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
OUR JOURNEY ON THE 5G ROAD

2016
Scenario definition
What is the problem?
What do we actually need?

2017
Compute slicing
Temporal isolation
Performance & deadline

2018
Containers
communications
OS-aware solution

2019
The low-cost PoC
Minimal SDN-NFV seed

2020
Radio access as a service
Virtualization of the Radio service

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 Shelf
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
HARQ 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
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.

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

**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 lifestyle. 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: Chetan Sharma Consulting)
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

Source: Ericsson and Arthur D. Little

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.
BEYOND 5G

3GPP
Rel-15
Rel-16
Rel-17 + evolution

5GNR
Rel-15
Rel-16
Rel-17 +

ECOSYSTEM
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,

Continue to evolve LTE in parallel as essential part of the 5G platform


WHY MOBILE?

104% North America
122% Western Europe
81% Africa
112% Middle East
114% APAC
114% China

102% Latin America
141% Central and Eastern Europe
85% Index

122%
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 ecosystem 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.

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.
MANO (ETSI)

DO YOU KNOW WHAT THEY ARE?

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
WHAT DOES IT MEAN SERVICE ORIENTED

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"
SLICING

This will enable operators to gravitate workloads closer to the massive data volumes generated by the 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.

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.

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.

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 the 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

5G, 5 PILLARS

SDN-NFV

A tool and a solution providing the 5G vertical service-oriented architecture
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.
WIDE SET OF NEEDED DEPLOYMENTS

RAN COMPUTE (SErver at the EDge)

HARDWARE PLATFORM CHARACTERIZATION

64 ARCHITECTURE
Faster SW availability from OpenSoftware Community
But Higher power consumption

LARGE HARDWARE ASSISTED VIRTUALIZATION COMPONENTS

AVAILABILITY
HA/V for VM context switch \( VT-x \)
HA/V 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

INTERFACES
OpenFlow, Northbound Open API, YANG

Guaranteed QoS
NETCONF, BGP, PCEP, LISP, OVSDB
OpenvSwitch interface
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.

Under Poissonian arrivals with average rate $\lambda$ and service times approximated as exponentially distributed with average rate $\mu$, $Q/P$ we have M/M/1 model.

Exponential distribution of a request size $s$ in a transmission time $t$ with $\nu$ average transmission rate we have still M/M/1 model.

Q = Budget
P = Period
D = Deadline
\( \Phi \) = Percentile of success
\( \lambda \) = Interarrival time
\( \mu \) = average processing time
\( \delta \) = networking latency


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.

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.

- Kernel-based solution
- Using DPDK with host in user mode
- 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

EASY WAY TO BE CONFUSED IN THE AREA

THE STRATEGIC ROLE OF COMMUNICATION (MATH!)
Hierarchical resources/data control

Dynamic Resources

Run-time data analysis

THE INTELLIGENT NETWORK!

Energy saving

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
Each cluster serves a set of industries

Enhanced video services 47%
Real-time automation 45%
Monitoring and tracking 28%
Connected vehicle 61%

Autonomous robotics 42%
Hazard and maintenance sensing 37%
Smart surveillance 28%
Remote operations 37%
Augmented reality 39%

Sectors:
- Manufacturing
- Energy & utilities
- Public safety
- Public transport
- Healthcare
- Media and entertainment
- Automotive
- Retail

Source: Ericsson and Arthur D. Little

DATA IS THE NEW OIL

OTT (External Network)

1. REGISTER
2. INSTANTIATE
3. CONTEXT UPDATE
4. CACHE
5. REGISTER
6. AUTHORIZATION
7. AUTHORIZATION
8. UE DATA LIST
9. UE DATA PUBLISHING
10-1. UE REQUEST FOWARD
10-2. 1. SEND CONTENTS TO UE
10-2. 2. PASS CONTENTS TO UE

NETWORK

3PP HOSTING
COMING
RADIO INTERFACE
STORAGE

2020-03-20
LAB, From theory…

LAB, … to practice
LAB, … to practice

LAB, … to practice
Thank You
Questions are welcome!