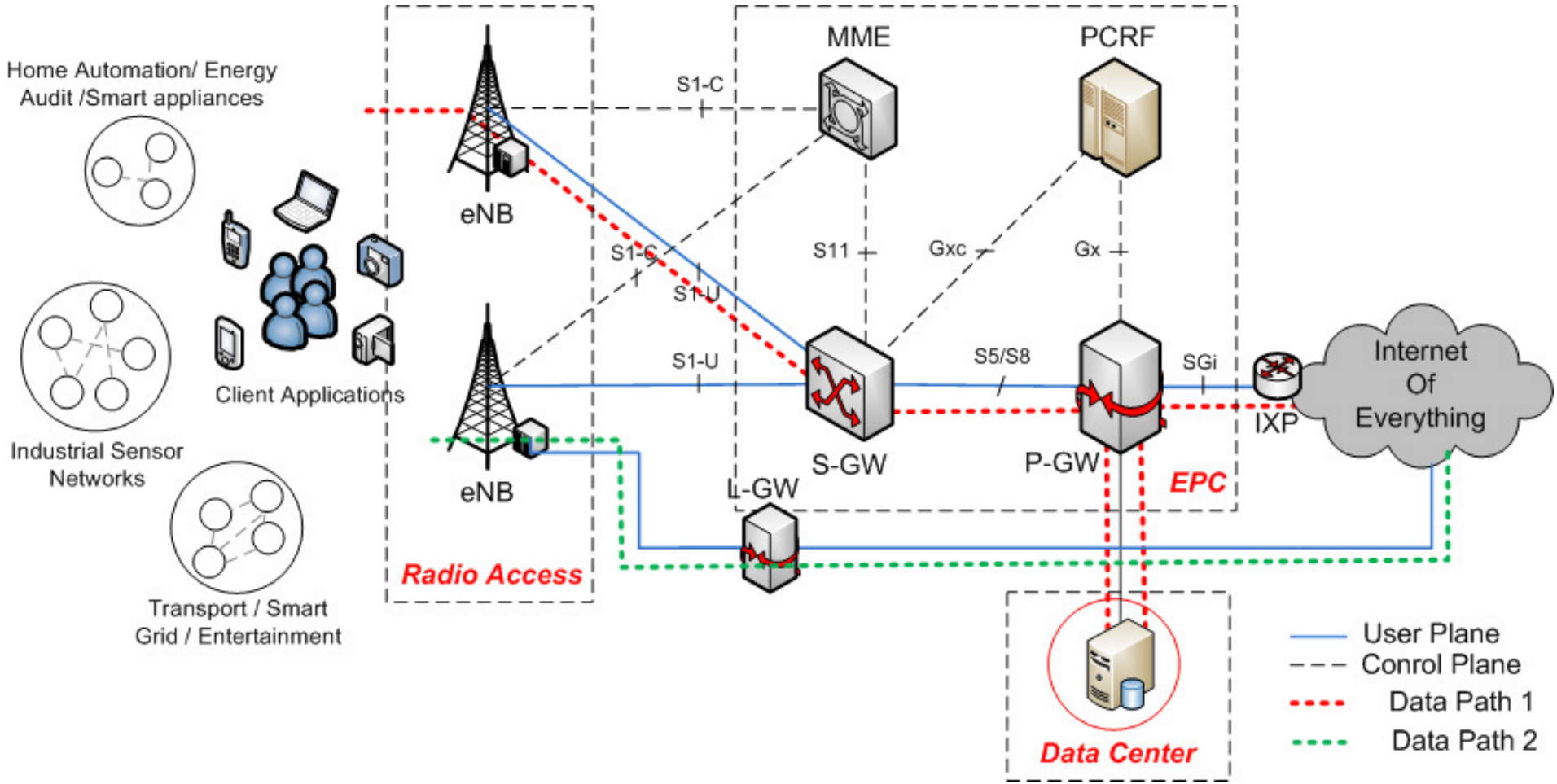
# The BIG ?

- How to handle this growth ?
  - Increase capacity by investing and deploying new hardware?
    - increase in CAPEX/OPEX
  - Existing resources are not optimally utilized
    - Up to 80 percent of base stations' processing capacity and up to half of core networks' capacity is unused.”
    - Disproportionately less ROI

- Development of new paradigms for the realization of 5G networks
  - Leveraging the existing **cloud technology/virtualization techniques** and applying them on mobile network

# Issues In Existing Mobile Networks

# 3GPP Mobile Communication Ecosystem

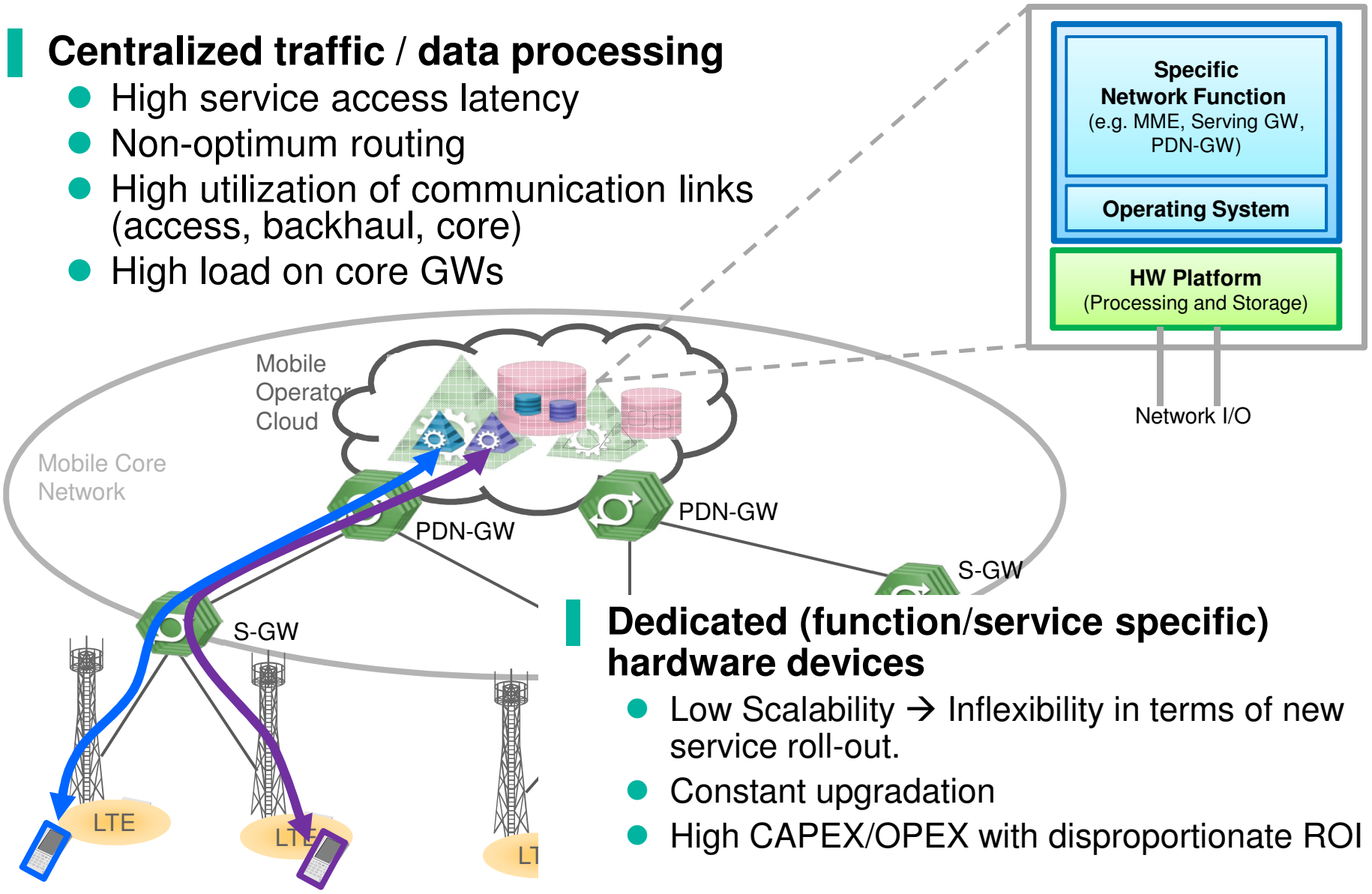


# Performance bottlenecks at the core must be resolved


# Issues in Existing Mobile Network Infrastructures

## Centralized traffic / data processing

- High service access latency
- Non-optimum routing
- High utilization of communication links (access, backhaul, core)
- High load on core GWs

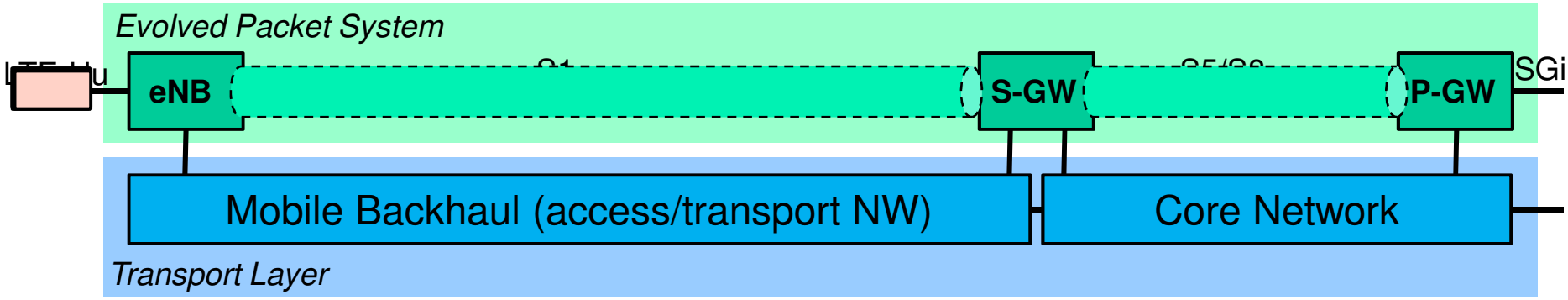



## Dedicated (function/service specific) hardware devices

- Low Scalability → Inflexibility in terms of new service roll-out.
- Constant upgradation
- High CAPEX/OPEX with disproportionate ROI

# Issues in Existing Mobile Network Infrastructures

- Mobile Networks are employed as an overlay on a transport network
  - assuming an “over-provisioned” transport network.
  - Static resource allocation
  - Different ownership
- Lack of coordination between the two network domains
  - Admission control
  - Resource reservation
  - Route management
- Resource issues at the transport network can affect service quality at the mobile network.



# Solution Approach

## Cloudification of mobile core network

Leverage and apply existing cloud technology / virtualization techniques on mobile networks nodes and architectures.

