# MOVING THE SDN-NFV INTO THE RAN

ICN 2020 The Nineteenth International Conference on Networks

February 23, 2020 to February 27, 2020 - Lisbon, Portugal

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## AGENDA

**01** **5G**

WHY & WHAT: from a story behind the 5G to purposes and solution

**02** **IMPACTS INTO THE RAN**

Moving close to the end user

**03** **ENPOWER THE SERVICES**

The studies done so far and the involved technologies

**04** **THE LAB**

A Proof of Concept, fully open-source SDN-NFV solution

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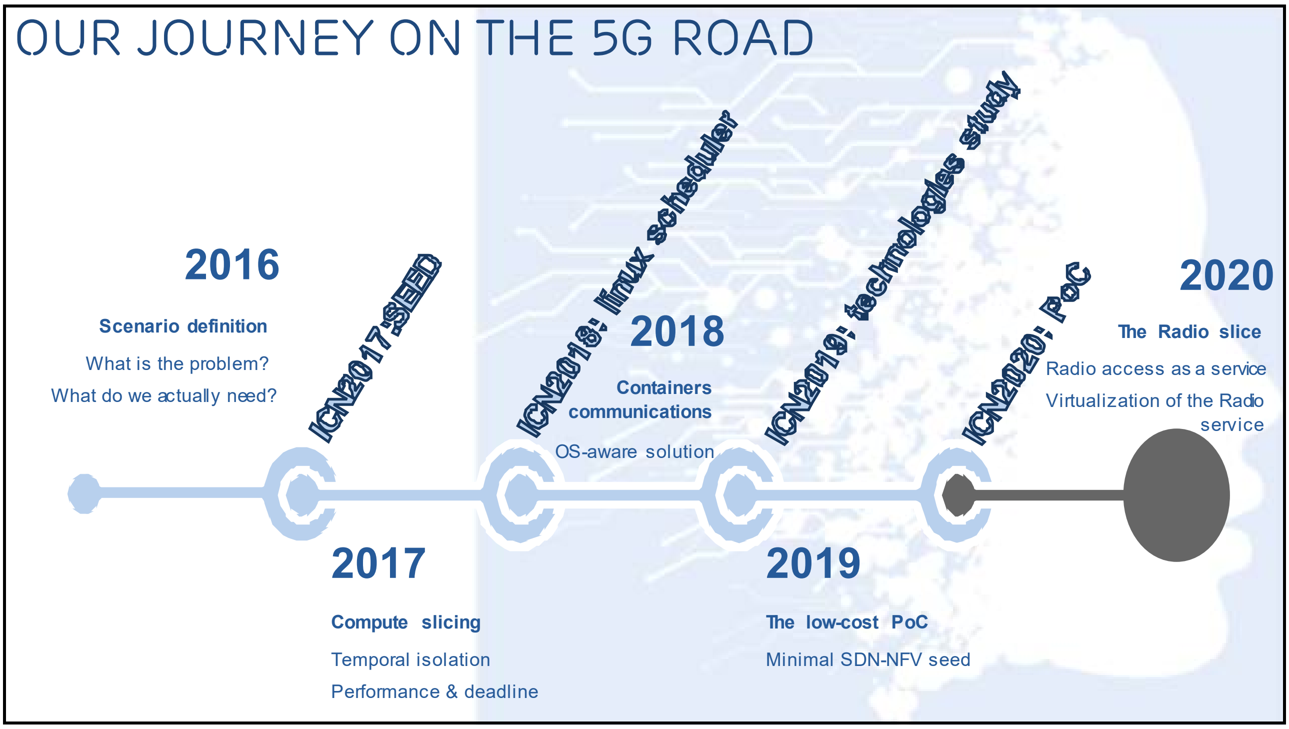


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## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ARP | Allocation and Retention Priority |
| ARQ | Automatic Repeat reQuest |
| BB | Base Band |
| BBU | Base Band Unit |
| BH | Backhaul |
| BS | Base Station |
| BTS | Base Transceiver Station |
| CAPEX | Capital Expenditure |
| CDN | Content Distribution Network |
| COTS | Common Off The Shelve |
| CPRI | Common Public Radio Interface |
| DPDK | Data Plane Development Kit - a Linux Foundation Project |
| DPI | Deep Packet Inspection |
| eMBB | Enhanced Mobile Broadband / Extreme Mobile Broadband |
| EMS | Element Management System |
| EPC | Evolved Packet Core |
| ETSI | European Telecommunications Standards Institute |
| H-ARQ | Hybrid Automatic Repeat reQuest |
| LTE | Long Term Evolution |
| MANO | Management and Network Orchestration |
| MIMO | Multiple-Input and Multiple-Output |
| NFV | Network Function Virtualisation |
| NFVI | Network Function Virtualisation Infrastructure |
| NFVO | Network Function Virtualisation Orchestration |
| NR | New Radio |
| OTT | Over The Top (service provider) |
| RAN | Radio Access Network |
| RAT | Radio Access Technology |
| SON | Self-Organising Network |
| SRIOV | Single Root Input/Output Virtualization |

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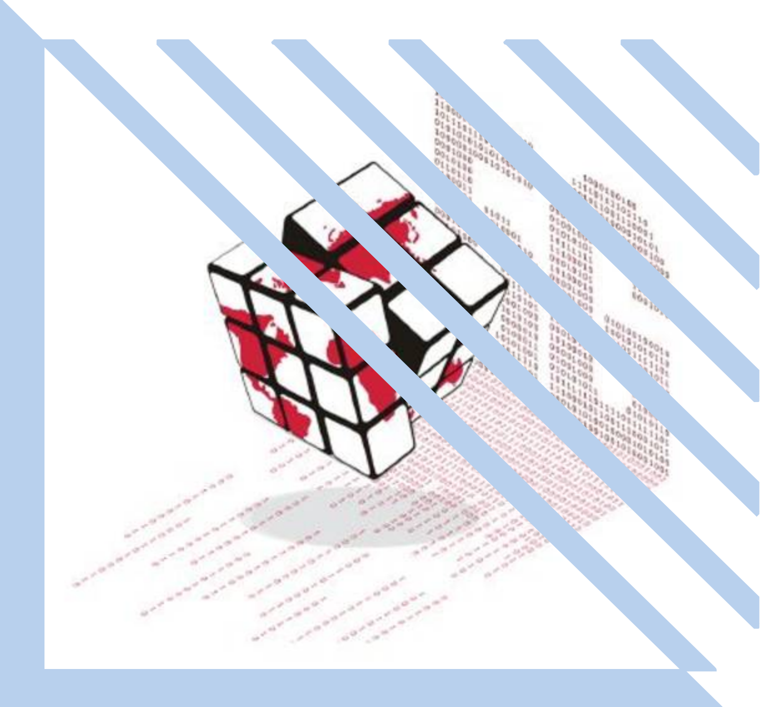

# 5G

As market after market switches on 5G, we are at a truly momentous point in time. No previous generation of mobile technology has had the potential to drive economic growth to the extent that 5G promises. It goes beyond connecting people to fully realizing the Internet of Things (IoT) and the Fourth Industrial Revolution.

Digital infrastructure can make distance less relevant than ever. 5G is the key to making it all work – driving economic value from enhanced mobile broadband to industry digitalization. That, in turn, will require an ecosystem of technology, regulatory, security and industry partners to deliver on the potential. Smart cities, Industrial IoT, augmented reality, autonomous transport and digital health are just some of the exciting prospects that can be made real with the support of the 5G ecosystem.

Ericsson Mobility Report, Jun 2019

But it is worth to understand why we are talking about 5G to really understand what 5G is and which system solutions are needed.

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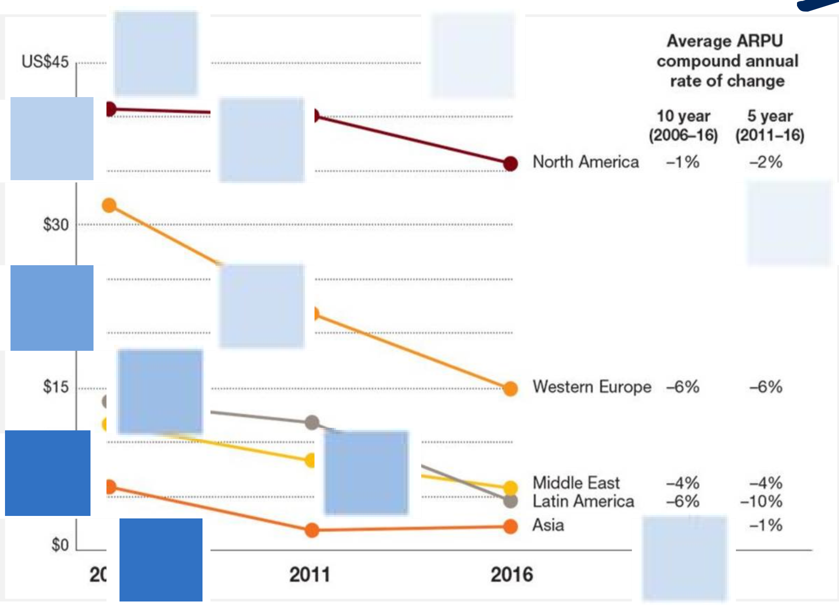
# BEHIND 5G

the Telecom realm is facing an epic moment, a technology step that will drive the evolution of the networked system in the future and, at the end of the day, the End User services and life style. The entire world of communication is driving the strong requirement for new services, where End User is at the center of the business case of a digital society, and Telecom operators could make the difference. Mobility is dominating the area with significant smartphone penetration growth, it has changed the usage of connectivity. With the emerging 5th Generation wireless system (5G) new great benefits opens up for the Telecom operators.

Edge computing opens up a whole new world for mobile operators in terms of what services they can deliver as well as for software developers that are writing the code. This also presents a massive new economic opportunity for both — one recent study says it will surpass $4.1 trillion by 2030.

(source: ChetanSharma Consulting)

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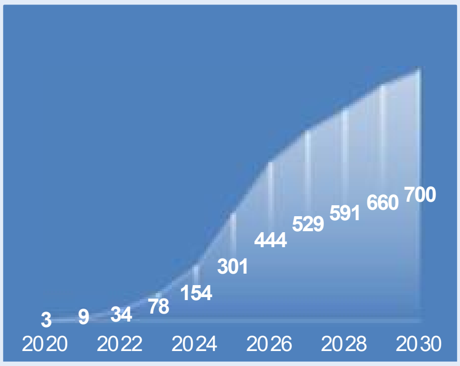
# The service provider challenge and potential - Critical to capture the growth in the next 5-7 years

By 2030, the expected industry digitalization revenues for ICT players worldwide across all industries are expected to amount to around USD 3.8 trillion. The question for service providers is how much of this revenue enabled by 5G is addressable for them. Investments driven by the value 5G is providing across these industries is expected to be around USD 1.5 trillion in 2030. But not all of this is expected to be addressable by service providers as the ability to take a role in the value chain will differ by industry and be subject to the speed of disruption, geographic relevance and the complexity of applications that the addressed use cases entail. The total value of the global addressable 5G-enabled market for service providers across the 10 industries is projected to be USD 700 billion in 2030, beyond mobile broadband.

