The 5G Operating System as a “Nervous System” for the Digital Society

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We dream a future full of ... “Intelligence”

Intelligence depends on the Nervous System's abilities to collect, process and integrate several kinds of pieces of information, in order to learn and to take actions for adaptation and survival in changing environments.
The ongoing **Digital Business Transformation** is steered by a complex intertwining of techno-economic drivers which are creating new challenges and business opportunities for Operators and Service Providers.

**Network Operators’ main challenges** include:

- simplifying their infrastructure while making it more flexible and secure;
- optimizing the Operations (e.g., management, control and orchestration processes) to cope with a growing “complexity” and dynamism;
- improving the Customers’ experience (**Customer is the King!**), by leveraging on Big Data analytics and Artificial/Computational Intelligence;
- developing new services and business models (access, contents, ads?).
• **Softwarization** of services and networks platforms (e.g., through the exploitation of SDN and NFV paradigms) is steering this Digital Business Transformation.

• In 3 to 5 years this transformation will bring to a common “infrastructure reference model”, valid for both Telecoms Operators and OTTs:
  - In fact, this transformation will be systemic and it will impact all the Players of the Telecommunications ecosystems, not only Network Operators, but also IT-Network Vendors, OTTs and whose Society.

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Marc Andreessen coined his famous sentence “Why Software Is Eating the World” in The Wall Street Journal about six years ago...
The three pillars of this common “infrastructure reference model” are:

- a physical layer: it includes and integrates compute, storage and network resources;
- a virtualization layer: it allows providing high-level abstractions of all the infrastructure resources;
- An Operating Systems (OS): a software framework integrating management, control and orchestration capabilities so to provide controlled access (through APIs) to high-level abstractions for all the infrastructure resources (e.g., virtualization of computing, storage and networking and other ones...).
Context and Drivers

• The common hosting infrastructure will provide “slices”, as pool of virtual resources, where to execute a variety of network functions/services (e.g., Virtual Network Functions) and various application services.

• Network functions and services will be dynamically combined and orchestrated in end-to-end “service chains” by using the OS capabilities.

• Another important aspect is the emerging of XaaS as a unifying service model.
Context and Drivers

- Services (applications, network functions and operations) will be executed in logical chains of resources.
- Services will be accessed via APIs (with proper policies) across the different levels of the infrastructure (e.g., IaaS, PaaS, SaaS).
- The Operating Systems (OS) those APIs both for the Operations of the infrastructure (by the Operator itself) and for the services/applications developments (also by Third Parties).
- As such, the OS will need to embed A.I. capabilities for XaaS orchestration and provisioning:
  - A “Natural Language Processing” for XaaS is needed.
Some reference architecture are being developed in the context of initiatives such as ONF (CORD, ONOS), ONAP, ETSI NFV, etc.
Reference architectures and Open Source Software

• Several pieces of open source software being developed or currently available to implement a Network Operating System, and there are several efforts in Standardization Bodies (on the right).
Convergence techno-socio-economic trajectories

1. collecting and processing open Big Data
2. analytics & planning
3. executing actions, automatic actuations

Network OS
4G-5G
Smart City Industry 4.0
Example: City Operating System

• Imagine an Operating System for 5G (5GOS)...
  • 5GOS integrates management, control and orchestration capabilities and it provides controlled access to high-level abstractions of the 5G infrastructure resources (e.g. abstractions of computing, storage and networking);
  • 5GOS 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 5GOS;
  • these capabilities can be extended for taming the complexity of the infrastructure and for extracting value from it.

• An OS for a Smart City (e.g., CityOS) can be based on the same principles for:
  • collecting and processing open Big Data of the city;
  • executing big data analytics (e.g., with A.I.) and comparing inferred decisions with plans;
  • actuating (even automatically) actions, with multiple actuators, devices, smart things to communicate, control and optimize city’s processes, etc...
Example: City Operating System based on a Network Operating System

Vertical services

Service enabling platform

ICT infrastructure

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Internal use
Example: I4.0 Operating System

- The same principles could be applied for an I4.0 Operating System
The “operating system” takes in information through the sensors, propagates it through the network, processes the information (e.g., AI in Cloud and Edge Computing) and triggers actions/reactions.

A “Natural Language Processing” for XaaS is needed

• **Central Offices will become Data Centers** (e.g., CORD), so future networks will interconnect several Data Centers (big, medium and small size).

• **The trend is “Data Centre as a Computer”** with a centralized OS in the Cloud (e.g., Google Cloud 3.0).

• **The management complexity can be “mitigated”** by architectural design and by introducing high levels of automation (through A.I. and Machine Learning capabilities) in the OS.

• **Target is automating FCAPS operations and XaaS orchestration and provisioning.**

A “Natural Language Processing” for XaaS is needed

Can we find a way to model services so that A.I. can speak the “XaaS language” with the OS?

- **Word2Vector (Google2013):** converting words into vectors, which deep learning algorithms can process, helps to formulate a much better understanding of natural language

- **Sentences are chains of words...**

- **Service2Vector (1):** converting services into vectors, which deep learning algorithms can process, helps to formulate a much better understanding of XaaS language

- **Services are chains of network-service components...**
Conclusions

1. A common “reference model” is emerging for both Telecoms Operators and OTTs networks and services infrastructures, which will be based on:

   • a physical layer which will include and integrate compute, storage (IT) and network resources (up to the edge);
   • a virtualization layer which will allow providing high-level abstractions of all the infrastructure resources;

2. Operating Systems (OS) is the emerging approach for integrating management, control and orchestration capabilities so to provide controlled access (through APIs) to high-level abstractions of all the infrastructure resources (e.g., virtualization of computing, storage and networking).

3. Another important aspect is the emerging of XaaS as a unifying service model. Services (applications, network functions and operations) can be accessed via APIs (with proper policies) across the different levels of the infrastructure. This will necessarily bring to automated XaaS orchestration and provisioning (leveraging on A.I. and Machine Learning features of the OS) to manage the “complexity”.

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Internal use

End-Users/Developers of Applications, Third Parties
XaaS
Operators for OSS/BSS processes

Operating System
(management, control and orchestration capabilities)
Conclusions

- The **OS** model is becoming widely shared in Industry, as a **strategic instrument** for:
  - 1) taming the “complexity” of future networks and service infrastructure and
  - 2) for playing the potential role of Service Enabler (OS-as-a-Service).

This will necessarily bring to **automated XaaS orchestration and provisioning** (leveraging on A.I. and Machine Learning features of the OS) to manage the growing “complexity”.

- Smart Cities and Industry4.0 are interesting scenarios/use-cases for exploiting this model.

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Thank You!

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