Towards «Operating Systems» for 5G Network and Services Infrastructures

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Introduction: context and motivations

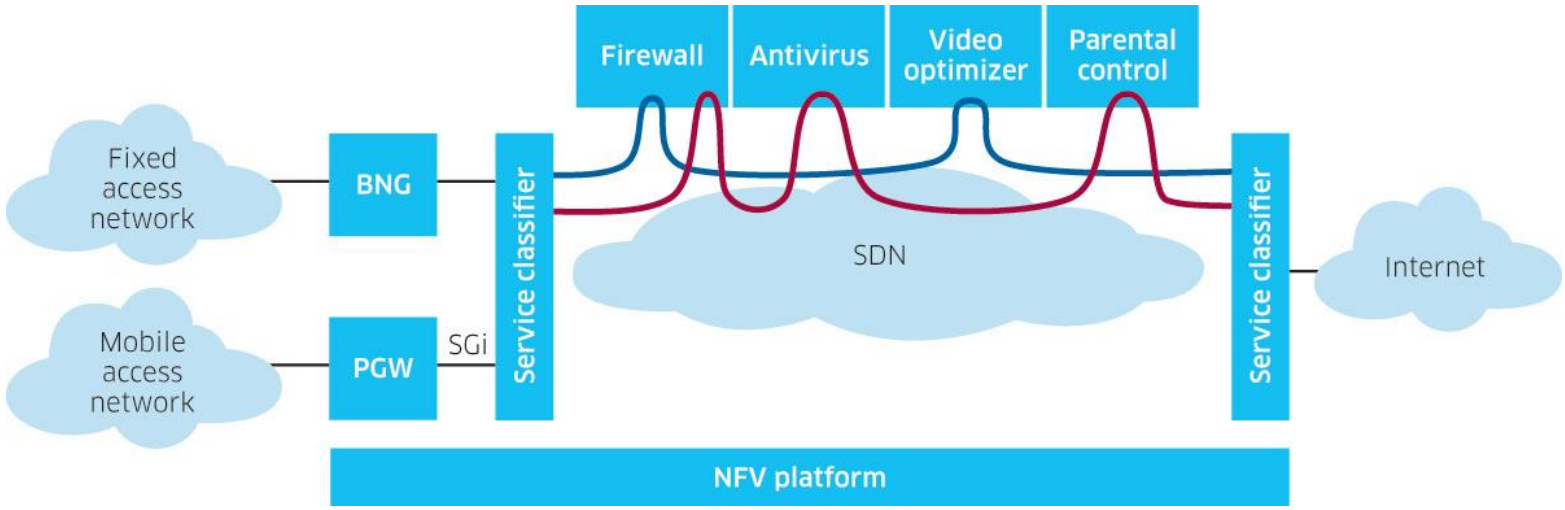
- Today, we are witnessing the interviewing of several techno-economic drivers, that are paving the way to a profound Digital Transformation of Society and Economy; among these drivers there are:
  - diffusion of ultra-broadband fixed and mobile
  - increasing of performance of IT systems vs its down-spiraling costs of HW
  - introduction of Software Defined Network (SDN) and Network Function Virtualization (NFV)
  - growing availability of open source software and hardware
  - new advanced terminals
  - impressive progressed of Artificial Intelligence

Network and Service Softwarization

- 5G (the 5th generation of fixed-mobile infrastructures) is going to become expression of this digital transformation. In fact, 5G will be an end-to-end software platform, where an hyper-connected ultra-broadband “fabric” will lead to a profound integration of processing, memory/storage and networking resources and services.
  - In this scenario Virtualized Network Functions (VNF) and services will be dynamically combined and orchestrated to create specific end-to-end “service chains”, using “slices of resource” for serving applications.

Introduction: context and motivations

- This digital transformation of Telco infrastructures is based on an high level architectural model, which has two main layers:
  - a physical layer which include computing, memory/storage and network resources (up to the edge and the users' premises);
  - a virtualization layer which provide high-level abstractions of all the infrastructure resources, functions and services, hosted in the physical layer.
- The convergence of SDN-NFV with Cloud and Edge Computing is one of the key trends…



SDN-NFV and Cloud-Edge Computing convergence

- **SDN** and **NFV** allow virtualizing cross-layers network service and functions in order to execute/manage/provide them as sort of appliances onto a software platform fully decoupled from an underlying hosting physical infrastructure
- **Multi-Access Edge Computing** (MEC) is a network and service paradigm for offering to application developers and content providers cloud-computing capabilities and an IT service environment at the edge of the network.

