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PANEL
on
Telecommunications and Mobility

Fast Mobility and the Telecommunications Convergence

MODERATOR
Petre Dini, IARIA

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Facts

- **Mobile user (smartphones, wearable: roaming-service, Whatsapp, Facebook, Tweet)**
- **Mobile service provider (mobile cloud, mobile center: mobile hubs)**
- **Mobile entity (any component: flying pieces, drones, manned/unmanned vehicles)**
- **High-speed vehicular-to-vehicular communications**
- **Mobility-as-as-a-service (systems delivering any kind of mobility)**
- **5G, Cognitive-monitoring/management, ML/Deep Learning, IoT, Biomimicry, Slicing/SDN/NFV**
- **Agricultural drones | fields (pesticides, crops video), livestock (mobile cowboys, herds tracking) + IoT | static (soil, crops) . mobile (crops, livestock)**
- **Urban drones | terrestrial/airborne | manned/unmanned | goods delivery, taxi, emergency (goods&/or patients)**

- **Mobility-as-a-Service**

Prediction

- **…. they are part of a 10-year plan to make the need to own a car obsolete.**
- **…. by 2040, transportation (goods, citizen) will have a new facet**
- **…. by xxxx (?) dreaming at (Moon, Mars, ….)**

Ideas | Starting points for discussion

Software - large, apps, speed, security, opensources, …
Networks technology - speed, security, resilience, safety, …
Mobility Services - safety, charging, affordability, availability, …

Digital transformation
MOBILITY

Education
Virtual travels
Transportation
Shopping
Cooking
Social relations
Political entities
……
..
.

Panelists

Moderator

Petre Dini, IARIA, USA

Panelists

- Carlo Vitucci, Ericsson, Sweden

  OpenSource & Mobility

- Eugen Borcoci, Univerity Politehnica Bucharest, Romania

  5G & Mobility

- Petre Dini, IARIA, USA

  Driverless fleets and the dynasty of drones

Open discussion

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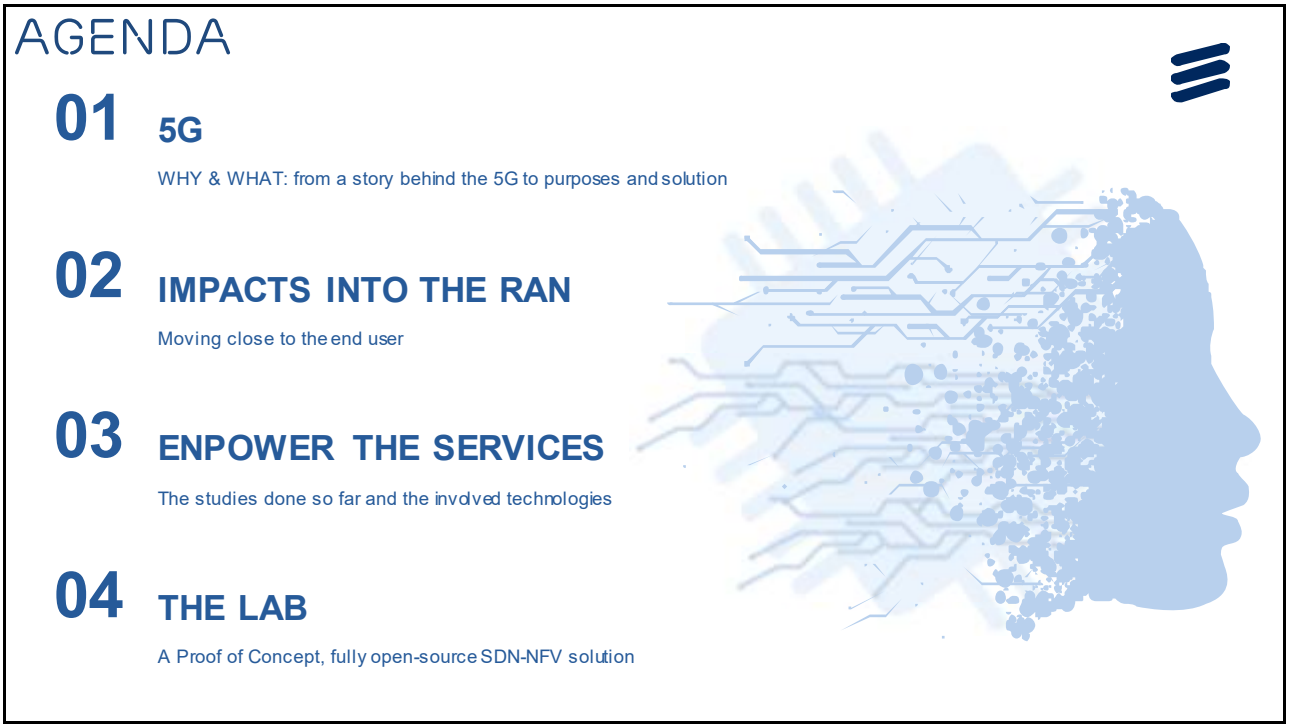
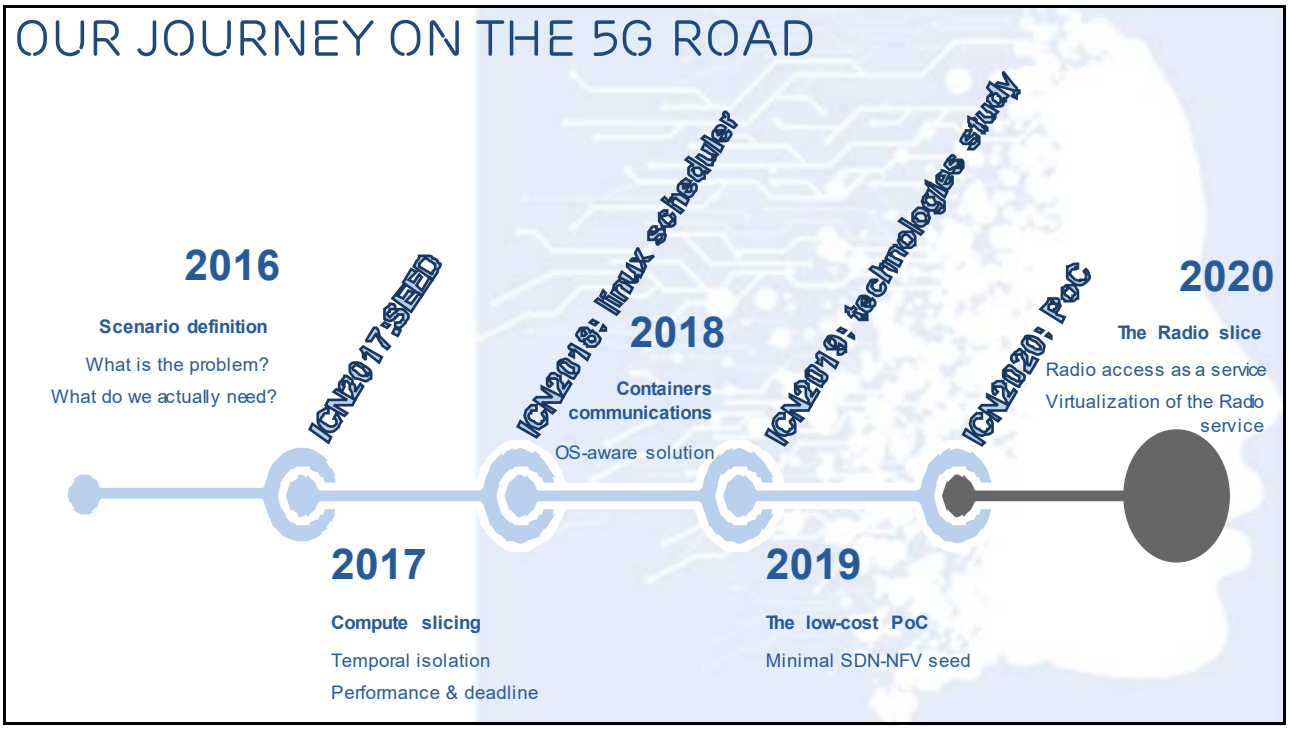
MOVING THE
SDN-NFV
INTO THE RAN
ICN 2020 The Nineteenth International Conference on Networks
February 23, 2020 to February 27, 2020 - Lisbon, Portugal

1


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 invdved technologies
04
THE LAB
A Proof of Concept, fully open-source SDN-NFV solution

2

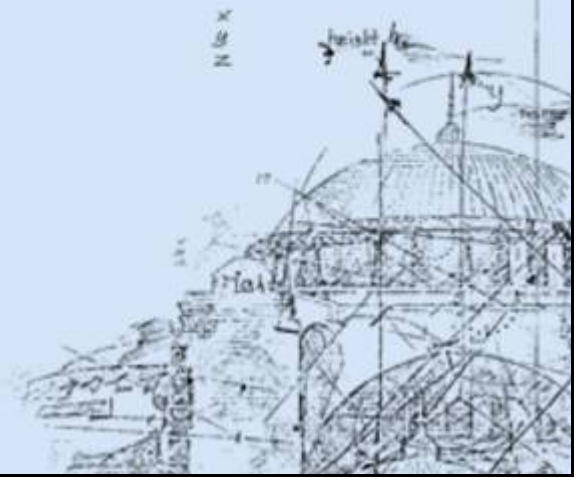
OUR JOURNEY ON THE 5G ROAD



3

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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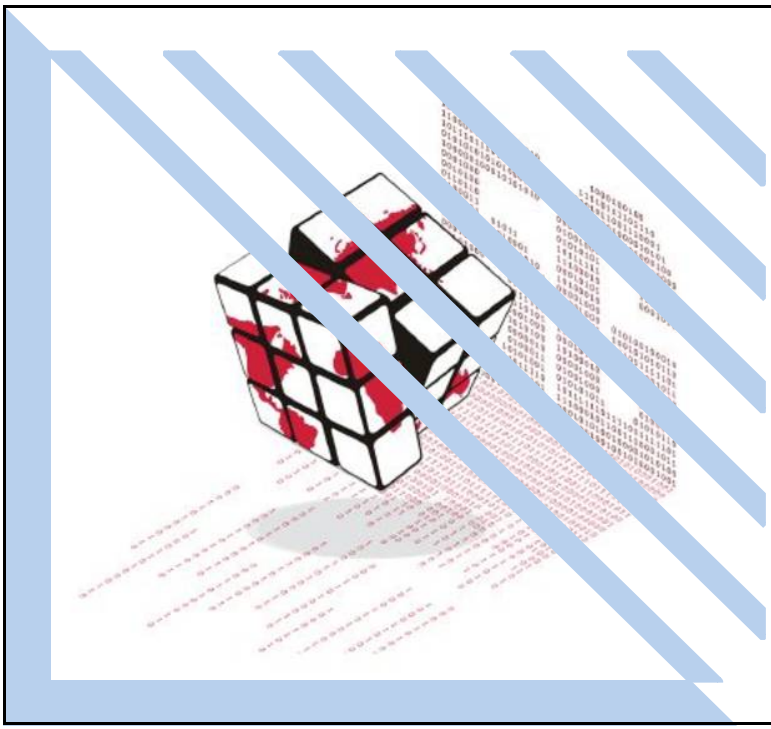


5G

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.

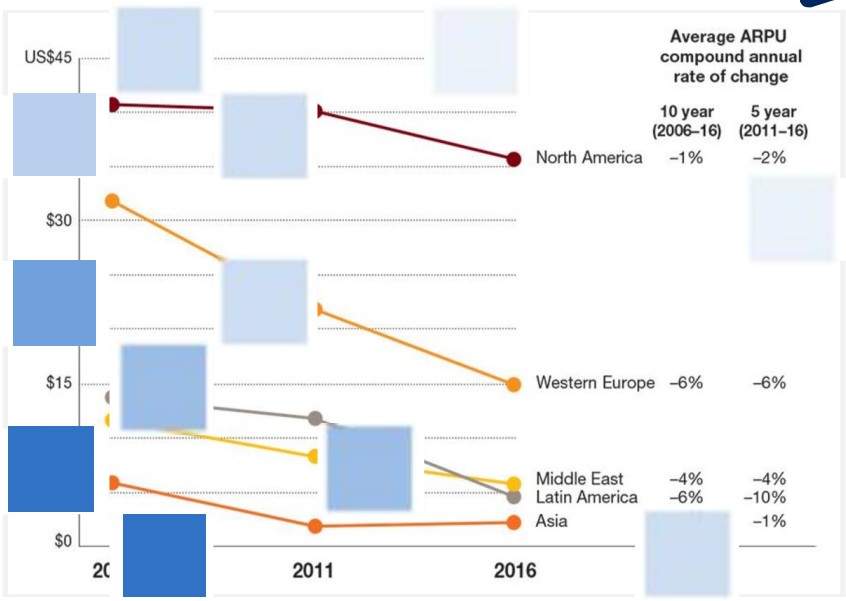
5

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)

