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Network function virtualization: some design and performance issues for network operators

(H2020 phase II project)

Fabrice Guillemin, Orange Labs, OLN/CNC/NCA
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Outline

- Introduction: Network operators in the SDN/NFV context and network architecture evolution
- Examples of virtualized network functions (under development at Orange Labs)
- Orchestration and ONAP
- Conclusion

Introduction

- The telecommunication network ecosystem is rapidly changing but:
  - The Internet is now ossified; the IP layer has become the convergence layer of most applications (partially except IoT); IP networks improve marginally (segment routing, BGP, etc.)
  - Mobile traffic (cellular and WiFi) is always growing; centralized mobile cores for cellular access introduce bottlenecks

    ⇨ Rigidity in networks unable to meet user's expectation
- New requirements by customers
  - Ever higher bit rates at the access (both fixed and cellular)
  - More flexibility to create virtual private networks with given characteristics (required by verticals: ultra low latency, massive broadband/activity sectors: Health, automotive, etc.)
- Risk for network operators: services offered by Over The Top (OTT) players (GAFA ⇨ feudal Internet), dumb pipe providers

Network operator's response: improve connectivity (FTTH for fixed access, 5G for cellular with high bit rates on the radio interface), improve radio coverage (WiFi and cellular), **make networks more programmable**

SDN/NFV: To make networks more programmable

- Virtualization techniques have become "mature":
  - They have been used for more than one decade by big OTT players (Amazon, Google, Microsoft, etc.) to host online applications
- Virtualization is emerging in networks, driven by two major needs:
  - User eXperience: Deployment and customization of network functions more flexible (ETSI's Network Function Virtualization (NFV))
  - Reduce CAPEX/OPEX: energy consumption, operations (CI/CD for upgrade), reuse the same hardware for various purposes, break the dependence upon delivery cycles by equipment providers
- In parallel to virtualization, Software Defined Networking (SDN) simplifies the configuration of network elements
  - SDN meets a recurrent requirement by operators to offer flexible configuration tools of network elements, instead of CLI and proprietary network management platforms – cf. CPS in the late 90's

⇨Networks become programmable platforms combining network and IT technologies

Challenges of SDN/NFV for a network operator

- Network functions migrating from dedicated hardware to off-the-shelf servers

Rigid, functions adherent to hardware, expensive …
but reliable

More flexible, functions independent of the hardware cheaper (in principle)…
but potentially less reliable

- Complete change in operator's trade
  - Operation of a programmable platform which is a mixed of network and IT resources ⇨ creation of a substrate (virtualized infrastructure) combining all types of resources and hosting (virtual) networks
  - The network of the operator is supported by the substrate
  - The operator network supports services but services can in principle be supported by other tenants (verticals) of the substrate – Some issues with regard to access to resources (fibers and radio frequencies)

⇨Redefinition of the role of the operator: virtualized infrastructure operator, network operator or both?

Some issues in SDN/NFV for an operator

- Some functions are critical for the network ⇨ Security and reliability issues since functions are now software suites
  - Reliability (formal verification, bug fixing, etc.)
  - Portability (compatibility between software versions)
  - Security (protection from intrusion, etc.)
  - Configuration of the software (verification that VNFs are correctly configured to run on a virtualized infrastructure beyond the correctness of the function they execute)
  - CI/CD chain for upgrading the virtualized infrastructure

⇨The operator has to become a software integrator and **an orchestrator of virtualized resources**

- Nevertheless some business issues:
  - Do virtualization and NFV reduce costs? What is the hidden cost of CI/CD chains?
  - What is the cost of integrating software?
  - Does virtualization reduce energy consumption?
  - Is there a market for private networks/network slices beyond business customers and verticals?

Evolution of network architectures

- In parallel to virtualization and SDN, technological advances modify network architectures
  - New optical technologies allow concentration of optical line terminations (OLT) higher in the backhaul network (100 – 250 km away from ONUs)
  - The separation of Remote Radio Head (RRH) and BBU (Base Band Unit) functions enables the creation of BBU hostels (50 – 100 km between an antenna and a BBU hostel)

⇨ Introduction of new elements: Main Central Offices (MCOs)*

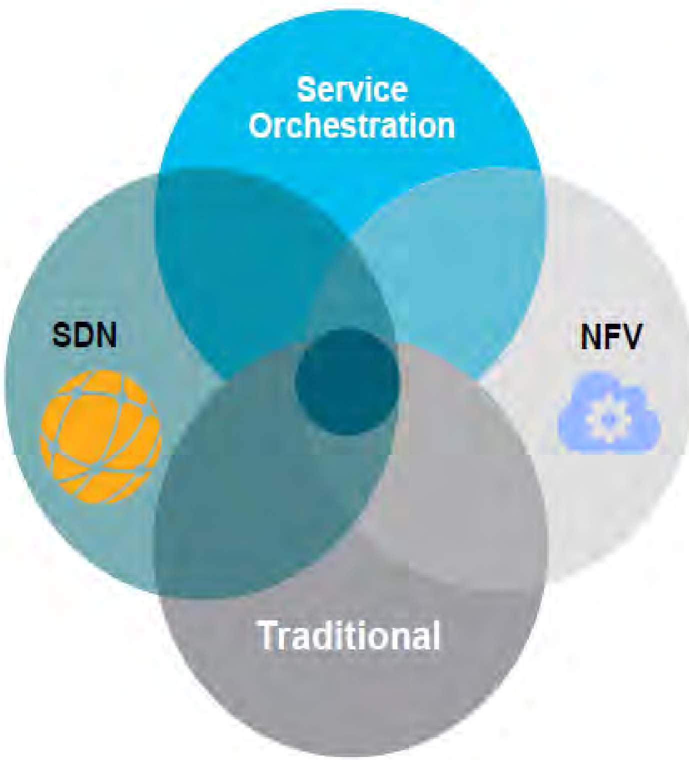
- Services are more constraining for the network
  - Massive consumption of video content push network operators to deploy distributed CDN, with servers in PoPs at the edge of the network
  - Open these storage capacities to OTTs? (vCDNs)
  - Emerging applications in relation with Mobile/Multi-access Edge Computing require very low latency and the possibility of reserving storage/computing capacities at the edge of the network

⇨ Introduction of Core Central Offices (CCOs)*

* MCOs and CCOs (5GPPP COMBO project) are also known as NGPoPs. In connection with CORD in the US

Summary of operator's position in the SDN/NF context

Network Function Virtualization: A Key Pilar of Telco Transformation



Service Orchestration
Automation, provisioning & management of physical & virtual resources to enable end to end service

NFV
Virtualized Network functions running on COTS hardware with automation

SDN
Centralized Control, programmability & abstraction, programmatic network & service instantiation

Traditional
Distributed control plane components, Bare Metal, Physical network entities

Example of commercial deployment: EasyGo Networks by Orange

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Virtualized network functions

- Some functions are under study :

network control
  - virtual Evolved Packet Core (vEPC): create a private mobile network for a company (only the control plane, the radio access is on the shared infrastructure) - the PGateWay (PGW) should remain in the data plane
  - virtualized IMS: private phone network for a company

data plane
  - RAN functions (RANaaS: dedicated radio access, cloudRAN
  - virtualized monitoring: for a tenant, to monitor its own VMs

- Network functions
  - Appear as Service Function Chains (SFC)
  - Comprise some components in the control plane and others in the data plane, with various requirements in terms of resources (storage, computing) and latency

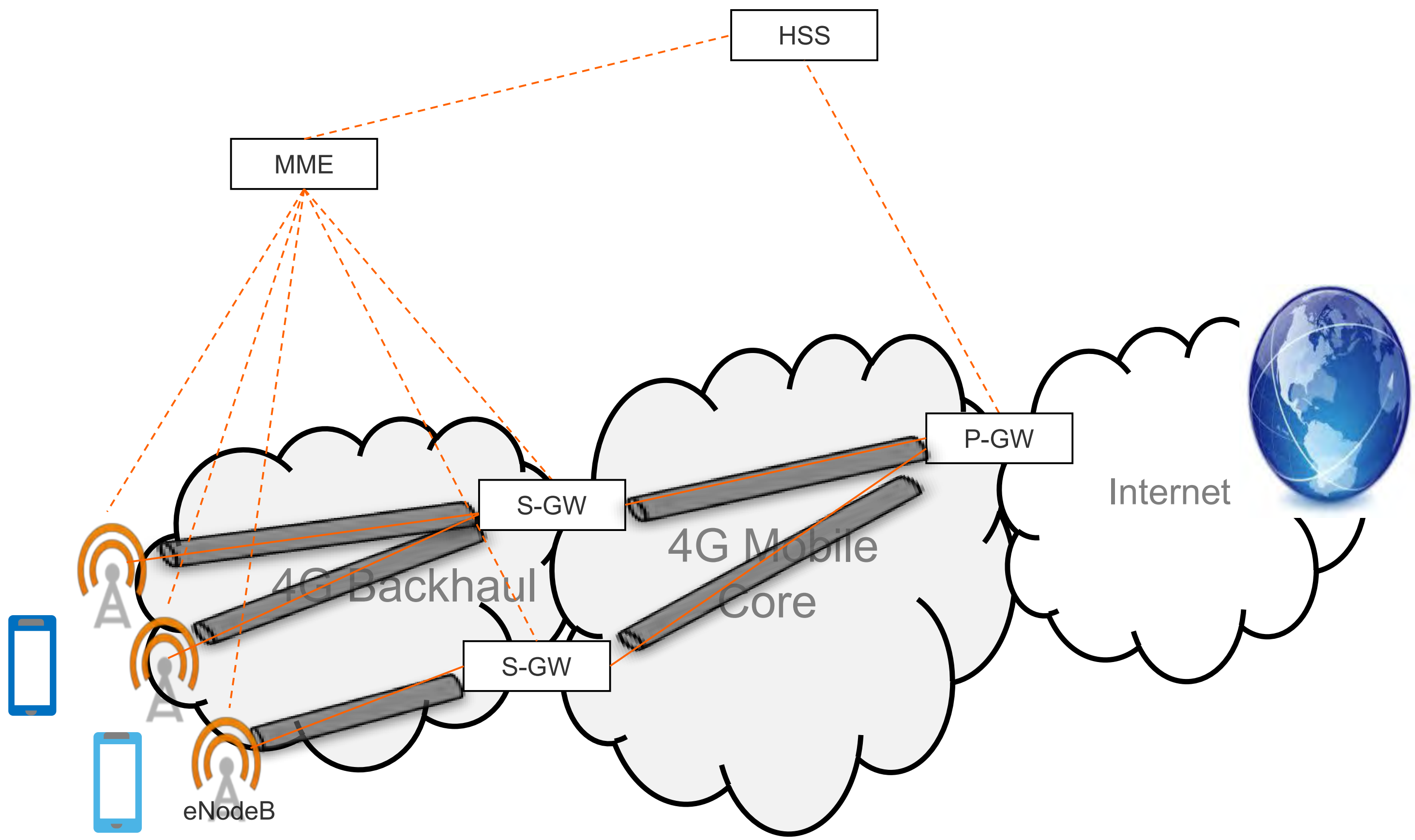
⇨ Orchestrating a virtualized infrastructure requires the placement of virtualized functions by taking into account the types and the constraints of the various components