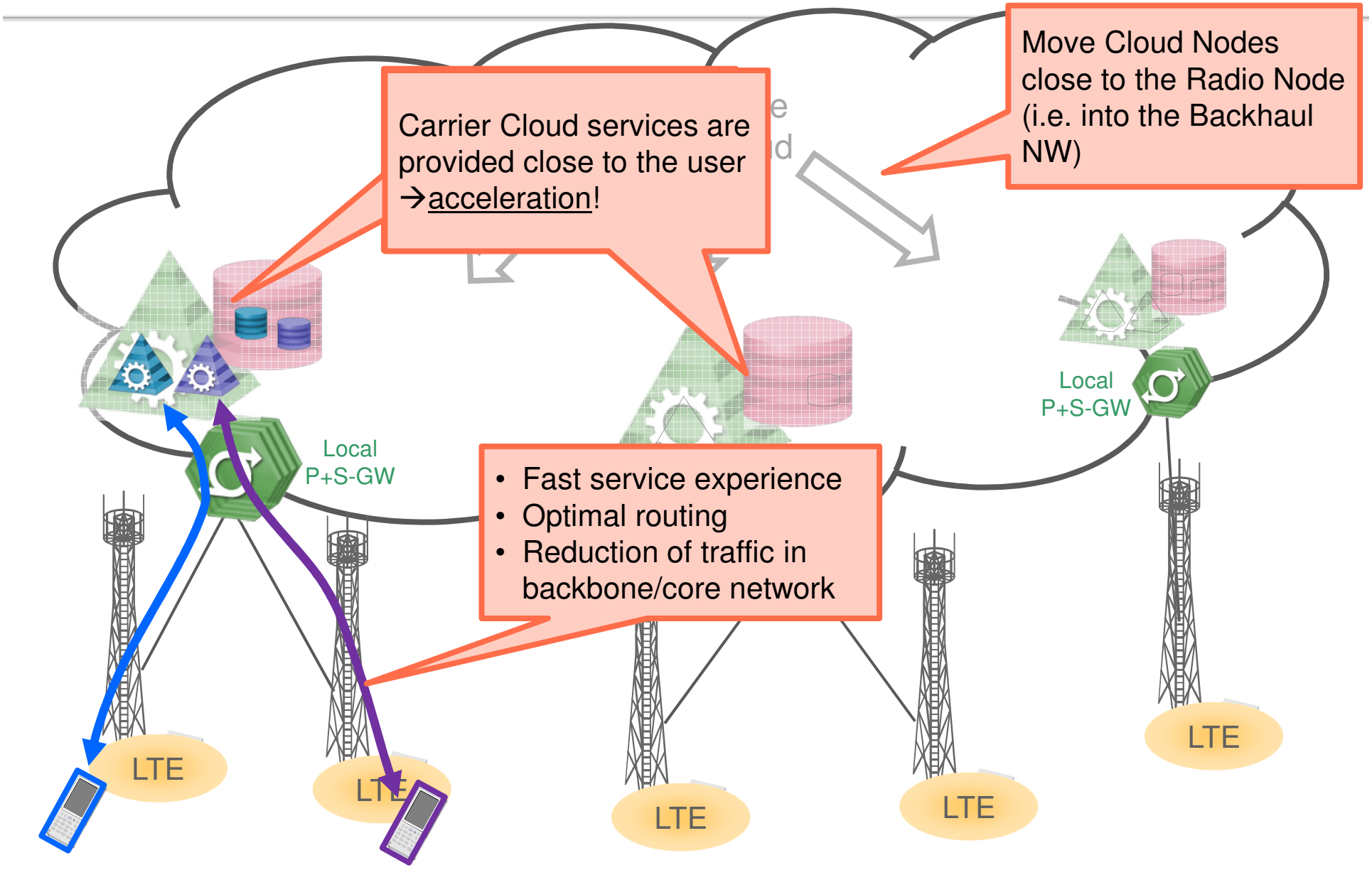
Traditional cloud services

- **I**nfrastructure **a**s **a** **S**ervice (IaaS)
- **P**latform **a**s **a** **S**ervice (PaaS)
- **S**oftware **a**s **a** **S**ervice (SaaS)

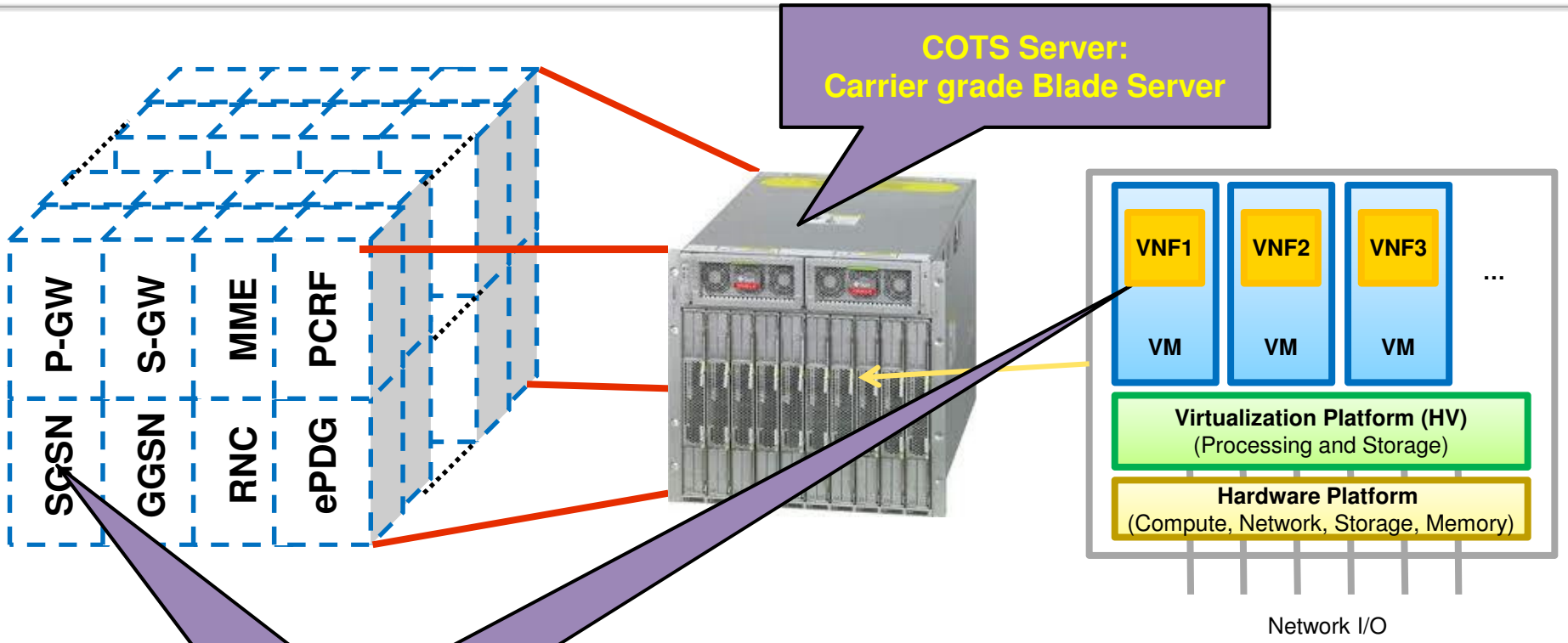
**New cloud service**-> **M**obile **N**etwork **a**s **a** **S**ervice (MNaaS)

- Virtualization of mobile core entities (Nodes; Functions; Services)

# “Cloudifying” the Mobile Operator Core



# Virtual Mobile Network Core – Concept & Realization




- Same physical node, multiple virtual instances -> avoid vendor lock-in.
- Multi-tenancy, multi-technology, multi ownership
- On-demand enabling of functions
- On-demand delivery of service
- Service relocation -> optimized access to network services.
- Load based dynamic resource provisioning
- **Vendor agnostic, agile network with lower CAPEX/OPEX and better control over managing QoS/QoE**

# NETWORK FUNCTION VIRTUALIZATION (NFV)

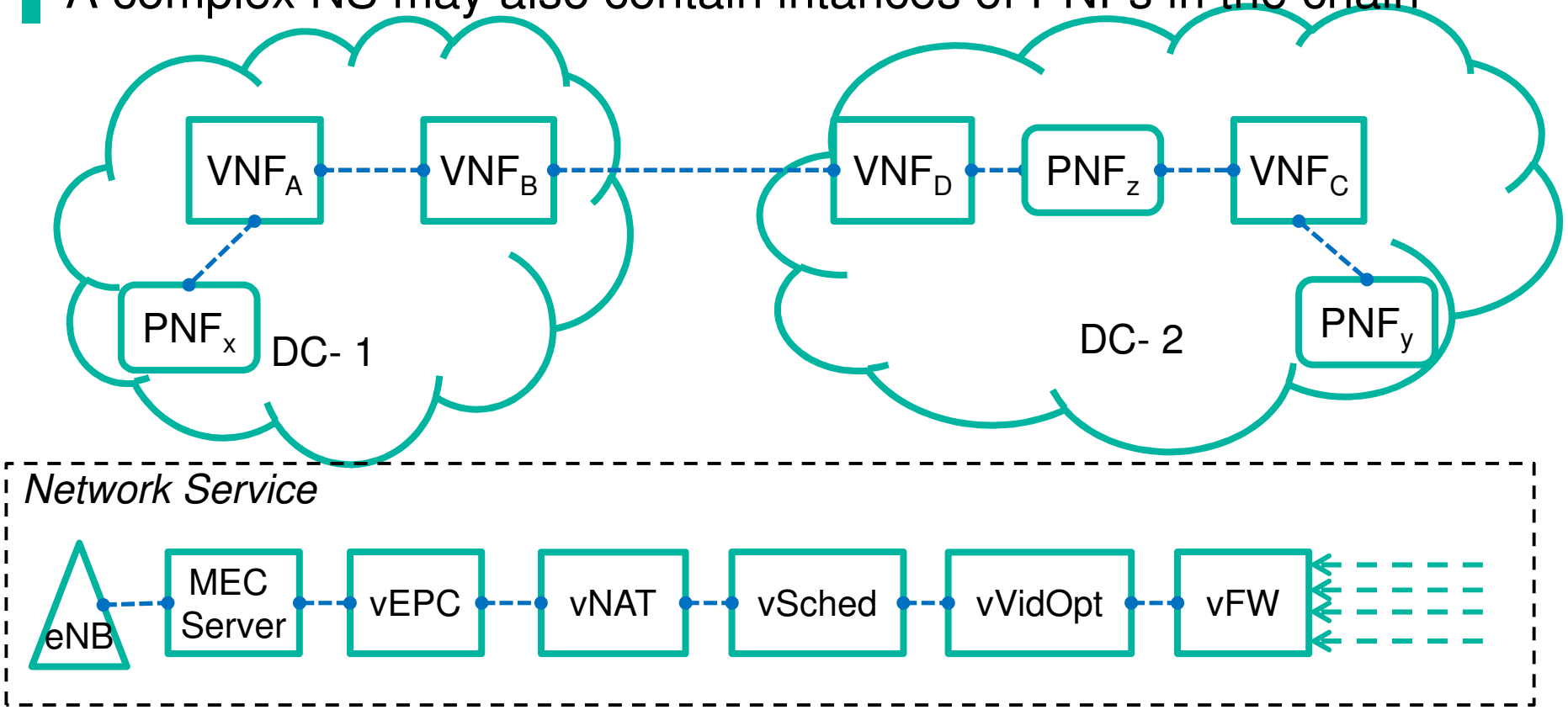
A Technology Enabler for Realizing 5G Mobile Networks

# Key definitions first !!

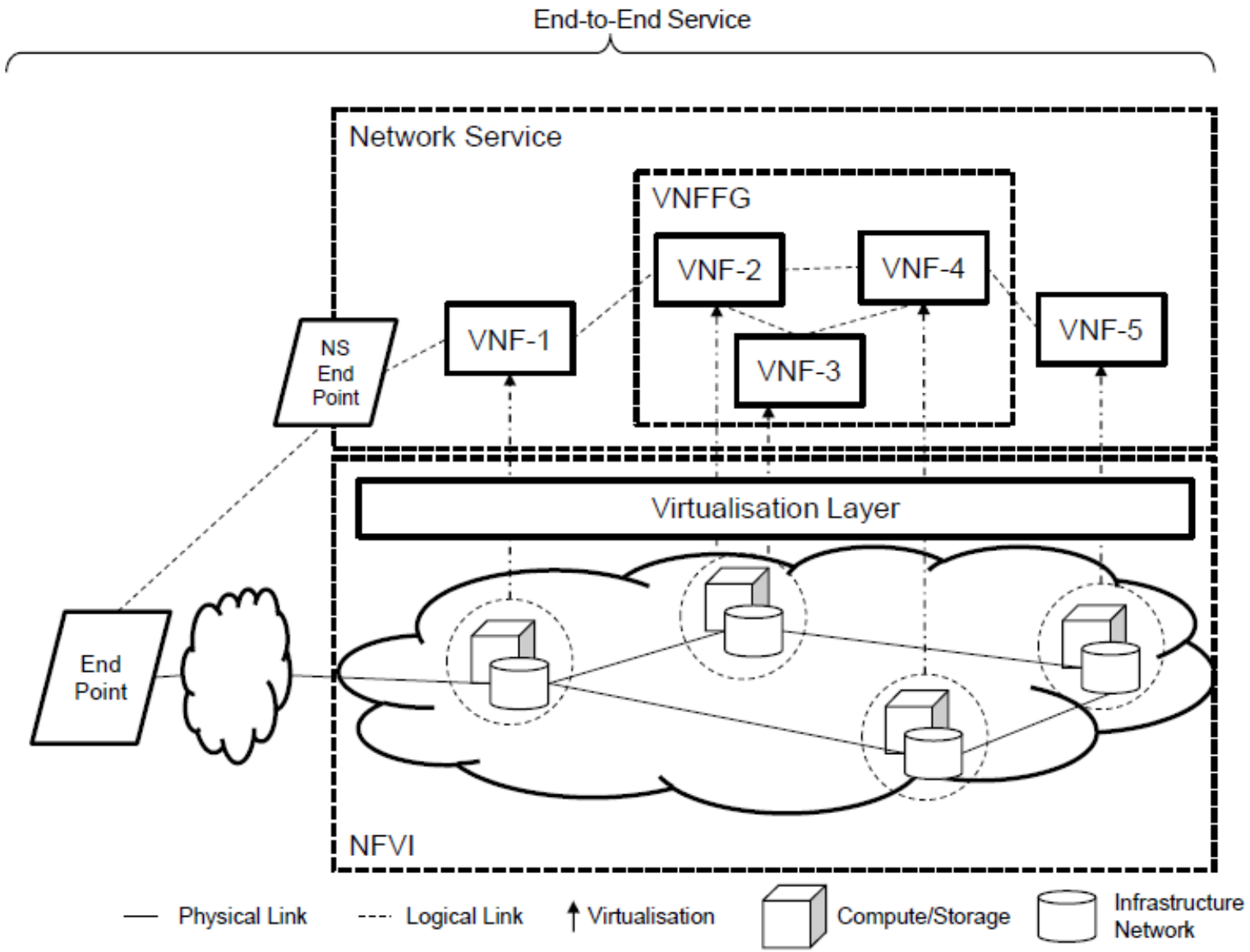
- Network Function (NF)
  - functional block within a network infrastructure that has well-defined external interfaces and well-defined functional behavior.
- Network Functions Virtualization (NFV):
  - principle of separating network functions from the hardware they run on by using virtual hardware abstraction.
- Virtual NF (VNF)
  - implementation of an NF that can be deployed on a Network Function Virtualization Infrastructure (NFVI). A complex VNF may be composed of multiple VNF components (VNFC), where a VNFC characterizes a specific sub-function of a VNF..
- Network Service (NS)
  - composition of Network Functions and defined by its functional and behavioral specification