Service provider addressable Service creator role USD bn




5G-enabled revenue potential for service providers

2030 potential:

+35%

on top of revenues from current scope of business

Source: Ericsson and Arthur D. Little

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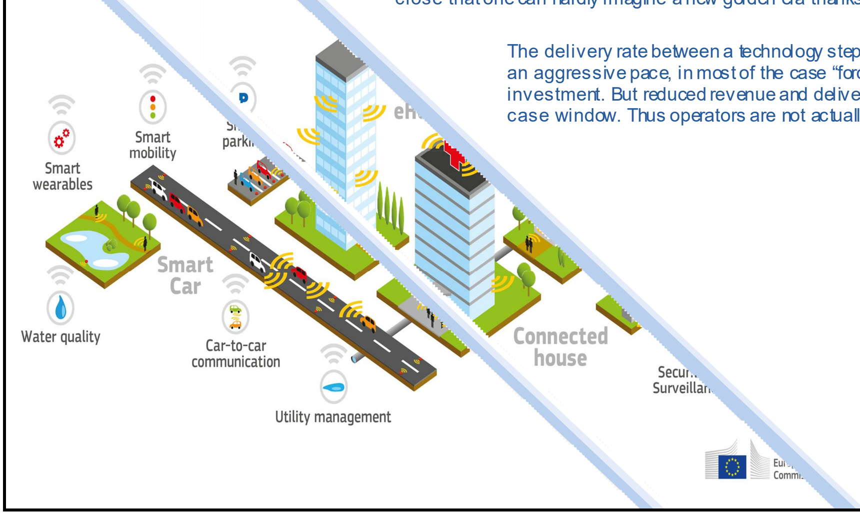
# OPERATORS DRIVE THE SWITCH

A common understanding is that 5G is a key to reduce Operating expenses (Opex) and Capital expenditures (Capex) and thereby increase margin for operators. It is not actually that huge of an incentive for the business of the operators. In fact, Opex and Capex have been reduced during the latest years. Mostly thanks to the cost reduction of technology, and the truth is that today total cost and revenue are so close that one can hardly imagine a new golden era thanks only to Opex and Capex reduction.

The delivery rate between a technology step (from 2G to 3G, from 3G to 4G and so on) has an aggressive pace, in most of the case "forcing" operators to make a new infrastructure investment. But reduced revenue and delivery interval is concurrently reducing the business case window. Thus operators are not actually too keen to join a new technology.




So far, their effort has been focused on a market where improvement of capacity and quality of the connectivity has been enough. But the richest market today is fully in the hands of the Over-The-Top (OTT) content media delivery companies (Google, Facebook, Netflix, etc.). A real shift of business for the operators is the key to enter such a rich market. Eventually, that will be a win-win condition, since OTT is perfectly aware that reducing the end-to-end (E2E) data contents latency will improve their business. They are also aware that accessing User Metadata (very well known by Telecom operators) will increase even more such a market thanks to new business cases.

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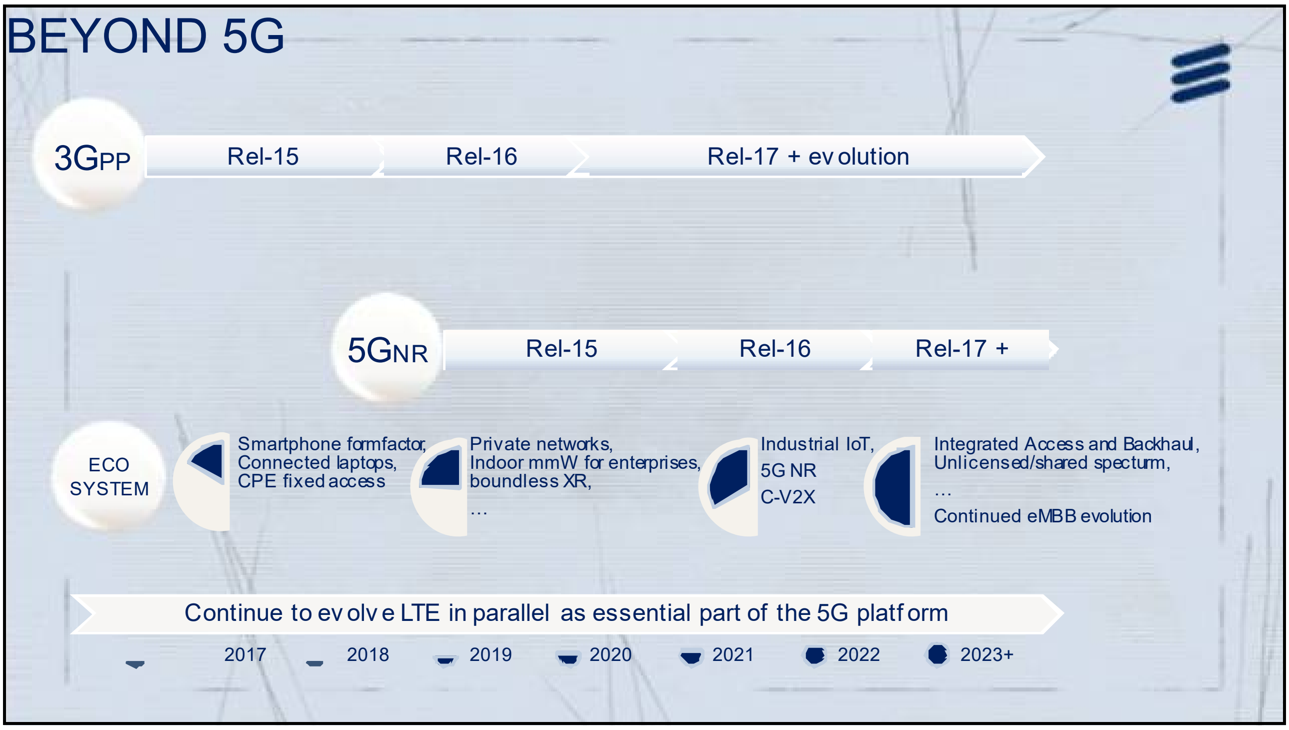
BEYOND 5G
3GPP
Rel-15
Rel-16
Rel-17 + evolution
5GNR
Rel-15
Rel-16
Rel-17 +
ECO SYSTEM
Smartphone formfactor, Connected laptops, CPE fixed access
Private networks, Indoor mmW for enterprises, boundless XR, …
Industrial IoT, 5G NR C-V2X
Integrated Access and Backhaul, Unlicensed/shared spectrum, … Continued eMBB evolution
Continue to evolve LTE in parallel as essential part of the 5G platform
2017
2018
2019
2020
2021
2022
2023+

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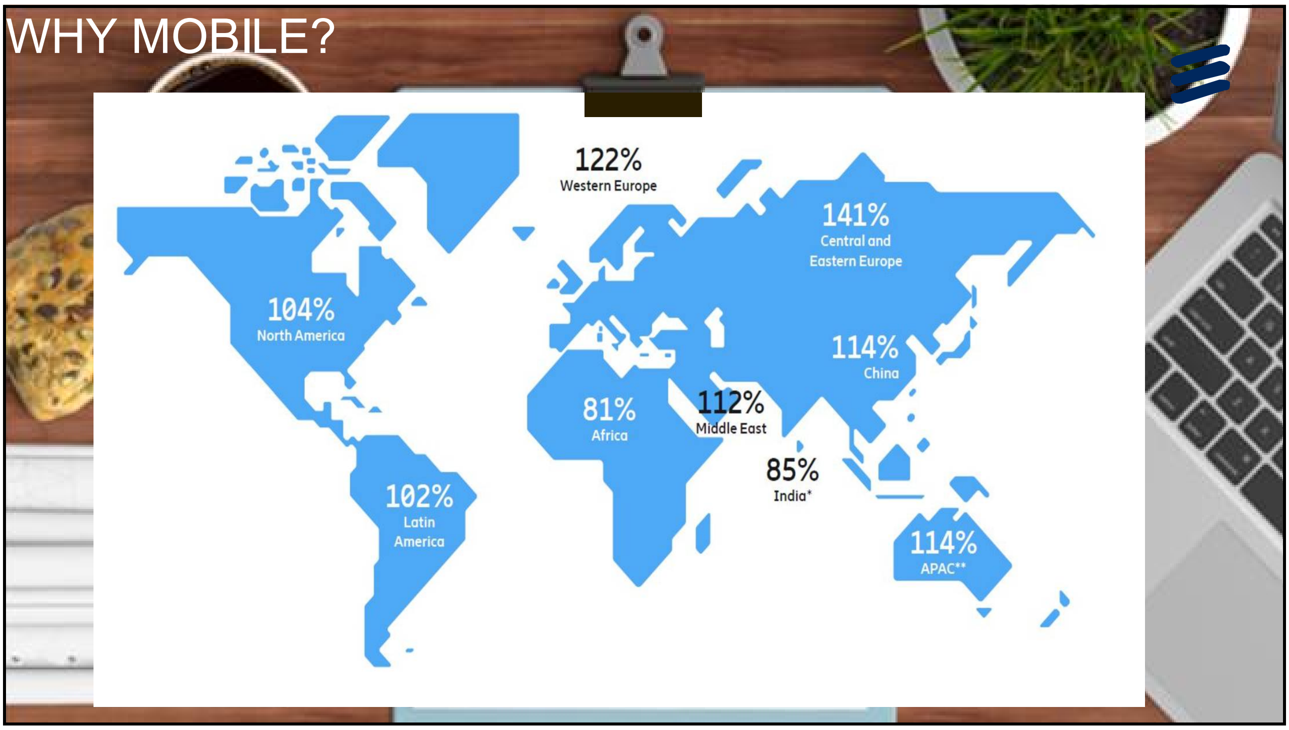
WHY MOBILE?
122%
Western Europe
141%
Central and Eastern Europe
104%
North America
114%
China
81%
Africa
112%
Middle East
85%
India*
102%
Latin America
114%
APAC**

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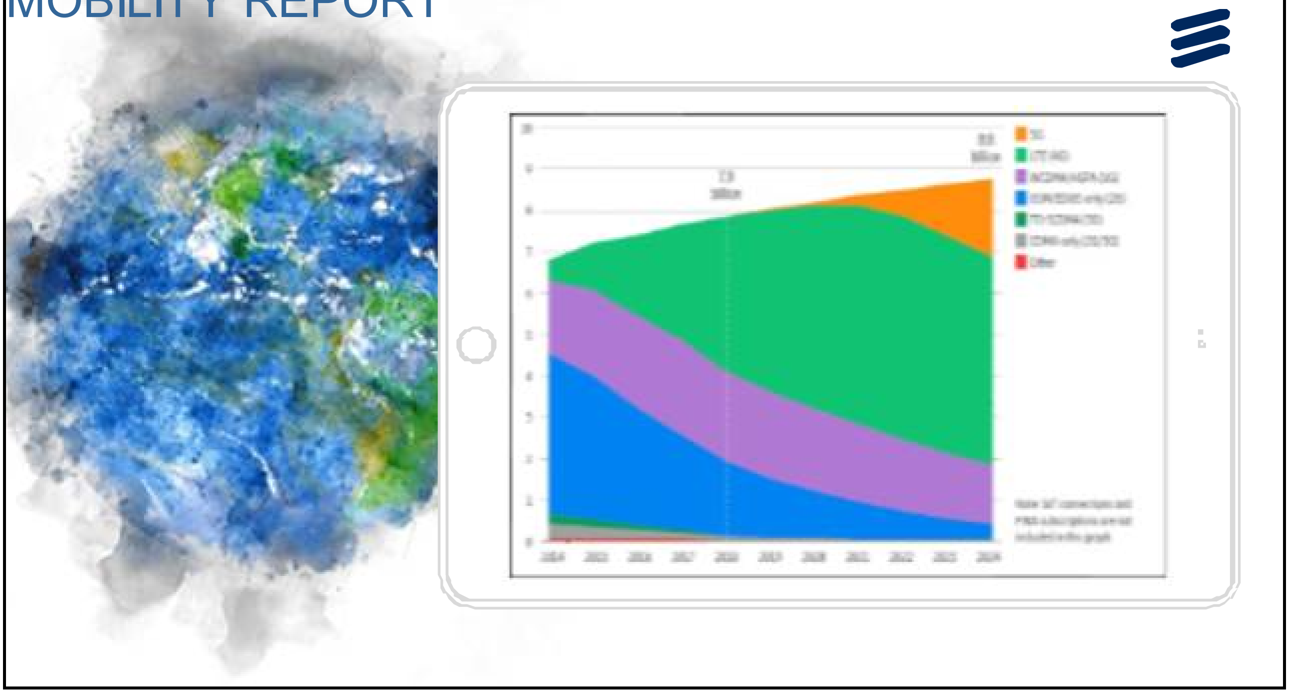
# MOBILITY REPORT



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# Ericsson 5G commercialization


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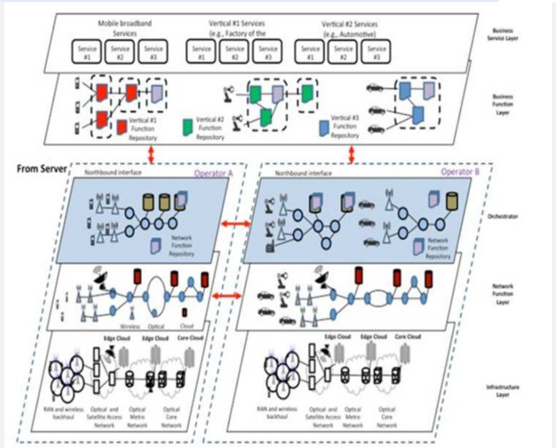
# 5G ARCHITECTURE

5G is the answer. It is not a bare new radio technology. 5G has the ambition to be a new framework, covering the system architecture, the network management and the software deployment to act as the enabler of the new business opportunity mentioned. Massive broadband, machine-type communication and time-critical autonomous control are the three groups where to find 5G requirements, with the declared scope to offer an eco-system for business innovation. 5G solution wants to support vertical markets, such as IoT, automotive connectivity, Mobile broadband.