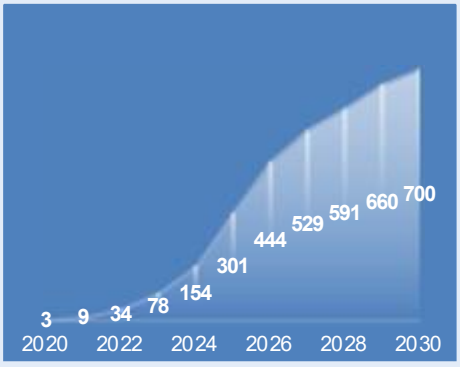


6

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



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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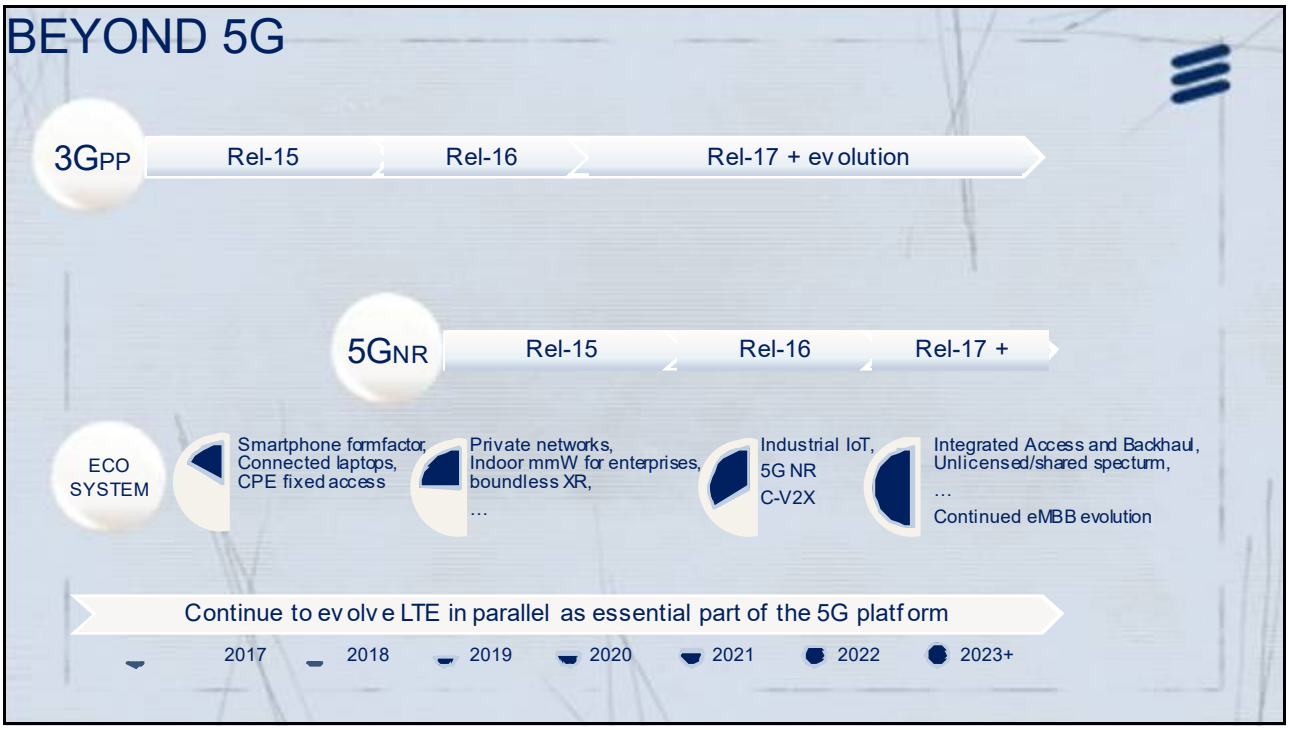
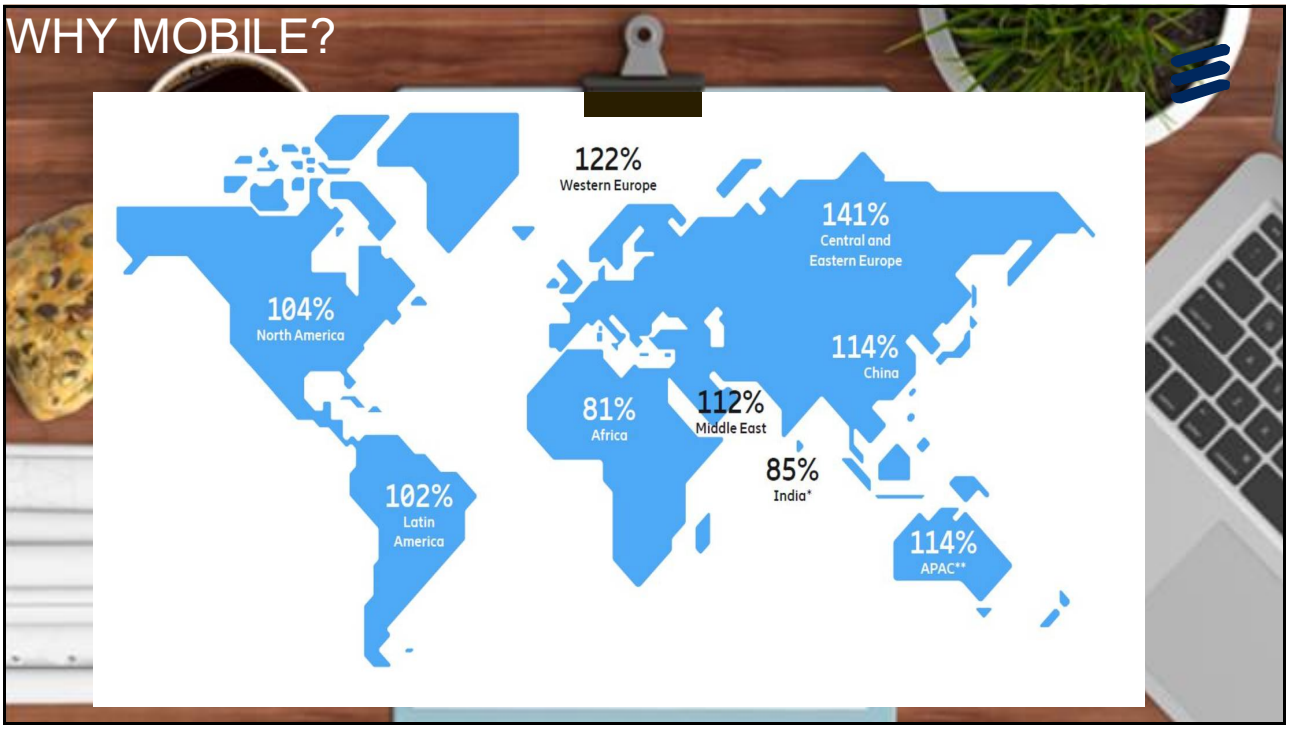
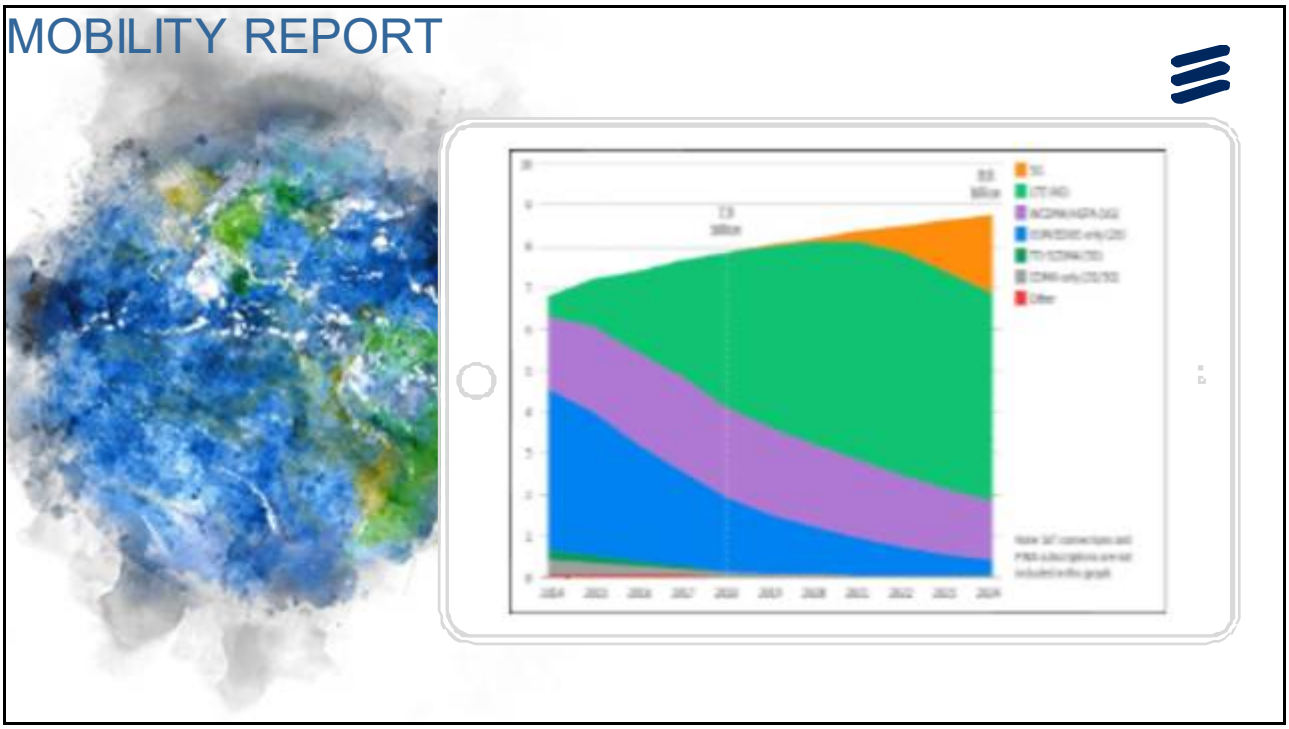

BEYOND 5G
3GPP
Rel-15
Rel-16
Rel-17 + evolution
5GNR
Rel-15
Rel-16
Rel-17 +
ECO SYSTEM
Smartphone formfactor, Connected laptops, CPE fixed access
Private networks, Indoor mmW for enterprises, boundless XR, ...
Industrial IoT, 5G NR C-V2X
Integrated Access and Backhaul, Unlicensed/shared specturm, ...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

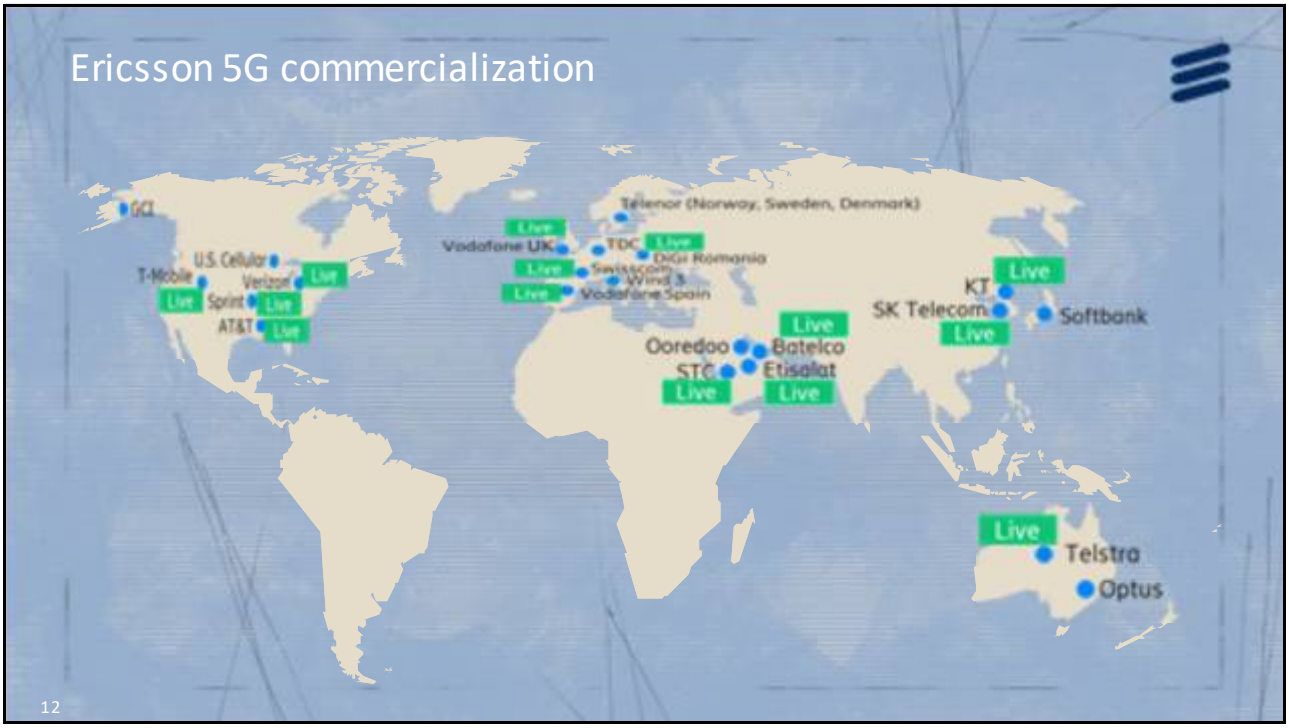
9


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**

10


MOBILITY REPORT

11


Ericsson 5G commercialization
GCI
U.S. Cellular
T-Mobile
Verizon
Sprint
AT&T
Live
Telenor (Norway, Sweden, Denmark)
Vodafone UK
TDC
DiGi Romania
Swisscom
Wind 3
Vodafone Spain
Ooredoo
Batelco
STC
Etisalat
KT
SK Telecom
Softbank
Telstra
Optus
12

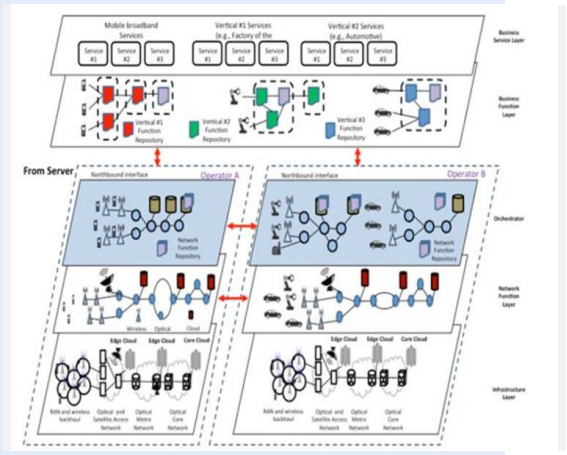
12

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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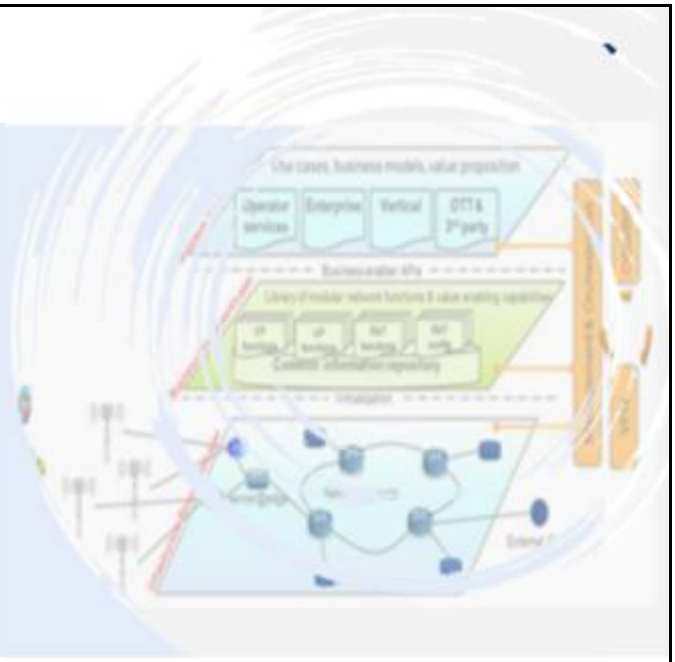
SDN-NFV ARCHITECTURE

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:

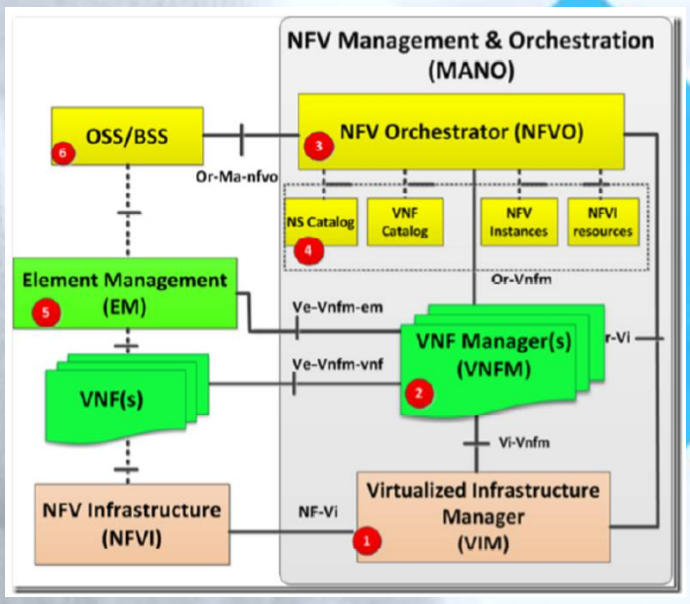
- Business Application Layer – where the enterprise business value model is defined
- Business Enablement Layer – where the enabling and capabilities value are defined
- Infrastructure Resources Layer – where the resources needed by the value are defined

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.



14

MANO (ETSI)

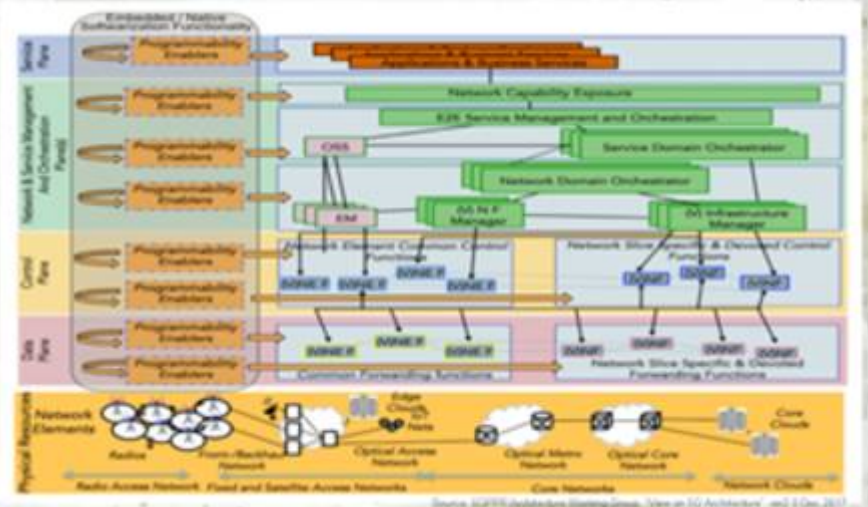


DO YOU KNOW WHAT THEY ARE?