- In the medium-long term, 5G will integrate fixed-mobile virtualized networks (SDN-NFV) with highly distributed Cloud-Edge Computing facilities (hosting VNF and services)
- Telco's Central Offices are going to become Data Centers, so future infrastructures will become end-to-end software platform based on a rather limited number of big-medium Data Centers, integrated with a greater number of small-medium Data Centers at the edge (access, distribution) of the current infrastructure.

Introduction: context and motivations

- In this direction, 5G will be much more than one step beyond today's 4G-LTE:
  - SDN-NFV will allow increasing the flexibility of network and service platforms while ensuring the levels of programmability, reliance and performance required by current and future services scenarios and applications.
  - Automation will allow optimizing the use of resources, thus radically reducing opex and capex costs.
- On the other hand, in order to make this digital transformation really feasible, it will be necessary to evolve the legacy networks and services management/control processes.
- In line with this vision, this presentation:
  - elaborates concepts and modeling of an Operating System (OS) as the software platform for enabling management, control and orchestration of future 5G services infrastructures;
    - …just like the OS for a PC
  - addresses the ways this transformation will bring to the cross-layers unification of the service modeling bringing to the emergence of the model "Anything-as-a-Service"

Introduction: context and motivations

- In Computing systems, the adoption of an Operating Systems is facilitating and boosting the applications development by providing controlled access to high-level abstractions for the hardware resources (e.g., memory, storage, communication) and information (e.g., files, directories);

- In 5G the OS should integrate management, control and orchestration capabilities and should provide controlled access to high-level abstractions of the 5G infrastructure resources (e.g. abstractions of computing, storage and networking);
  - This OS is like a brain, i.e. it is enabling any vertical applications (e.g., IoT, Industry4.0, etc.) to be executed on the 5G infrastructure. ONAP, CORD-ONOS etc. may represent main open source building blocks for the OS;
  - …for example the OS capabilities integrated with AI systems can be extended for managing the complexity of a city and extracting value from it
  - **In China, Alibaba's data-hungry AI is controlling (and watching) cities**
    - http://www.wired.co.uk/article/alibaba-city-brain-artificial-intelligence-china-kuala-lumpur

An Operating System for 5G

- In the long term, Cloud-Edge computing and the network systems domains will “merge” together in a sort of “continuum” of resources and functions, offering flexibility and programmability through global operations.

- **Orchestration** will eventually become an essential part of the operations of future services infrastructures.

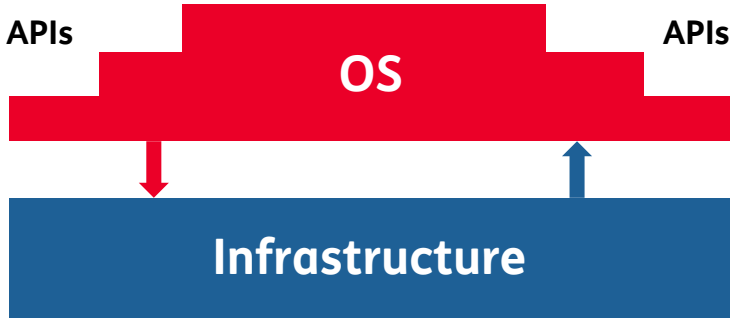
  It will span across the different service layers:

  - **Infrastructure as a Service** (IaaS): the CPU, storage, and network resources will not be deployed anymore only in a collection of Data Centers, but also into the PoPs of the network in its Core, Edge and Access segments;
  - **Platform as a Service** (PaaS): will feature a pool of software appliances that facilitate the end-to-end lifecycle of services and applications integrated with other network appliances to design complex service chains, functions and applications;
  - **Software as a Service** (SaaS): will integrate multiple, interoperable PaaS and IaaS resources to deliver services and applications to the end users.