Universal Gateway (UGW)

- Fixed/mobile convergence
- Control and user plane separation (CUPS) – 5GPP requirement for 5G
- SDNification of the backhaul network

In collaboration with b<>com Rennes

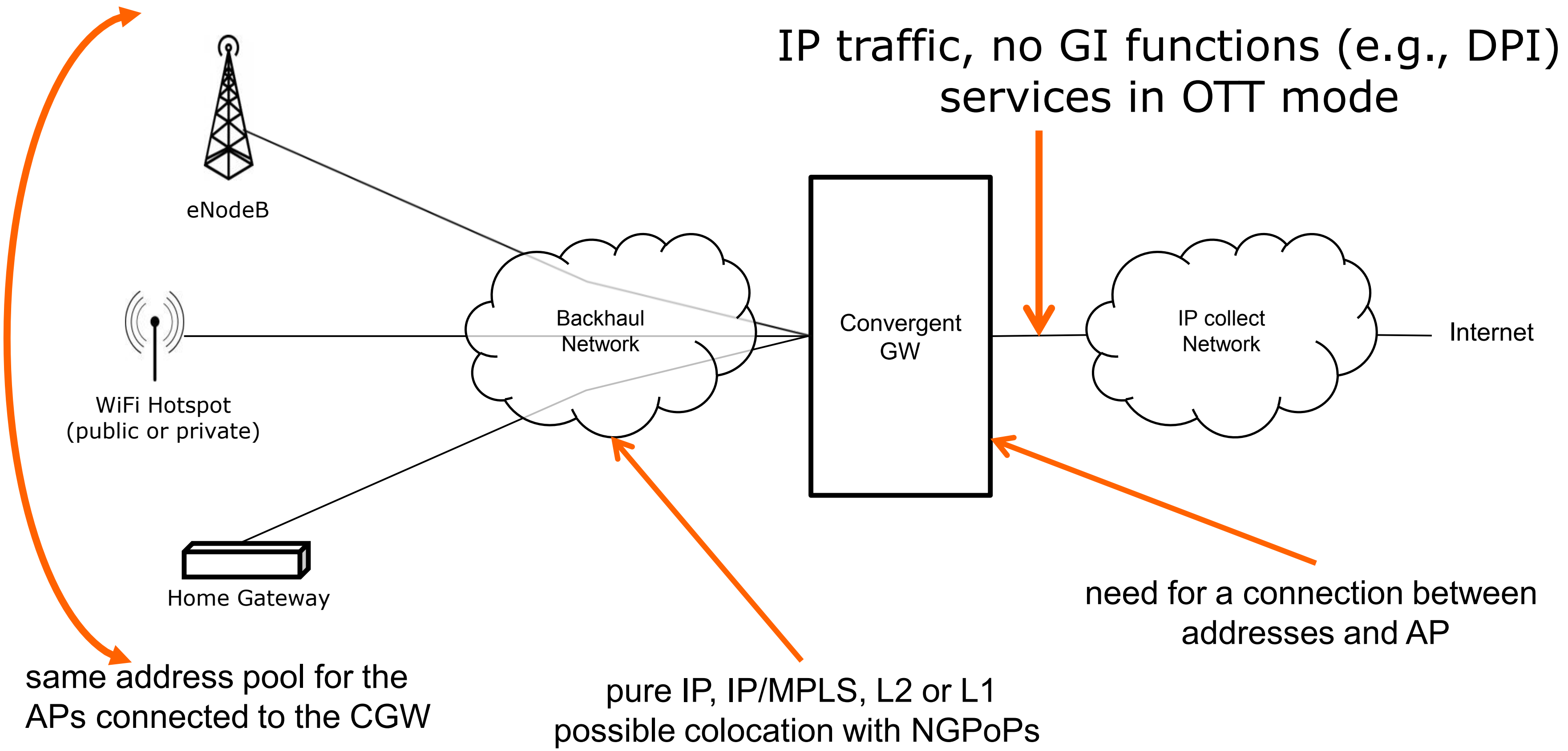
4G legacy architecture (LTE/EPC)



- Data and Control planes managed in same functional elements
  - Scaling issues with data traffic explosion
  - Complex implementation of Virtualized EPC

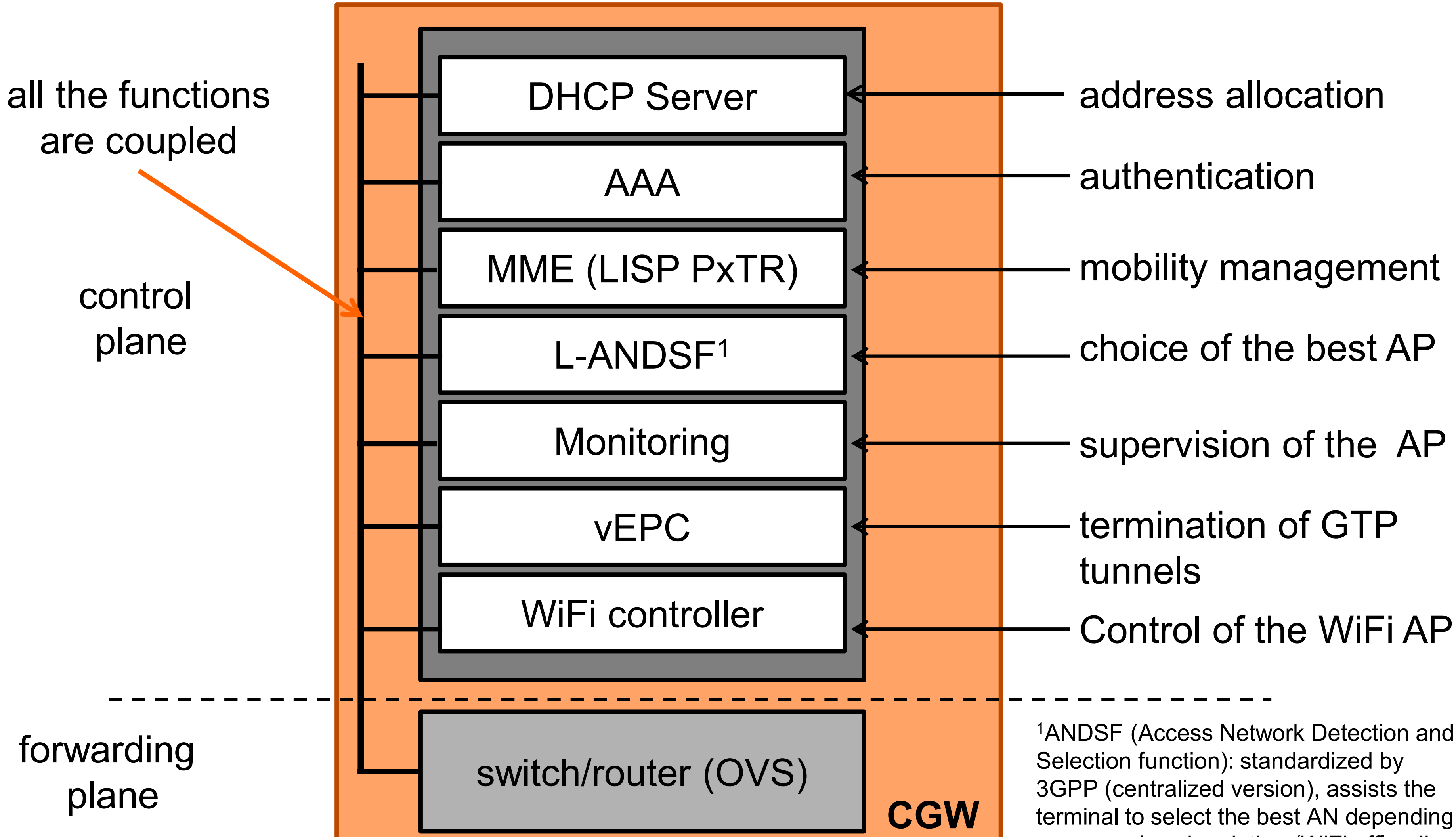
Universal Convergent Gateway (under development by BCOM)

Backhaul all access technologies (fixed, WiFi, cellular) through the same gateway all-IP design