The vertical deployment approach is based on a complex integration of: distributed computing, storage, networking and spectrum capabilities. Slicing those underlying resources is fundamental. A vertical service deployment needs a system where it is possible to have: multi-tenancy and multi-service, respecting the Service Level Agreement (SLA), providing different Quality Of Service (QoS) level to achieve different Service characterization and different network policy. The diversity of that system needs an orchestrator responsible to allocate computing, storage and networking resources to the network functions. Then allocate those network functions to the vertical services.

Automation of service deployment is also very important. In the traditional system, installation of a new service required months because it depended on a number of installation parameters. That traditional way of working is very expensive and often the root cause of performance drawback or bad reputation for infrastructure providers. The 5G system needs to be more autonomous, self-organizing resources when and where needed. These characterizations are important enablers to a successful system, but they explain very well the complexity of the new architecture too

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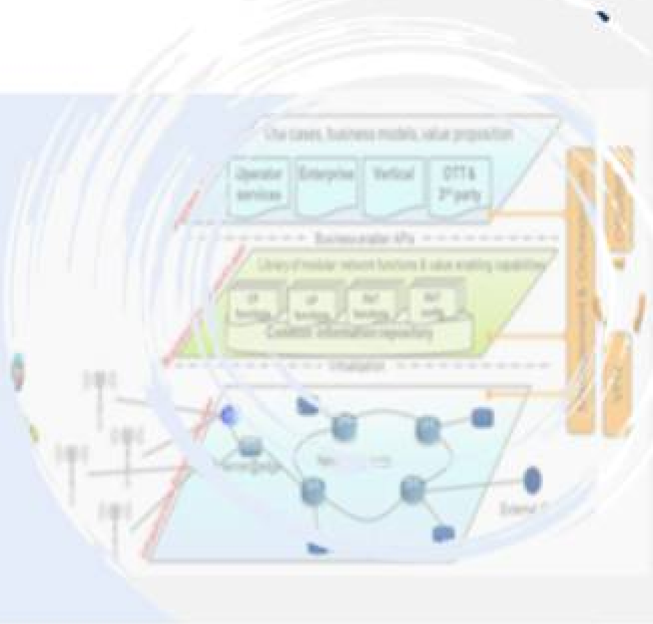
# SDN-NFV ARCHITECTURE

The SDN-NFV target is to allow vertical multiservice deployment and, at the same time, reduce Opex and CapEx; thereby creating a more green-power environment and allows an easy deployment of a new technology in a shorter, safer and comfortable new way. The “core” promise of SDN-NFV is to guarantee a new “business environment” where telecom operators are a stakeholder in service creation. SDN-NFV architecture is built over three layers:

- Business Application Layer – where the enterprise business value model is defined
- Business Enablement Layer – where the enabling and capabilities value are defined
- Infrastructure Resources Layer – where the resources needed by the value are defined

The SDN-NFV layered vision is the most useful to understand the service oriented approach supported by the architecture itself. The comparison between 5G and SDN-NFV architecture is self-explaining: it is the same concept. The European Telecommunications Standards Institute (ETSI) has set regulations and indications to design and define SDN-NFV architecture.



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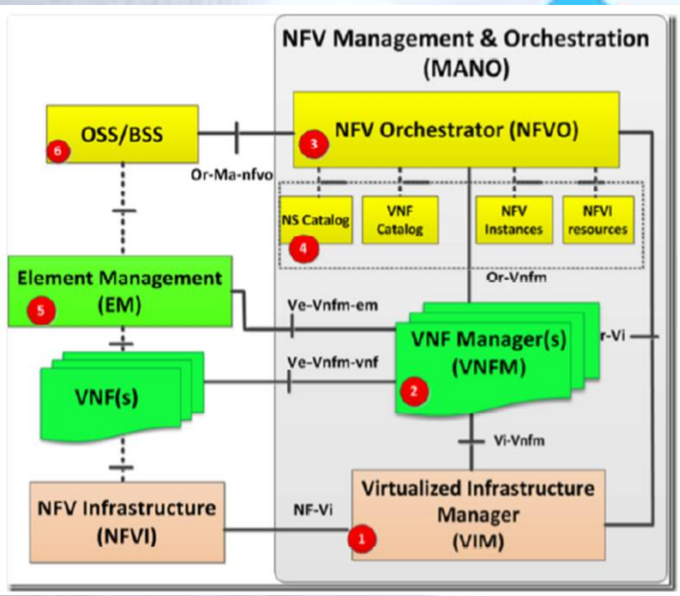
# MANO (ETSI)




DO YOU KNOW WHAT THEY ARE?

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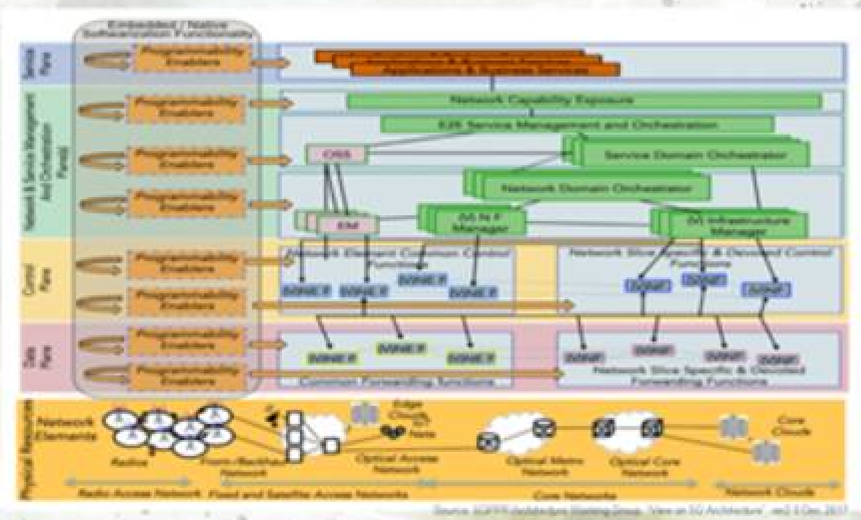
# THE SDN-NFV MEANING

The request for a multi-service architecture, that is an architecture where it is possible to deploy services with strongly different requirements over a common infrastructure, is a mandatory and characteristic requirements for 5G. This requires an extremely flexible architecture. Programmability is the technical solution: through programming, it is possible to assign and control common network infrastructure to different applications. This is the very nature of the SDN-NFV



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# WHAT DOES IT MEAN SERVICE ORIENTED

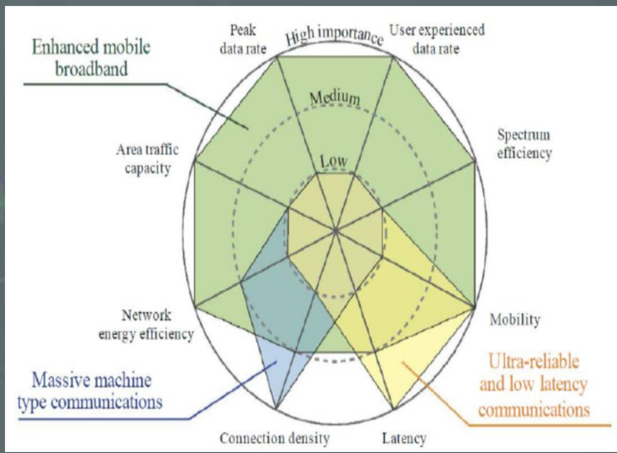
Heterogeneous services

↓

Different requirements

↓

Different resources allocation policy

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## SDN

- A mechanism
- Physical Networking hardware is managed by software
- Relies on Physical network topology
- Can program/make changes to physical infrastructure
- Separates control plane and data plane

## NFV

- A solution
- All virtual/logical networks are replicated in software
- Independent of physical network topology
- Can program/make changes to virtual/logical networking components
- Creates virtual network tunnels and functions on top of physical network

"SDN-NFV IN A NUTSHELL"

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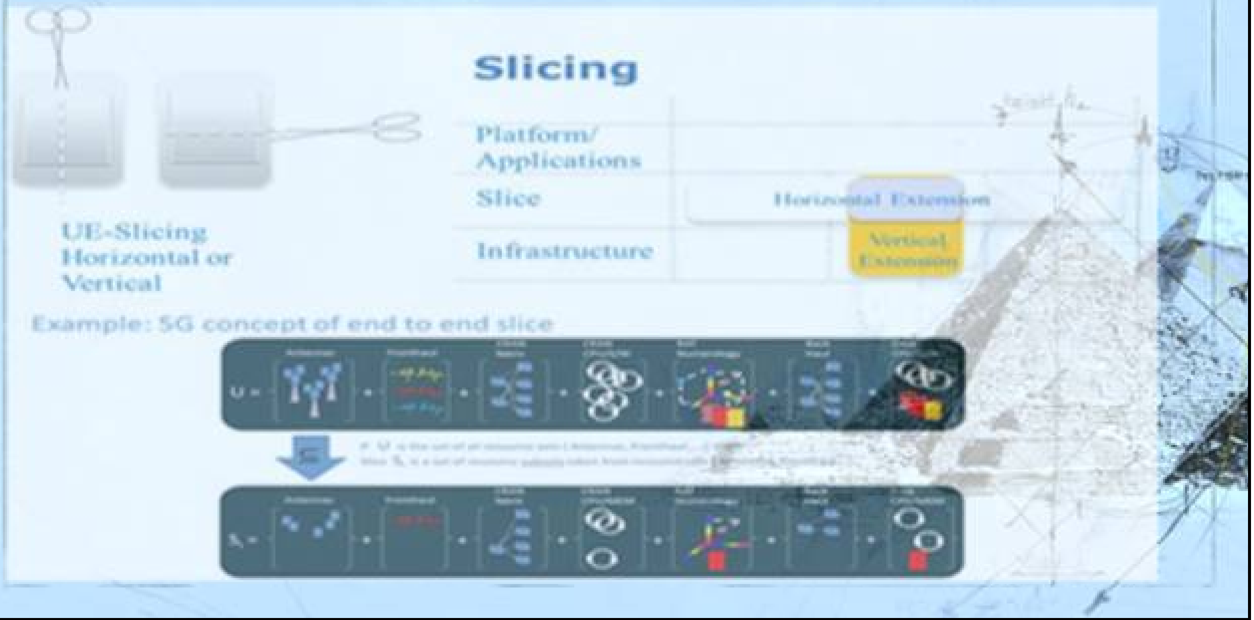
# SLICING

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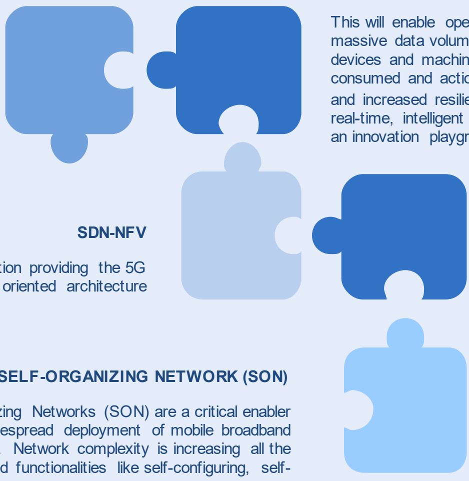
# 5G, 5 PILLARS



**RADIO TECHNOLOGY: MIMO**

Massive MIMO with beam forming improves the end user experience by significantly increasing network capacity and coverage while also reducing interference. This is done by increasing the effectiveness of the transmission. Sending out radio waves as highly focused beams delivers a stronger radio signal, with a higher data throughput for greater distances.