15

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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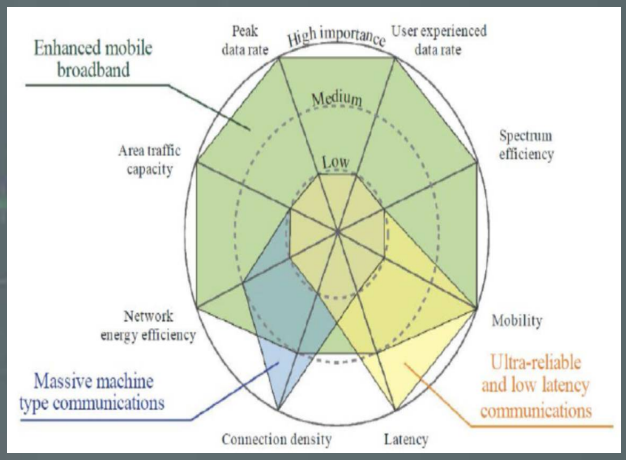
WHAT DOES IT MEAN SERVICE ORIENTED

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

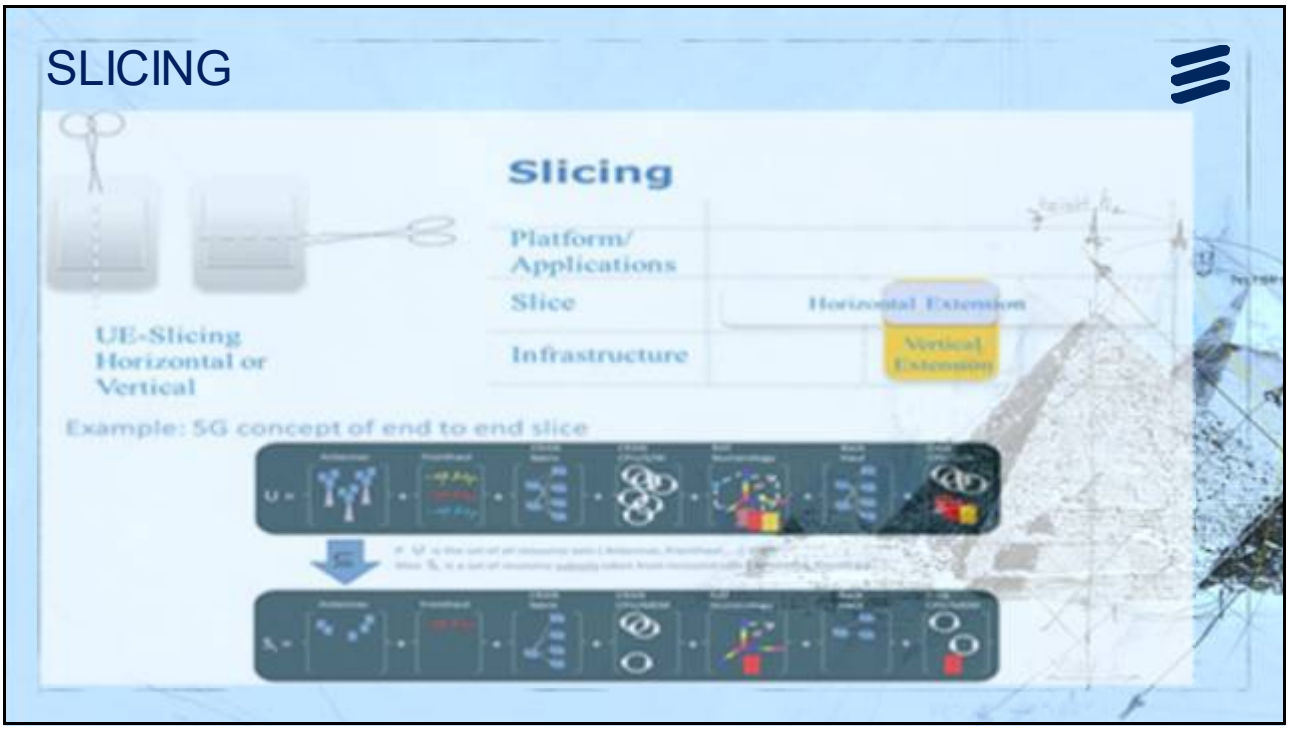
NFV

- 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"

18

SLICING



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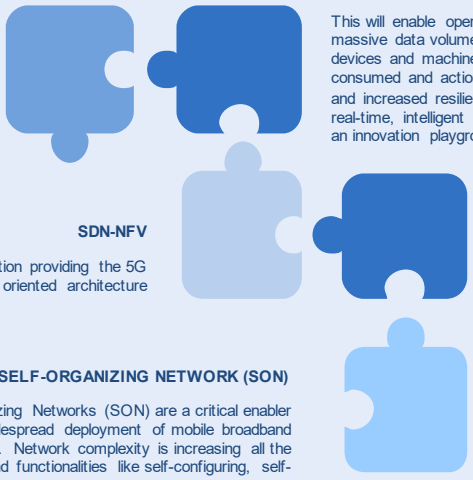
5G, 5 PILLARS

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

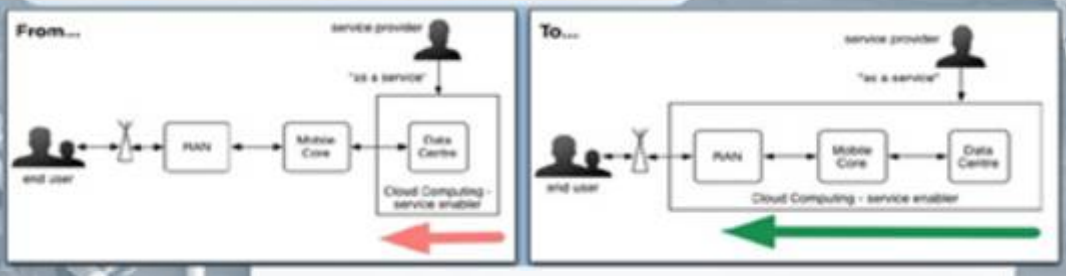
Services and their supporting infrastructure, both network and IT, are quickly becoming more real-time oriented, driven by customers' preferences for innovation, excitement and speed, and the need to meet or exceed those expectations with increased agility and lower cost structures. Orchestration answers 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.

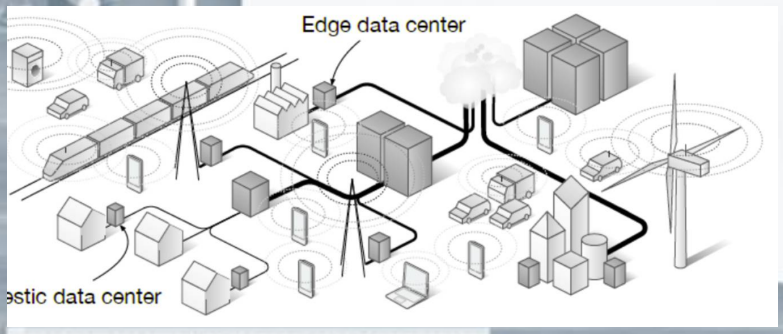
SELF-ORGANIZING NETWORK (SON)

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.

20

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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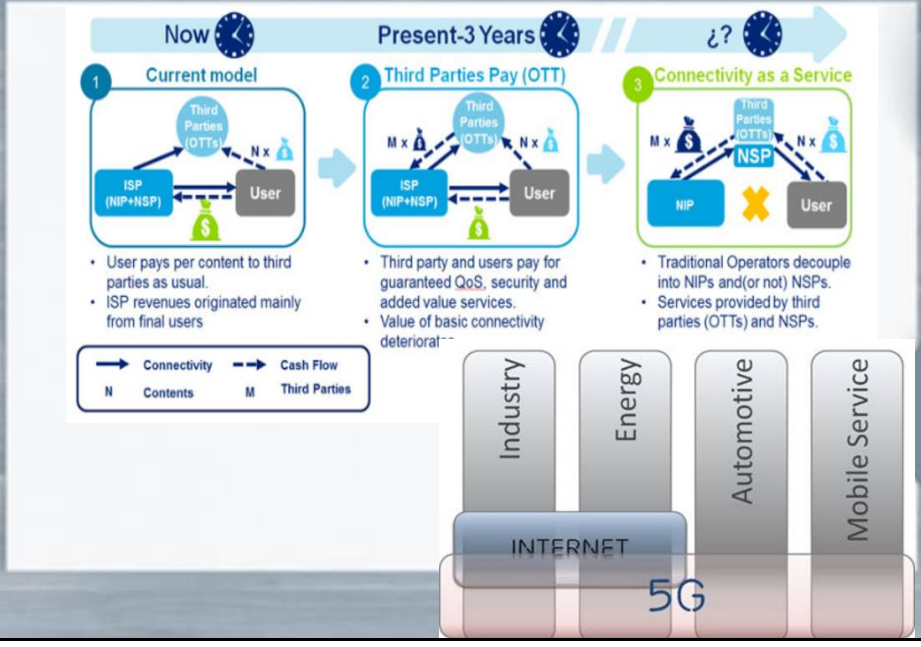
RAN COMPUTE (SErver at the EDge)



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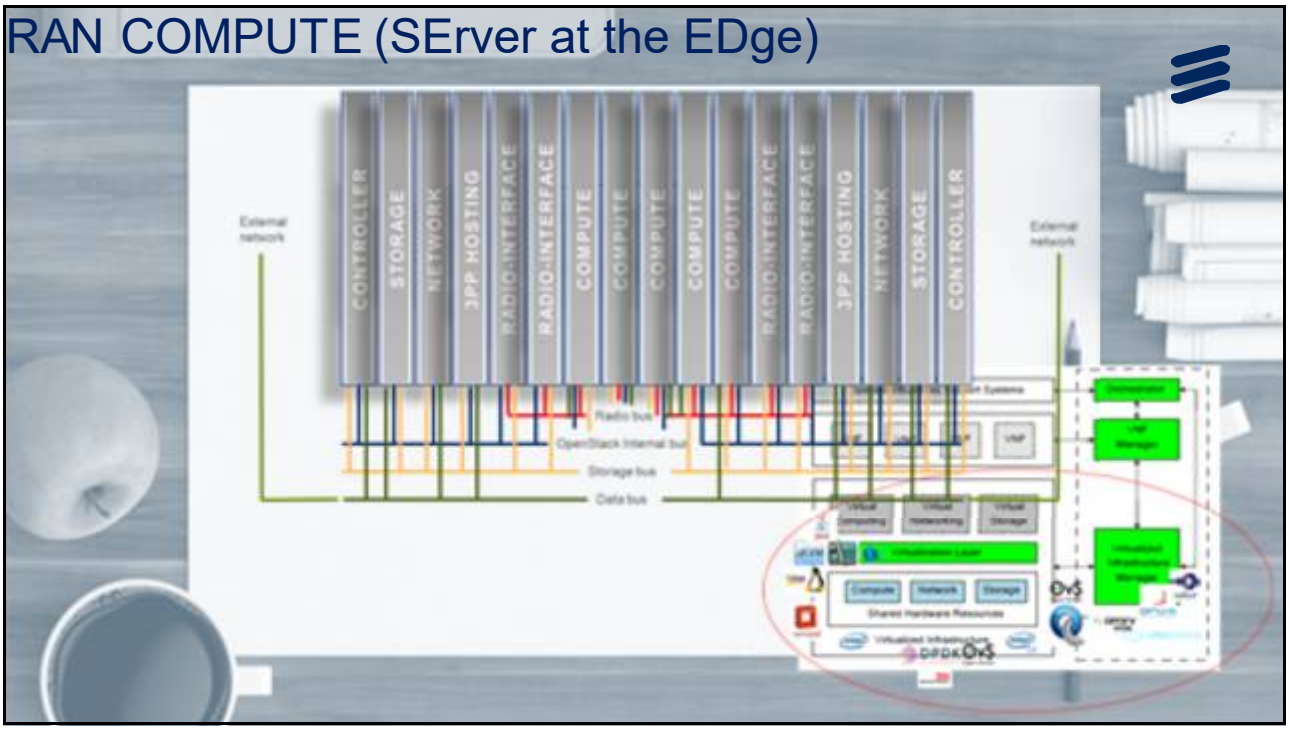
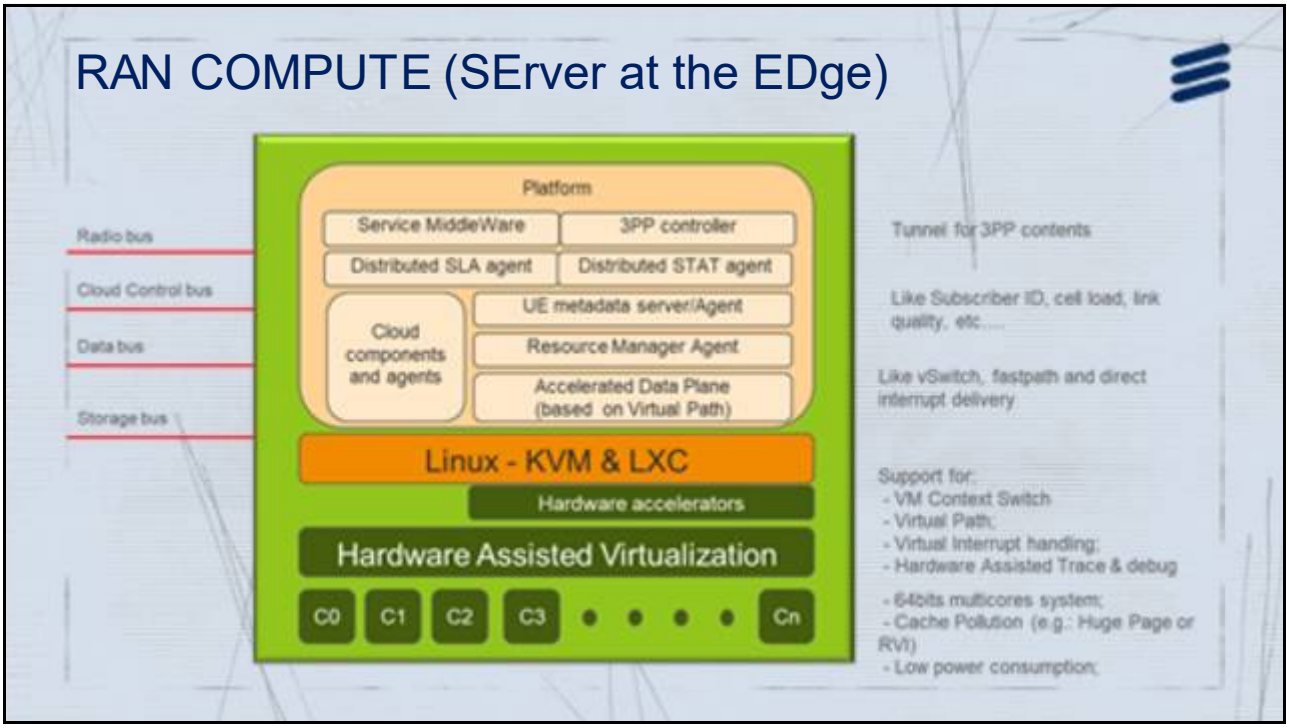
RAN COMPUTE (SErver at the EDge)



23

RAN COMPUTE (SErver at the EDge)



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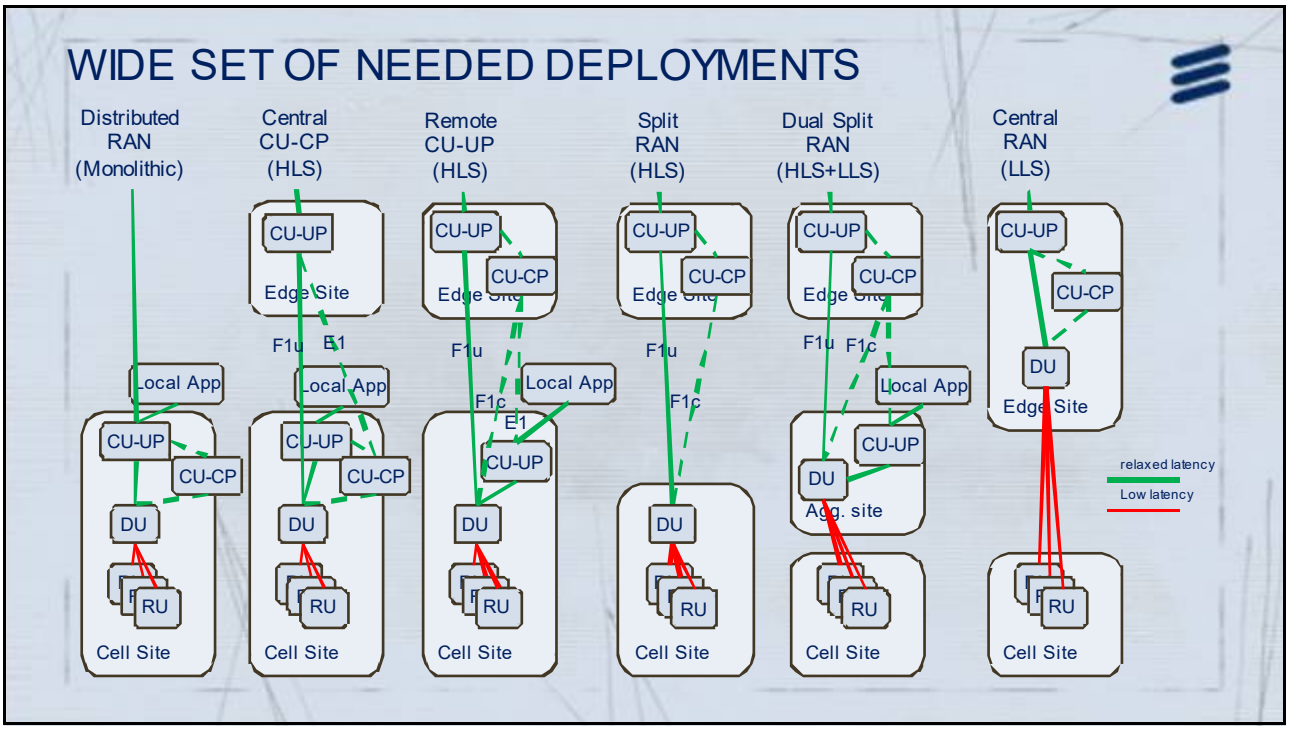