# Network Service (NS)

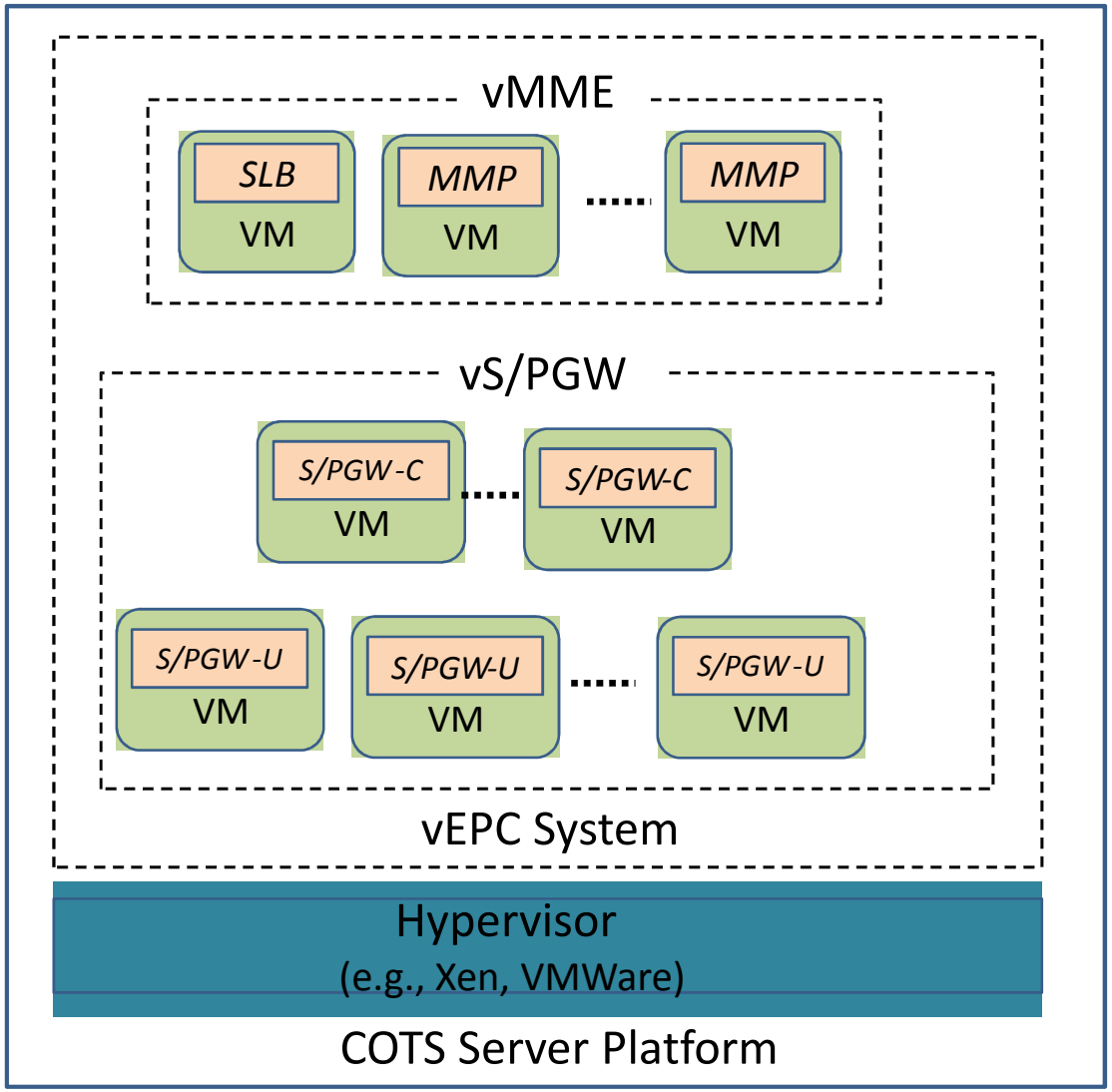
- A NS is composed of specific types of VNFs, „chained“ in a specifc order to provide a complete e2e service.
- A NS may be in a single DC or may traverse across multiple DCs.
- A complex NS may also contain intances of PNFs in the chain



# E2E Network Service (NS) in a NFV System

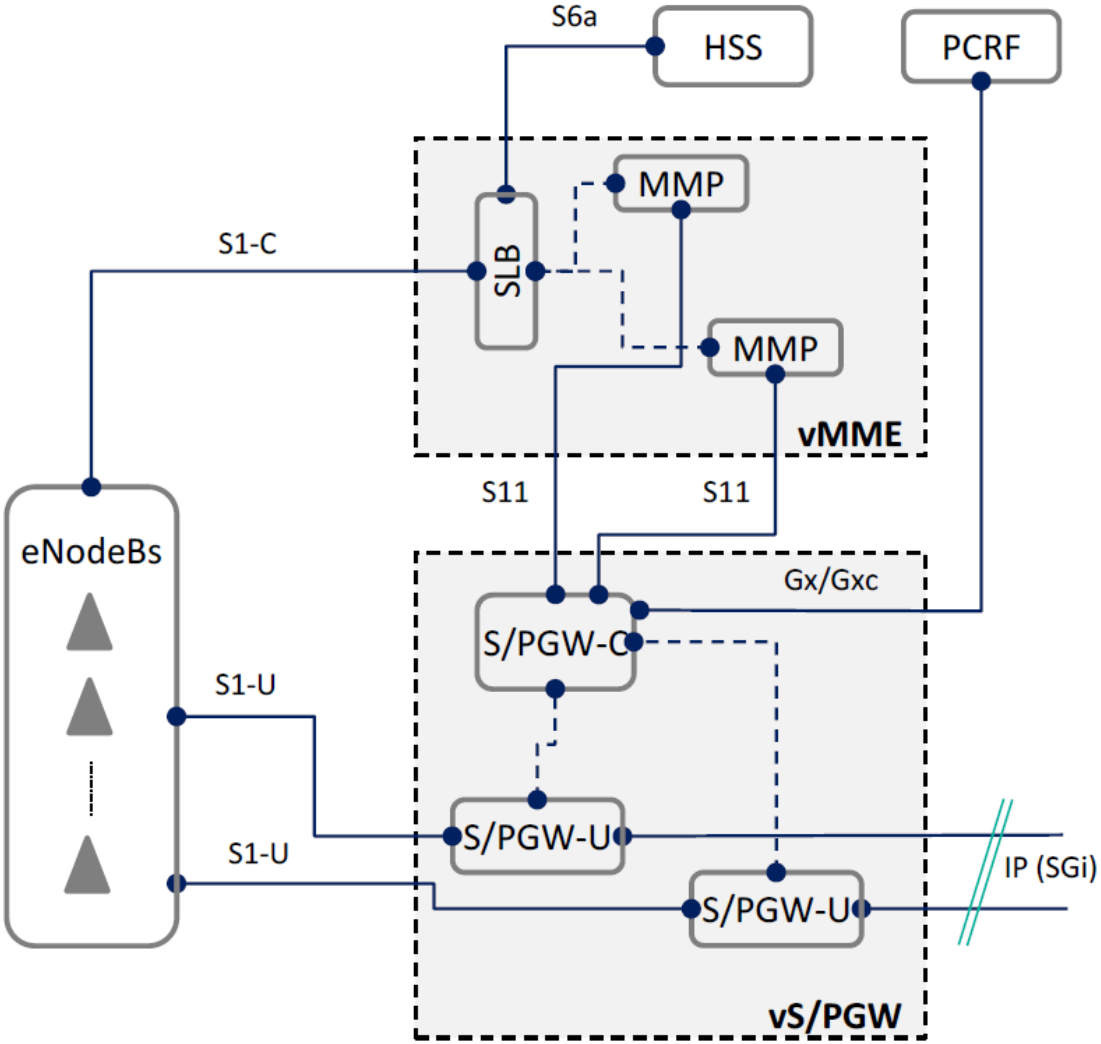


# A Virtualized Evolved Packet Core (vEPC) VNF(C)



# Interconnection challenges for a vEPC

- Preserving [bandwidth, delay, error] constraints
- Ensuring 99.9999% service integrity
- Fault management
- Performance Management
- Resource Management