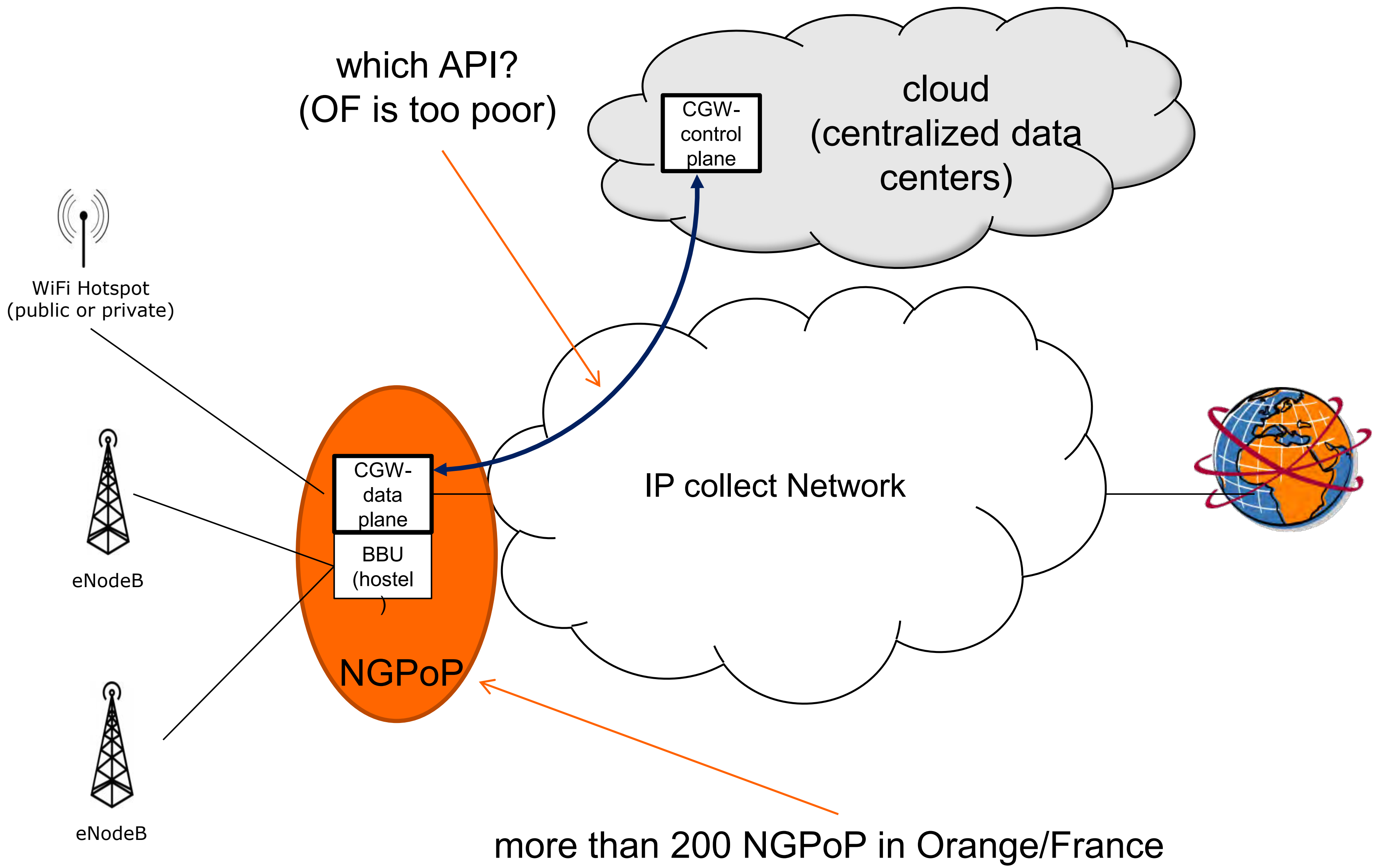
The functional blocks of the UGW (~MCORD)

all the functions are hosted by virtual machines or containers (NFV) and are based on open source software



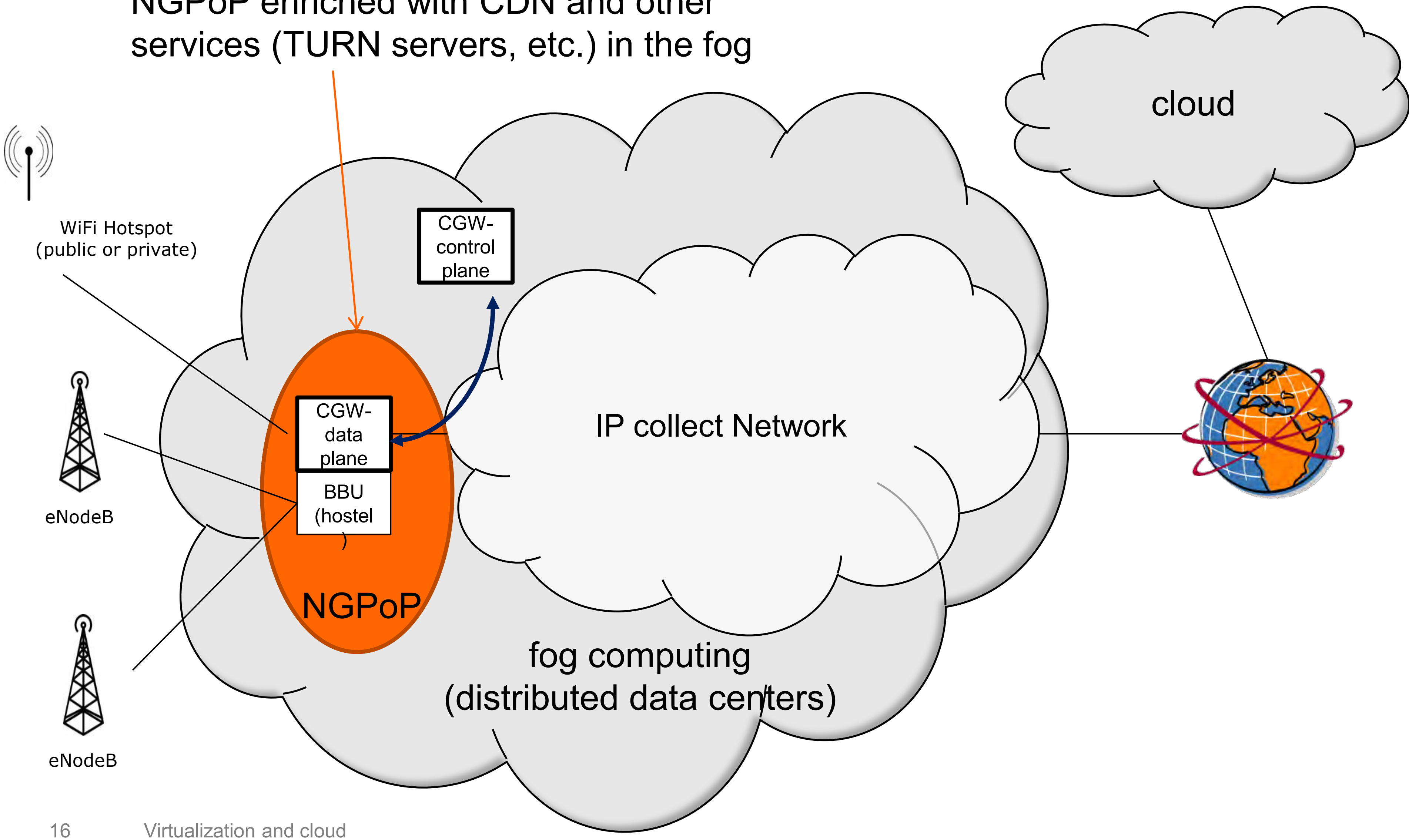
[1]ANDSF (Access Network Detection and Selection function): standardized by 3GPP (centralized version), assists the terminal to select the best AN depending upon user's subscription (WiFi offloading)