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RAN COMPUTE (SErver at the EDge)

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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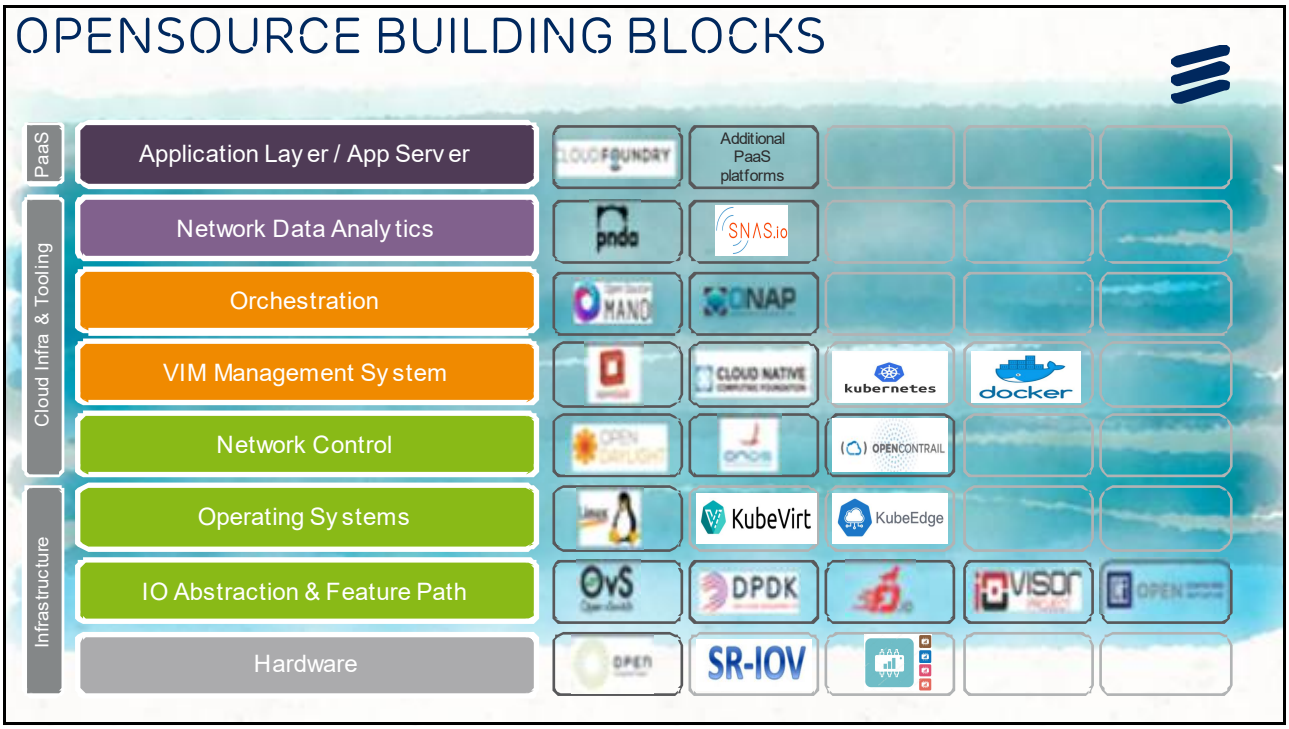

OPENSOURCE BUILDING BLOCKS
PaaS
Application Layer / App Server
Additional PaaS platforms
Cloud Infra & Tooling
Network Data Analytics
Orchestration
VIM Management System
Network Control
Infrastructure
Operating Systems
IO Abstraction & Feature Path
Hardware
CLOUDFOUNDRY
pnda
SNAS.io
MANO
ONAP
CLOUD NATIVE
kubernetes
docker
OPENCONTRAIL
KubeVirt
KubeEdge
OvS
DPDK
VISORI
SR-IOV

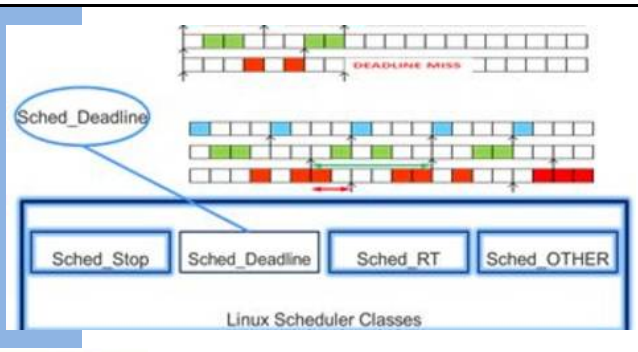
27

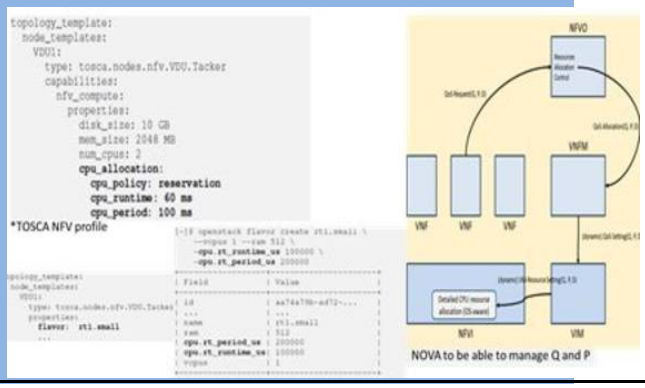

O-RAN
ALLIANCE
AT&T
中国移动 China Mobile
docomo
orange
T··
airtel
中国电信 CHINA TELECOM
Jio
kt
Singtel
SK telecom
TIM
Telefónica
TELSTRA
verizon
dish
KDDI
SoftBank
Sprint
ERICSSON
Infineon
BROADCOM
intel
Lenovo
redhat
XILINX
NXP
NEC
FUJITSU
Ball
CertusNet
Radisys
cisco
NOKIA
ZTE
SAMSUNG
ciena
OPERATORS DRIVING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

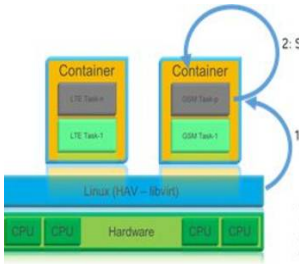
28

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



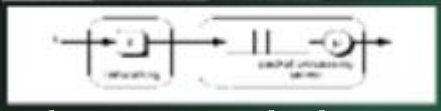




AT THE ROOT LEVEL, A CPU RESERVATION (IMPLEMENTED AS A SCHED_DEADLINE SCHEDULING ENTITIES) SCHEDULES THE VARIOUS CONTAINERS (BASICALLY, LXC VMS); AT THE SECOND LEVEL (INSIDE THE CONTAINER), A FIXED PRIORITY SCHEDULER (BASED ON SCHED_FIFO OR SCHED_RR) SCHEDULES THE REAL-TIME TASKS INSIDE THE CONTAINER

29

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

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

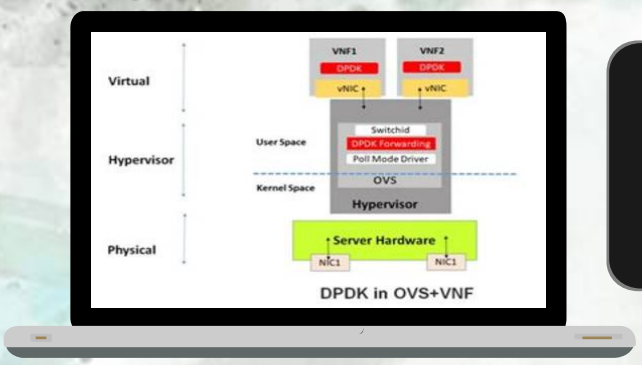
T. Cucinotta, M. Marinoni, A. Melani, A. Parri and C. Vitucci: "Temporal isolation among LTE/5G network functions by real-time scheduling" Proceedings of the 7th IEEE International Conference on Cloud Computing and Services Science, 2017

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

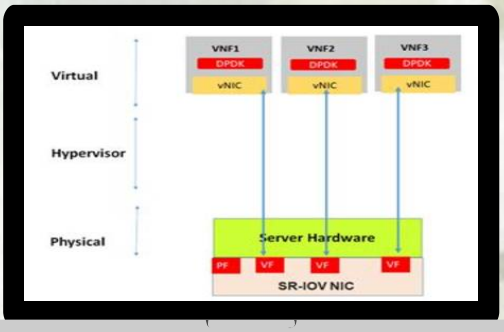
30

THE STRATEGIC ROLE OF COMMUNICATION



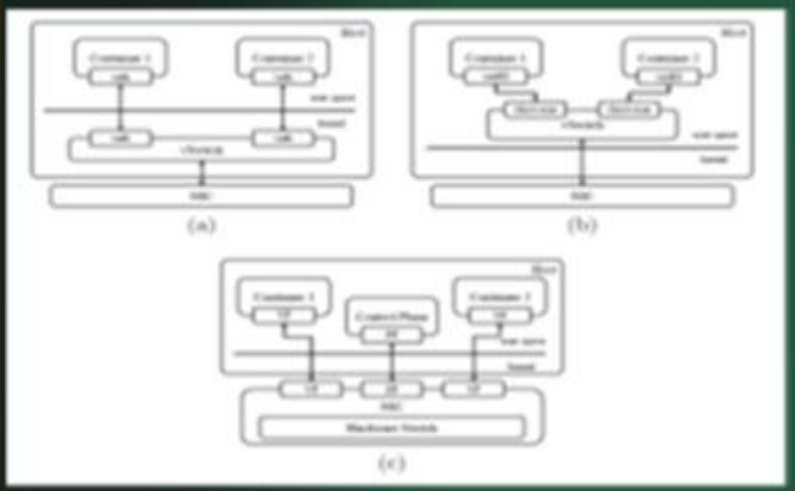
It is widely understood there is not a golden child in the communication technologies. Inter-container control communication, data path, external communication have totally different requirements and so they request totally different technology solution.

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.



31

THE STRATEGIC ROLE OF COMMUNICATION (MATH)

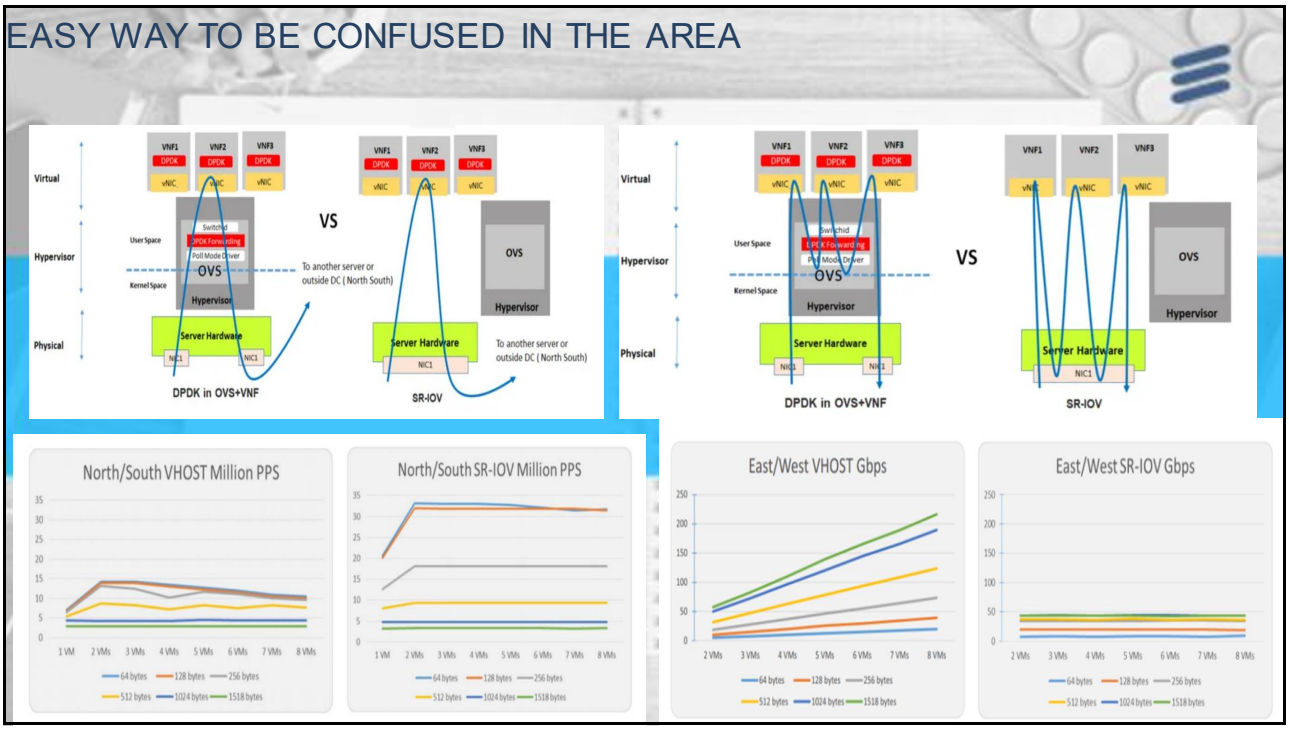


a) Kernel-based solution
b) Using DPDK with vhost in user mode
c) using SR -IOV support

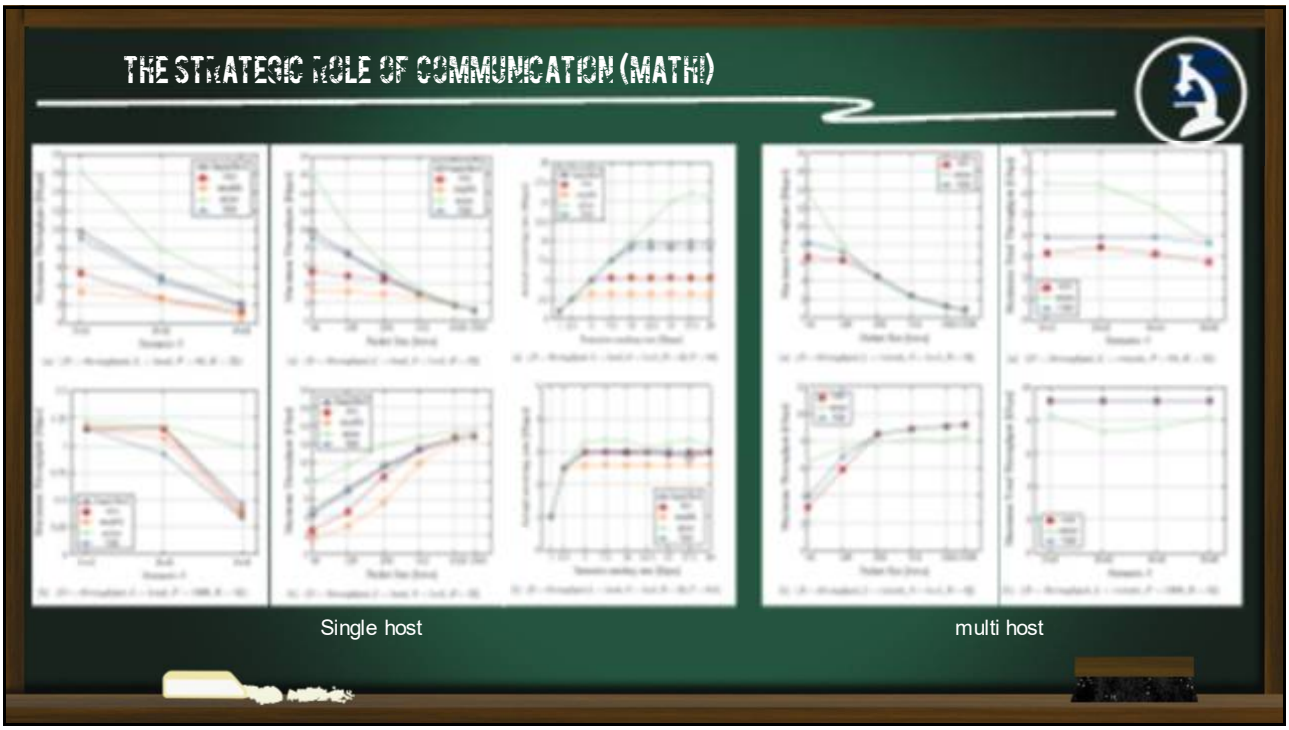
C. Vitucci, L. Abeni, T. Cucinotta and M. Marinoni: "The Strategic Role of Inter-Container Communications in RAN deployment scenario" The Eighteenth International Conference on Networks, 2019