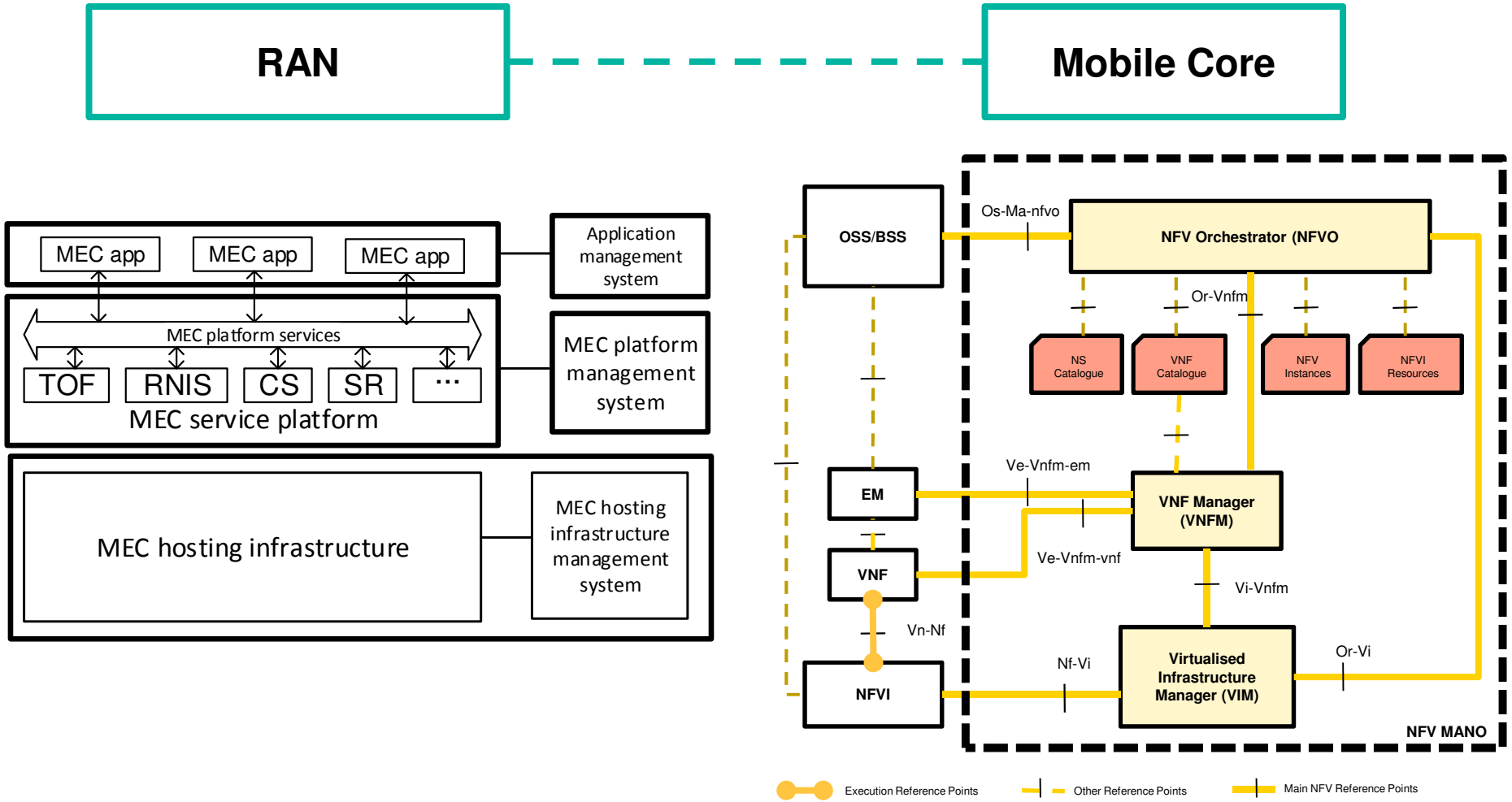


# Datacenter Resources – Compute, Network and Storage

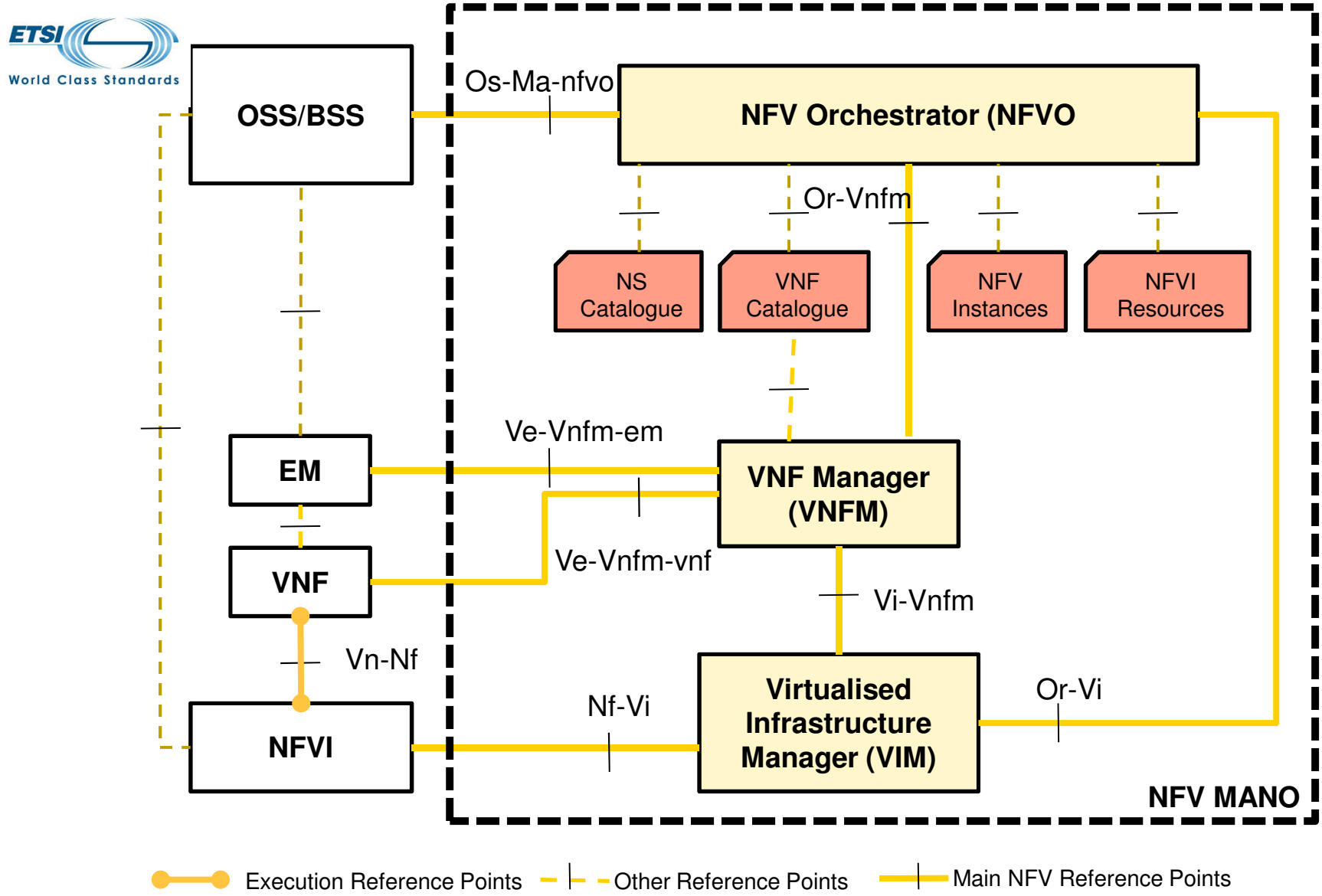
# ETSI Proposed NFV Frameworks

## ETSI MEC (Mobile Edge Computing)

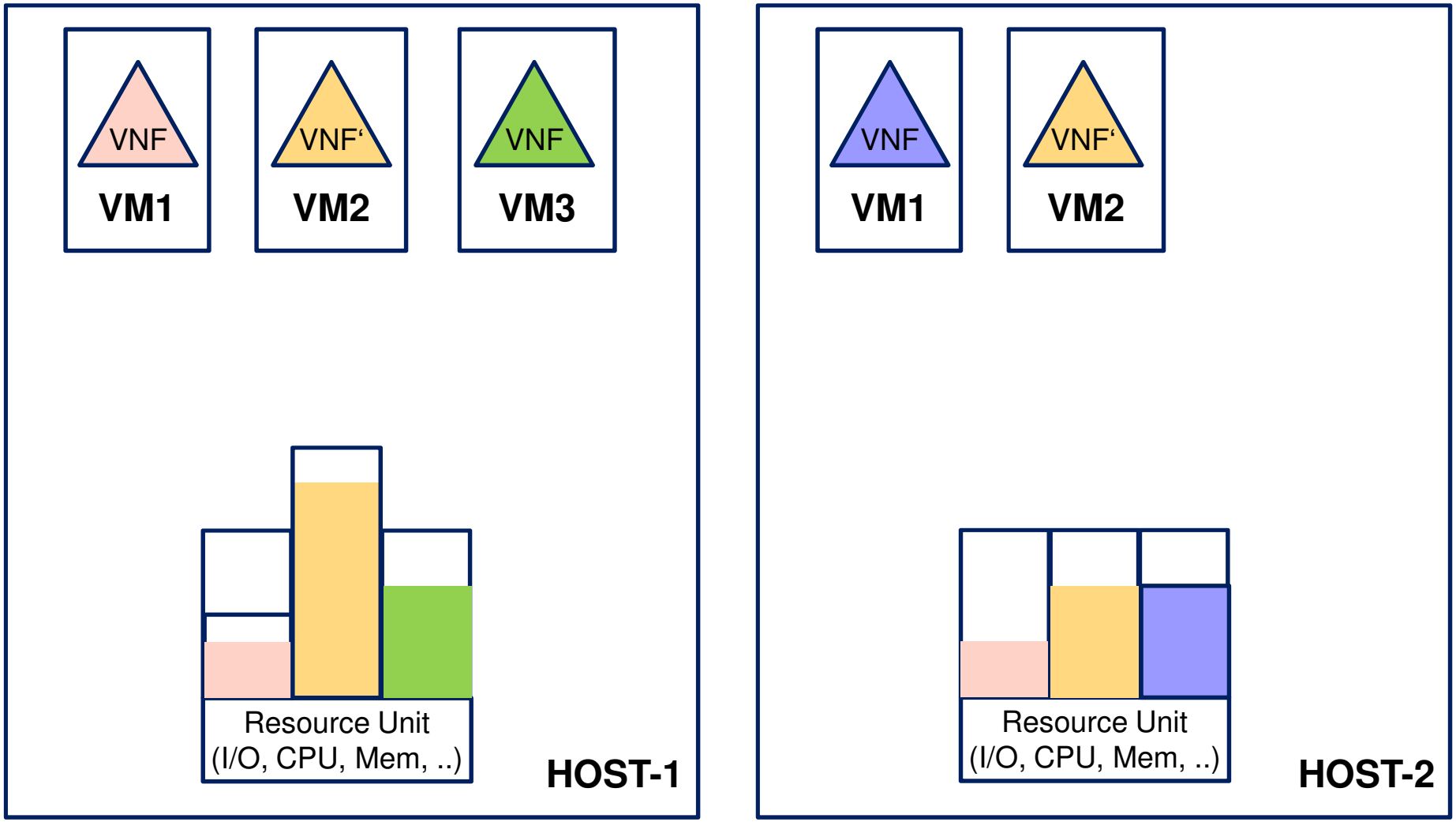
## ETSI NFV (Network Function Virtualization)



# ETSI NFV MANO Architecture



# Lifecyle Management (LCM) Concepts – VNF Scaling (up/down/in/out) & Migration



# NFV Orchestrator (NFVO) functional Block (1)

## Main Responsibilities

- Network Service (NS) Orchestration – Lifecycle Management (LCM) operations
  - Update, query, scaling, collecting performance measurement results, event collection and correlation, termination.
- Resource Orchestration of NFVI resources across multiple VIMs

## NFVO Capabilities for NS Orchestration

- NS instantiation and LCM
- Management of the instantiation of VNFMs
- Management of the instantiation of the VNFs & VNFMs
- Validation and authorization of NFVI resource requests from VNFMs.
- Management of the NS topology (e.g. create, update, query, delete VNF Forwarding Graphs).
- Policy management for the NS and VNF instances (e.g. policies related with affinity/anti-affinity, scaling, fault and performance, NS topology, etc.).

# NFV Orchestrator (NFVO) functional Block (2)

## NFVO Capabilities for Resource Orchestration

- NFVI resource management
  - distribution, reservation and allocation of NFVI resources to NS/VNF instances
- Collection of usage information of NFVI resources by VNF instances
- Policy management/enforcement for the NS/VNF instances
  - NFVI resources access control, reservation and/or allocation policies, placement optimization based on (anti)affinity rules resource usage, etc.).

# VNF Manager (VNFM) functions

Responsible for the LCM of VNFs,

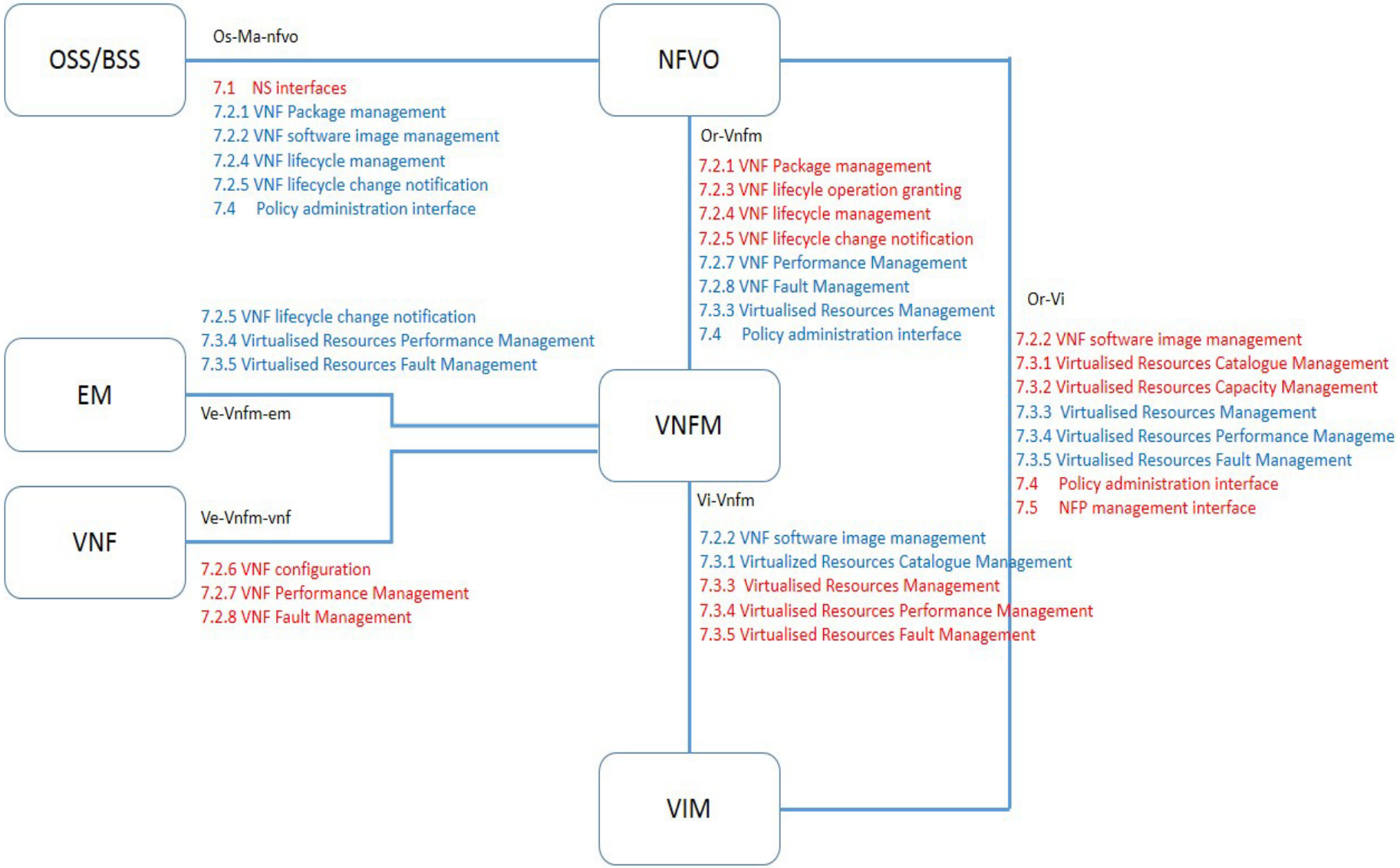
In addition to the traditional FCAPS management, newer management functions are introduced by the NFV.