Ideal design/cloud

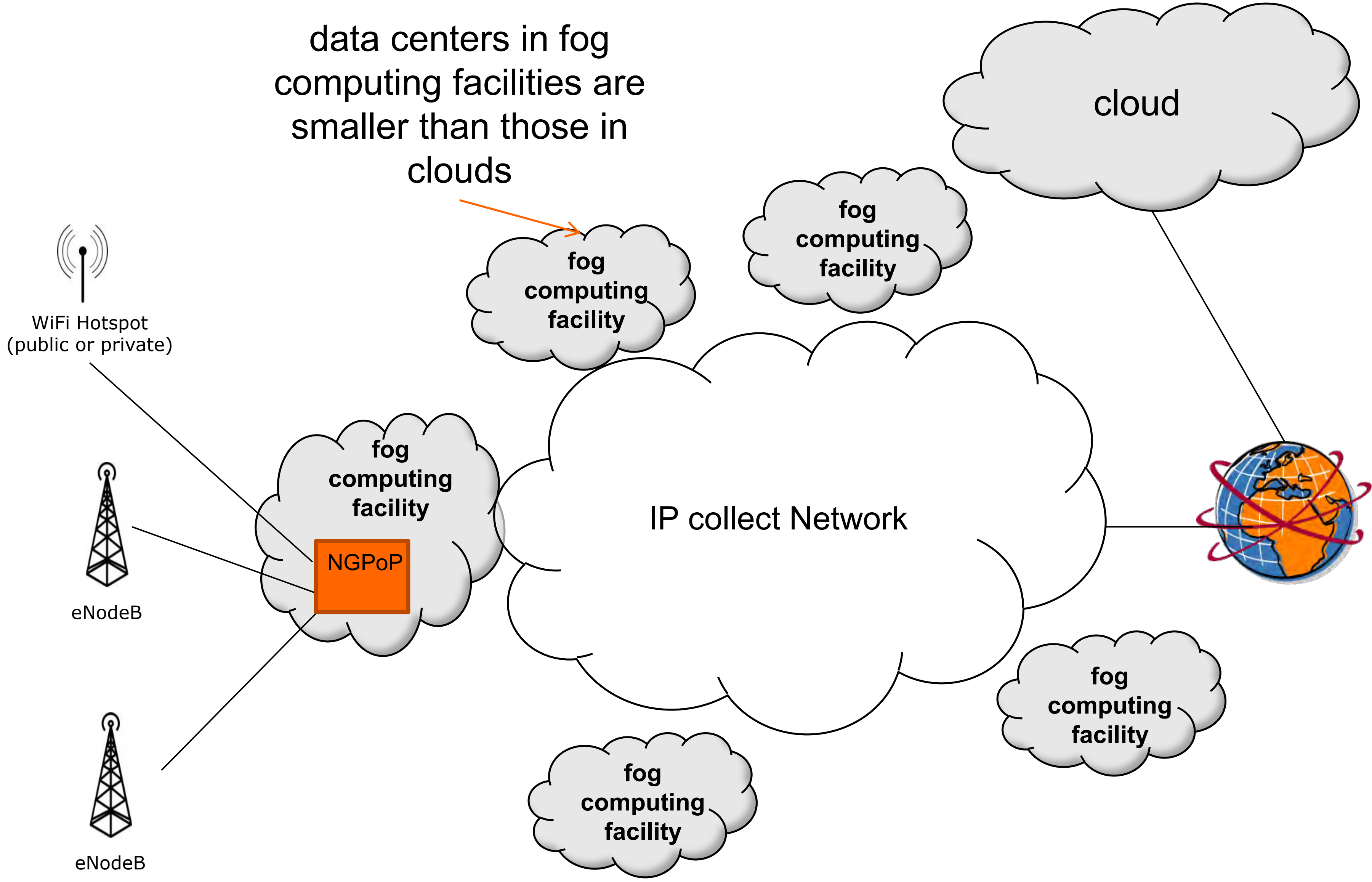


Ideal design/fog computing

NGPoP enriched with CDN and other services (TURN servers, etc.) in the fog



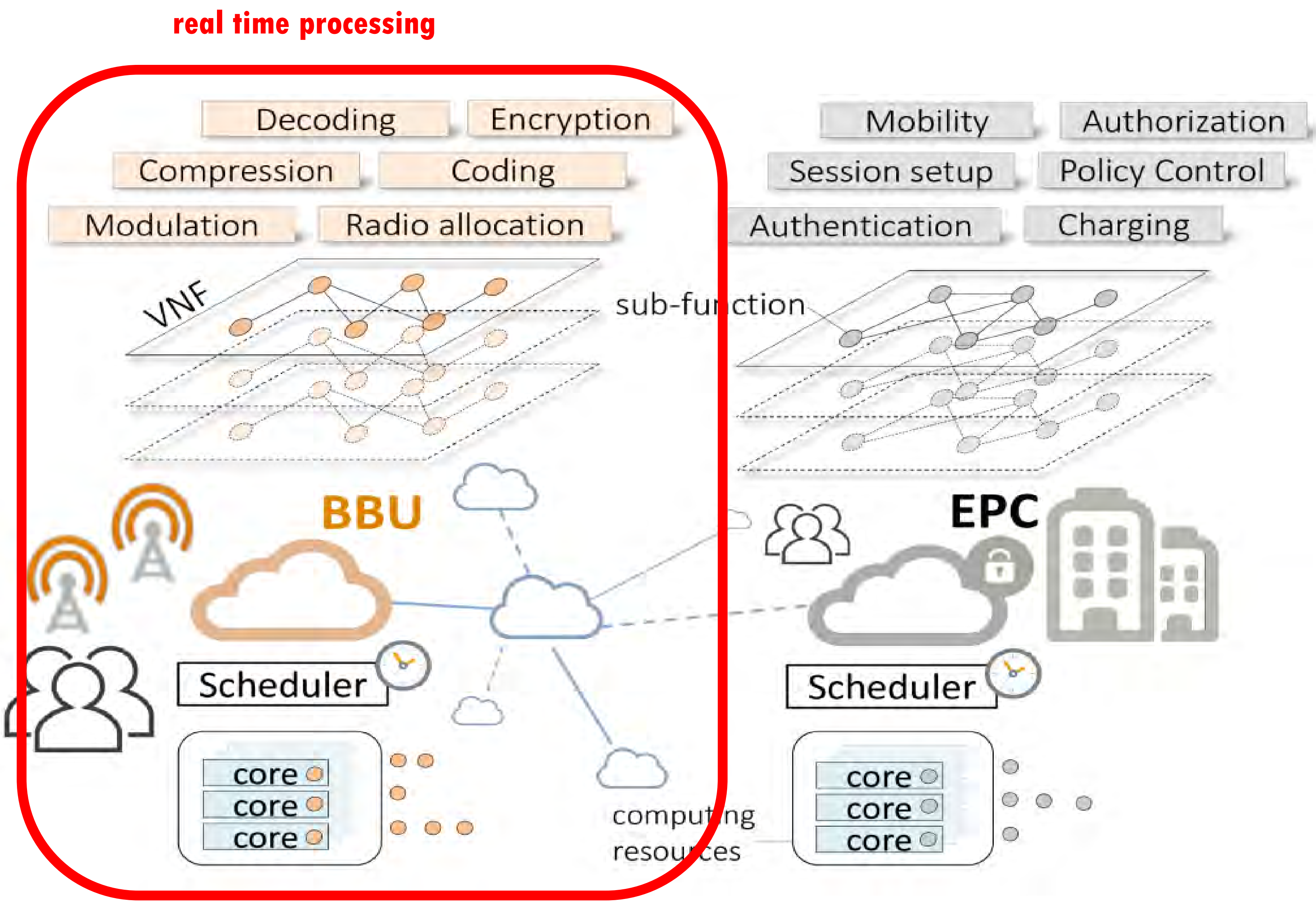
Global view of the network



Cloud RAN

- Separation of RRH and BBU functions
- Grouping BBUs in a data center
- Cloudification of RAN functions
- Goal: RAN functions as NFV

The case of CloudRAN (C-RAN)



Implementation of C-RAN

Resource pooling with a global scheduler

Implementation of a VNF in the form of a chain of components to be executed on a multi-core platform.

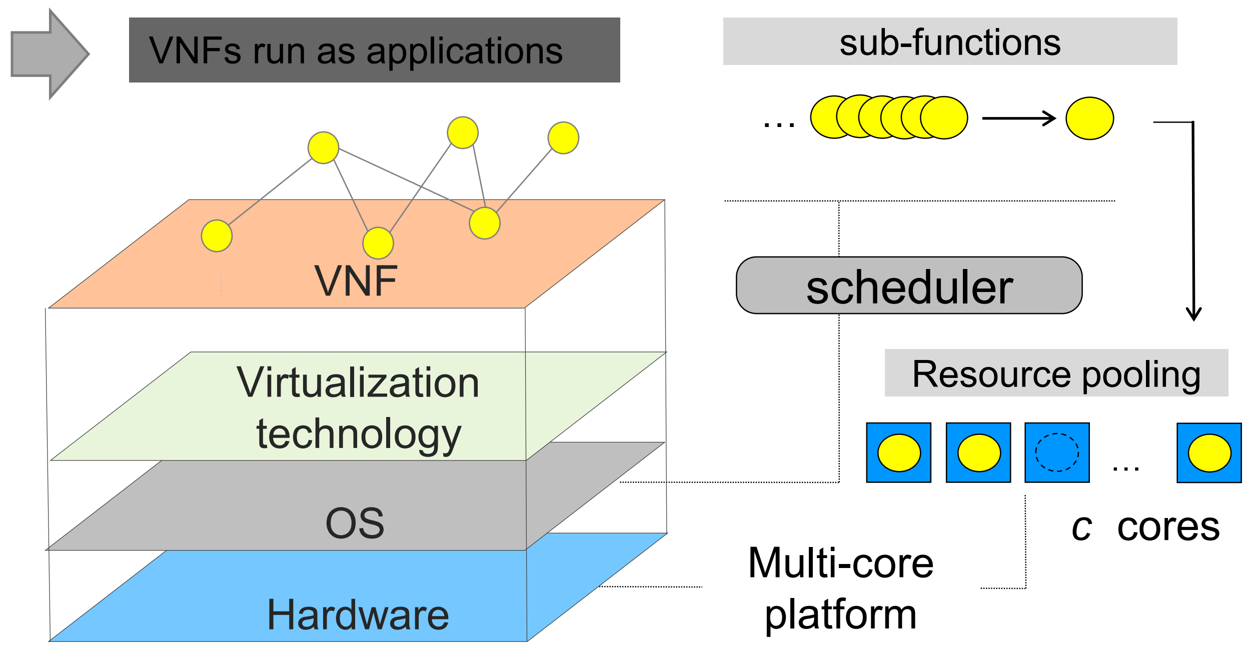
A VNF is a suite of executable processes.

Container-based virtual environment

Cores are controlled by a global scheduler which allocates the capacities of the cores.

~~Static resource allocation~~

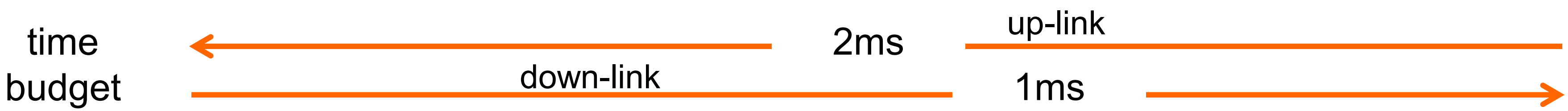
VNF decomposition plays a crucial role on resource sharing models.

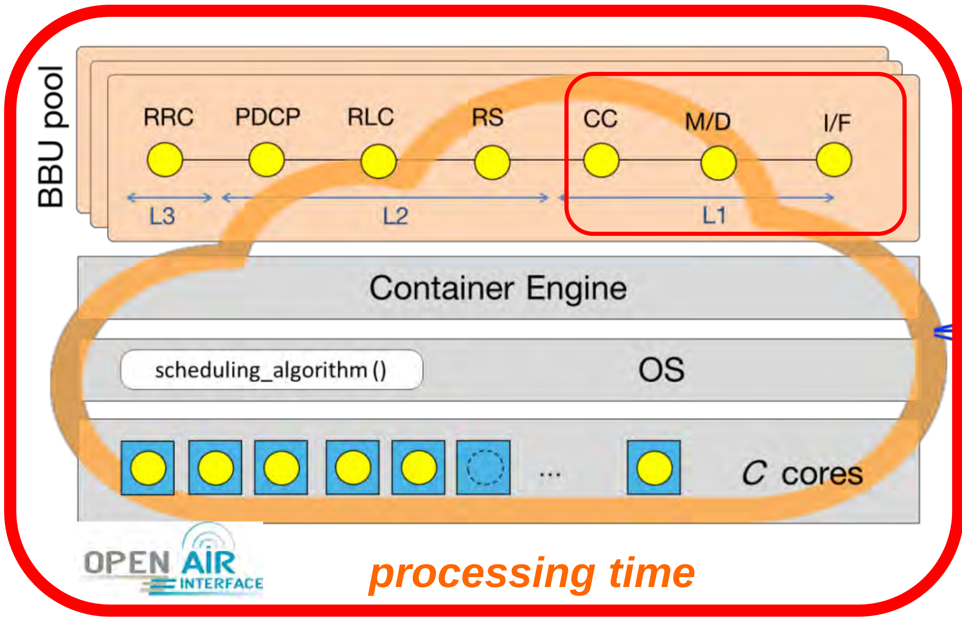


A core executes a single sub-function at a time.