**THE MOBILE EDGE COMPUTING**

This will enable operators to gravitate workloads closer to the massive data volumes generated by next generation of connected devices and machines – where the data is produced, insights are consumed and actions are taken. Low latency, high bandwidth and increased resiliency of mobile edge computing will enable real-time, intelligent and autonomous decision-making – making it an innovation playground for intelligent society and industry.

**SDN-NFV**

A tool and a solution providing the 5G vertical service oriented architecture

**CENTRALIZED MANO**

Services and their supporting infrastructure, both network and IT, are quickly becoming more real-time oriented, driven by customers' preferences for innovation, excitement and speed, and the need to meet or exceed those expectations with increased agility and lower cost structures. Orchestration answers the call for more dynamic management of information and technology in converged ICT networks. It provides a unified orchestration framework supporting service and resource through their lifecycle – from planning to fulfillment to closed-loop assurance.

**SELF-ORGANIZING NETWORK (SON)**

Self-Organizing Networks (SON) are a critical enabler for the widespread deployment of mobile broadband technologies. Network complexity is increasing all the time and functionalities like self-configuring, self-optimizing and self-healing functions are now indispensable for running a modern mobile network.

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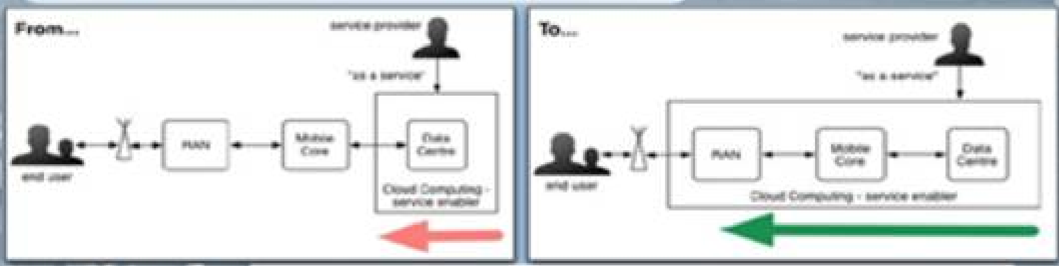
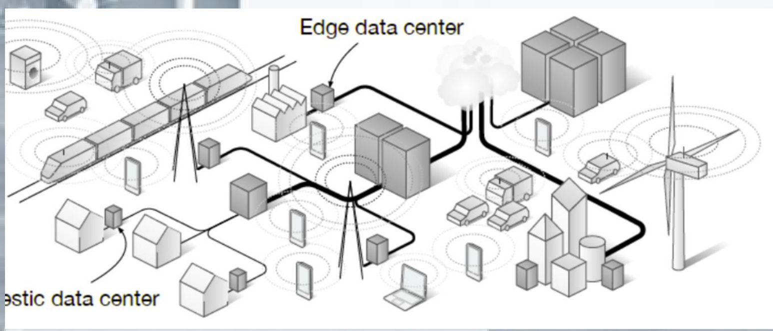
# RAN COMPUTE




It is not correct to move the cloud into the RAN, but it should be moved the RAN into the SDN-NFV, allowing the benefits of SDN-NFV described in previous slides and, concurrently, answering the specific requirements needed at the edge of the network.

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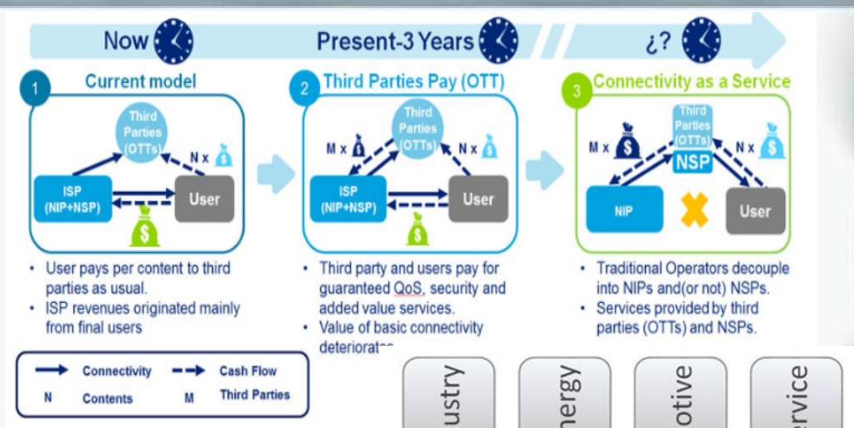
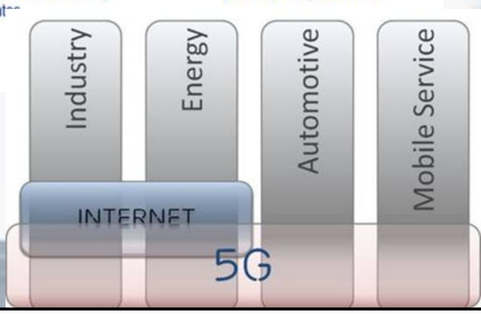
# RAN COMPUTE (SErver at the EDge)

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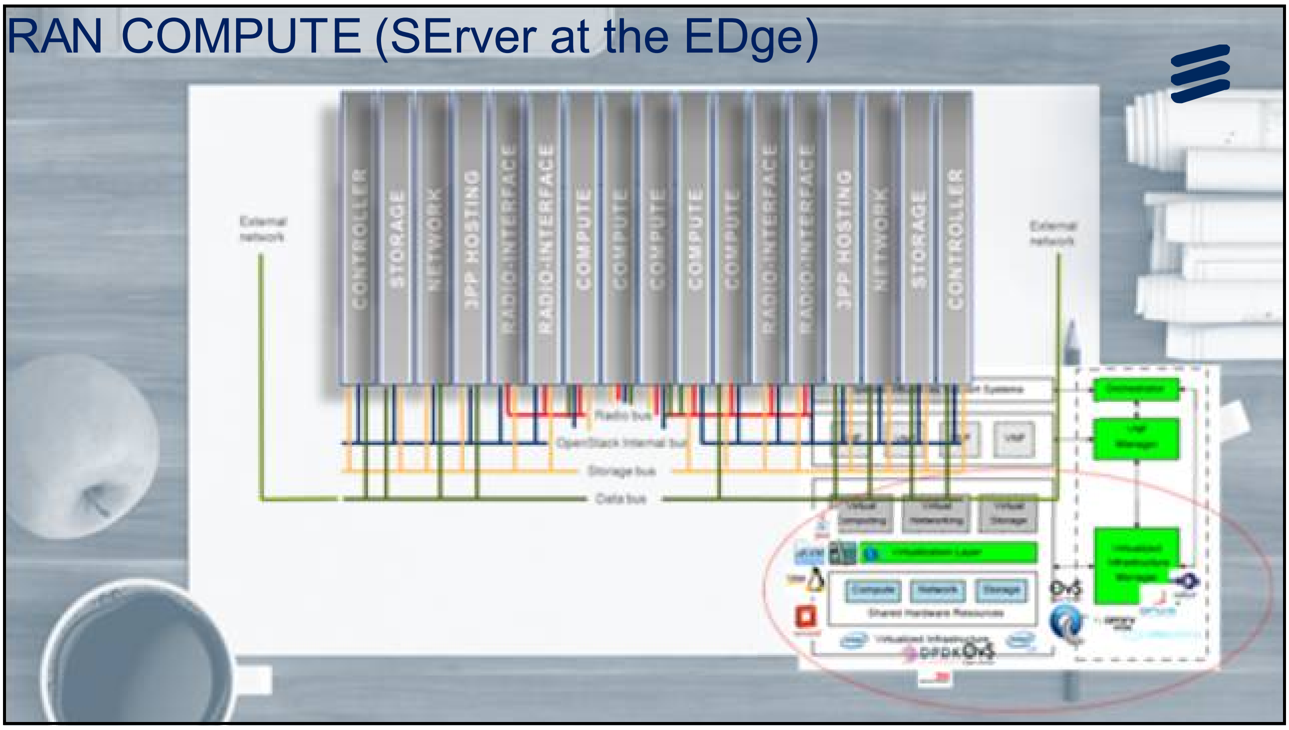
RAN COMPUTE (SErver at the EDge)
External network
CONTROLLER
STORAGE
NETWORK
3PP HOSTING
RADIO INTERFACE
RADIO INTERFACE
COMPUTE
COMPUTE
COMPUTE
COMPUTE
COMPUTE
RADIO INTERFACE
RADIO INTERFACE
3PP HOSTING
NETWORK
STORAGE
CONTROLLER
External network
Radio bus
OpenStack internal bus
Storage bus
Data bus

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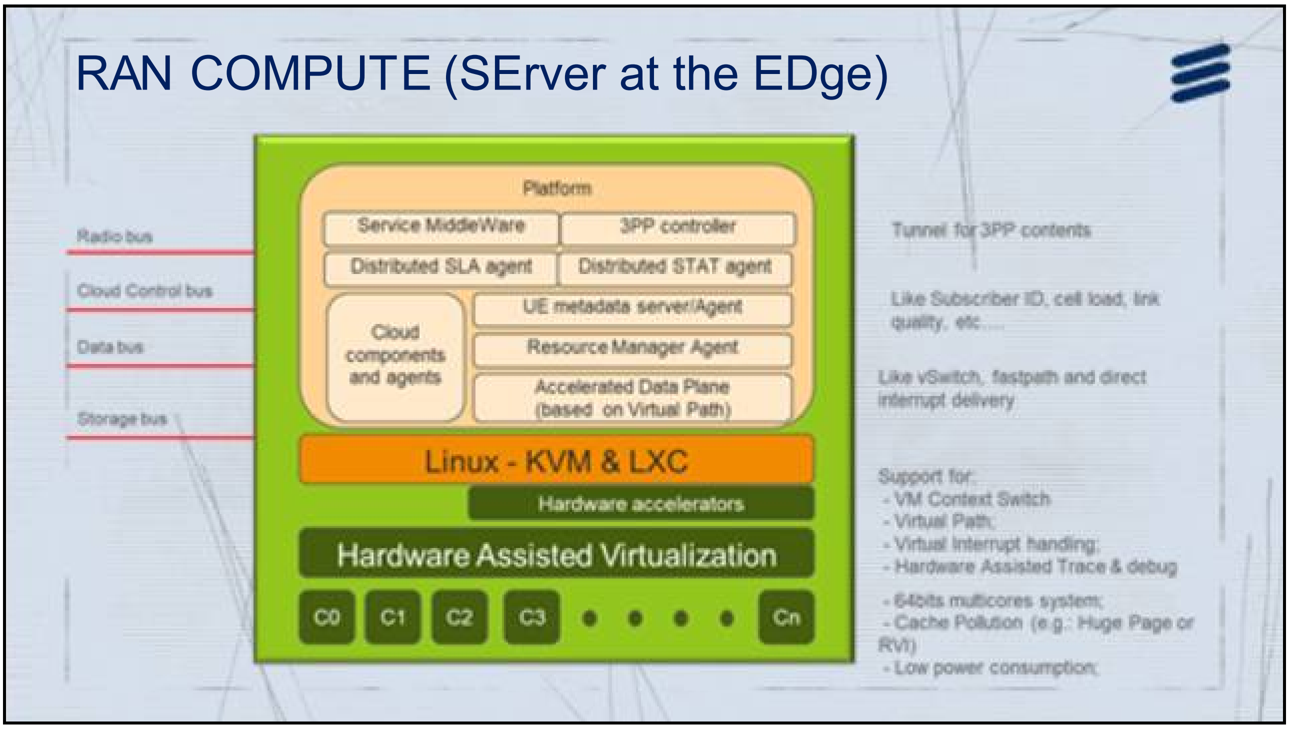
RAN COMPUTE (SErver at the EDge)
Radio bus
Cloud Control bus
Data bus
Storage bus
Platform
Service MiddleWare
3PP controller
Distributed SLA agent
Distributed STAT agent
Cloud components and agents
UE metadata server/Agent
Resource Manager Agent
Accelerated Data Plane (based on Virtual Path)
Linux - KVM & LXC
Hardware accelerators
Hardware Assisted Virtualization
C0
C1
C2
C3
Cn
Tunnel for 3PP contents
Like Subscriber ID, cell load, link quality, etc....
Like vSwitch, fastpath and direct interrupt delivery
Support for:
- VM Context Switch
- Virtual Path;
- Virtual Interrupt handing;
- Hardware Assisted Trace & debug
- 64bits multicores system;
- Cache Pollution (e.g.: Huge Page or RVI)
- Low power consumption;