- VNF instance software update/upgrade.
- VNF instance modification (e.g., configuration information).
- VNF instance scaling out/in and up/down.
- Collection of performance & fault related information for the VNF(s)
- VNF instance assisted or automated healing.
- VNF instance termination.
- VNF lifecycle management change notification (to the NFVO)
- Overall coordination and adaptation role for configuration and event reporting between the VIM and the EM.

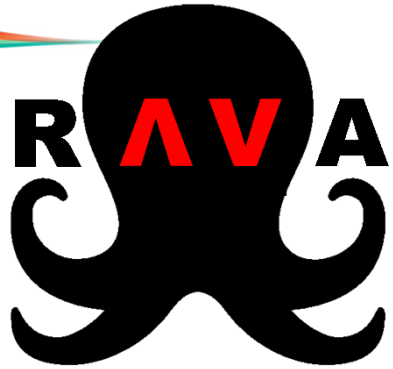
# Virtualized Infrastructure Manager (VIM) functions

- Responsible for the control and management of the NFVI hardware (compute, storage and network) and software (e.g., hypervisors) resources
  - Orchestrating the allocation/upgrade/release/reclamation of NFVI resources
  - Supporting the management of VNF Forwarding Graphs (create, query, update, delete)
  - Managing discovery of the capabilities and features of NFVI resources.
  - Management of the virtualised resource capacity.
  - Management of software images (add, delete, update, query, copy) as requested by other NFV-MANO functional blocks (e.g. NFVO).
  - Collection of performance and fault information of hardware/software/virtualized resources.

# Interface Mapping to ETSI NFV MANO Reference Points.



# RESOURCE AWARE VNF AGNOSTIC (RAVA) NFV ORCHESTRATION METHOD

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# Resource Aware VNF Agnostic (RAVA) NFV Orchestration Method/System

## (Demonstrated in NEC Research OpenHouse Event 2015 & IEEE NFV-SDN Conference, USA, 2015)

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MCN Mobile Cloud Networking

openstack™

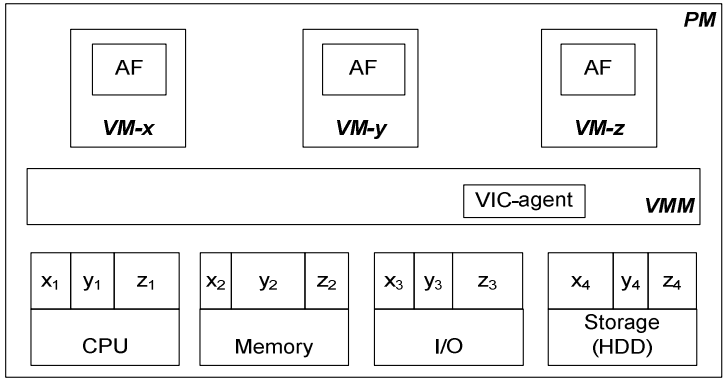
# RAVA - Key Technology Feature

- The objective of the demo is to showcase NLE‘s novel „Resource Aware VNF Agnostic (RAVA)“ orchestration method as an effective Service Orchestrator (SO) for NFV service(s) (e.g., IMSaaS, EPCaaS).

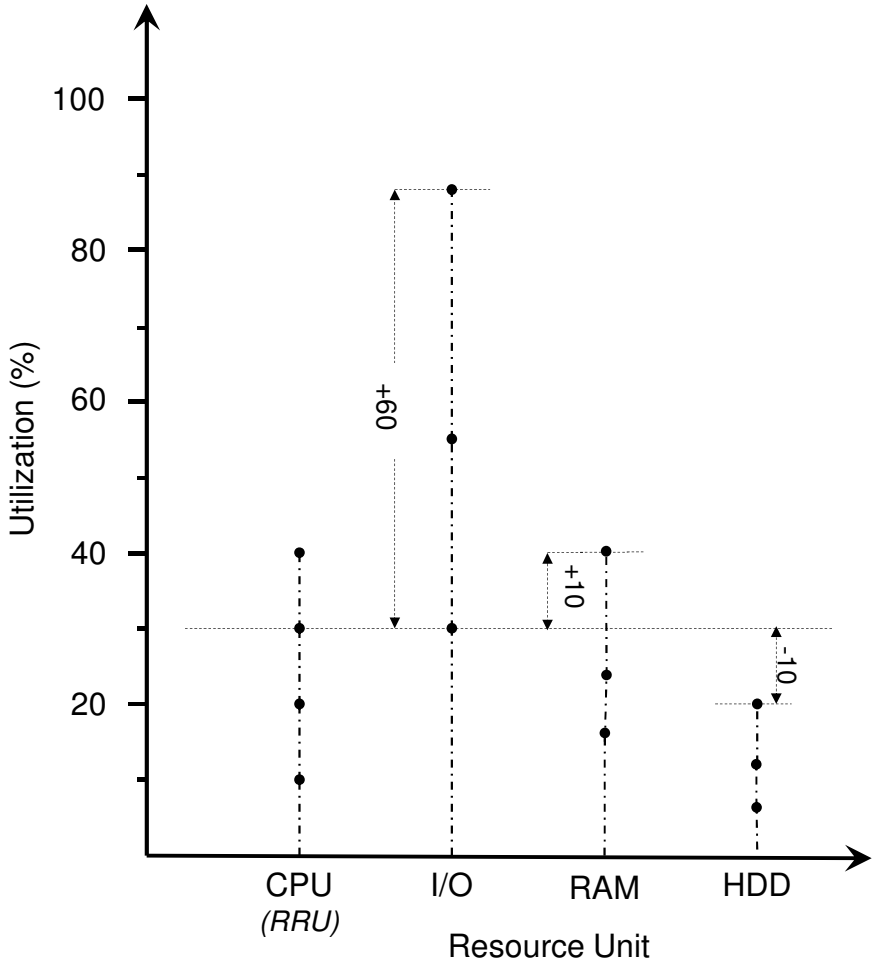
- **“RAVA”** takes into consideration the correlation and prediction of **internal resource utilization pattern** by individual VNFs, which provides the controller the VNFs‘ run-time operational/functional profile (i.e., VNF behavior).
  - This capability/feature will enable the controller to make **optimized management decision** by matching the predicted utilization pattern of VNFs in a server to the target VNF which needs to be migrated or scaled.
  - The controller will thus select a server that best **matches the target VNF‘s predicted run-time behavior** without impacting the performance of the co-located VNFs.

- RAVA in addition will also resolve any race condition that may occur under situation when any other placement method may select multiple hosts as being suitable for placement based on singe dimension consideration.