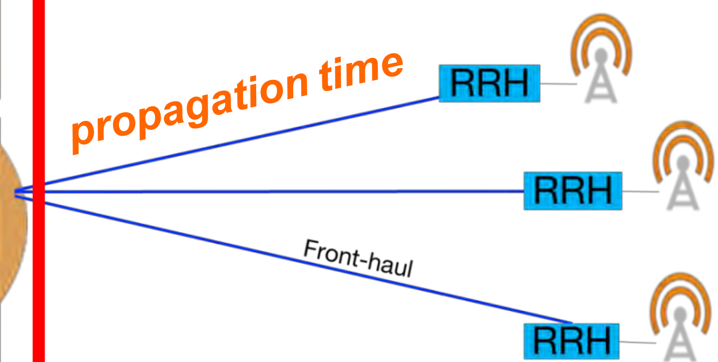
Main challenges of C-RAN: Real time behavior

Cloud-RAN dissociates RRHs and BBUs while keeping distributed radio elements and centralized BBUs. The separation of RRHs and BBUs imposes stringent runtimes of base-band functions to respect LTE deadlines





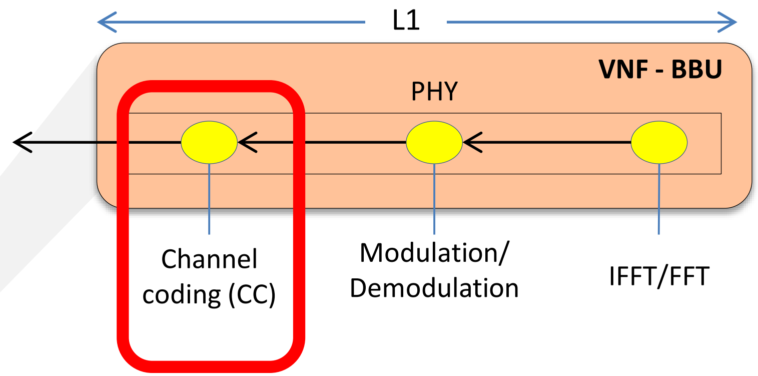
The time budget should be shared between the propagation time and the processing time



When minimizing the processing time, the resulting gain shall allow the increase of the distance between the BBU-pool from antennas

Processing BBU functions in the Cloud

Runtime of PHY functions



The channel coding function (encoding – decoding) is the most expensive one in terms of latency (runtime)

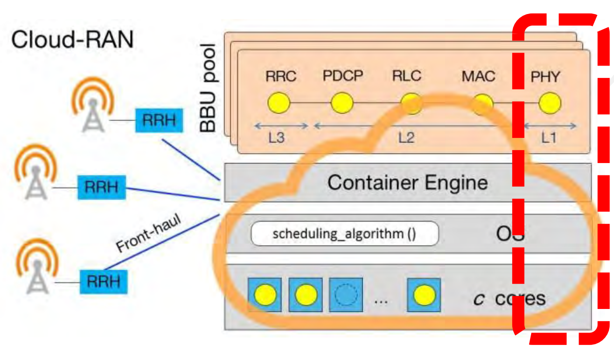
The execution time of the channel coding function depends of:

(1) Modulation and Coding Scheme (MCS)

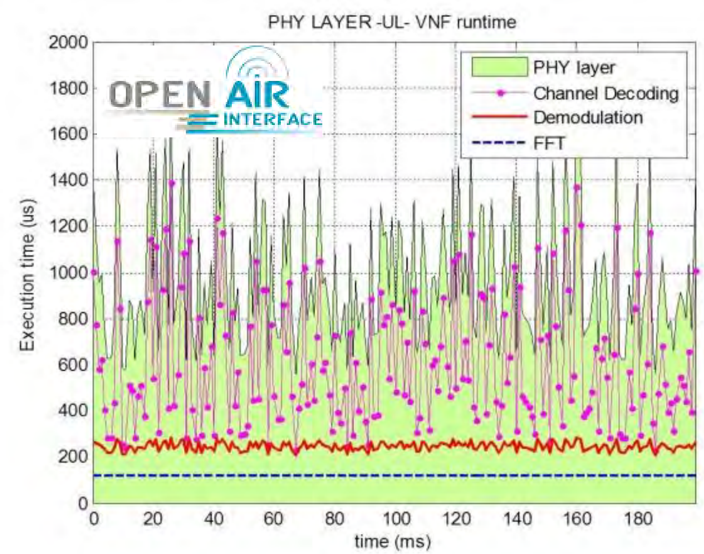
→ **SINR, CQI**

(2) Number of resource blocks (RB)

→ **eNB bandwidth**



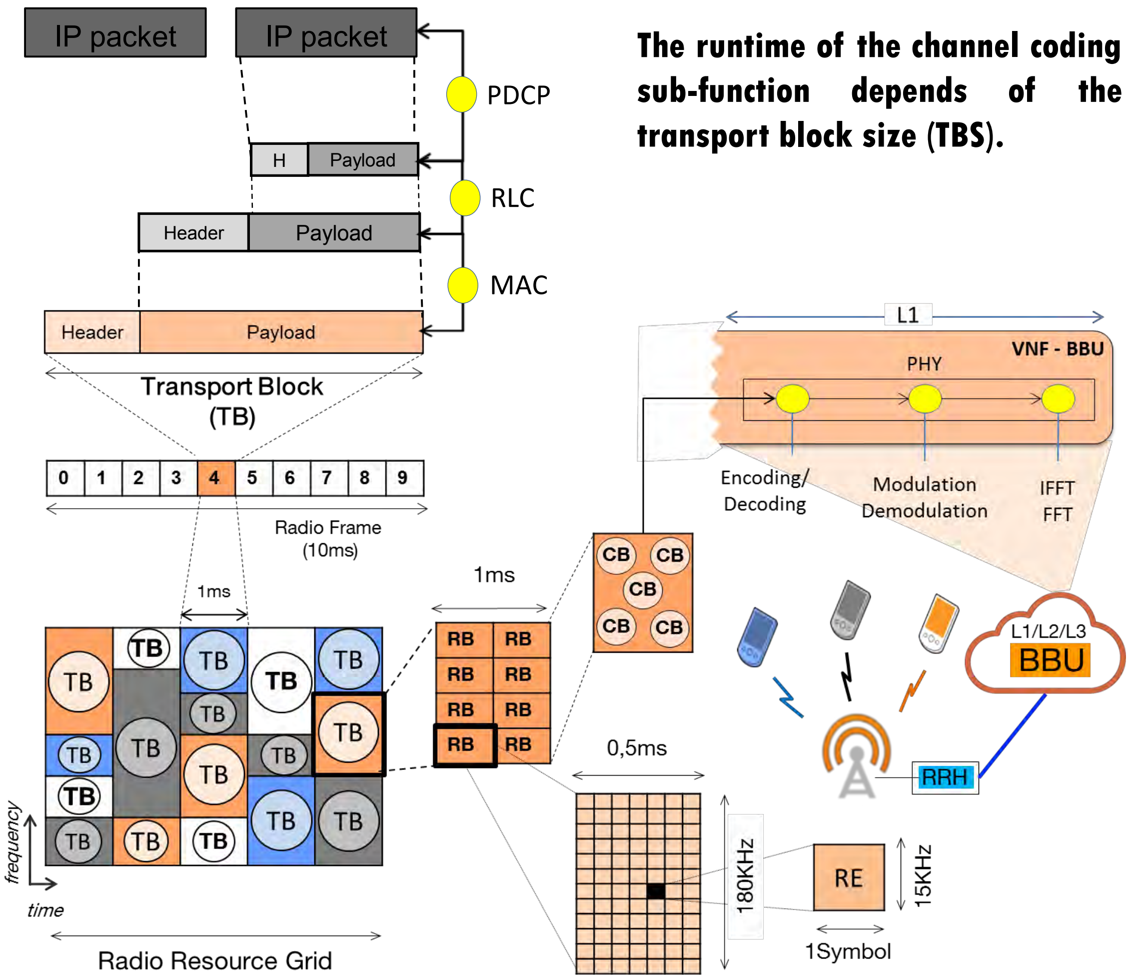
Processing Time (RX)	
Decoding	~ 1800 µs
Demodulation	~250 µs
FFT	~ 100 µs



non-deterministic behavior

Functional decomposition of BBUs

Channel Coding: Parallel processing



The runtime of the channel coding sub-function depends of the transport block size (TBS).

A Transport Block (TB) is a group of Resource Blocks (RBs) with a common Modulation and Coding Scheme (MCS).