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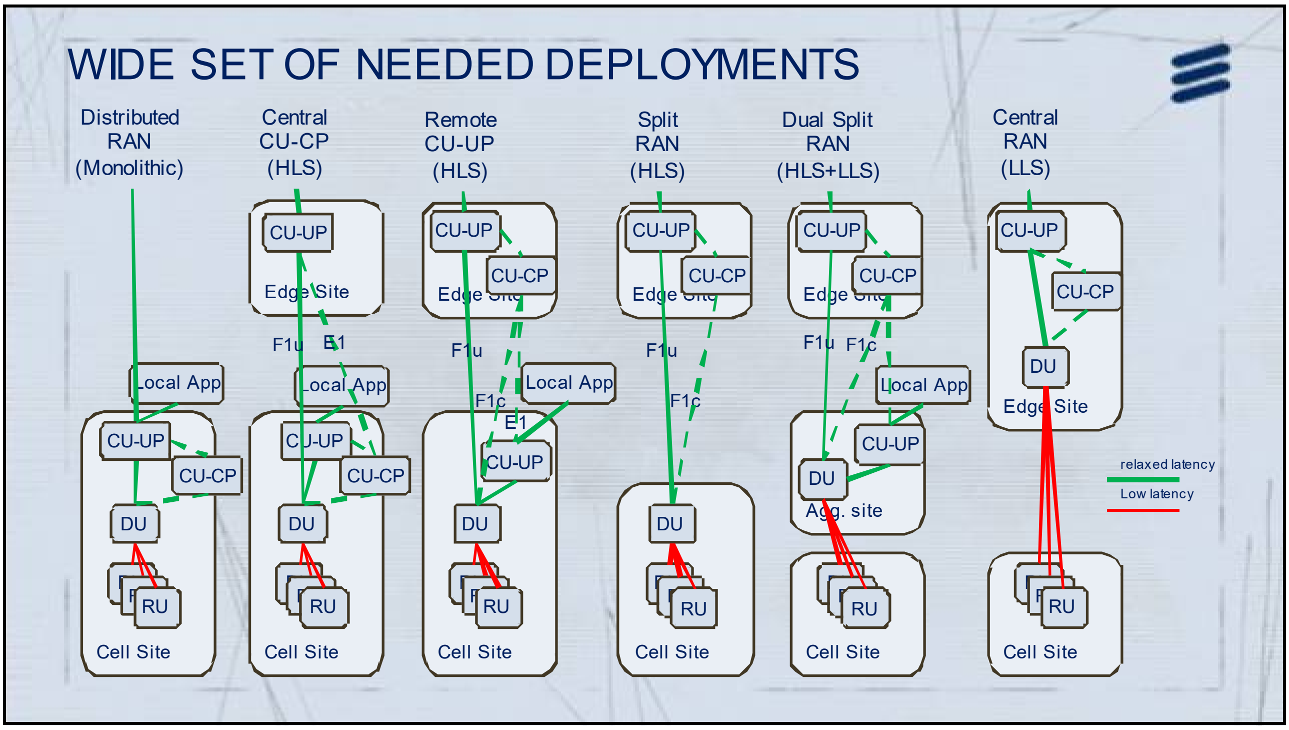


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# RAN COMPUTE (SErver at the EDge)

HARDWARE PLATFORM CHARACTERIZATION

I64 ARCHITECTURE

Faster SW availability from OpenSoftware Community

But Higher power consumption

LARGE HARDWARE ASSISTED VIRTUALIZATION COMPONENTS AVAILABILITY

| | |
|---|---|
| HAV for VM context switch | VT-x |
| HAV for MM (DMA, extended Page Table and Huge Page) | VT-x |
| SR-IOV, Direct-IO | VT-d |
| Interrupt walking through (APIC virtualization) | vAPIC |

HARDWARE FEATURES SUBSET

Encryption/decryption , cryptography and data compression

Memory Buffer Manager

QoS based traffic queues – support for vSwitch

SW FEATURES CHARACTERIZATION

DATA HANDLING

DPDK

NETWORK OS

Linux 64bits

Container

OpenStack

Radio Access Connectivity Service

Guaranteed QoS

INTERFACES

OpenFlow, Northbound Open API, YANG

NETCONF, BGP, PCEP, LISP, OVSDB

OpenvSwitch interface

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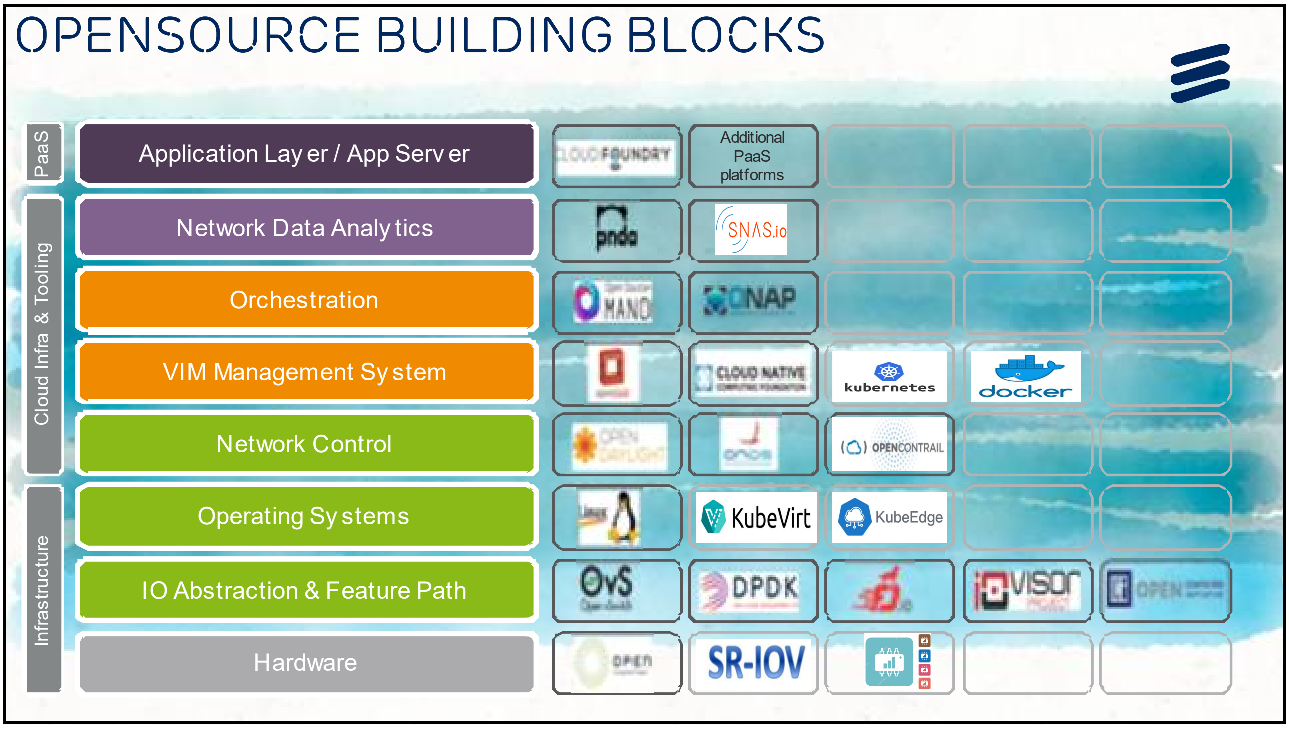

OPENSOURCE BUILDING BLOCKS
PaaS
Cloud Infra & Tooling
Infrastructure
Application Lay er / App Serv er
Network Data Analy tics
Orchestration
VIM Management Sy stem
Network Control
Operating Sy stems
IO Abstraction & Feature Path
Hardware
Additional PaaS platforms
SNAS.io
ONAP
kubernetes
docker
OPENCONTRAIL
KubeVirt
KubeEdge
OvS
DPDK
SR-IOV


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O-RAN
ALLIANCE
AT&T
中国移动 China Mobile
docomo
orange
airtel
中国电信 CHINA TELECOM
Jio
kt
Singtel
SK telecom
TIM
Telefonica
TELSTRA
verizon
dish
KDDI
SoftBank
Sprint
OPERATORS DRIVING INNOVATION
ERICSSON
infineon
BROADCOM
intel
Lenovo
redhat
XILINX
NXP
NEC
FUJITSU
Ball
CertusNet
Radisys
cisco
NOKIA
ZTE
SAMSUNG
ciena


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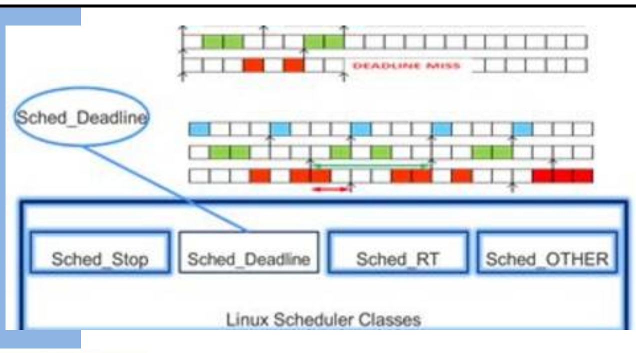
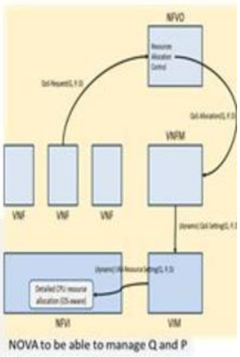
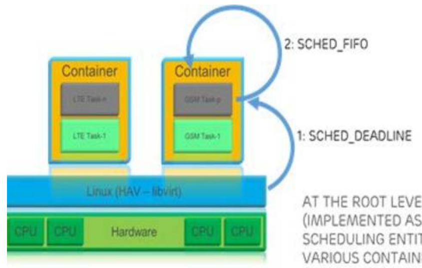
# THE COMPUTE SLICE

ensuring stable performance of co-located distributed cloud services in a resource-efficient way. It is based on using a real-time CPU scheduling policy to achieve a fine-grain control of the temporal interferences among real-time services running in co-located containers








AT THE ROOT LEVEL, A CPU RESERVATION (IMPLEMENTED AS A SCHED_DEADLINE SCHEDULING ENTITIES) SCHEDULES THE VARIOUS CONTAINERS (BASICALLY, LXC VMS); AT THE SECOND LEVEL (INSIDE THE CONTAINER), A FIXED PRIORITY SCHEDULER (BASED ON SCHED_FIFO OR SCHED_RR) SCHEDULES THE REAL-TIME TASKS INSIDE THE CONTAINER

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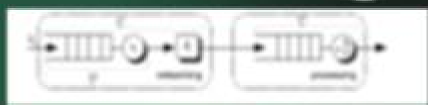
# THE COMPUTE SLICE (MATH!)