An Operating System for 5G

- Orchestration should then satisfy:
  - horizontal interoperability requirements, when considering the interoperability between the same tiers in different infrastructure stacks (such as cross-SaaS, cross-PaaS, or cross-IaaS);
  - vertical interoperability requirements, when addressing downstream-compatible infrastructure tiers in different stacks.
- On top of that, an open, vendor-agnostic, and interoperable North-Bound Interface (NBI) is expected to allow orchestrators to effectively control the underlying heterogeneous infrastructures and, ultimately, orchestrate multi-technology resources.

- **The concept and model of Operating System for the 5G (5G OS) can be defined as an integrated software platform for enabling management, control and orchestration processes in future 5G infrastructures.**



An Operating System for 5G

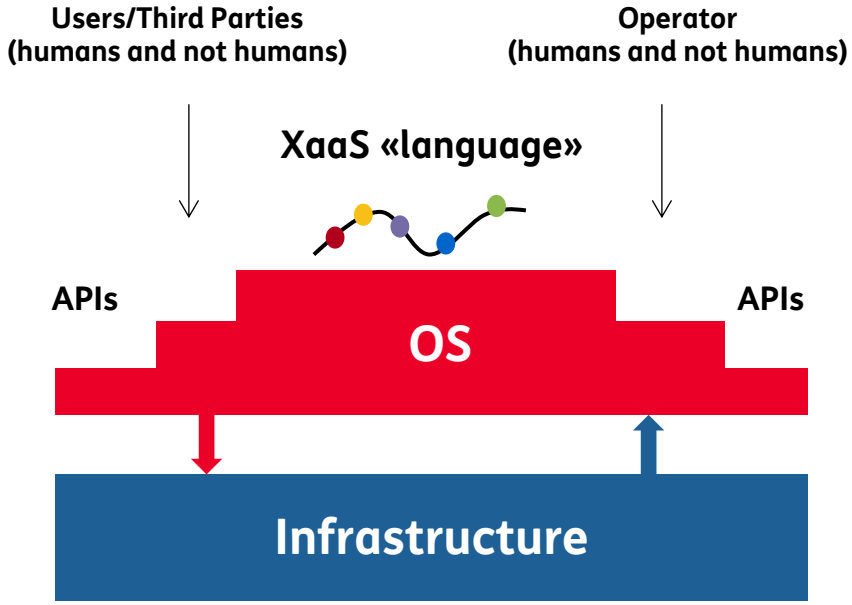
- The 5GOS will provide controlled access to high-level abstractions of the 5G infrastructure resources encouraging the development of vertical applications of all sorts to be executed on the 5G infrastructure.
- The 5GOS will run on every machine and provide applications with API's for resource management and scheduling across networks and services environments.

- It will enable:
  - automated resources management
  - scheduling processes placement
  - inter-processes communication
  - simplified installation and management

- 5G will have to face the security challenges typical of current Telecommunication infrastructures, but with a radically new and IT-oriented perspective (related to Softwarization).