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

32


EASY WAY TO BE CONFUSED IN THE AREA
Virtual
Hypervisor
Physical
VNF1
VNF2
VNF3
DPDK
vNIC
User Space
Kernel Space
OVS
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

33


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

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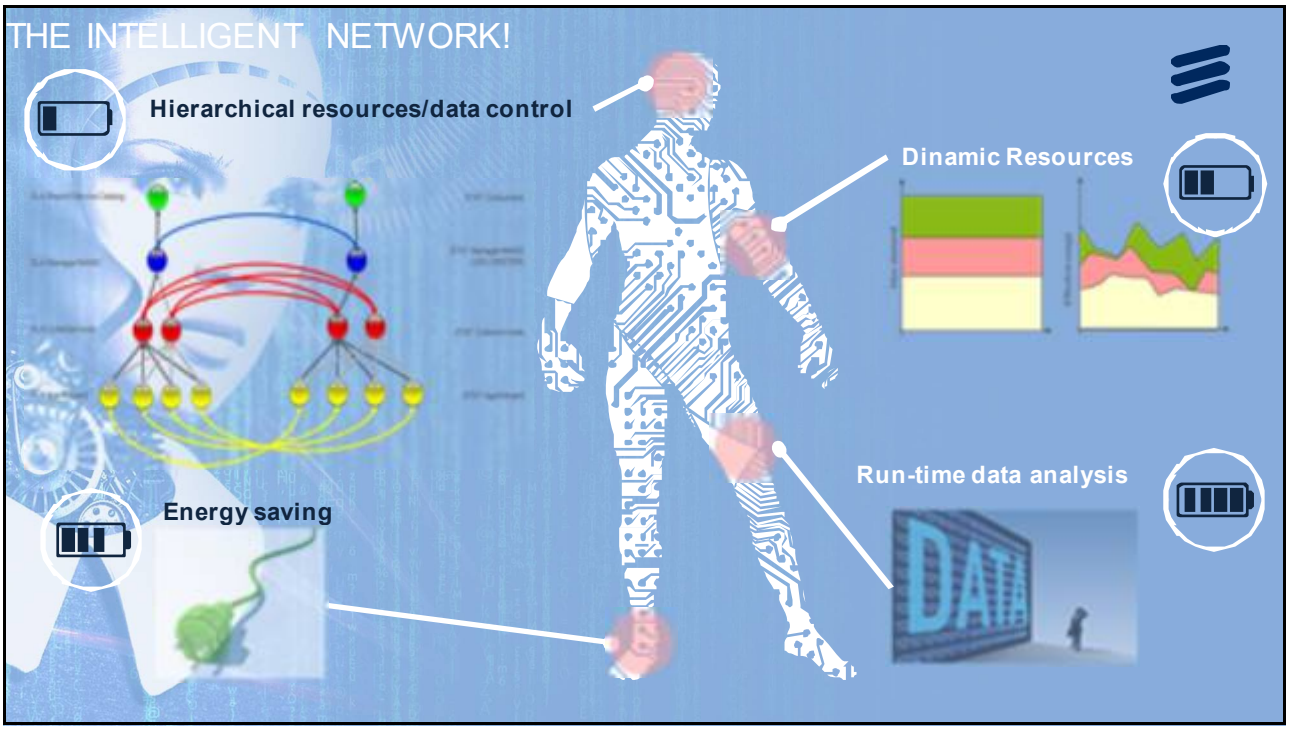

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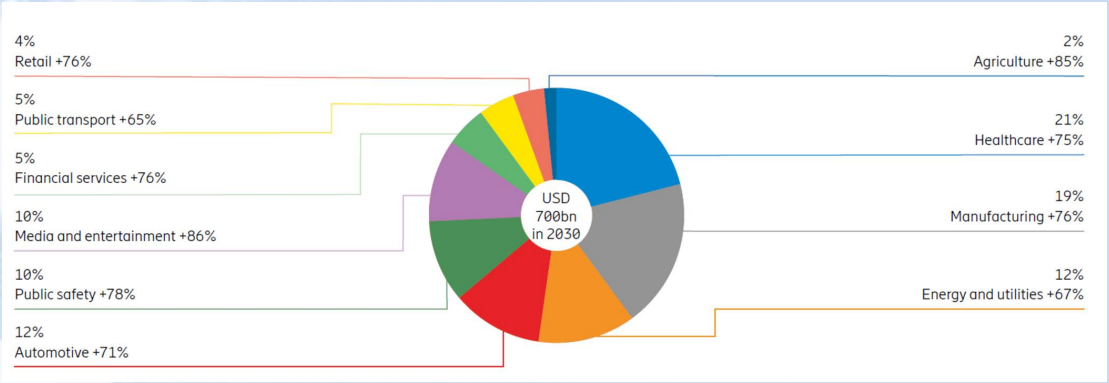
SERVICE IS THE VALUE

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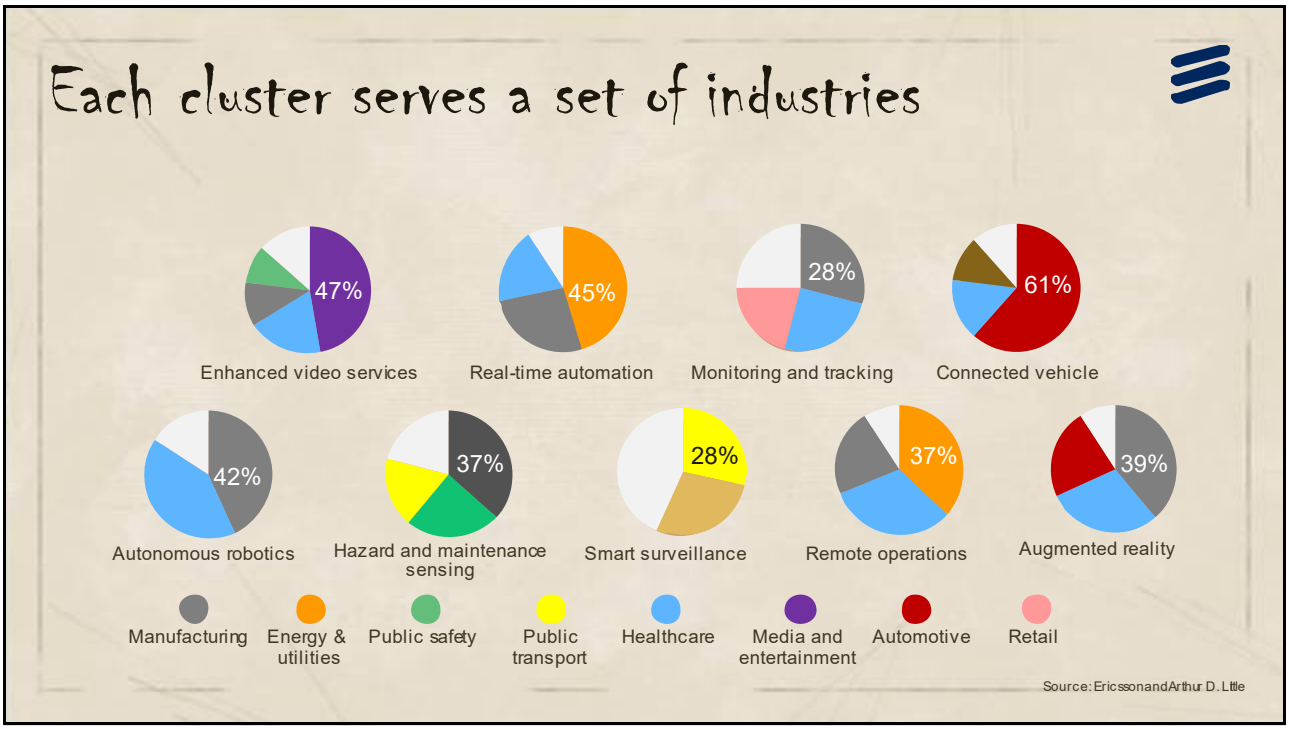
Each cluster serves a set of industries
47%
Enhanced video services
45%
Real-time automation
28%
Monitoring and tracking
61%
Connected vehicle
42%
Autonomous robotics
37%
Hazard and maintenance sensing
28%
Smart surveillance
37%
Remote operations
39%
Augmented reality
Manufacturing
Energy & utilities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

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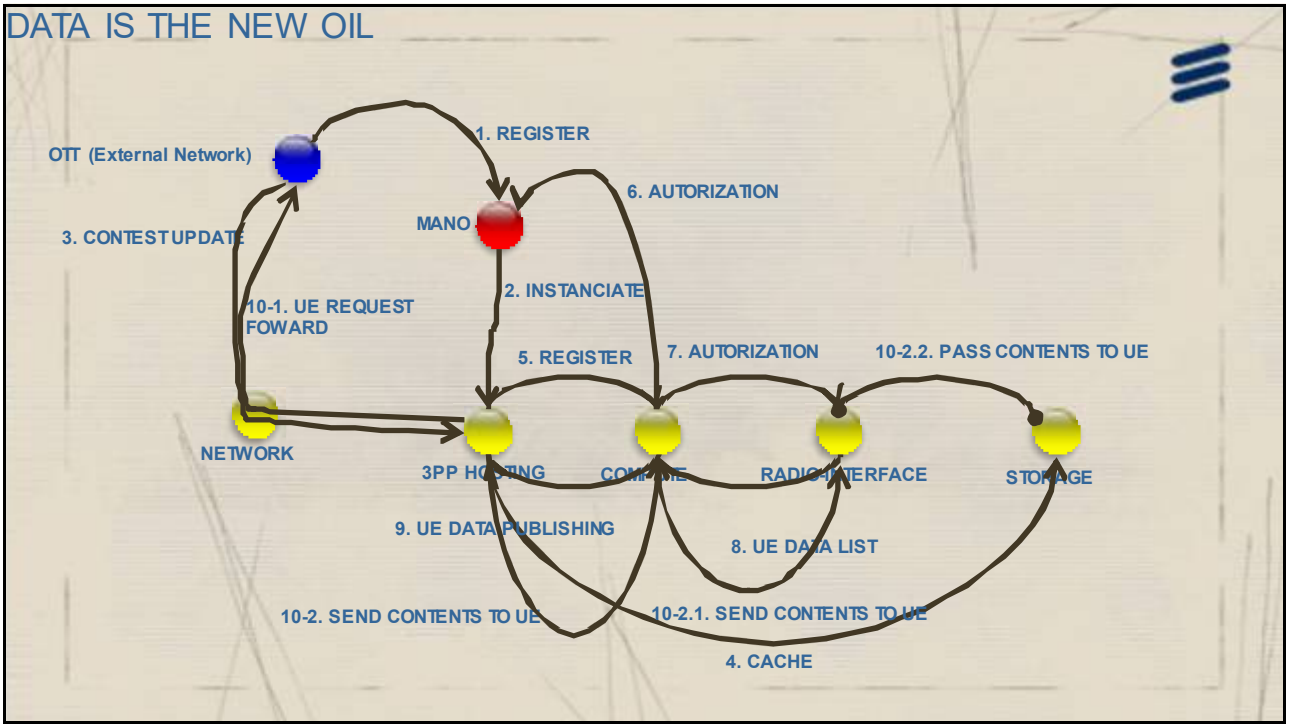
DATA IS THE NEW OIL
OTT (External Network)
1. REGISTER
6. AUTORIZATION
MANO
3. CONTEST UPDATE
2. INSTANCIATE
10-1. UE REQUEST FOWARD
5. REGISTER
7. AUTORIZATION
10-2.2. PASS CONTENTS TO UE
NETWORK
3PP HOSTING
COMPUTE
RADIO INTERFACE
STORAGE
9. UE DATA PUBLISHING
8. UE DATA LIST
10-2. SEND CONTENTS TO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

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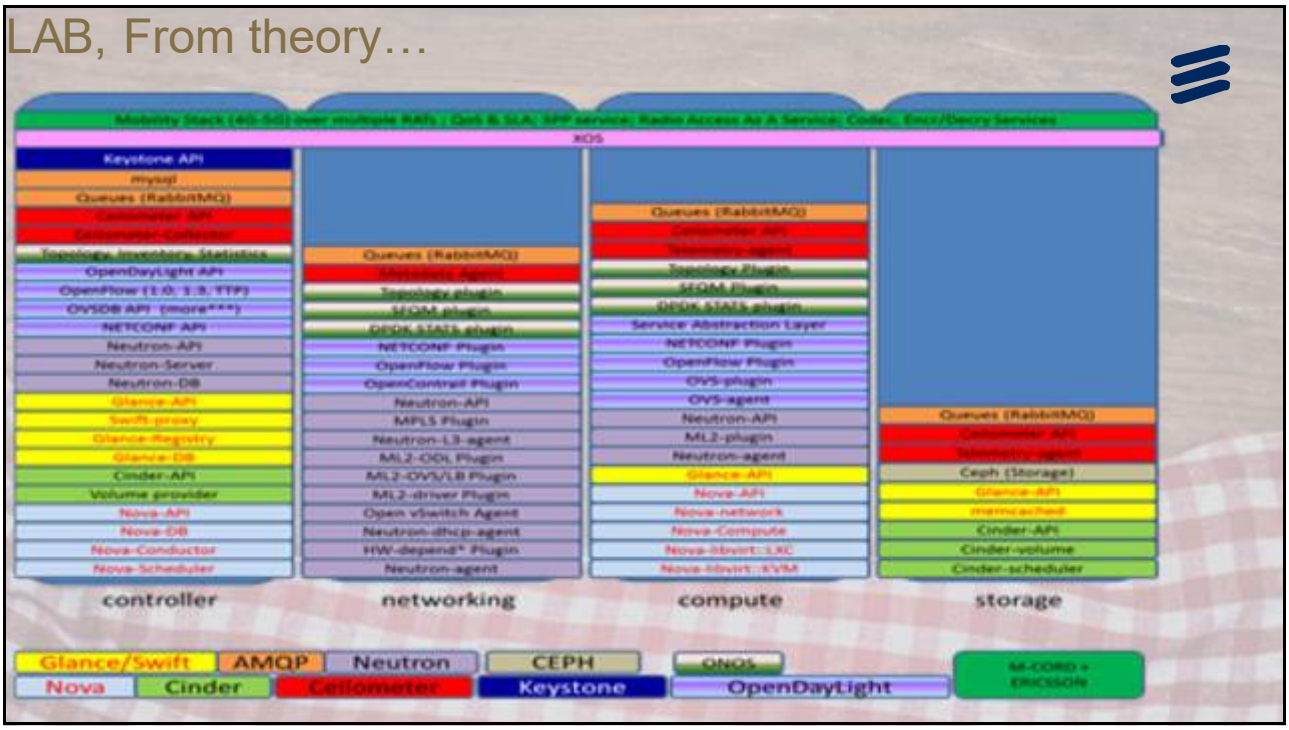
LAB, From theory…