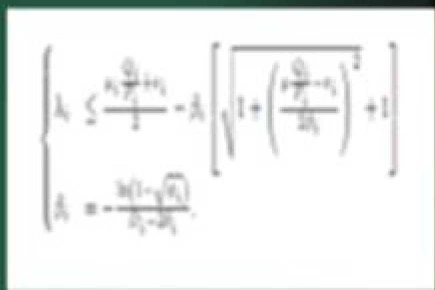
*Under Poissonian arrivals with average rate λ and service times approximated as exponentially distributed with average rate μ Q/P we have M/M/1 model*

$$\lambda_i \le \mu_i \frac{Q_i}{P_i} + \frac{\ln(1-\phi_i)}{D_i - 2\delta_i}, \quad D_i \ge 2\delta_i - \frac{\ln(1-\phi_i)}{\mu_i \frac{Q_i}{P_i} - \lambda_i}$$

*Q = Budget*
*P = Period*
*D = Deadline*
*Φ = Percentile of success*
*λ = Interarrival time*
*μ = average processing time*
*δ = networking latency*



*Exponential distribution of a request size (s) in a transmission time t' with v average transmisison rate we have still M/M/1 model*




T. Cucinotta, M. Marinoni, A. Melani, A. Parri and C. Vitucci: "Temporal isolation among LTE/5G network functions by real-time scheduling" Proceedings of the 7th IEEE International Conference on Cloud Computing and Services Science, 2017

M. Marinoni, T. Cucinotta, L. Abeni and C. Vitucci: "Allocation and Control of Computing Resources for Real-Time Virtual Network Functions" The International Symposium on Advances in Software Defined Networking and Network Function Virtualization, 2018

T. Cucinotta, L. Abeni, M. Marinoni, A. Balsini and C. Vitucci: "Reducing Temporal Interface in Private Coulds through Real-Time Containers" Processings on the 2019 IEEE international Conference of Edge Computig, 2019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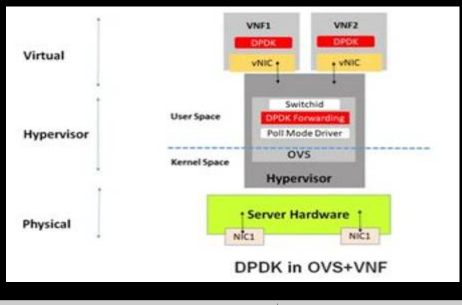
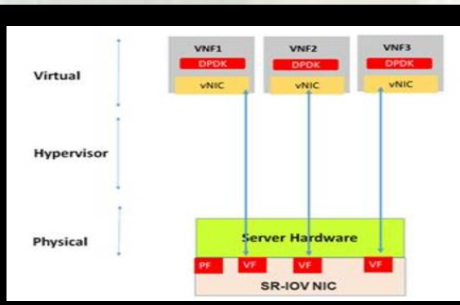
## THE STRATEGIC ROLE OF COMMUNICATION




It is widely understood there is not a golden child in the communication technologies. Inter-container control communication, data path, external communication have totally different requirements and so they request totally different technology solution.

The most obvious consequence is that, as done by the compute slices, it is more optimized to support different technology-based Virtual communication channel, to be assigned on application requirements/characterizations.

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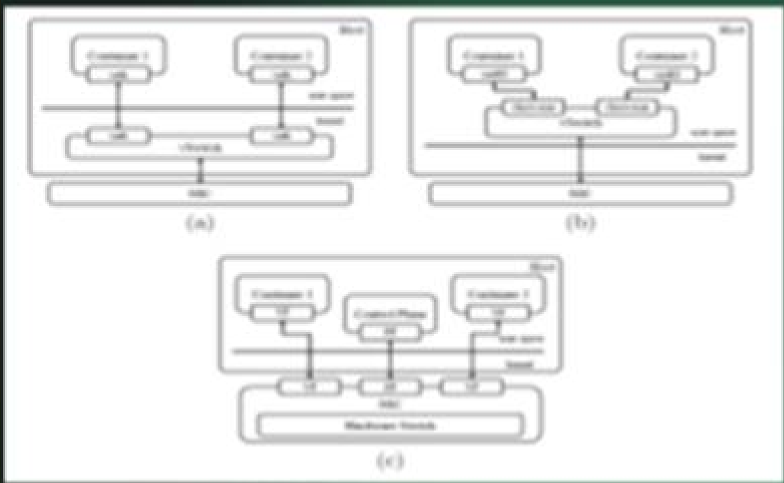
## THE STRATEGIC ROLE OF COMMUNICATION (MATH)



G. Ara, L. Abeni, T. Cucinotta and C. Vitucci: "On the use of Kernel mechanism for high-performance inter-container communications" 14th Workshop on Virtualization in High-Performance Cloud Computing, 2019

a) Kernel-based solution
b) Using DPDK with vhost in user mode
c) using SR-IOV support

C. Vitucci, L. Abeni, T. Cucinotta and M. Marinoni: "The Strategic Role of Inter-Container Communications in RAN deployment scenario" The Eighteenth International Conference on Networks, 2019

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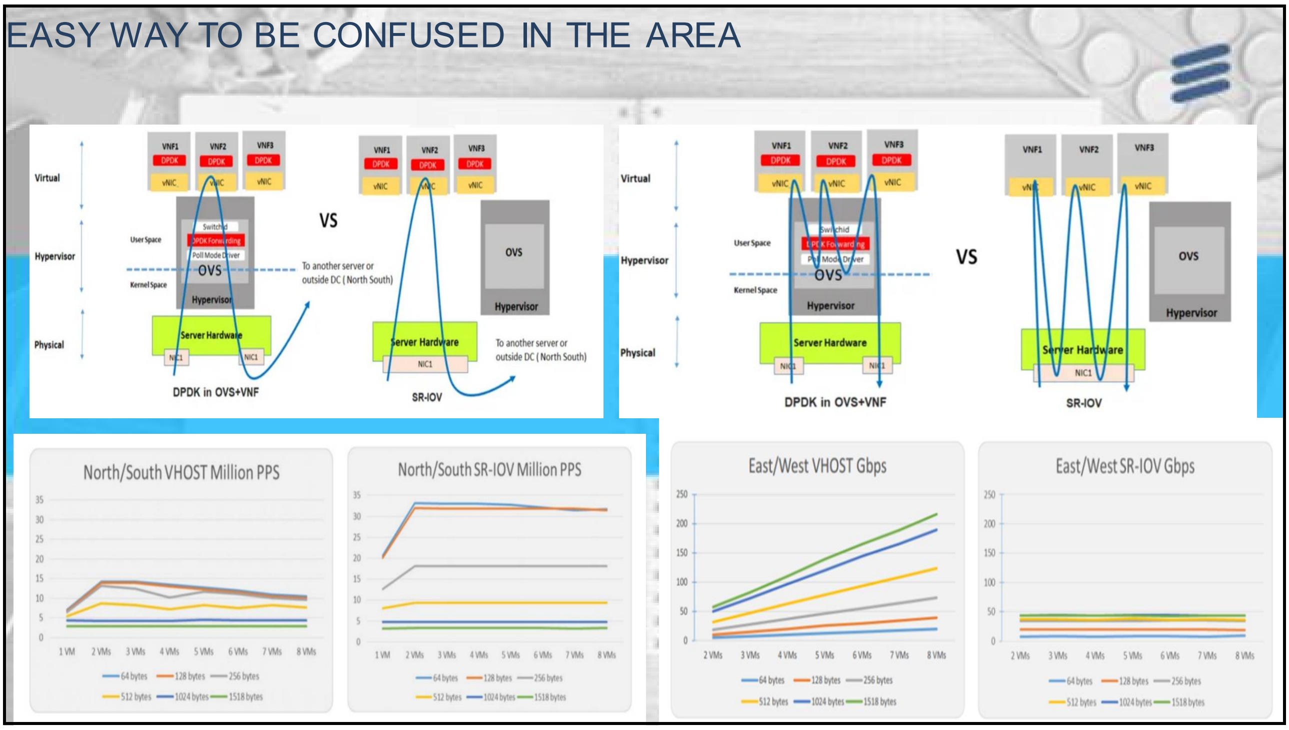
EASY WAY TO BE CONFUSED IN THE AREA
Virtual
Hypervisor
Physical
VNF1
VNF2
VNF3
DPDK
vNIC
User Space
Kernel Space
OVS
Hypervisor
Server Hardware
NIC1
VS
To another server or outside DC (North South)
DPDK in OVS+VNF
SR-IOV
North/South VHOST Million PPS
North/South SR-IOV Million PPS
East/West VHOST Gbps
East/West SR-IOV Gbps
64 bytes
128 bytes
256 bytes
512 bytes
1024 bytes
1518 bytes

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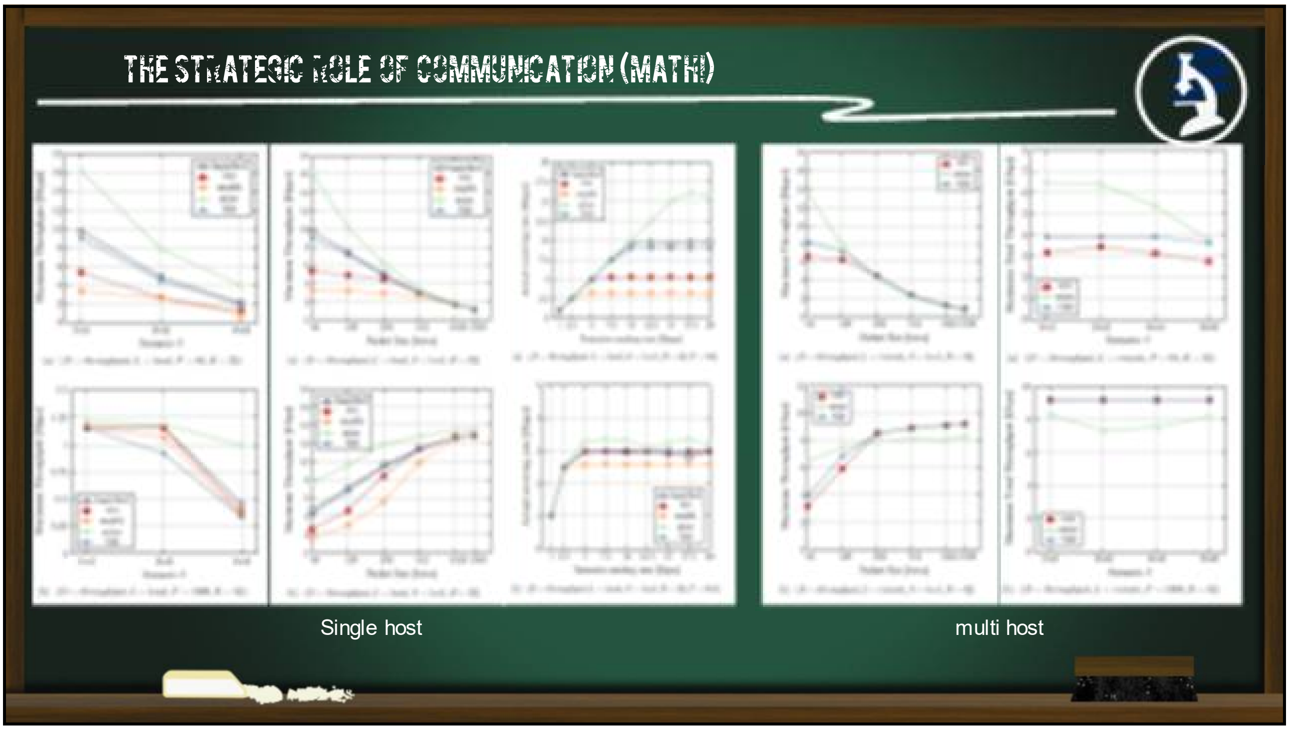
THE STRATEGIC ROLE OF COMMUNICATION (MATH)
Single host
multi host