Data parallelism

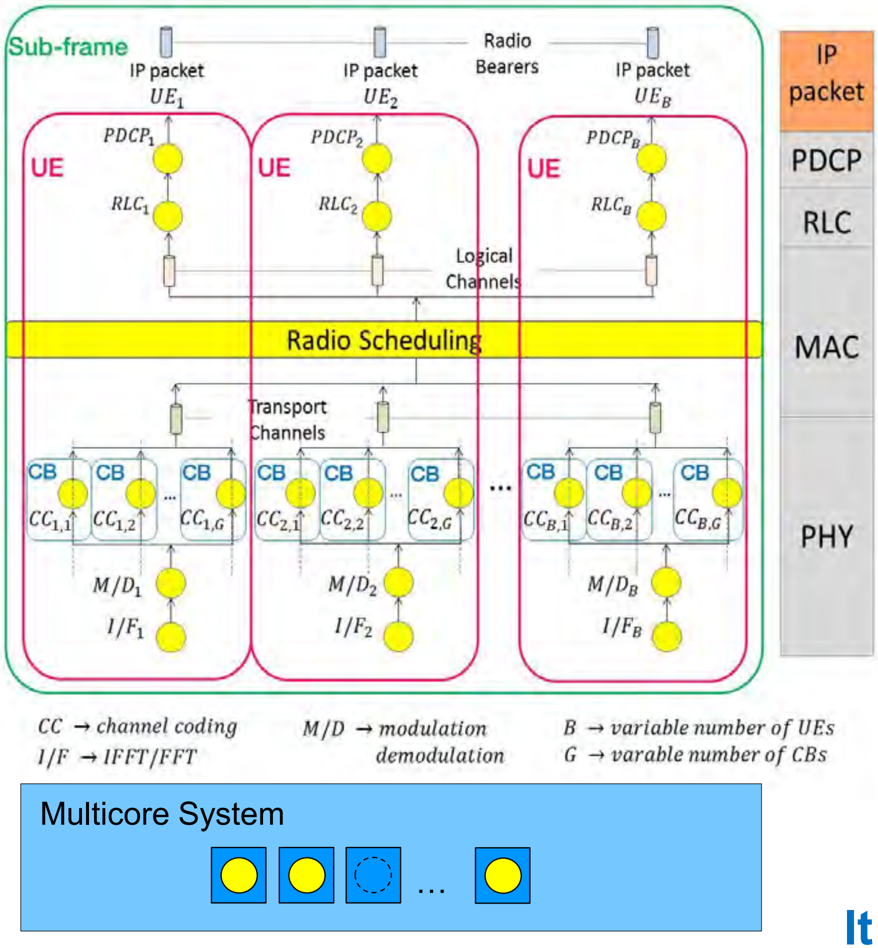
Parallelism by UEs, processing TBs in parallel.

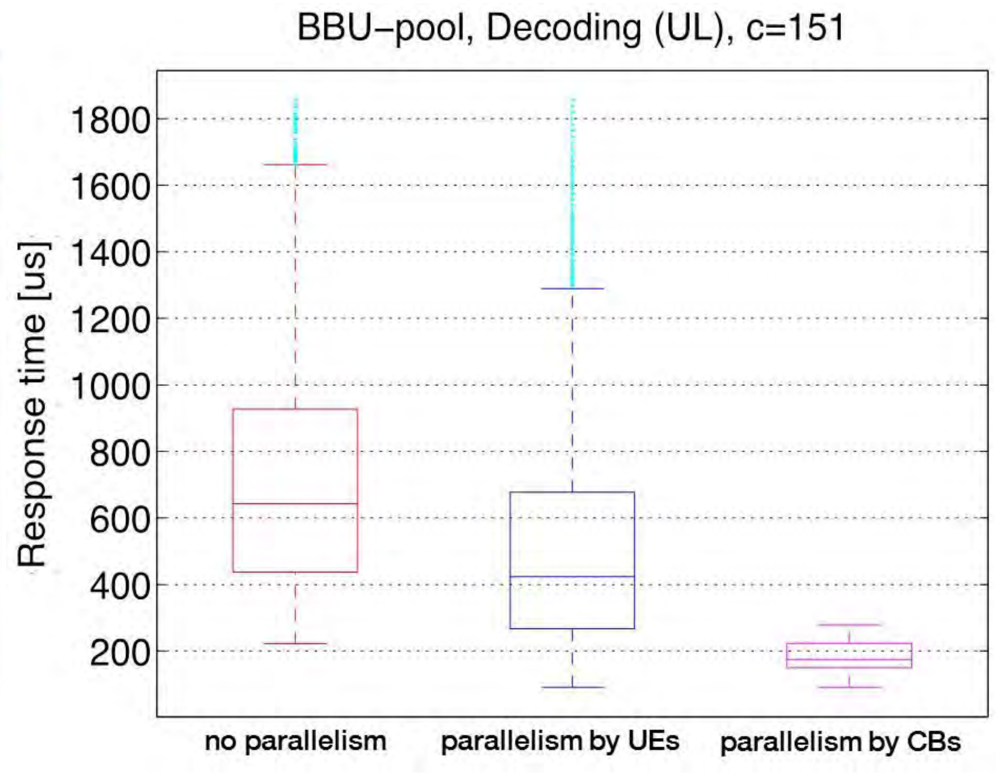
Parallelism by CBs, processing TBs per segments - Code Blocks (CBs).

Performance Analysis

KPI: Latency (runtime of BBU functions)

Results show important gain when performing parallelism per CBs





eNB settings: FDD - 20MHz – SISO.
front-haul size: 100 km.

It is possible to cloudify RAN functions, but fronthaul issues!

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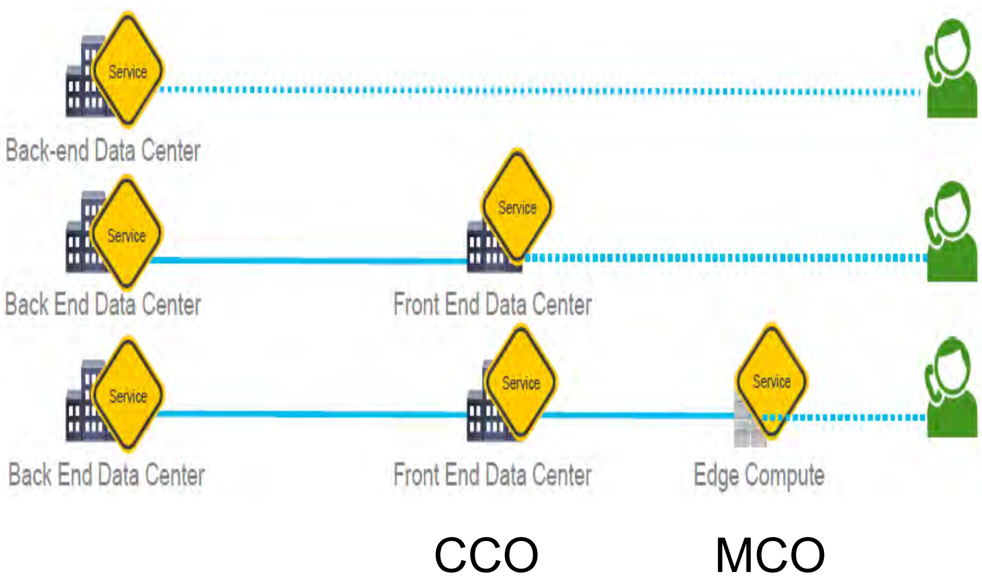
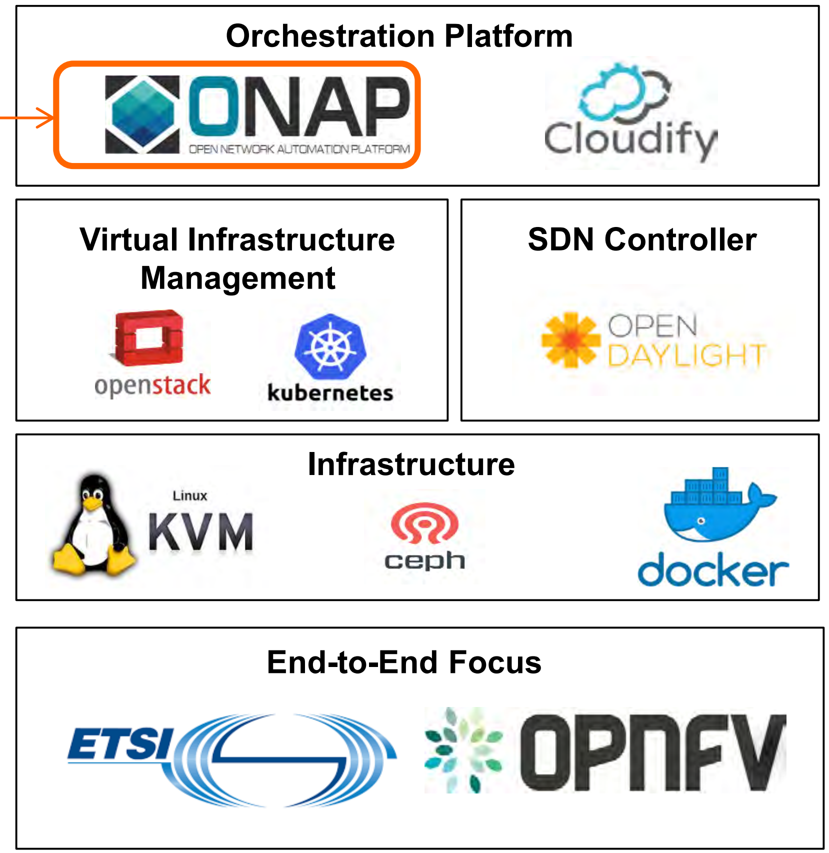
Network architecture vs. technologies