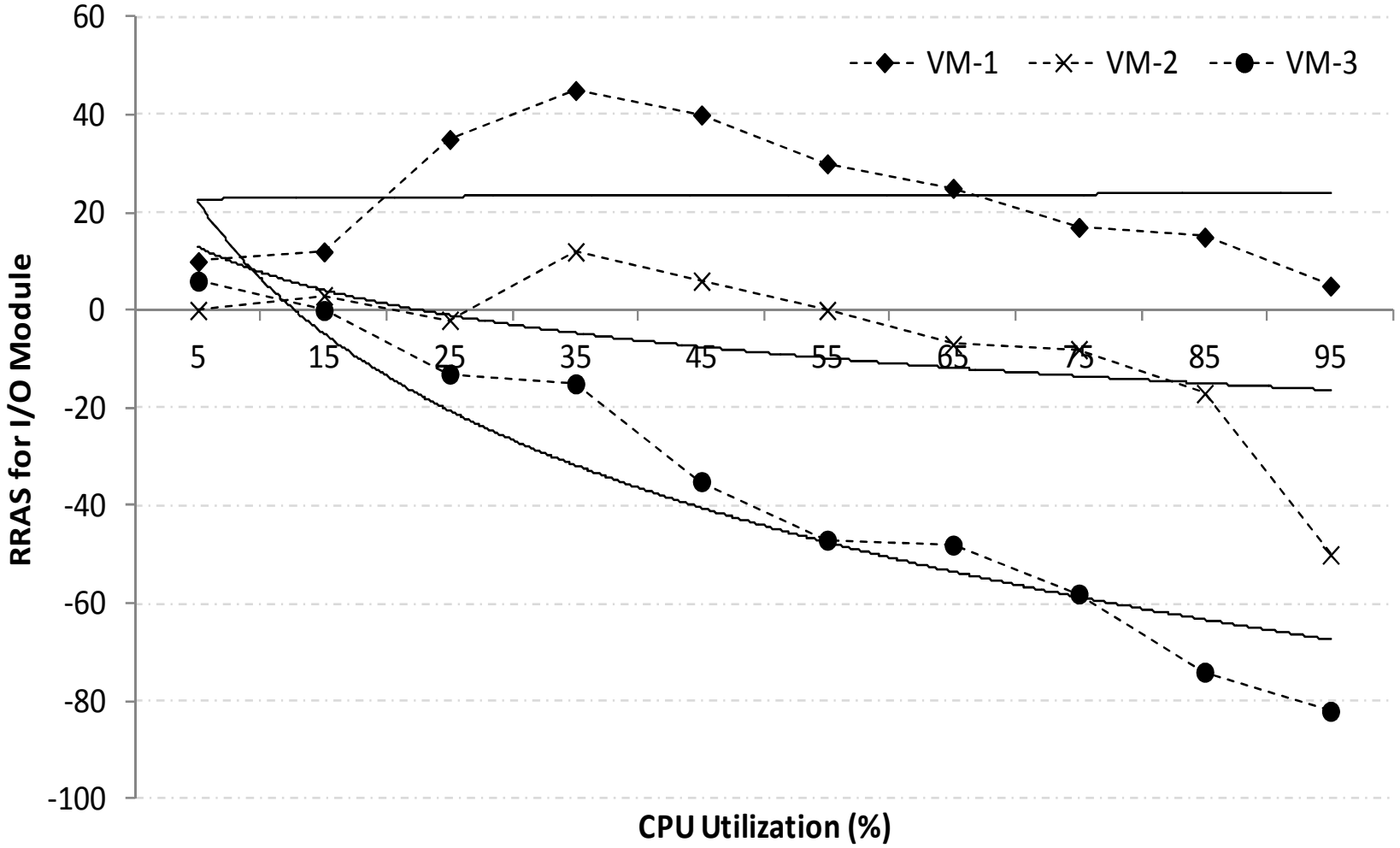
# RAVA Method Overview



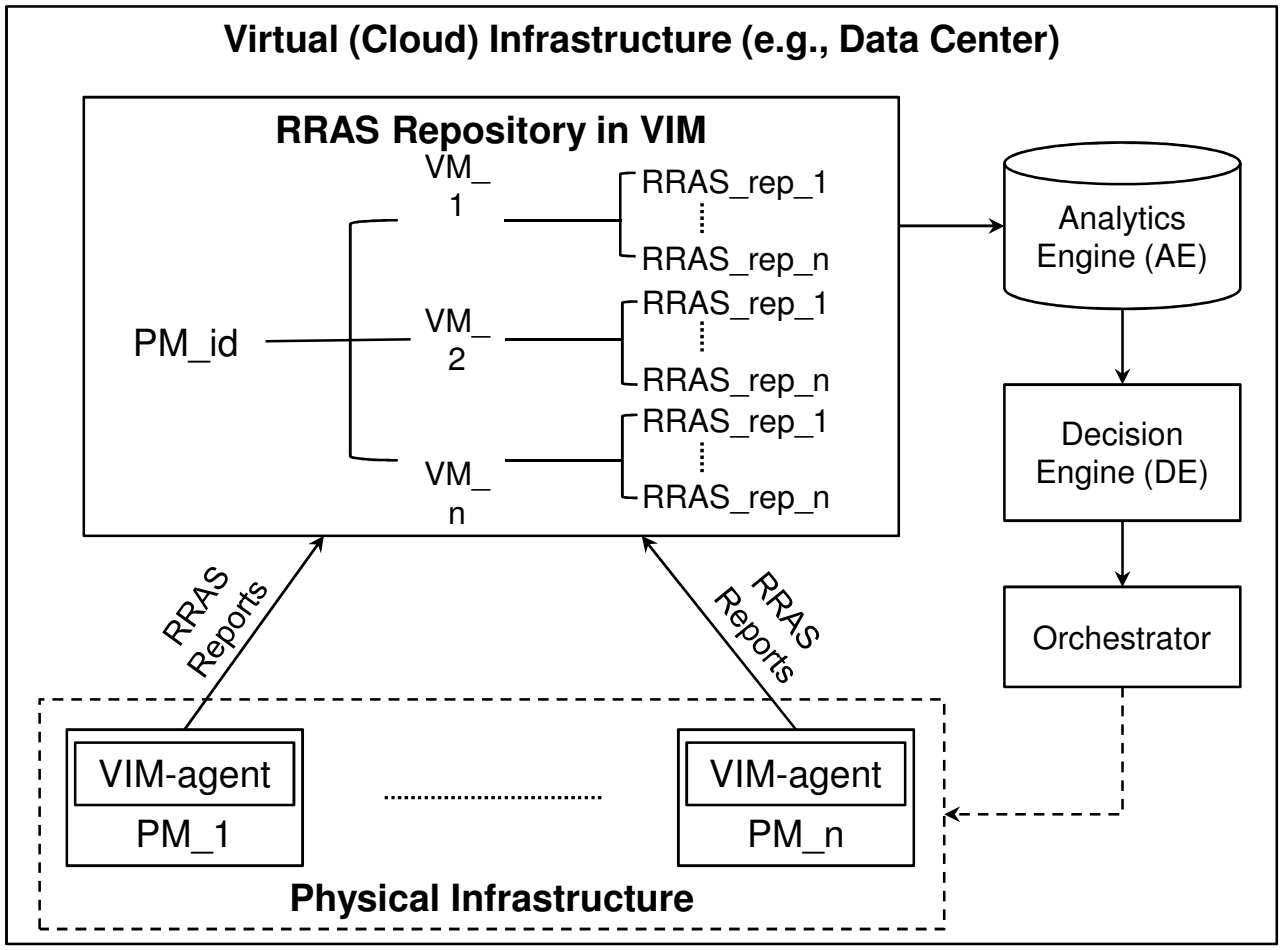

| *Reference Resource Unit* | *Absolute Average Utilization (%)* | *Reference Resource Affinity Score* | | | |
|---|---|---|---|---|---|
| | | *CPU* | *I/O* | *RAM* | *HDD* |
| *CPU* | 30 | - | +60 | +10 | -10 |
| *I/O* | 90 | -60 | - | -50 | -70 |
| *RAM* | 40 | -10 | +50 | - | -20 |
| *HDD* | 20 | +10 | +70 | +20 | - |



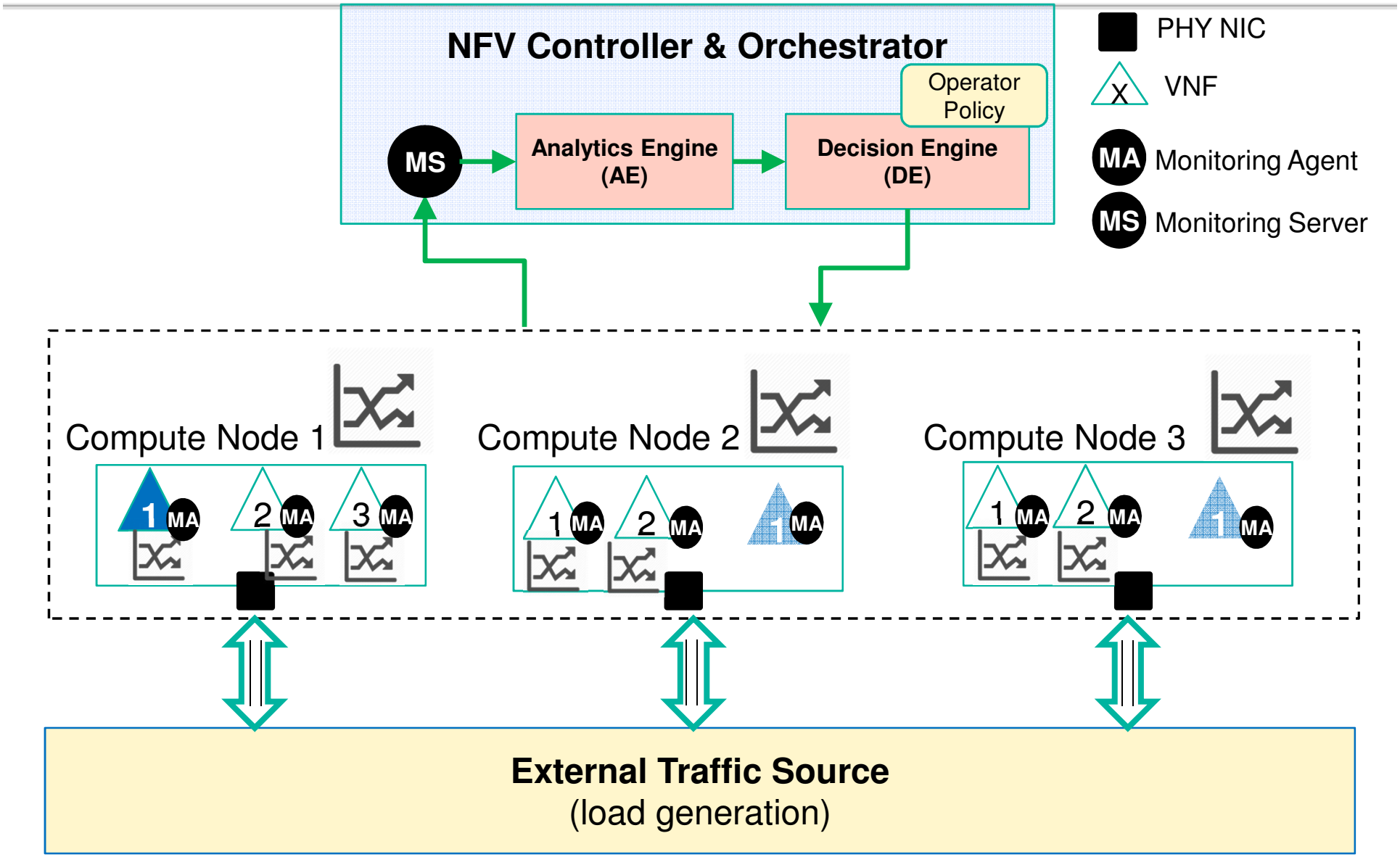
# Affinity Signature for making lo ng-term decisions



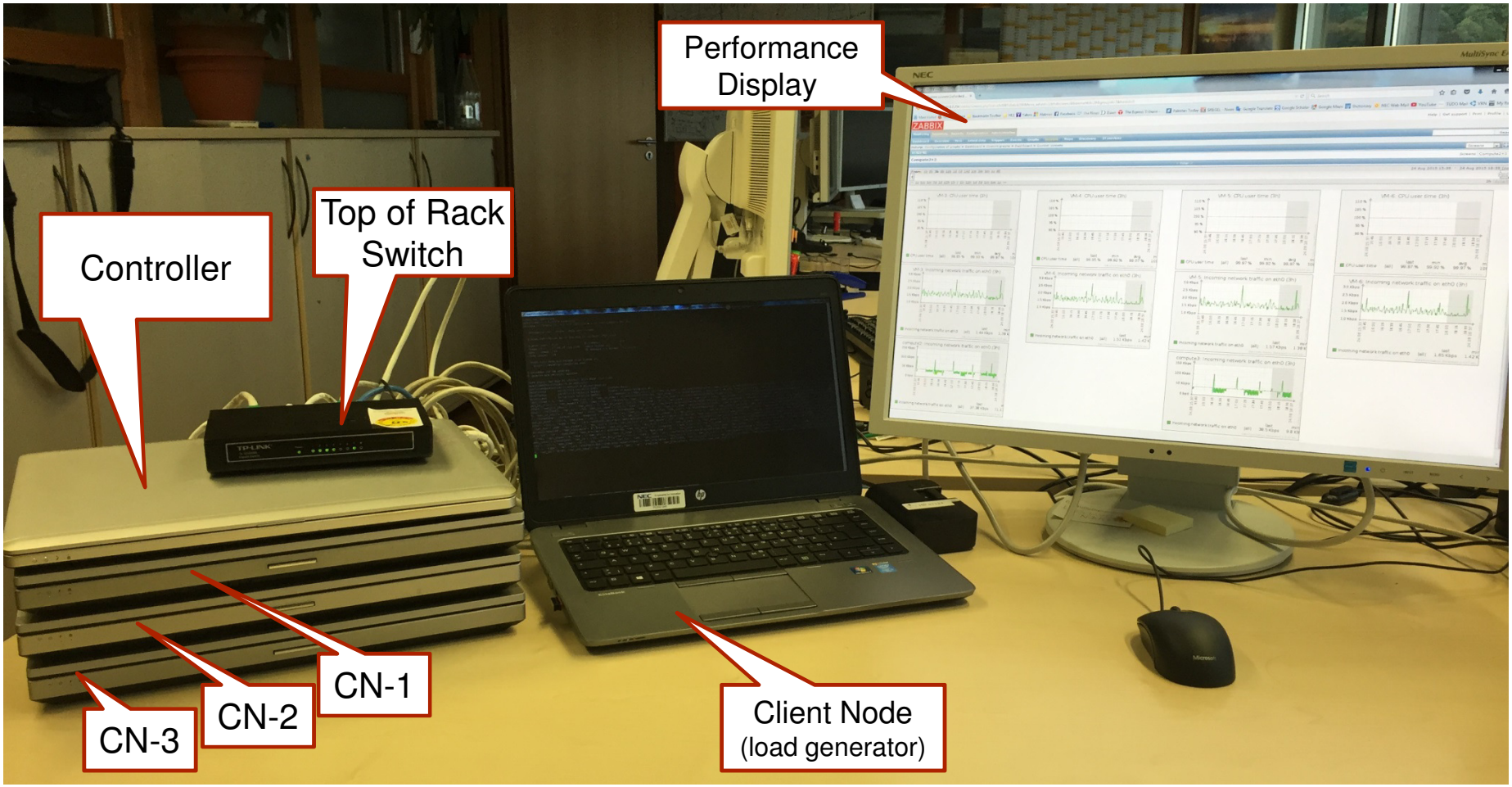
# Current Scope of the System Under Development (MCN/OH)



# Demo System Overview



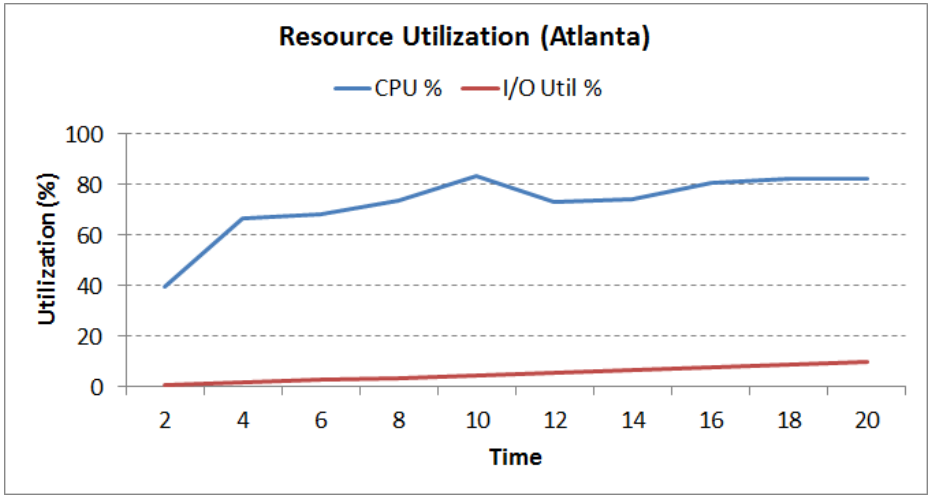
# Physical Demo Setup

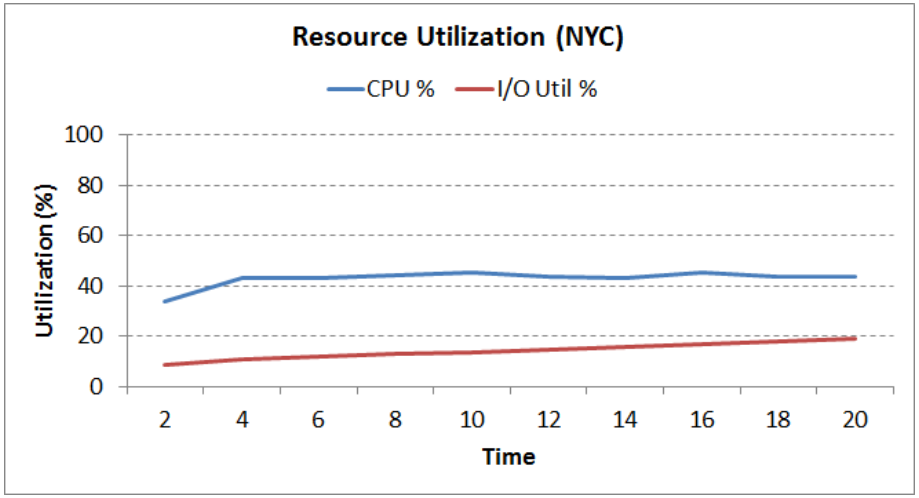



- CN-1: Compute Node 1
- CN-2 : Compute Node 2
- CN-3: Compute Node 3
- The ToR switch connects the CNs with the controller and the client node..