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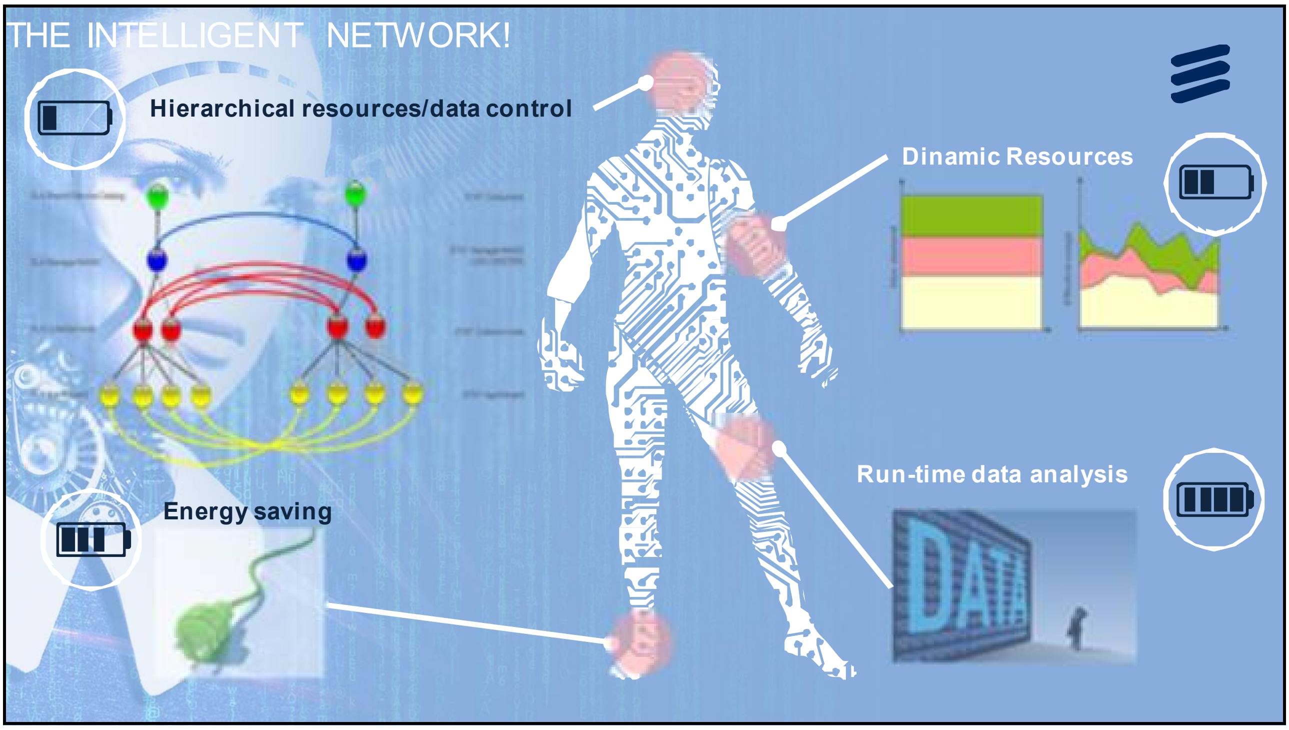


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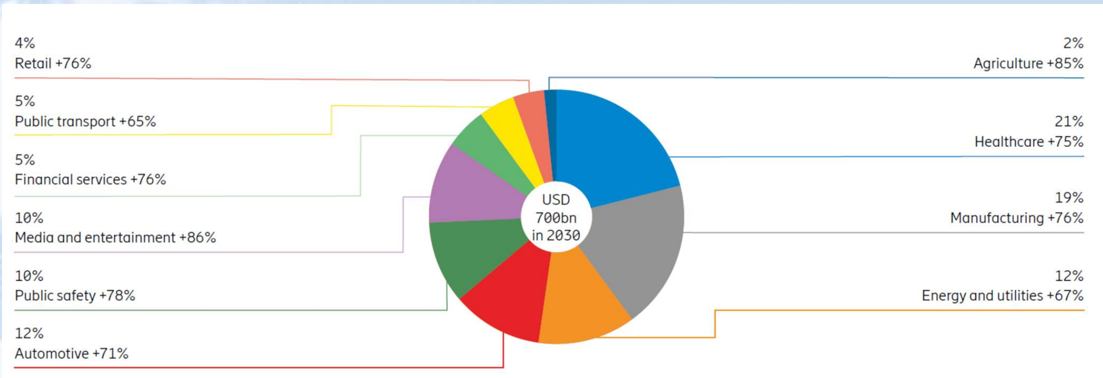
# SERVICE IS THE VALUE

Share and growth rate for global total 5G-enabled B2B potential for service providers




The 5G–enabled revenue potential for service providers is split by industry. Even if some of the industries seemingly have larger shares of the revenue potential, it is far from the only thing that matters for service providers to decide to address a certain industry. Evaluating factors including competition, scope and scale effects, as well as risks and expected returns is key to estimating the business potential.

Source: Ericsson and Arthur D. Little

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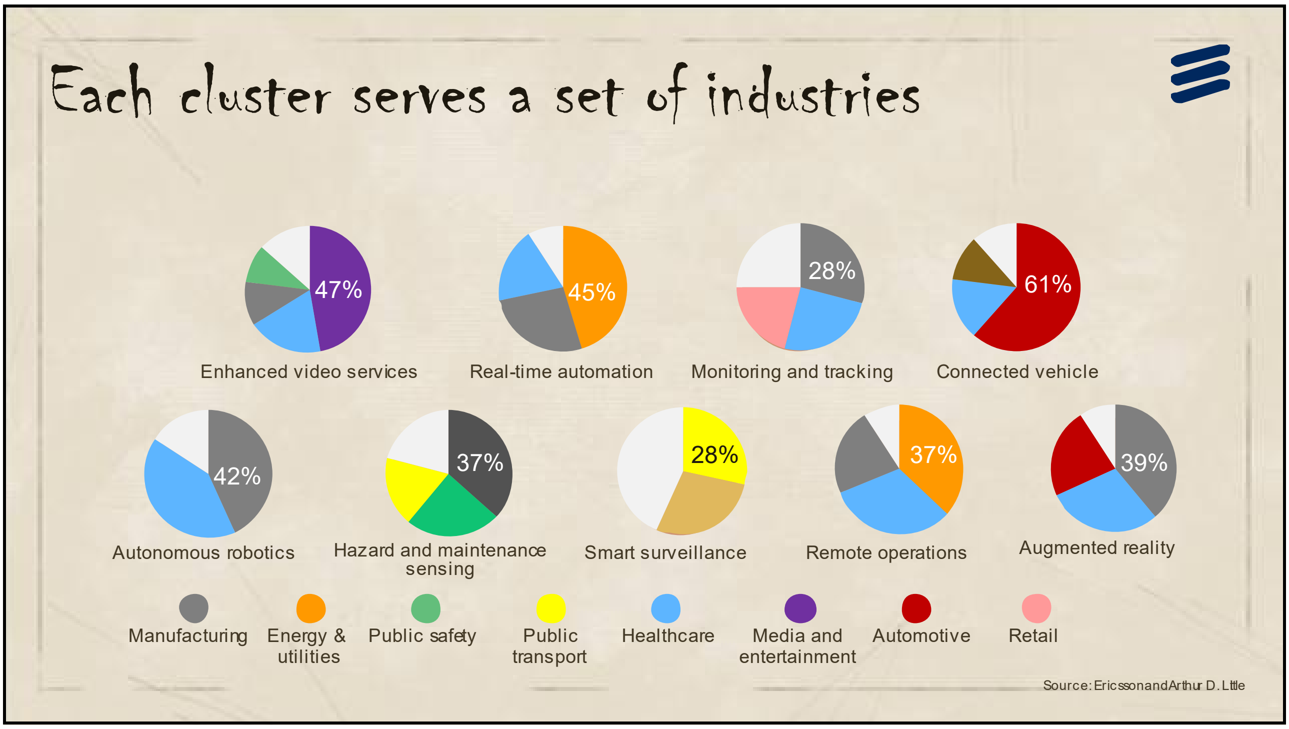
Each cluster serves a set of industries
47%
Enhanced video services
45%
Real-time automation
28%
Monitoring and tracking
61%
Connected vehicle
42%
Autonomous robotics
37%
Hazard and maintenance sensing
28%
Smart surveillance
37%
Remote operations
39%
Augmented reality
Manufacturing
Energy & utilities
Public safety
Public transport
Healthcare
Media and entertainment
Automotive
Retail
Source: Ericsson and Arthur D. Little

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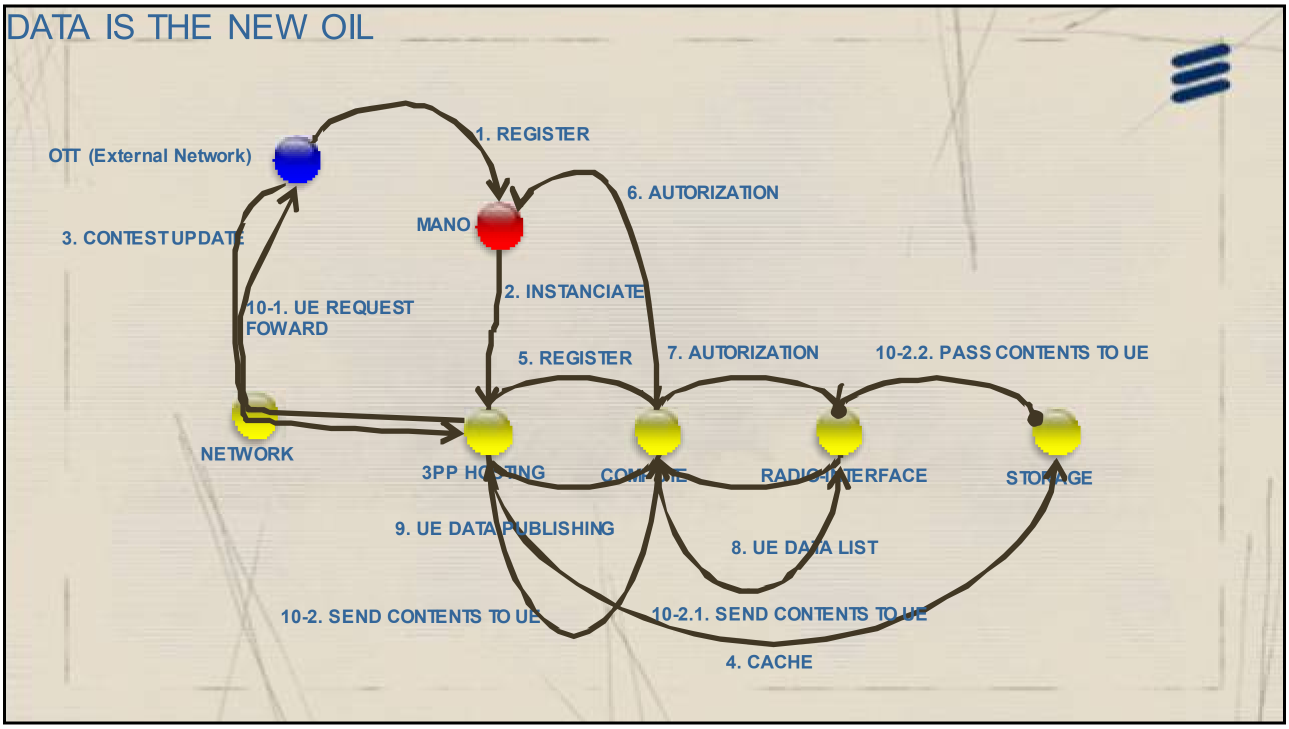
DATA IS THE NEW OIL
OTT (External Network)
1. REGISTER
6. AUTORIZATION
MANO
3. CONTEST UPDATE
2. INSTANCIATE
10-1. UE REQUEST FOWARD
5. REGISTER
7. AUTORIZATION
10-2.2. PASS CONTENTS TO UE
NETWORK
9. UE DATA PUBLISHING
8. UE DATA LIST
10-2. SEND CONTENTS TO UE
10-2.1. SEND CONTENTS TO UE
4. CACHE