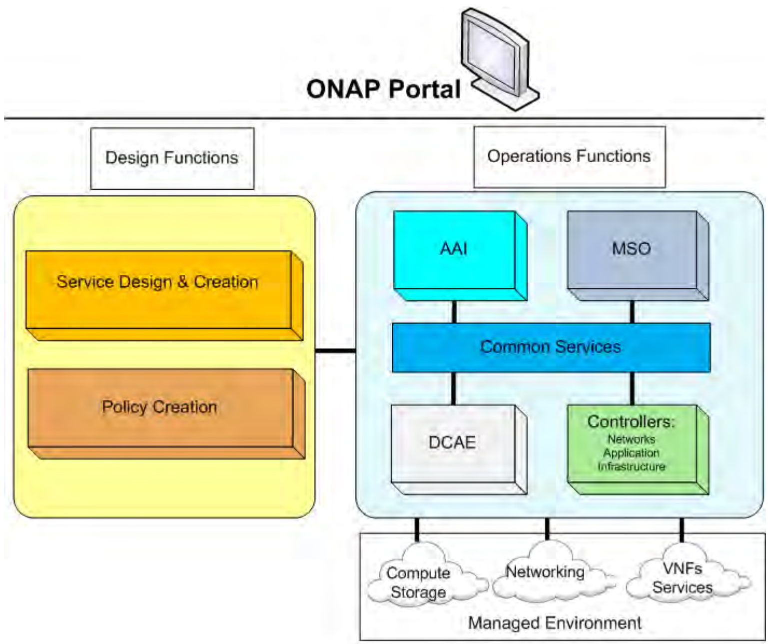
Open Automation Platform
(based on ECOMP and OpenO)



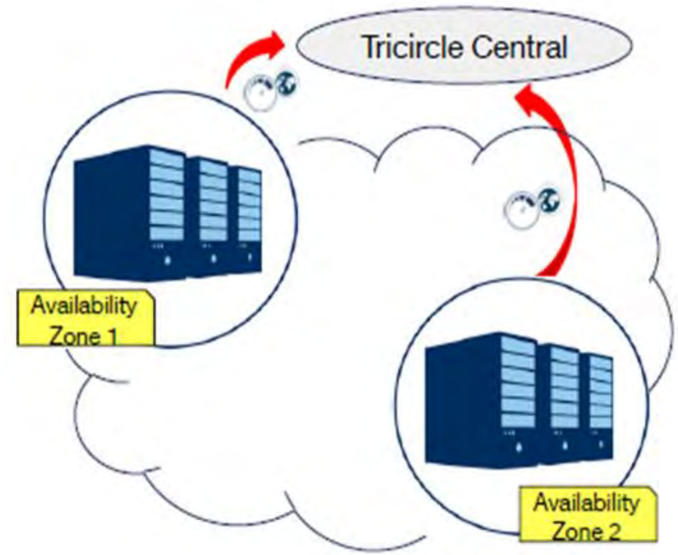


ONAP at a glance

ONAP Simplified Architecture



Resource Allocation for Distributed Cloud in OpenStack



The most available capacity from the zone respecting the services' constraints (without considering latency)

ONAP is a complete framework for the dynamic design and instantiation of Virtual Network Functions(VNFs)

We focus on resource allocation

ONAP functional blocks

- Service Design and Creation (SDC)
  - Based on meta data description, entirely describes how VNFs or services are managed
- Policy Creation
  - Set of rules defining control, orchestration and management policies
- Active and Available Inventory (AAI):
  - Continually updated to provide a real-time view of the topology and the underlying available resources
- Controllers
  - A controller is in charge of managing the state of a single resource, several controllers based on the Opendaylight platform.
  - An additional controller for infrastructure's orchestration, in particular, cloud's infrastructure (Openstack platform)
- Master Service Orchestrator (MSO)
  - Handles capabilities of end-to-end service provisioning
- Data Collection, Analytics and Events (DCAE)
  - Collect telemetry from VNFs and deliver analytics

Resource allocation issues

- In current ONAP implementation, resource allocation is centralized and relies on optimization
- Our approach:
  - Assumptions:
    - Large networks with many “small” edge data centers
    - The demand is volatile, composed of VNF, MEC and other applications
    - Because of volatility of demand, it is difficult to maintain an accurate view of the network
  - Principles:
    - Prevent from traffic “tromboning”
    - Dimensioning instead of perfect optimization (assess data center capacity to accommodate demand)
    - In case of congestion, use the degree of freedom offered by latency to offload delay tolerant applications in order to free capacity for data plane functions which cannot be displaced
    - Use thresholds to anticipate data plane functions blocking

Placement constraints

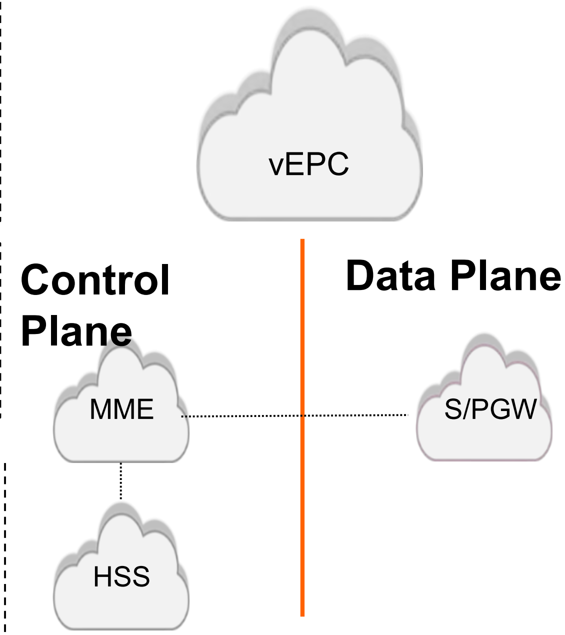
Taking into account the performance requirements

- A Virtualized Network Function (VNF) is composed of suite of components which are executed at different functional levels of the network:
  - ❖ The Data Plane
  - ❖ The Control Plane

- Data plane components have stringent requirements in terms of latency.
- Control components are more tolerant to delay.

- VNFs compete with MEC applications
- MEC applications may have stringent latency requirements but at worst could be displaced

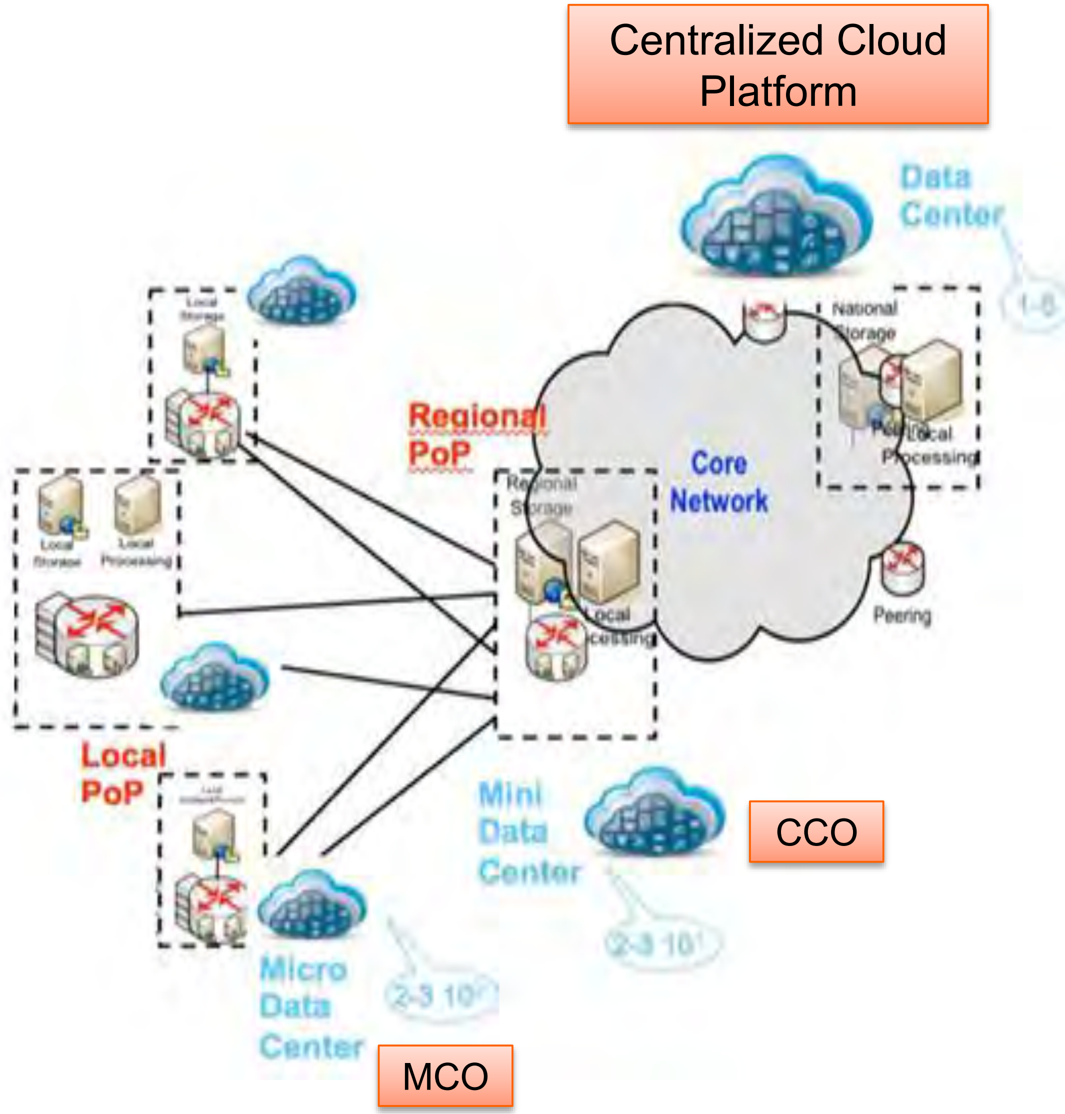
- We ignore applications with loose delay constraints



To meet global latency objectives, control plane components could be displaced at worst into centralized cloud platforms in order to favor the data plane functions placement along the data path.