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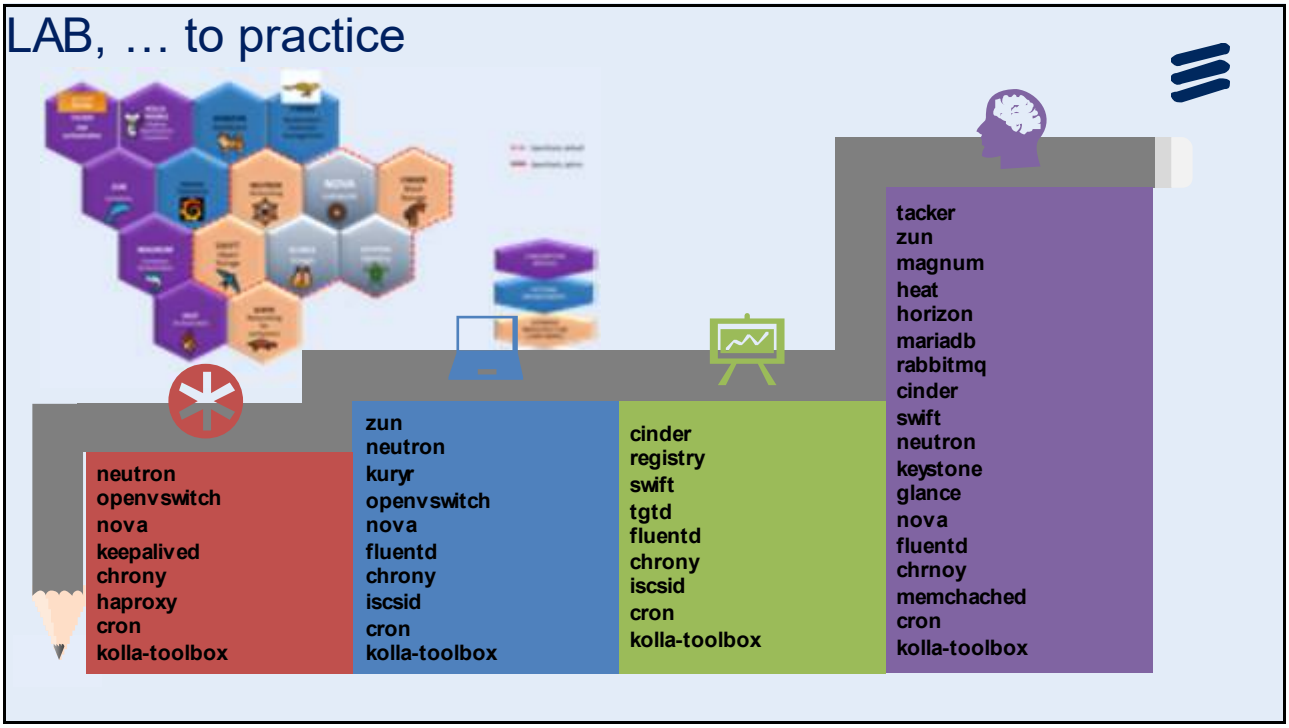
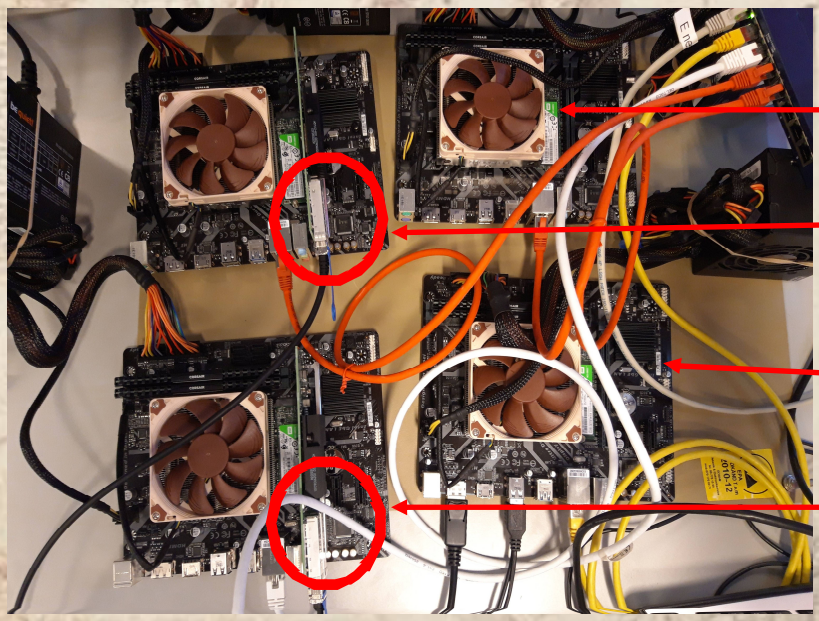
LAB, … to practice



40

LAB, … to practice



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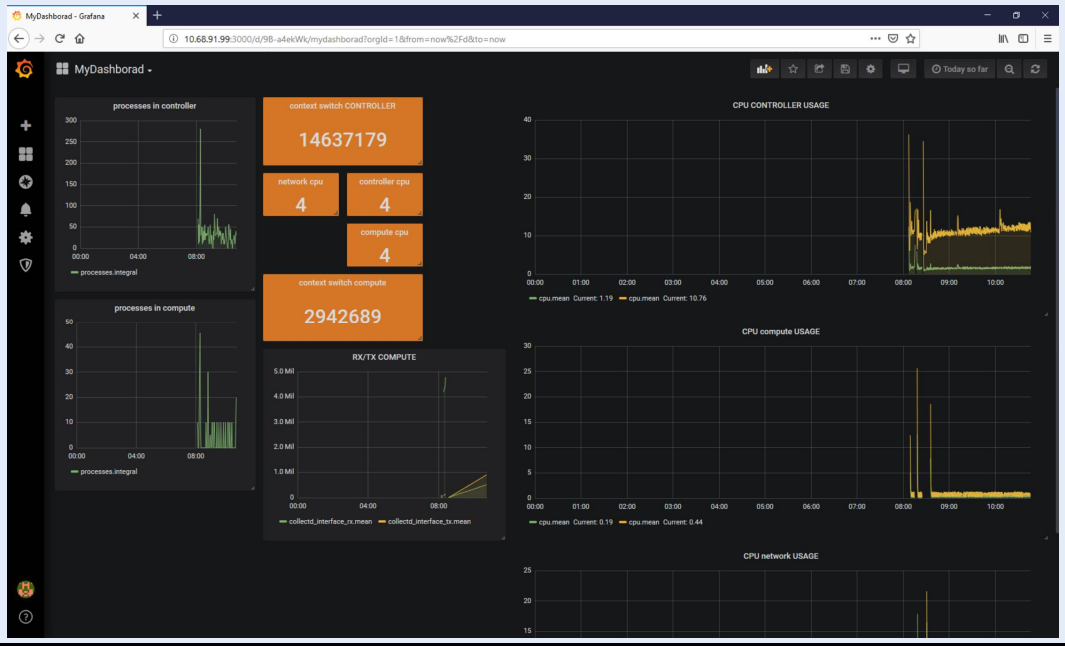
LAB, … to practice



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NexComm 2020

Panel on Telecommunications and Mobility

Theme: Fast Mobility and the Telecommunications Convergence

Mobility aspects in 5G slicing

Eugen Borcoci
University POLITEHNICA of Bucharest, Romania
Eugen.Borcoci@elcom.pub.ro

NexComm 2020 Lisbon 23-27 February 2020

Mobility aspects in 5G slicing

- **Mobile communications and services** –significant development in the last decade

- **Typical example of mobility aware systems**
- **Basic vehicular communications**
  - **vehicle-to-vehicle (V2V)-direct communication**
  - **vehicle-to-road/infrastructure (V2R/V2I)**
-
- **Extended communication models :**

  Vehicular-to-everything (V2X) - (see 3GPP Release 14, 15, 16**)**

  adds several communication modes: vehicle- to-
  - **pedestrian (V2P)**
  - **vulnerable road user (VRU)**
  - **network (V2N)- including cellular networks and Internet**
  - **sensors (V2S)**
  - **home (V2H)**
  - **power grid (V2G)**

Mobility aspects in 5G slicing

- **Typical use cases and services/applications**
  - **Active road safety applications**
    - **Warnings, notifications, assistance, autonomous driving, ..**
  - **Traffic efficiency and management applications**
  - **Infotainment applications**

- **Internet of Vehicles (IoV)**
  - **IoV global network of vehicles – enabled by various *Wireless Access Technologies (WAT)***
  - **involves Internet and includes heterogeneous access networks**
  - **IoV – can be seen a special use case of *Internet of Things (IoT)***

  - **IoV Target domains:**
    - **Vehicles driving and safety (basic function – in VANET)**
    - **Novel domains:**
      - traffic management, automobile production repair and vehicle insurance, road infrastructure construction and repair, logistics and transportation, etc.

Mobility aspects in 5G slicing

- **5G : new generation of mobile networks** offering a large range of services to satisfy various customer demands with different requirements

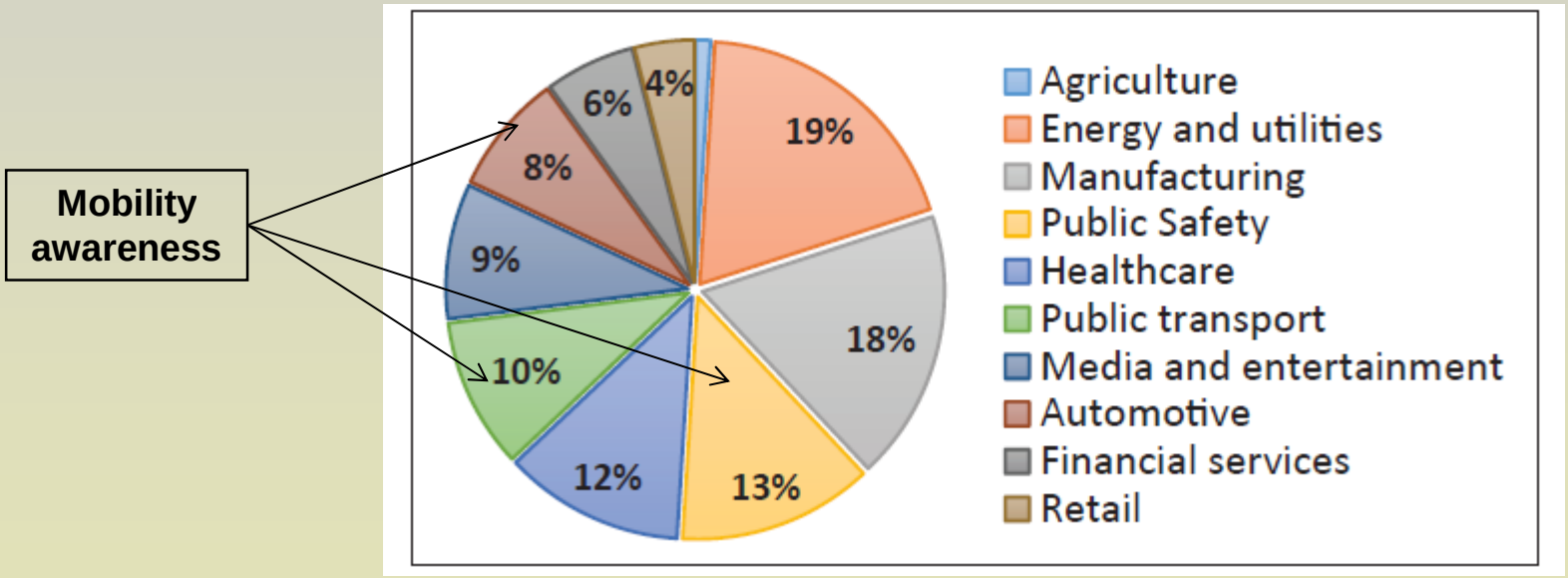
- Different from 4G concept: "one-fit-all", 5G supports
  - **dedicated, separated - logical slices** – on top of a shared infrastructure
  - customization for various business demands with different requirements

- Driving forces for 5G: IoT, smart cities, industry, governance, **IoV/automotive, safety/emergency**, entertainment, environment, etc.
→ **multiple types of "verticals" and tenants**

- Standardization/fora organizations and projects are involved
  - NGNM, 3GPP, 5GPPP, ETSI, ITU-T, GSMA, BBF, ONF, IETF, IEEE, many int'l and European projects

Mobility aspects in 5G slicing

- 5G – powerful support for mobile applications. and services
- **5G revenues provided by the different industry segments**



Source: Ericsson White Paper, "The 5G Business Potential: Industry Digitalization and the Untapped Opportunities for Operators," 2017.

Mobility aspects in 5G slicing

- **Examples of problems for 5G network mobility scenarios**

- **5G – integration of Multiple Radio Access Technologies (RATs)**
- Application data streams flows) have different (QoS) criteria
- Service continuity is needed during UE mobility (seamless mobility)
- Multi-RAT Handovers (HO)
  - for each flow's HO one should select appropriate
    - RAT and AP,
    - IP packet forwarding,
    - and/or route optimization methods
- **Open research issues**
  - The current MM mechanisms met the above requirements
  - However, a 10-x increase in user density + heterogeneity in flow types and network - will limit their capabilities.
    - Existent methods generally do not have a sufficiently powerful QoS aware HO solution
  - Need of new MM solutions e.g., de-centralized MM, flexible and able support multiple use cases simultaneously

Mobility aspects in 5G slicing

- **Examples of problems for 5G network mobility scenarios**

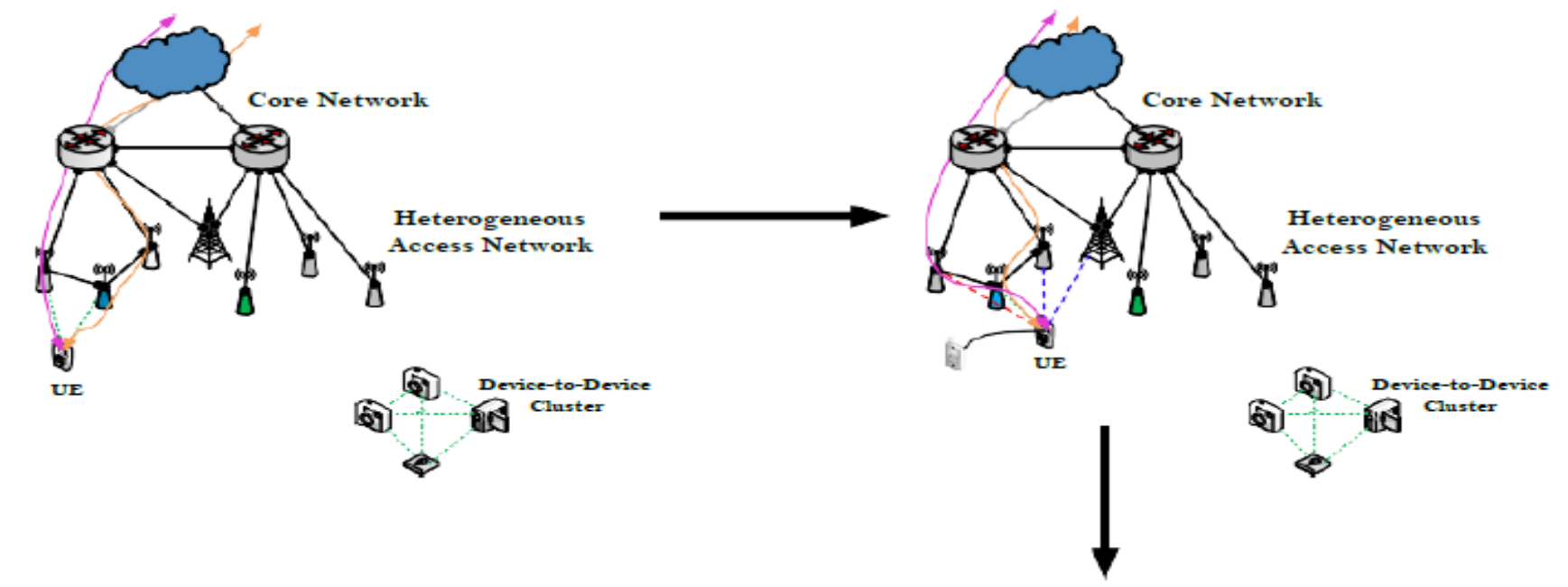
- **Open research issues** (cont'd)

  - Decentralized - MM mechanisms will allow service for
    - increasing number of users
    - with different mobility profiles
      (e.g., static IoT devices … users in high- speed trains

  - flexibility: adaptation to the user and/or network context
    - QoS
    - user mobility profile
    - network load
    - flow types
    - etc.