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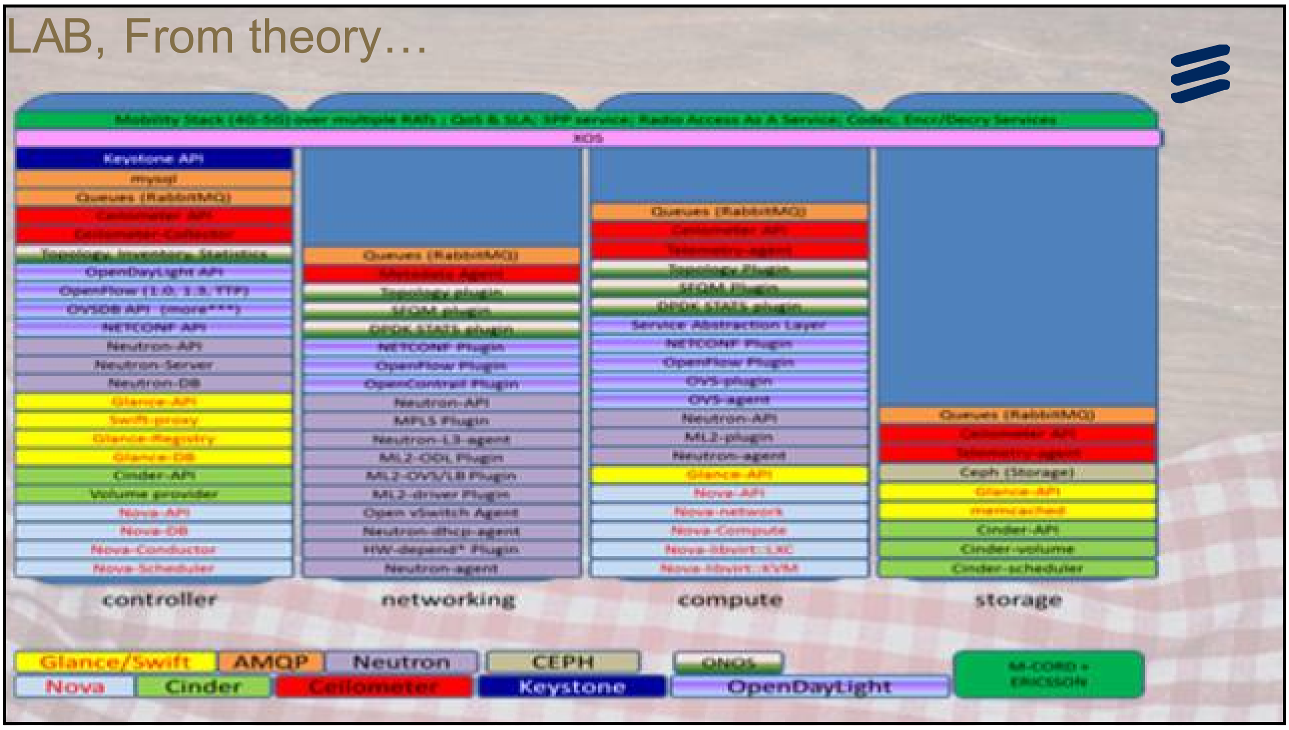
LAB, From theory…
Keystone API
mysql
Queues (RabbitMQ)
Topology, Inventory, Statistics
OpenDayLight API
OpenFlow (1.0, 1.3, TTP)
OVSDB API (more***)
NETCONF API
Neutron-API
Neutron-Server
Neutron-DB
Glance-API
Swift-proxy
Glance-Registry
Glance-DB
Cinder-API
Volume provider
Nova-API
Nova-DB
Nova-Conductor
Nova-Scheduler
Queues (RabbitMQ)
Topology plugin
SFQM plugin
DPDK STATS plugin
NETCONF Plugin
OpenFlow Plugin
OpenContrail Plugin
Neutron-API
MPLS Plugin
Neutron-L3-agent
ML2-ODL Plugin
ML2-OVS/LB Plugin
ML2-driver Plugin
Open vSwitch Agent
Neutron-dhcp-agent
HW-depend* Plugin
Neutron-agent
Queues (RabbitMQ)
Topology Plugin
SFQM Plugin
DPDK STATS plugin
Service Abstraction Layer
NETCONF Plugin
OpenFlow Plugin
OVS-plugin
OVS-agent
Neutron-API
ML2-plugin
Neutron-agent
Glance-API
Nova-API
Nova-network
Nova-Compute
Queues (RabbitMQ)
Ceph (Storage)
Glance-API
memcached
Cinder-API
Cinder-volume
Cinder-scheduler
controller
networking
compute
storage
Glance/Swift
AMQP
Neutron
CEPH
ONOS
Nova
Cinder
Ceilometer
Keystone
OpenDayLight

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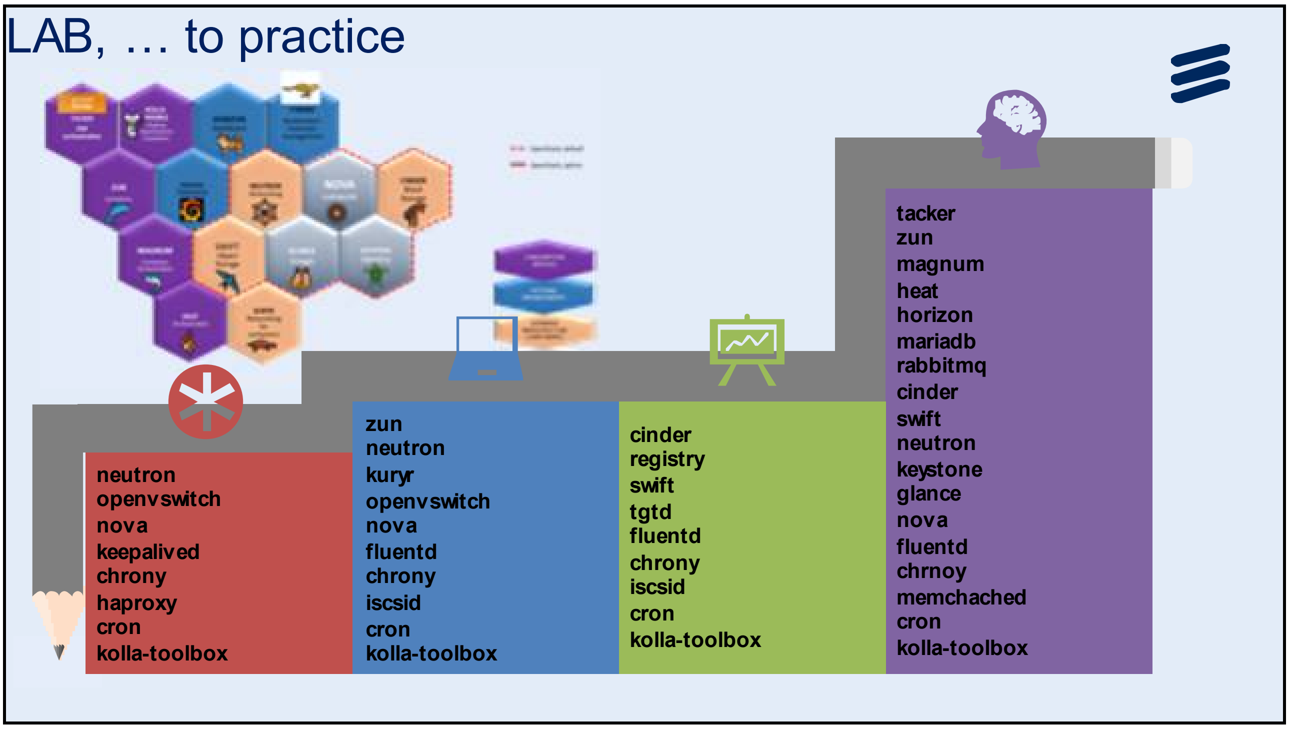
LAB, … to practice
neutron
openvswitch
nova
keepalived
chrony
haproxy
cron
kolla-toolbox
zun
neutron
kuryr
openvswitch
nova
fluentd
chrony
iscsid
cron
kolla-toolbox
cinder
registry
swift
tgtd
fluentd
chrony
iscsid
cron
kolla-toolbox
tacker
zun
magnum
heat
horizon
mariadb
rabbitmq
cinder
swift
neutron
keystone
glance
nova
fluentd
chrnoy
memchached
cron
kolla-toolbox

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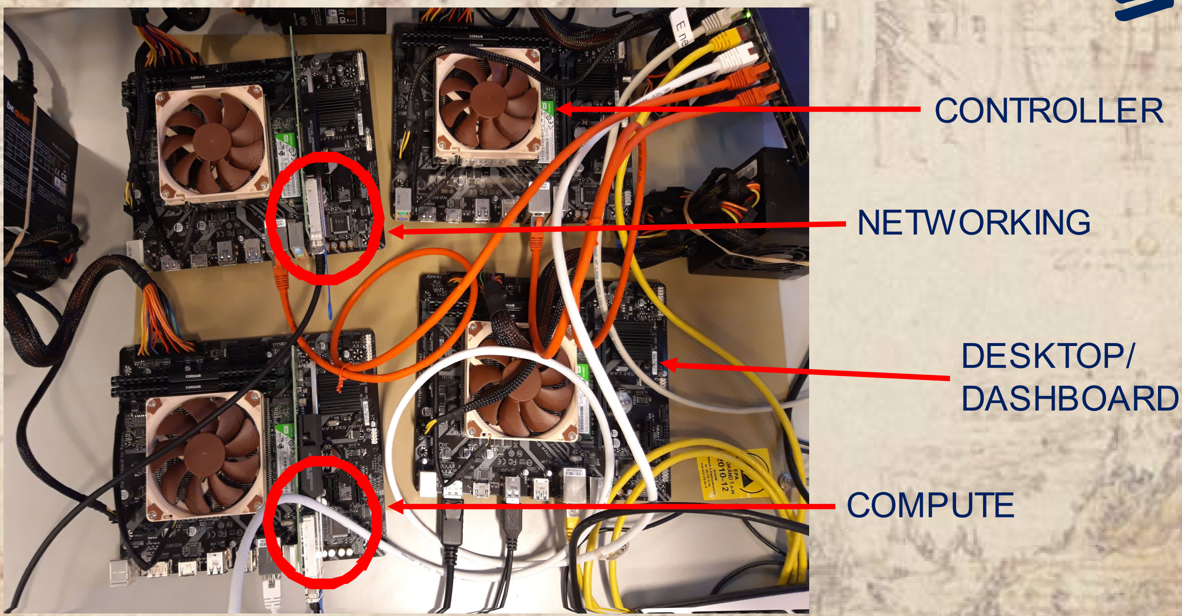
# LAB, … to practice

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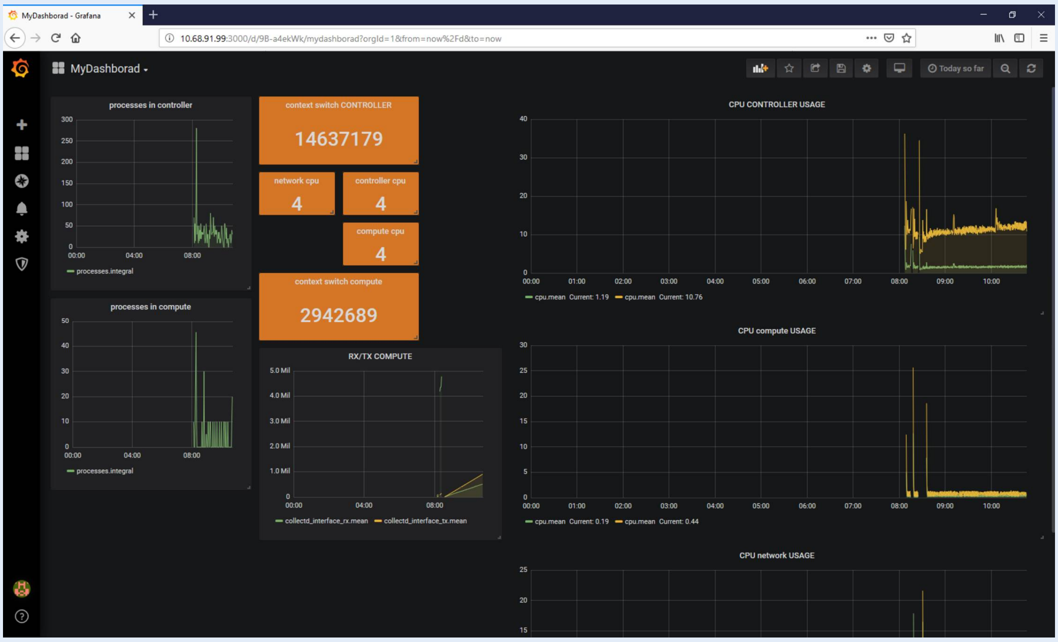
# LAB, … to practice

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