- The client node generates load towards the VNFs in the 3 CNs
- The display exhibits the load profile of different VNFs in the 3 CNs

# Hosts resource utilization disparity



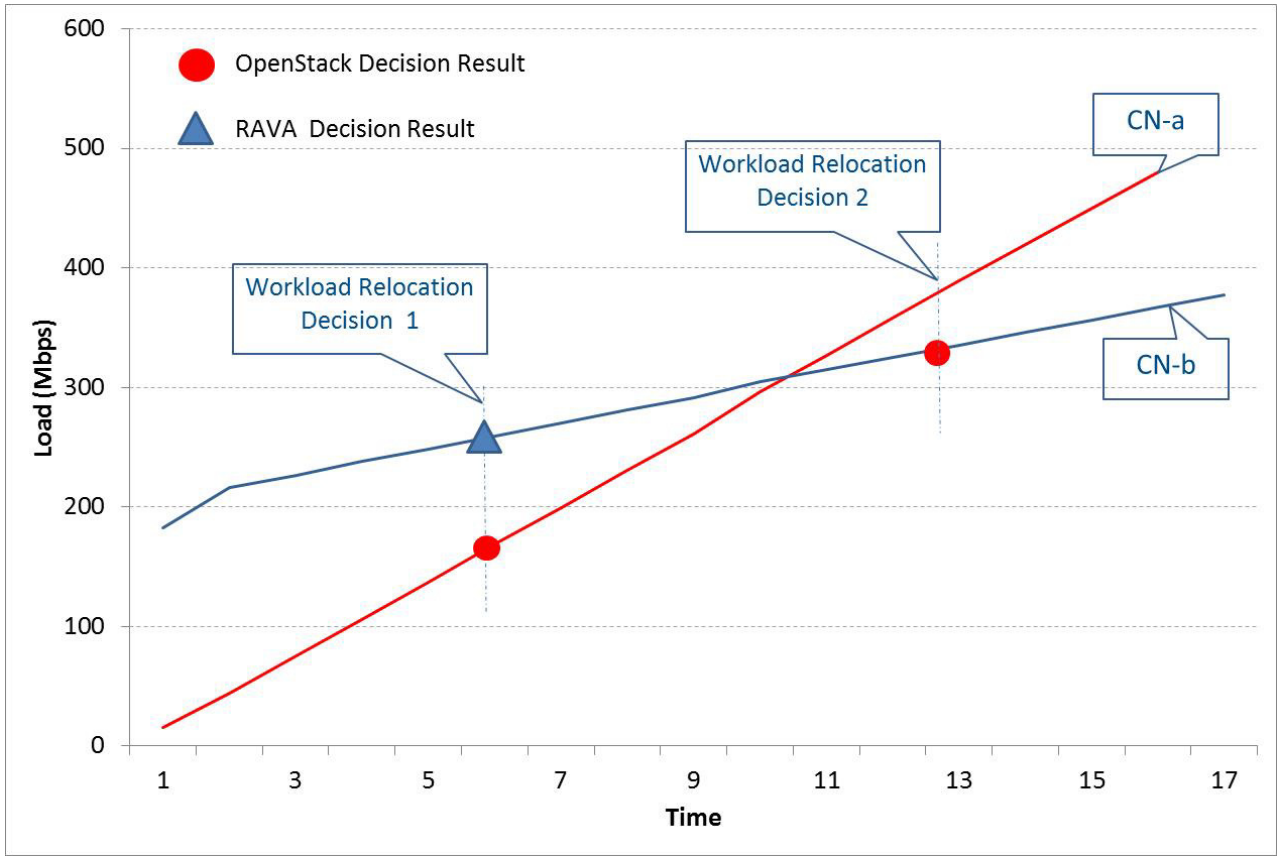

## Compute Node 2

- The input network traffic impacts the CPU utilization.
- CPU utilization increases from ~40% to ~80%

## Compute Node 3

- The impact of the network traffic on CPU utilization is negligible
- CPU utilization remains in the range of ~40%

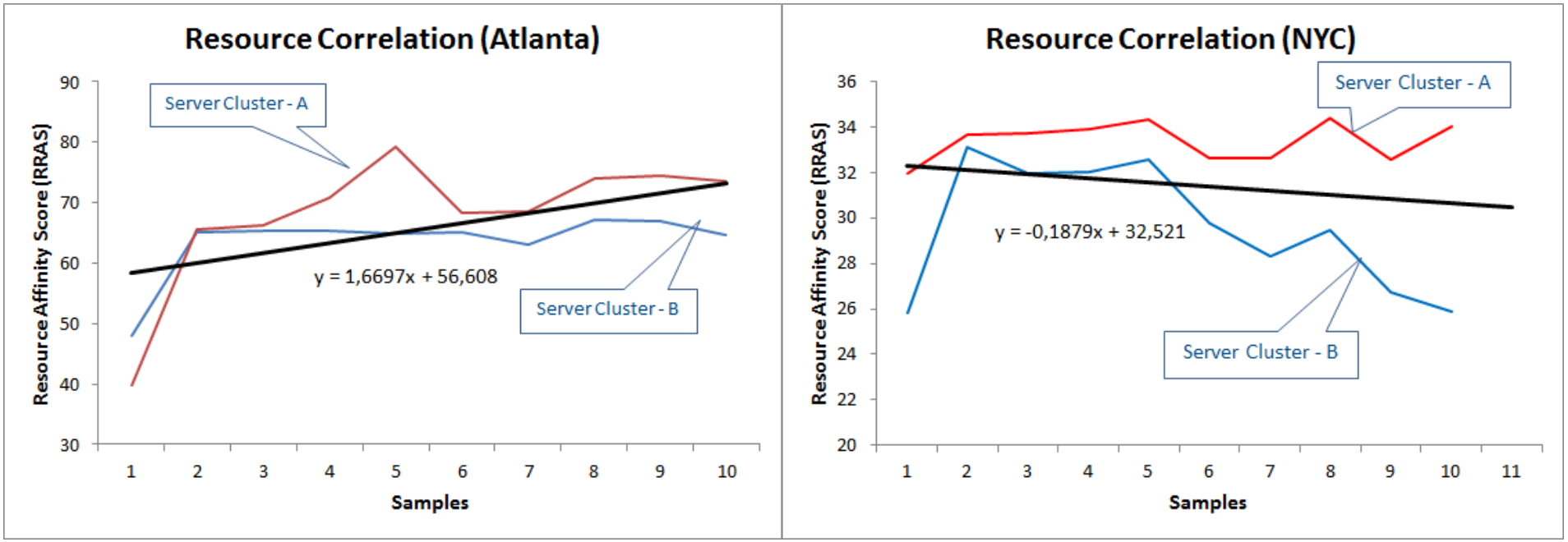
# Instantaneous allocation decision vs. forecasting based




- At the time of deciding between the destination hosts where the target-workload (ie., a VNF) should be migrated to,the existing technology will usually select the one with lower resource utilization.

- The existing technology will also not take into account the correlation (i.e., affinity) between the different resource units (e.g., CPU, I/O, Memory), and their prediction.

# RAVA – Determining Resource Correlation

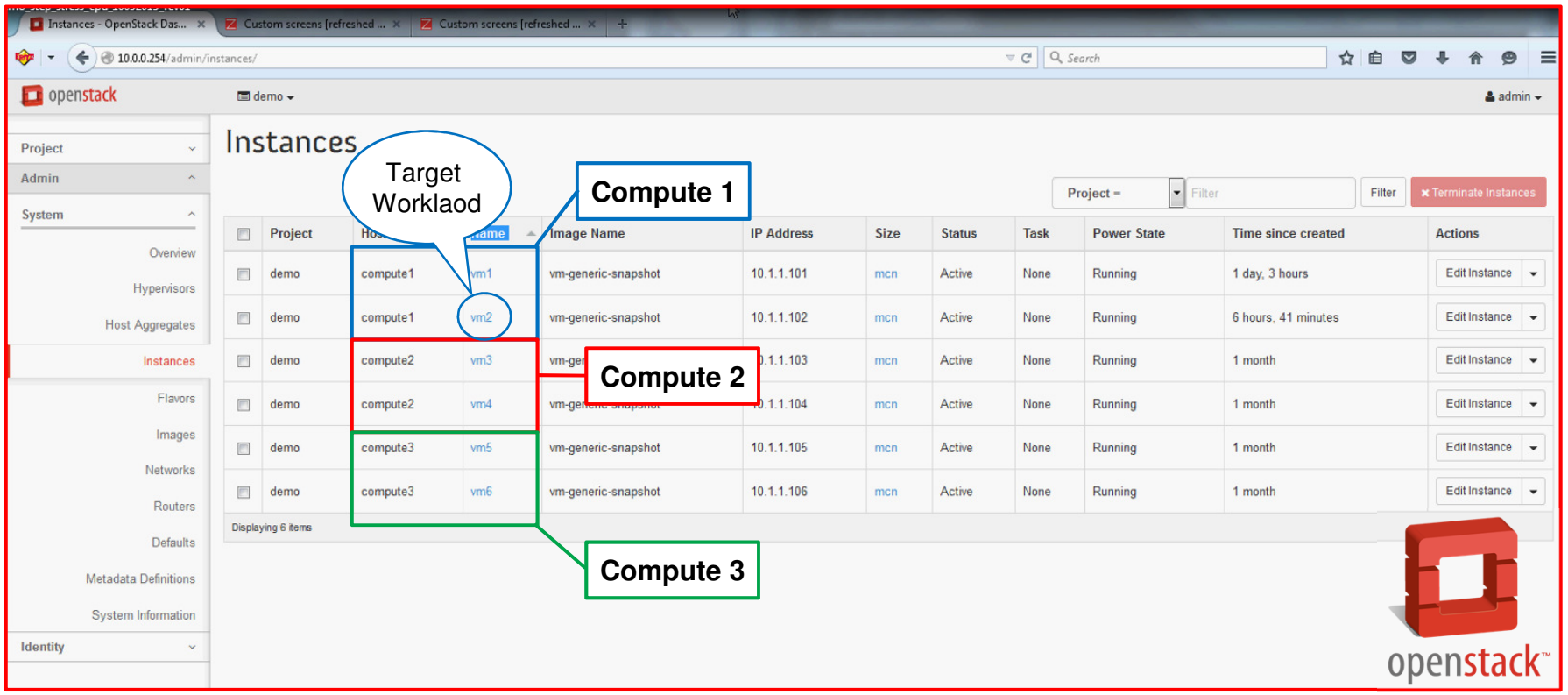



- RAVA determines the degree of correlation (i.e., dependence) between the network traffic load and the CPU utilization, and also predicts the future trend of such a correlation.