Mobility aspects in 5G slicing

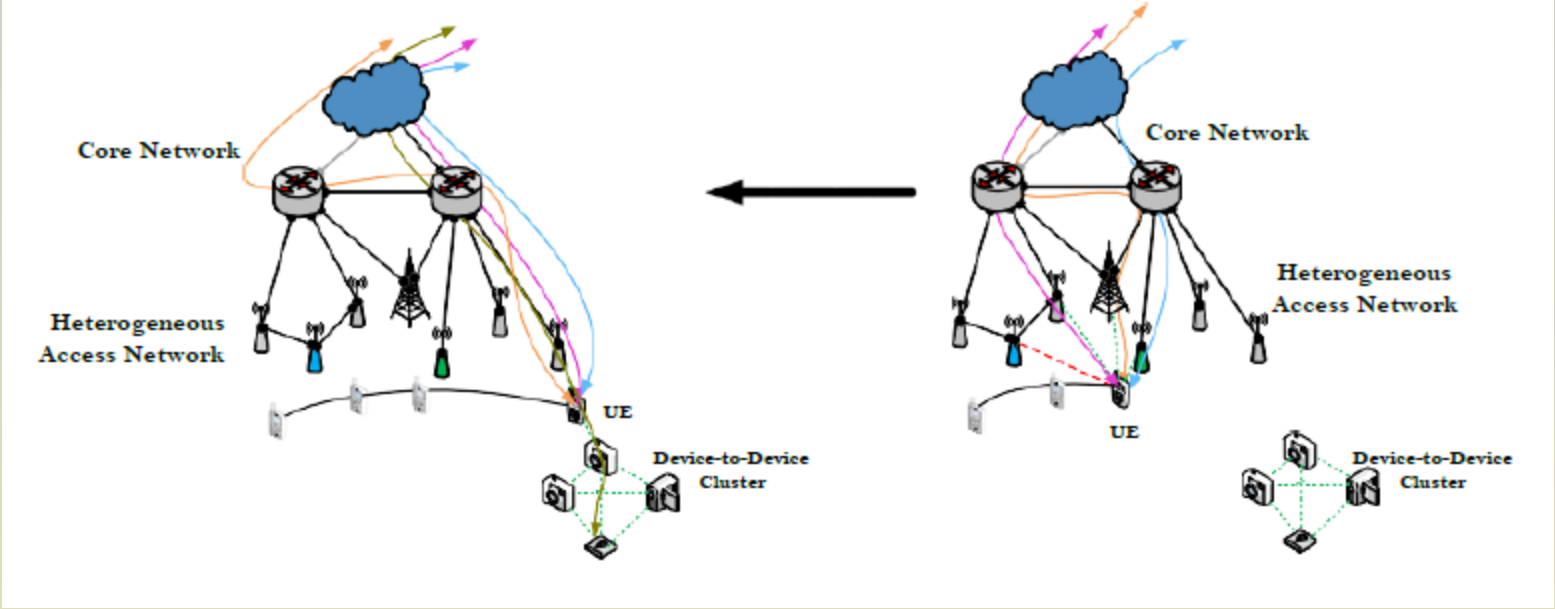
- **Examples of 5G network mobility scenarios**



Source: A. Jain, et al., Are Mobility Management Solutions Ready for 5G?, EU H2020 research and innovation programme under grant agreement No. 675806 (5GAuRA),

Mobility aspects in 5G slicing

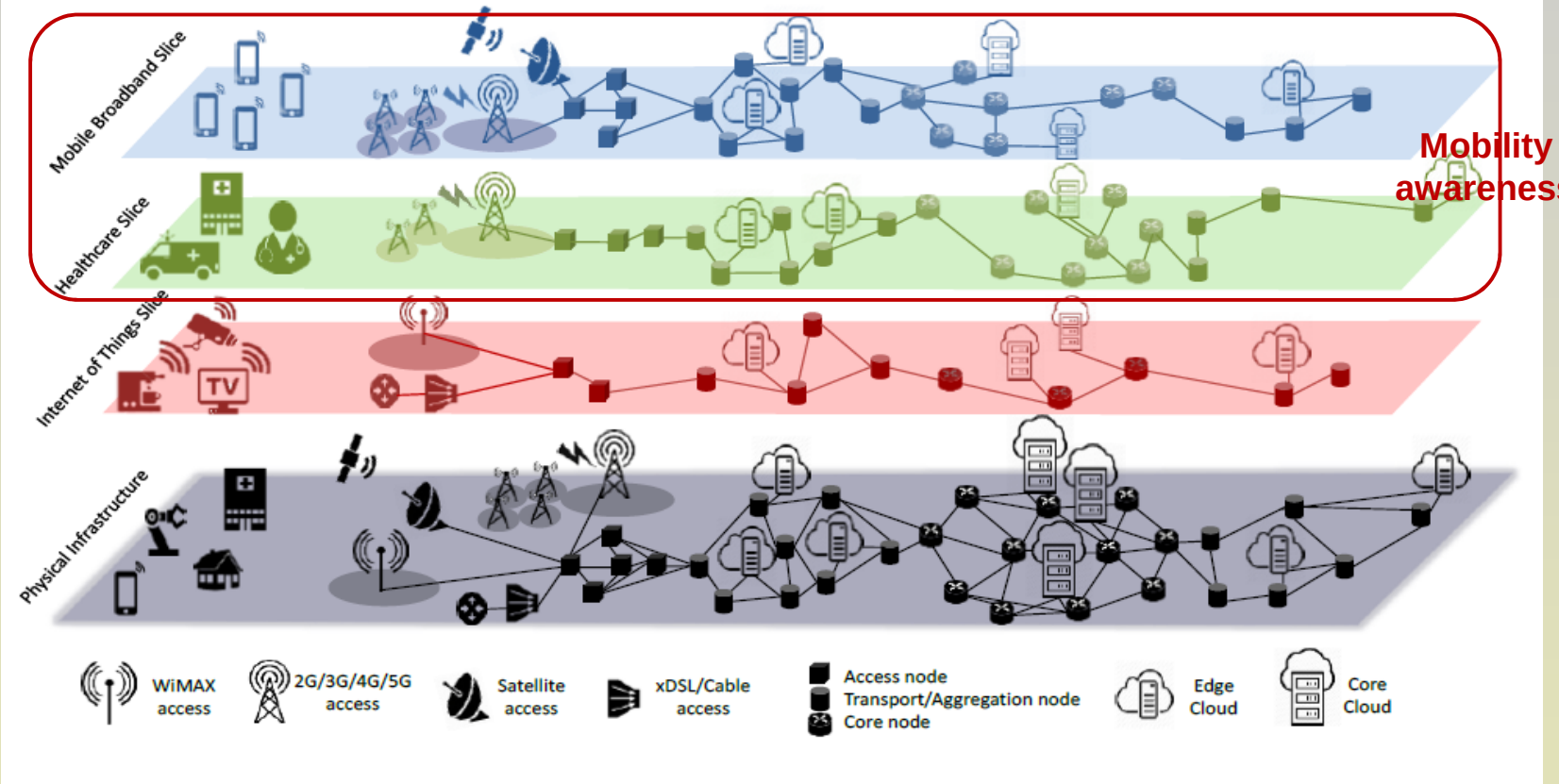
- **Examples of 5G network mobility scenarios**



Source: A. Jain, et al., Are Mobility Management Solutions Ready for 5G?,
EU H2020 research and innovation programme under grant agreement No. 675806 (5GAuRA),
NexComm 2020 Lisbon 23-27 February 2020

Mobility aspects in 5G slicing

- 5G slicing – examples of dedicated slices (End to End)



Source: J. Ordonez-Lucena, P. Ameigeiras, D. Lopez, J.J. Ramos-Munoz, J. Lorca, J. Folgueira, Network "Slicing for 5G with SDN/NFV: Concepts, Architectures and Challenges" , IEEE Communications Magazine, 2017, Citation information: DOI 10.1109/MCOM.2017.1600935

Mobility aspects in 5G slicing

- **Categories of 5G fundamental scenarios (3GPP)**
  - **Ultra reliability low latency communication (URLLC)**
  - **Enhanced mobile broadband (eMBB)**
  - **Massive machine type communication (mMTC)**

Slice models usable for mobility oriented services, e.g. V2X (need additional cusomizations)

Characteristics	mMTC	URLLC	eMBB
Availability	Regular	Very High	Regular (baseline)
E2E latency	Not highly sensitive	Extremely sensitive	Not highly sensitive
Throughput type	Low	Low/med/high	Medium
Frequency of Xfers	Low	High	High
Density	High	Medium	High
Network coverage	Full	Localized	Full

Mobility aspects in 5G slicing

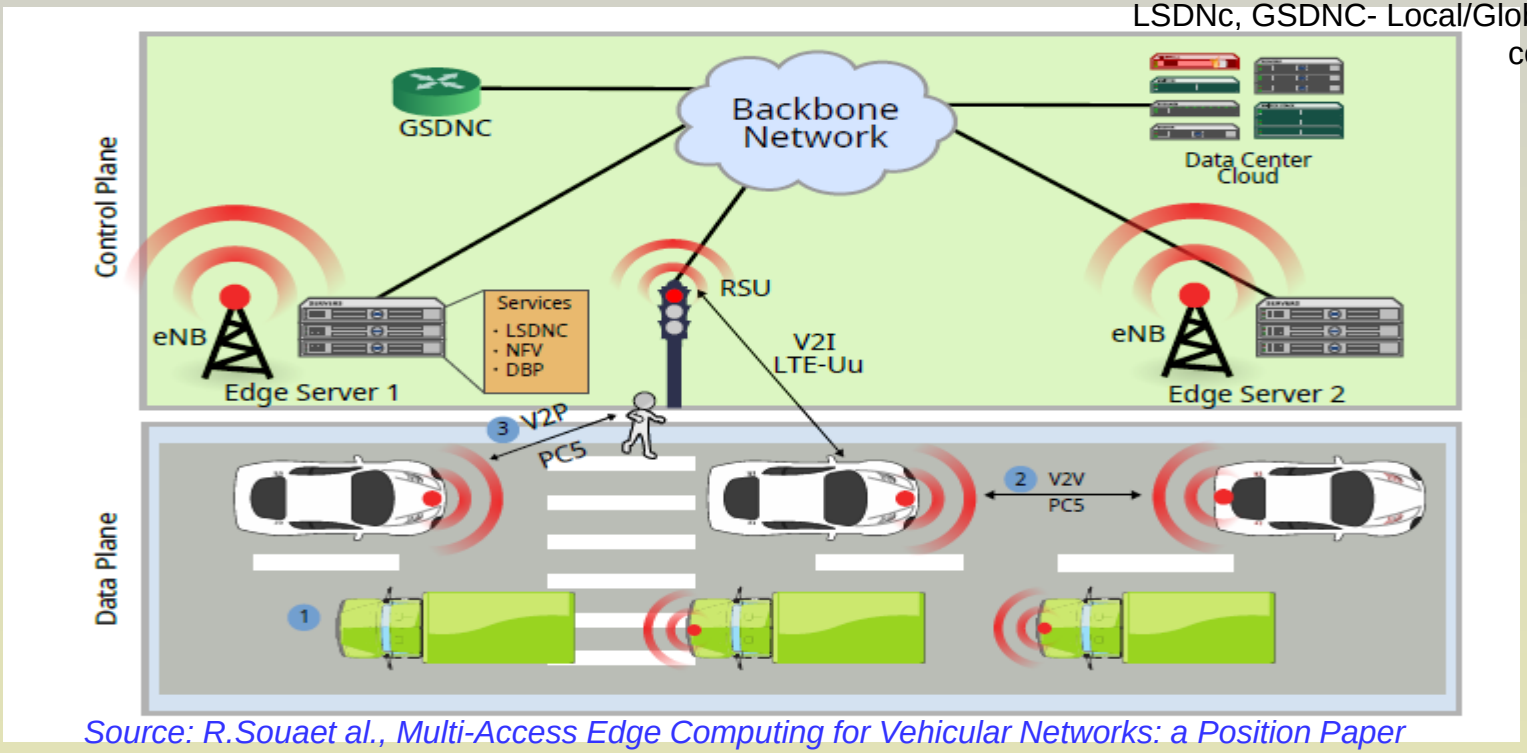
- **Specific aspects of V2X oriented slices (to serve** automotive verticals)
- network functions can be deployed both in the **edge** and **central cloud,** according to the requirements.
  - The **edge cloud** hosts Network Functions (NFs) which need to be allocated in proximity of the UEs,
  - potentially including additional features such as **Multi-access Edge Computing (MEC)** and storage facilities
- The **central cloud** contains the slice-specific NFs for use cases requiring connectivity with a remote public network

- **Multi-tenancy is needed in vehicular applications**
  - tenant : the company, vertical, or service provider offering the services supported by one slice, or one set of slices
  - Examples of tenants for automotive applications are **mobile network operators, road operators, and automakers**

Mobility aspects in 5G slicing

- **Specific aspects of V2X oriented slices**
- An example of MEC-enabled architecture with three mobility-aware use cases: (1) platooning, (2) collaborative networking and (3) VRU safety

DBP -Distance Bounding Protocol
LSDNc, GSDNC- Local/Global SDN controller



Source: R.Souaet al., Multi-Access Edge Computing for Vehicular Networks: a Position Paper
https://www.researchgate.net/publication/331854387_Multi-Access_Edge_Computing_for_Vehicular_Networks_A_Position_Paper

Mobility aspects in 5G slicing

- **Specific aspects of V2X oriented slices** (cont'd)

- Today's **mobility management protocols** are highly centralized and hierarchical
- 5G network has to cope with extreme situations by providing mobility on demand based on each device and service's requirements.

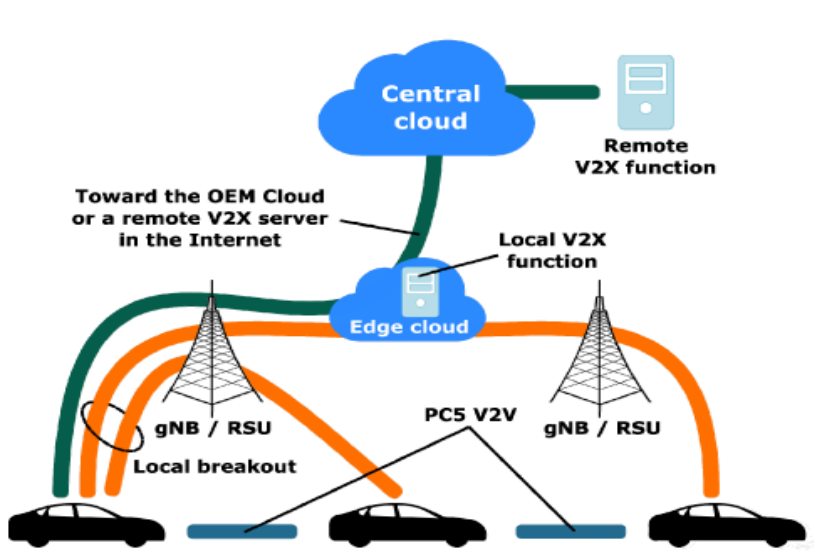
- For the full mobility support, enhancements to the current mobility management procedures are needed

  - **Examples**
    - the handover procedures and a topology-aware gateway selection and relocation algorithm
    - 5G distributed mobility management (DMM) could be a solution to overcome the current mobility management limitations

Mobility aspects in 5G slicing

Example of a V2X oriented projects

- **H2020 5GCAR**
- **Use cases selected**
  - Lane merge (Cooperative maneuver)
  - See-through (Cooperative perception)
  - Network assisted vulnerable pedestrian protection (Cooperative safety)
  - High definition local map acquisition (Autonomous navigation)
  - Remote driving for automated parking



5GCAR is focused on automotive needs and redefines the E2E concept

A **road user** (vulnerable /vehicle) is **one end**;
the **other end can either be a remote server, a server located at the edge of the cellular network, or a vehicle in proximity**

V2X include messages
- directed to servers located in the Internet
- locally routed by the infrastructure (in local breakout configuration),
- direct V2V transmissions over the PC5 interface (unicast and broadcast)

Source: 5GCAR: Fifth Generation Communication Automotive Research and innovation H2020-ICT-2016-2, https://5g-ppp.eu/5gcar/

Mobility aspects in 5G slicing

Conclusions

- **5G slicing-technology versus mobility**
  - **Powerful candidate to serve mobility-oriented services and applications**
  - Vertical extension of : multi-tenant capabilities
  - Horizontal extension; E2E multi-domain, multi- operator capabilities
  - Adaptation to different flows' QoS requirements and mobility models

Mobility aspects in 5G slicing

- Thank you !