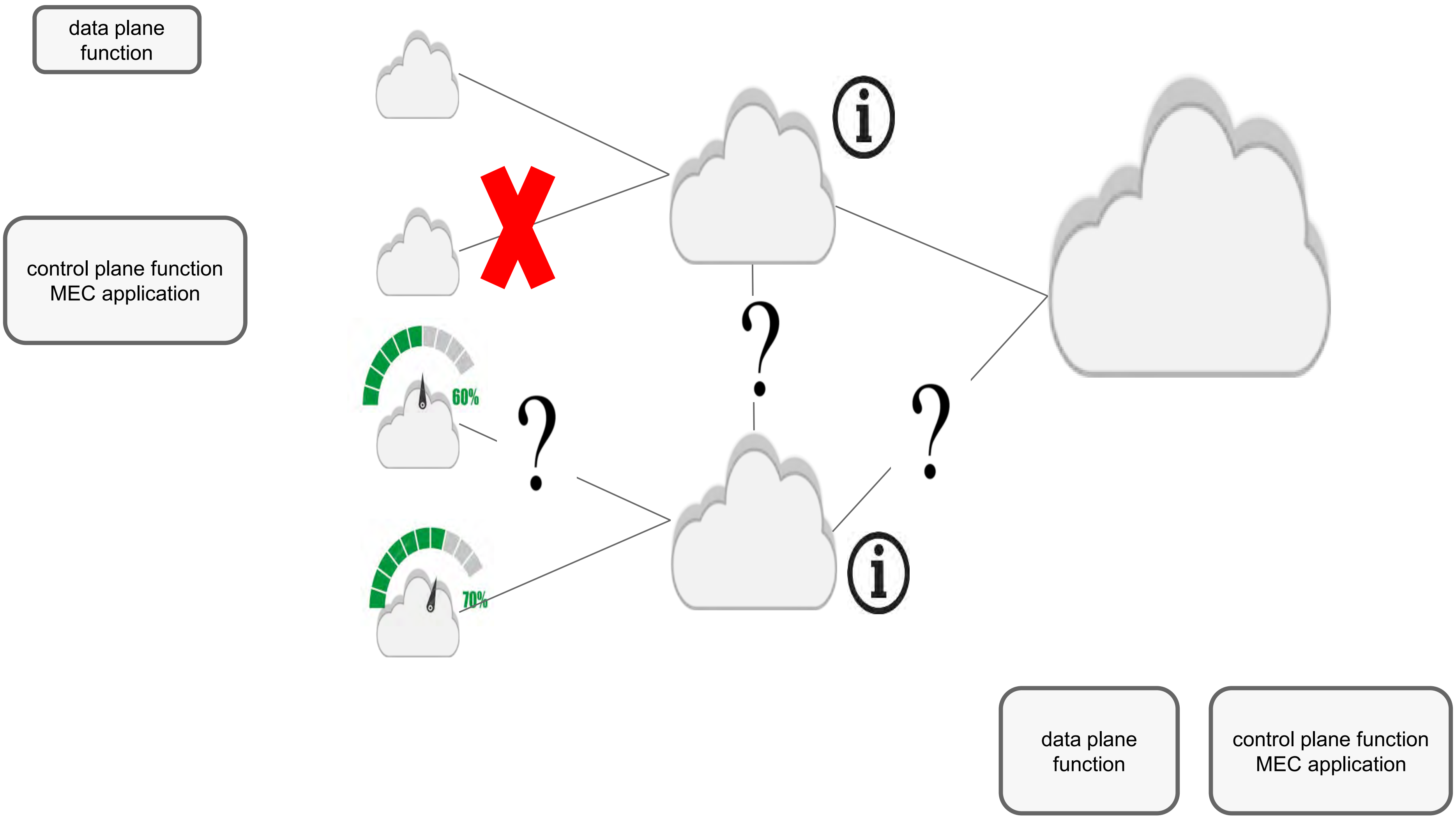
Reference network topology

- **Edge level (local Pop)**
  - ✓ Installed within Main Central Office(MCO)
  - ✓ Will host data plane functions, control plane functions and MEC applications.
- **Regional level**
  - ✓ Installed within Core Central Office(CCO)
  - ✓ Will host control plane functions and MEC applications
- **Nationwide level**
  - ✓ Centralized Cloud platform
  - ✓ Will host control plane functions and delay tolerant applications



Proposal: A dynamic adaptive NFV offloading strategy for ONAP

Resource Allocation Scheme

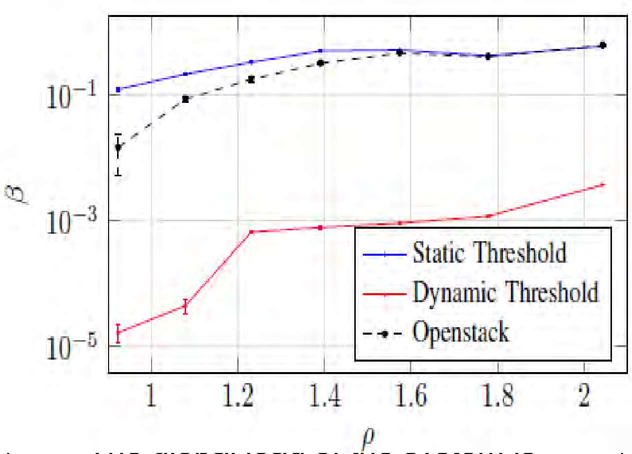


Evaluation

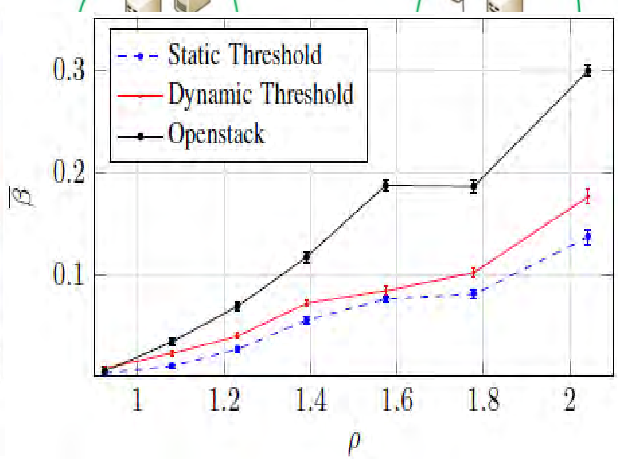
Simulation Settings

Data plane functions

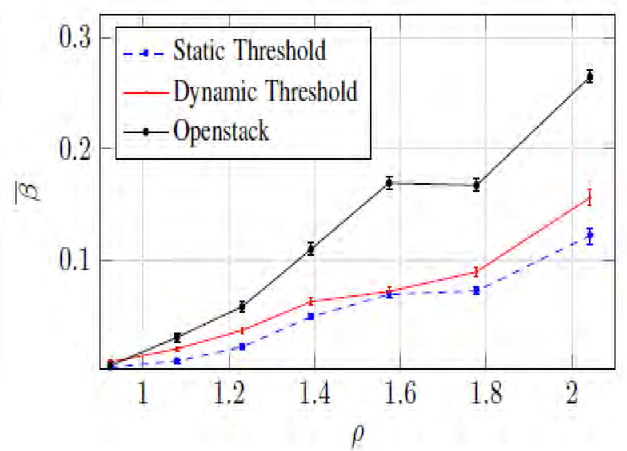
Zone 1



Control plane functions



MEC applications

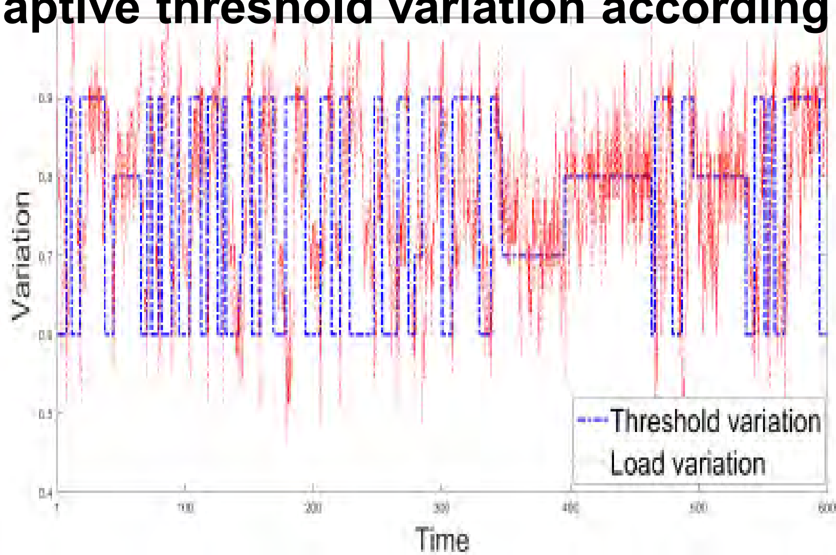


def

$$\rho \overset{def}{=} \sum_{i=1}^{N} \frac{\rho_i}{N * C}$$

With $\rho_j \overset{def}{=} \lambda_j/\mu_j$

Adaptive threshold variation according to the current load



he fraction of requests

ven by:

$\sum_{j=1}^{N} \lambda_j$

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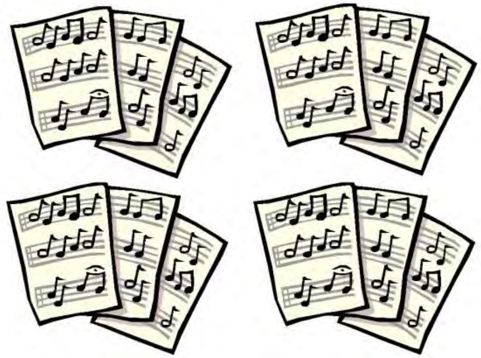
Conclusion

- SDN + NFV make networks more programmable
  - Early deployments (e.g., Easy Go Networks by Orange)
  - VNFs are released by “software” providers and tested by operators
  - RAN and vEPC are first candidates with big impact on networks
  - Many issues to be solved: security, CI/CD, deployment, orchestration, etc. And business cases
- SDN/NFV cannot de considered independently of the evolution of network technologies and services
  - FTTH, 5G, higher concentration levels
  - Services are ever more bandwidth greedy
  - New players (verticals with specific requirements)
- ONAP is an emerging for the orchestration of NFV
  - placement of functions by taking feedback of the network (telemetry)
  - Proposition of a strategy based on thresholds and local decisions instead of centralized optimization

Thank you!







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