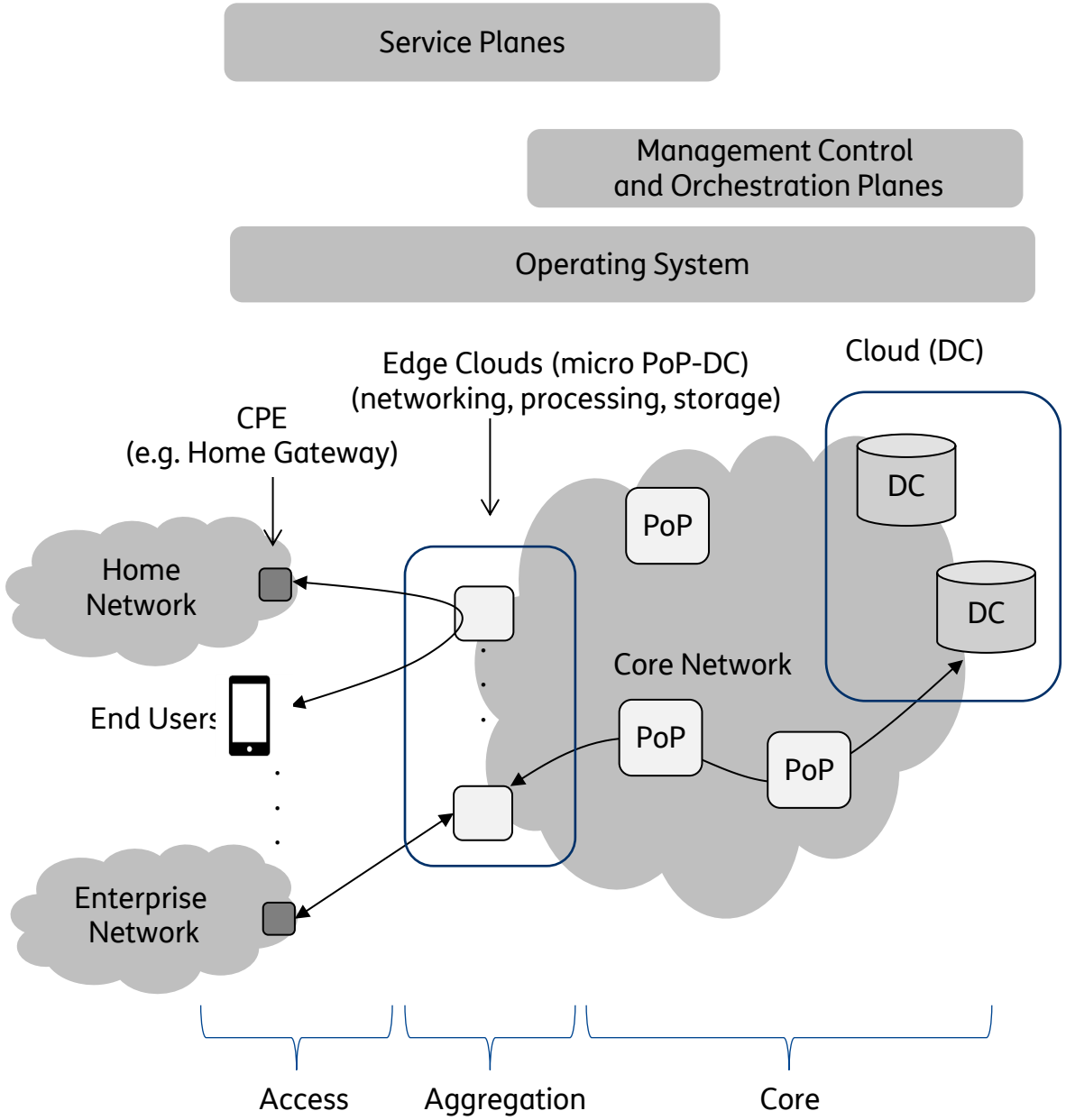
Example of 5GOS functional architecture

- The 5GOS will:
  - include the basic functions of any operating system
  - be the repository for basic network state information through
    - a shared data structure capable of supporting multi-vendors systems
    - applications enabling the sharing of common data amongst different protocols through standardized data models
  - adopt the Anything as a Service unifying model
  - be closely aligned with one of the major Linux distributions



Example of 5GOS functional architecture

- 5GOS will reach, with some “nervous” terminations, even the Fog Computing and IoT resources becoming a platform for executing Anything-as-a-Service crossing all layers of the infrastructure.
- Resources, functionalities and services shall be able to be orchestrated across the Cloud and Edge Computing resources.
- A service chain which will have to be executed in an infrastructure slice may require hooking orchestrated resources and functions which are both local (edge) and centralized (cloud).



Conclusions

- 5G will be much more than one step beyond today's 4G-LTE networks: 5G will be a truly distributed artificially intelligent "nervous system" of the Digital Society and Economy.
- Any resources, functionalities, capabilities will be provided/accessed/managed as pieces of services/applications through standard APIs, which will be made available, in a secured way, across the different levels of this future infrastructure.
- In order to make this huge digital transformation possible and it will be necessary to evolve legacy networks and services infrastructures and the management and operations processes.
- In this direction we envision an Operating System (OS) as a distributed software platform for enabling management, control and orchestration of future 5G services infrastructures. Operators and Service Providers can adopt the 5GOS as a strategic instrument not only for operating efficiently their 5G infrastructures but also for exploiting diverse roles and business strategies.
- A global effort is still required from hardware & software vendors to participate in the OS architectures standardization: moreover the design and development activities will have also include collaborations between academia, industry bodies and standard forums.

Grazie