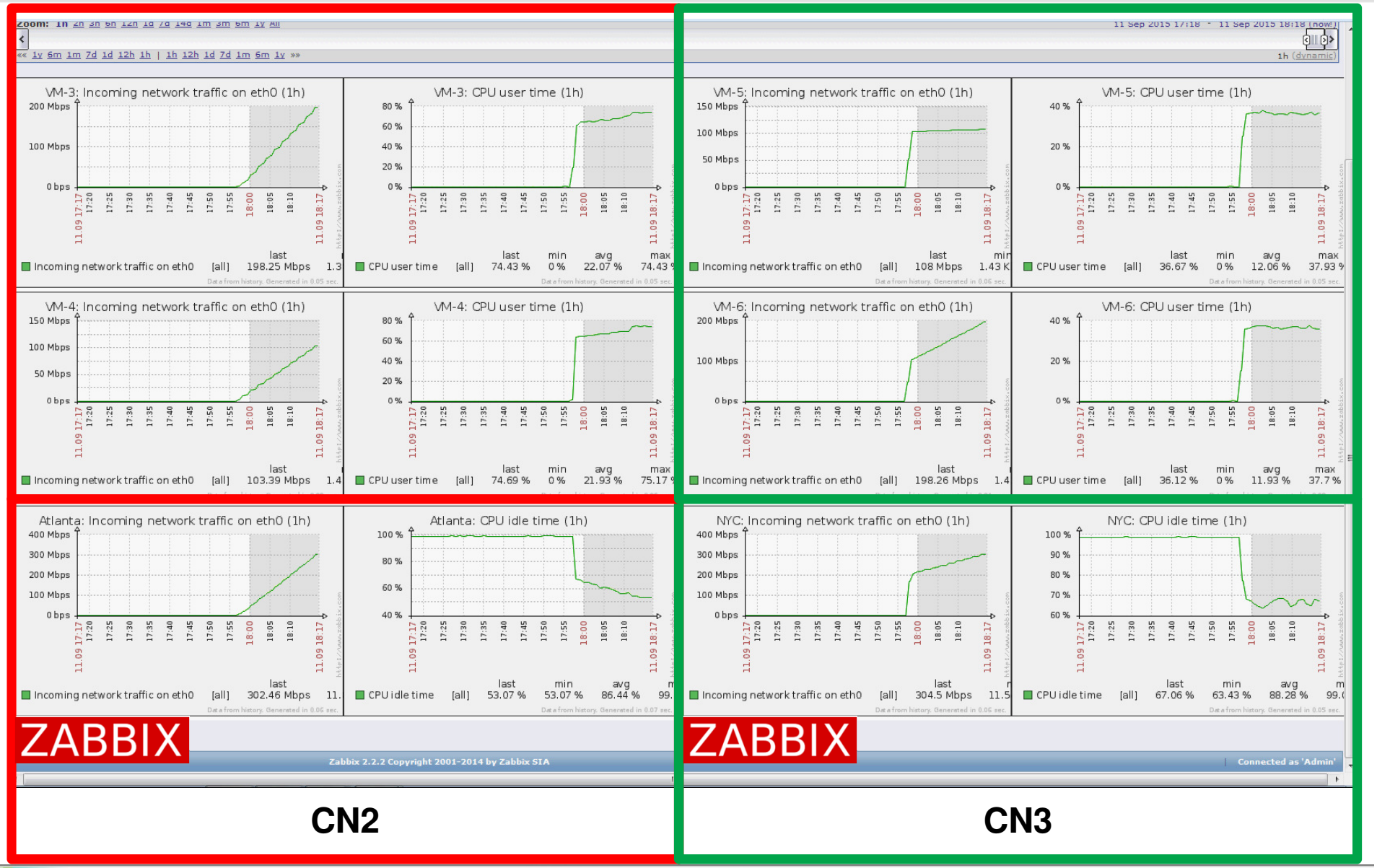
- Despite resources available in both hosts (CN2 & CN3) at the time of decision, RAVA will select NYC to meet the „long-term“ resource requirements of target-workload.

# Original workload assignment per datacenter

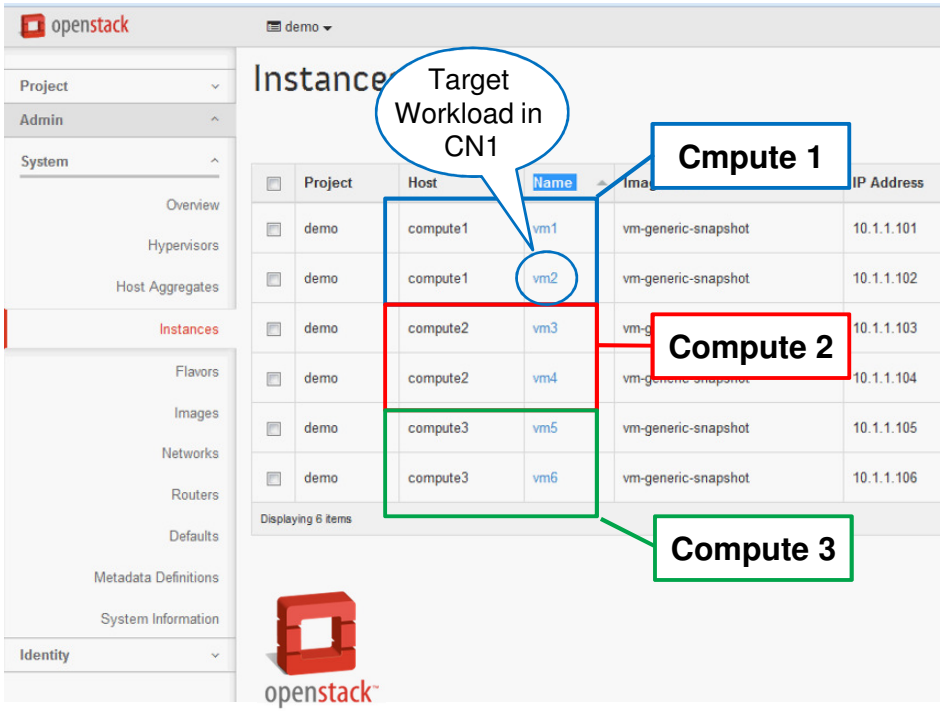
- OpenStack dashboard

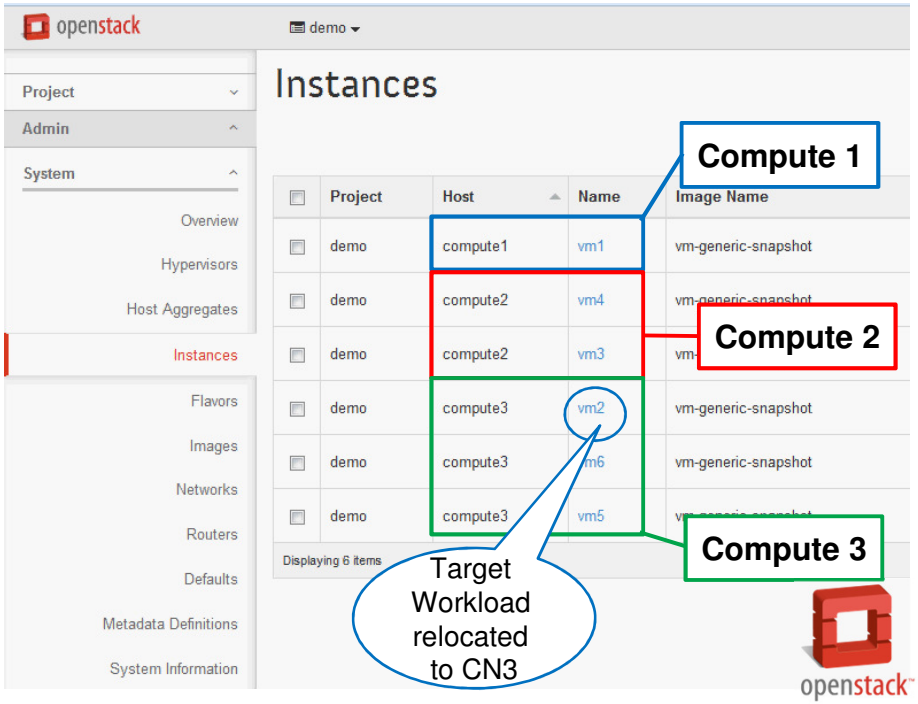


# Resource Utilization Profile in CN2 and CN3



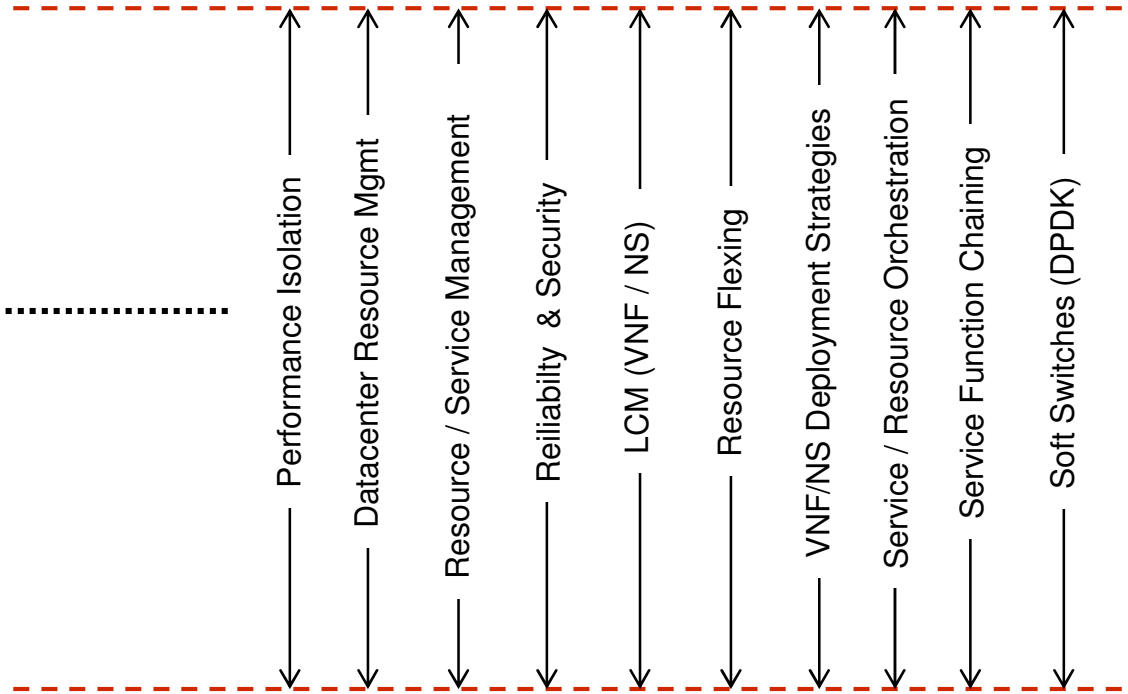
# Optimal target workload relocation

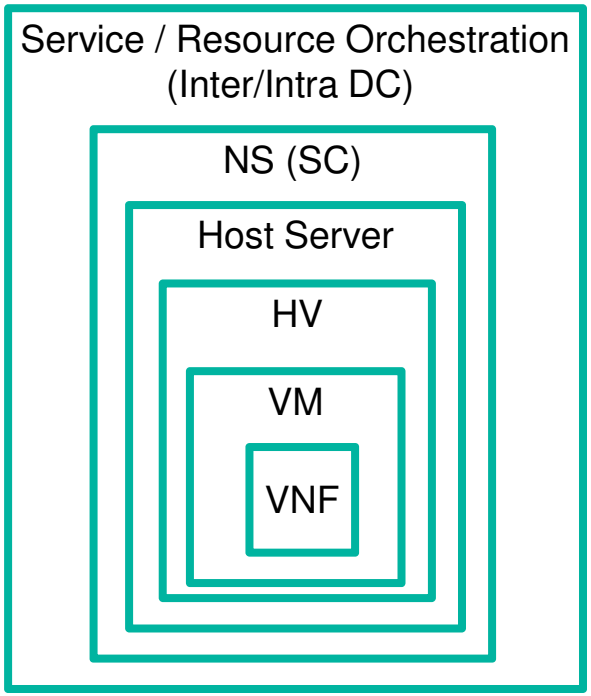


# Research Prospects and Scope

- To make the NFV infratstructure „Carrier Grade“.
- ETSI NFV, IETF, OPNFV etc



# Open Source NFVO and VNFM Projects

- Open Source Projects on NFVO and VNFM
  - OpenMANO (https://github.com/nfvlabs/openmano)
  - Tacker – An Open Stack Project on VNFM (https://wiki.openstack.org/wiki/Tacker)
  - NTT Gohan (https://www.openstack.org/summit/tokyo-2015/videos/presentation/gohan-an-open-source-service-development-engine-for-sdnnfv-orchestration)
  - TCS Telecloud (http://www.tcs.com/SiteCollectionDocuments/Brochures/Service-Orchestration-Solution-0515-1.pdf)
  - Cloudify: (http://getcloudify.org/)
  - OpenBaton – A project by Fraunhofer FOKUS (http://openbaton.github.io/)
  - Open O – a project by China Mobile
- Open Source Projects on VIM
  - OpenStack (http://www.openstack.org)
  - CloudStack (https://cloudstack.apache.org )
- Open Ource Projects on SDN
  - Opendaylight



OPNFV

# Thank you !


IETF


ZABBIX

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