References

1. Ericsson White Paper, “The 5G Business Potential: Industry Digitalization and the Untapped Opportunities for Operators,” 2017.
2. J. Ordonez-Lucena, P. Ameigeiras, D. Lopez, J.J. Ramos-Munoz, J. Lorca, J. Folgueira, Network “Slicing for 5G with SDN/NFV: Concepts, Architectures and Challenges” , IEEE Communications Magazine, 2017, Citation information: DOI 10.1109/MCOM.2017.1600935
3. 5G-PPP Architecture Working Group, “View on 5G Architecture”, Version 3.0, June, 2019, https://5g-ppp.eu/wp-content/uploads/2019/07/5G-PPP-5G-Architecture-White-Paper_v3.0_PublicConsultation.pdf, [retrieved June, 2019]
4. R.Souaet al., Multi-Access Edge Computing for Vehicular Networks: a Position Paper https://www.researchgate.net/publication/331854387_Multi-Access_Edge_Computing_for_Vehicular_Networks_A_Position_Paper
5. 5GCAR: Fifth Generation Communication Automotive Research and innovation H2020-ICT-2016-2, https://5g-ppp.eu/5gcar/
6. A. Jain, et al., Are Mobility Management Solutions Ready for 5G?, EU H2020 research and innovation programme under grant agreement No. 675806 (5GAuRA)

Petre Dini - Panelist

Issues and Achievements on Drones and Driverless Vehicles

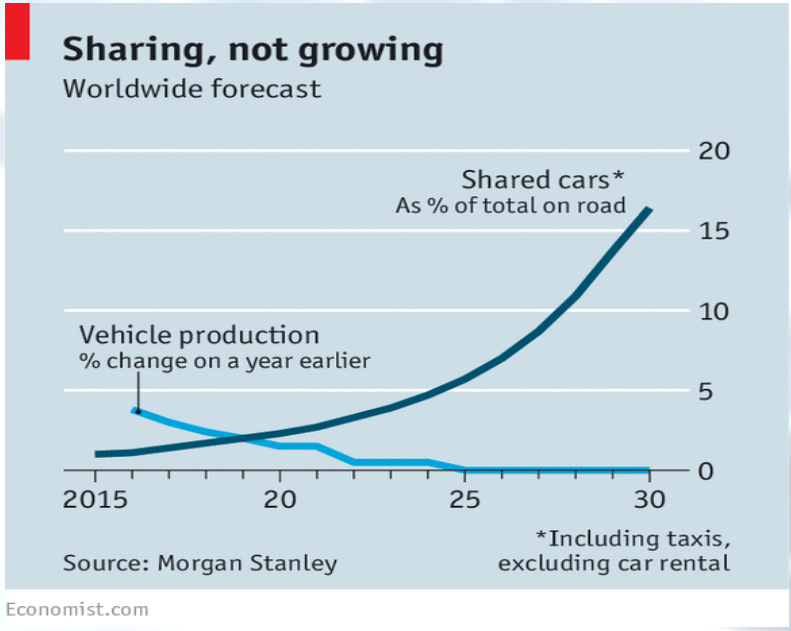
Petre Dini, IARIA, USA

Long term vision

Self-driving II | *Partnership and Incentives*

Partnership
http://www.economist.com/news/business/21685459-carmakers-increasingly-fret-their-industry-brink-huge-disruption

"A rumored tie-up between Ford and Google to produce driverless cars failed to materialize at the show, but even the rumors underlined the disruption that tech firms are bringing to the motor industry. And other partnerships were announced: Ford is teaming up with Amazon to connect its cars to sensor-laden smart homes. It was also revealed at CES that Toyota would adopt Ford's in-car technology, which is a competitor to Apple's CarPlay and Google's Android Auto, to access smartphone apps and other features."



"So when will the fully autonomous car hit the showrooms? Google, whose cars have done 1.3m test miles (2.1m km) on public roads, once promised 2018, whereas most analysts reckoned the 2030s more plausible as carmakers introduced automated-driving features in stages.
Barclays, another bank, forecasts that the fully driverless vehicle will result in the average American household cutting its car ownership from 2.1 vehicles now to 1.2 by 2040. A self-piloting car may drop off a family's breadwinner at work, then scuttle back to pick up the kids and take them to school. The 11m or so annual sales of mass-market cars for personal ownership in America may be replaced by 3.8m sales of self-driving cars, either personally owned or part of taxi fleets, Barclays thinks.
Driverless cars still have problems in bad weather. They may struggle to recognize that light shining off a puddle is harmless or guess that a pedestrian is about to step into the traffic without looking. But sophisticated systems for hands-free driving on motorways, and for automated parking, are already available on a number of manufacturers' models. Fully driverless cars will ferry workers round GM's technical centre in Detroit in late 2016."

Drive and Steer by Web / *e-Vehicle*

http://www.altreonic.com/content/steer-web-kurt

Altreonic has demonstrated for the first time "steer by web" capability for its KURT vehicle.

Using a camera input and a smartphone, the vehicle was remotely steered over Internet using a web application. Even with the application server and the vehicle being widely apart (about 3000 km) and using a standard ADSL connection, the control was with minimal delay.

This brings KURT in the domain of Internet of Things, enabling semi-autonomous driving for a fleet of KURT vehicles.

events (March 2016)

http://www.citycarsummit.com/ http://www.autotechnica.be/en

→ **urban mobility (uncontrolled behavior of the pedestrian crowd, driverless, drones,…)**

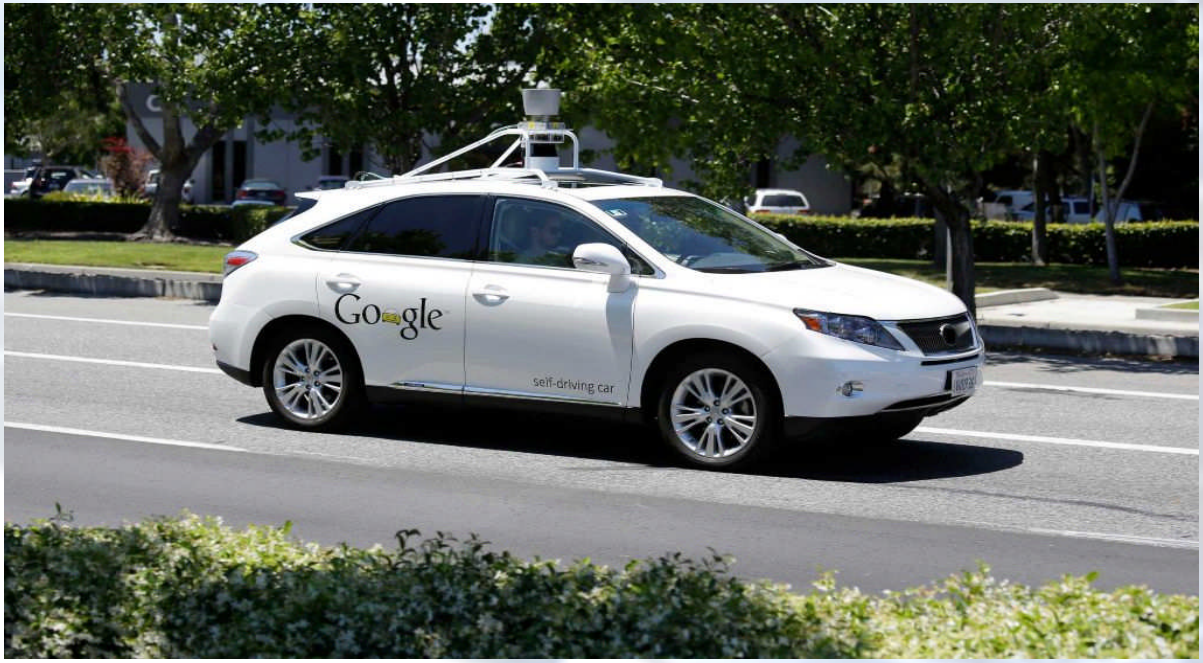
→ **driverless cars, e-vehicle, exceptions handling**

→ **special regulations**

Self-driving I *Legal aspects*

- **Driverless car journey starts in Las Vegas**
- ***Published 7:59 pm, Friday, May 30, 2014***
- **http://www.timesunion.com/business/article/Driverless-car-journey-starts-in-Las-Vegas-5517869.php#photo-6379150**
- **The Nevada Legislature and the Department of Motor Vehicles have enacted legislation and regulations to enable the testing and operation of autonomous vehicles in the Silver State. Currently, the DMV is accepting applications for testing only. Autonomous vehicles are not available to the general public.**

- **http://www.dmvnv.com/autonomous.htm**



The Cheapest | Terrafugia | Geely

- **Photo: pbc / Mavrixphoto / Profimedia**
- **2009: Terrafugia**
- **Geely (acquirer)**
- **Geely own Volvo, Lotus and 10% in Mercedes-Benz.**
- **Electric + Gas**
- **Retractable: Wings and wheels**
- **Parking: Garage**
- **~ 280.000 euros**
- **Autonomy: 644/km | 76l gas**
- **Speed: 161 km/h**
- **Max altitude 2743 meters**
- **2 places | 227 loading**
- **➔ Terrafugia TF-X (new model)**

Dubai Police / Uber

- Uber Copters
- ~ $200/order
- S Model / 265/charge

- Dubai Police / ~ 15-20 minute drive
- $150.000,
- Autonomy: 300km
- Speed: 250km/h

Self-driving | *Drones + IoE*

- **CES 2016: drones, driverless cars and smart brewers**
- **http://www.telegraph.co.uk/technology/ces/12081995/CES-2016-drones-driverless-cars-and-smart-brewers.html**
- **Beyond the Internet of Everything, drones took centre-stage. The Telegraph's picks of drones on the showfloor include winner of the CES 2016 Innovation Award, Lily Robotics which makes a "throw-and-shoot camera" – a 2.8 pound camera drone ($799, shipping begins in February 2016), which follows the user via a tracking device.**

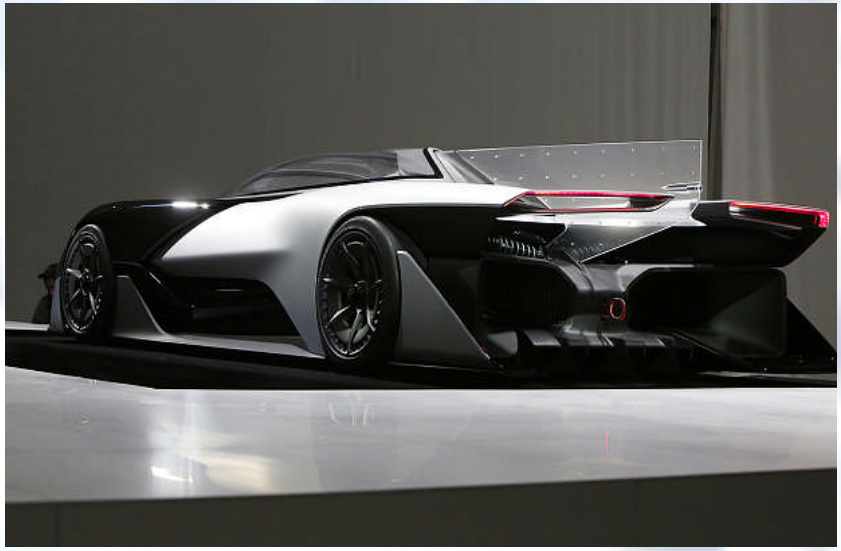
"Chinese drone giant DJI showcased its new Phantom 3 4K – its first-ever sub-$1000 drone with a 4K camera and WiFi transmission upto 1.2km.
And finally, popular drone-maker Parrot showed its giant Disco Drone – a 50-miles-per hour sleek fixed-wing aircraft with a 1080p camera onboard, weighing just 700 grams.
When the show opens officially on Wednesday, there will be an Unmanned Systems marketplace, with 26 different exhibitors."

Self-driving | *Computing for vehicles*

Connected cars

http://www.telegraph.co.uk/technology/ces/12081995/CES-2016-drones-driverless-cars-and-smart-brewers.html

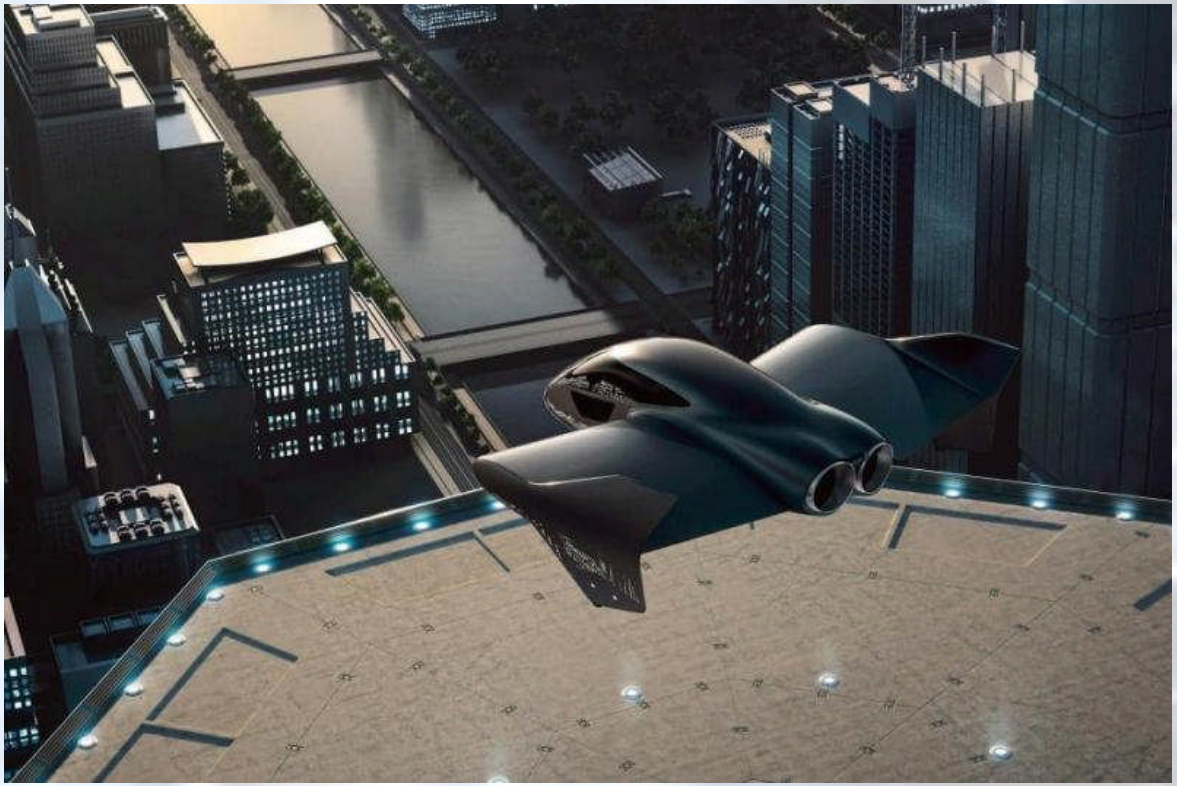
- **That prophecy has already started to fulfill itself – GPU chip maker Nvidia kicked off the week's keynote speeches with the announcement of its "supercomputer" for driverless cars. This new system apparently has power equivalent to 150 Macbook Pros, squeezed into a lunchbox-sized case and can tell apart cars, humans and street signs.**
- **Its supercomputer is already being tested in cars by companies ranging from Volvo to BMW, Daimler, Ford and Audi, which managed to train its cars to read German road signs better than any other computer, and even humans could.**
- **Nvidia wants to supercharge the self-driving car phenomenon by launching a supercomputer designed specifically for the vehicles.**



The Faraday Future Zero 1 concept car was unveiled at the Consumer Electronics Show in Las Vegas, Jan. 4, 2016. Photo: David Gilbert

Porsche-Boeing

- **1.3 millions**
- **Driver/driverless**
- **NOW: Market study**
- **VIP**



AeroMobil 4.0 Stol

- FOTO: Claudia Albuquerque / Bestimage / Profimedia
- autonomy: 700 km
- 7.5 l/100km
- $1.2 millions
- VTOL (vertical take-off and landing)
- 5.0 VTOL

Facts

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  germany:
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To be done

- Legal back-up and regulations
- Social acceptance
- Cognition/adaptation advanced theory/algorithms
- Encouraging partnership/incentives
- Specialized/high performance computing devices
- Appropriate monitoring/surveillance infrastructures
- Urban computing to be carefully supported
- Continuously revisiting progress/issues
- Governmental enforced regulations

Thanks

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