Inclusion of Intelligence in the Network Edge through NFV and Cloud Computing: The SESAME Approach

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Introductory Scope_(1)

- **Electronic communication networks** are ***"fundamental tools"*** for the **offering** of an extended "set of services and/or related facilities" and for the **benefit** of all involved market "actors" *(i.e.: corporate users, residential users, the State and local authorities, etc.).*
- Such infrastructures can **support** the **provision of modern Internet**, not only by covering necessary network-*related* aspects but also by involving the disposal of services/facilities, the use of numerous equipment/devices, the provision of content, etc., ***under a broader scope of "convergence".***

- A variety of **Critical Infrastructures** *(energy, transport, health, water, etc.)* also **depends on Internet connectivity, "adequacy" and automation.**

- **Modern Internet is correlated to an immense multiplicity of underlying networks, services and equipments** and can be perceived as a **"key factor"** *for making real the progress and the evolution of the "digital economy", bringing* ***huge socio-economic value****.*

➡ ***This implicates the necessity for an enhanced and/or automated use of all related available resources, of any probable origin/nature.***

Introductory Scope_(2)

- **5G will "integrate" networking, computing and storage resources into *"one programmable and unified infrastructure".***
- **This sort of "unification" of functions will allow for *an optimized, more enhanced, and fully dynamic usage of all distributed resources*, *within a fully converged environment.***
- **5G will also support multi-tenancy models, *enabling operators and other market "players" to collaborate in new ways, within an intelligent network environment.***
- **Based upon the features of existing cloud computing, 5G will support further progress of the single digital market**, *e.g. by "paving the way" for virtual pan-European operators relying on nation-wide infrastructures.*

- 5G has to be a **sustainable and fully scalable technology**.
- **Cost reduction through human task automation and hardware optimization** *will allow for supportable business models for all actors*.

NFV and Cloud Computing as "Enablers" of Network Intelligence_(1) – **Concerns for Future Networks**

***Future Networks* have to:**

- ***Be deployed much "more densely"*** *than today's networks;*
- ***become significantly "more heterogeneous";***
- ***use multi Radio Access technologies*** *(RATs);*
- ***scale their operations,*** *even for short-time periods depending on the varying traffic capacity requirements;*
- ***remain energy-efficient,*** *as long as possible;*
- ***support fast selection and/or combination of variable physical interfaces;***
- ***use an "adaptive set" of virtual interfaces and functions.***

- ***Small Cells (SCs) can contribute to the effort of making "best use" of novel applications offered by "denser" and more heterogeneous RATs.***
- ***SCs can efficiently support several widely varying traffic needs.***
- ***SCs also support scalability issues.***

*NFV and Cloud Computing as "Enablers" of Network Intelligence_(2) – **Challenges for OAM** (Operation & Management)*

- Future network deployments have to **allow for network/infrastructure/resource sharing** and **potential re-utilization on all levels**, *because of the fast growing demands on network resources management and operation.*

- Future network deployments should **promote the inclusion of cognitive capabilities in the network design on all layers**, *so that to:*
  - ***support** a **flexible network adaptation** at low operational costs and*
  - ***provide** exactly the **performance required** for the determined user context.*

- The ***Operation and Management (OAM)*** of the wireless/mobile network infrastructure ***plays an important role in suitably "addressing" network management and automation***, in terms of:
  - *constant performance optimization,*
  - *fast failure recovery,*
  - *fast adaptations to changes in network loads, architecture, infrastructure and technology.*

NFV and Cloud Computing as "Enablers" of Network Intelligence_(3) – **Inclusion of SON Features**

- ***Self-Organising Networks (SON) are the first step towards the automation of networks' OAM tasks****, for example via the introduction of closed control loop functions dedicated to* ***self-configuration, self-optimization*** *and* ***self-healing.***

- ***SON is a collection of procedures/functions*** ***for automatic***
  - ***Planning and configuration,***
  - ***optimization,***
  - ***diagnostication and***
  - ***healing of (cellular) networks.***

- ***SON is conceived as a "major necessity"*** ***in future mobile networks and operations****, mainly due to possible savings in capital expenditure (CAPEX) and operational expenditure (OPEX).*
  The tendency *introduced with SON is to* ***enable system's OAM at local level****, as much as possible.*

NFV and Cloud Computing as "Enablers" of Network Intelligence_(4) – SON Functionalities

- ***SON functionalities are also referred to as "Self-x" functionalities. These correspond to a set of features and capabilities for automating the operation of a network, so that "operating costs can be reduced and human errors minimized".***

- **With "Self-x" features, classical manual planning, deployment, optimization and maintenance activities of the network *can be replaced and/or supported* by *more autonomous and automated processes*,** thus ***making network operations simpler and faster.***

- ***"Self-x" functions can automatically "tune":***
  - **Global operational SC settings** *(such as maximum transmit power, channel bandwidth, electrical antenna tilt*) ***as well as***
  - **specific parameters corresponding to Radio Resource Management (RRM) functions** *(e.g., admission control threshold, handover offsets, packet scheduling weights, etc.).*

*NFV and Cloud Computing as "Enablers" of Network Intelligence_(5) – **NFV (General Overview)***

Areas to be addressed:

- ***Network Functions Virtualization (NFV)* "addresses" previous issues by leveraging standard IT virtualization technology to consolidate many network equipment types onto industry standard high volume servers, switches and storage,** *which could be located in data centres, network nodes and in a variety of end-user premises.*

- **NFV is applicable to any data plane packet processing and control plane function,** *both in fixed and mobile network infrastructures.*

- ***There are various challenges to implement NFV -also within the SESAME context- and are mainly relevant to:***
  - *Management and orchestration;*
  - *the perspective of automation,* ***and;***
  - *options of security and resilience.*

NFV and Cloud Computing as "Enablers" of Network Intelligence_(6) – ***NFV (Management & Orchestration)***

- For a ***consistent management and orchestration architecture***, **NFV presents an opportunity,** *through the flexibility afforded by software network appliances operating in an open and standardized infrastructure,* ***to rapidly "align" management and orchestration northbound interfaces to well-defined standards and abstract specifications.***
  - ***This can significantly reduce the cost and time to integrate new virtual appliances into a network operator's operating environment.***

- Besides, ***Software Defined Networking (SDN) further extends this to streamlining the integration of packet and optical switches into the system*** *(e.g., a virtual appliance or NFV orchestration system may control the forwarding behaviors of physical switches by using SDN).*
  - Traditionally, **SDN and NFV** although not dependent on each other**, are seen as "*closely related*" and/or as "complementary" concepts**.

NFV and Cloud Computing as "Enablers" of Network Intelligence_(7) – ***NFV (Management & Orchestration)***

- The **orchestration and federation of network resources as *"network functions",*** is an **important aspect** of the **future network ecosystem**.

- ***There is interest on the way in which resources and functions are described****, about:*
  - ***protecting the "know-how"*** *of the network and service providers* ***and****, at the same time,*
  - ***opening the right interfaces*** *to enable new business models to appear.*

- ***Service Level Agreements (SLAs)*** **automated definition and monitoring/control of network functions** is also a relevant topic.

*NFV and Cloud Computing as "Enablers" of Network Intelligence_(8) – **NFV (Automation)***

- ***NFV will only scale if all of functions can be automated.***
- ***Automation of processes is of paramount importance towards improving OAM.***

NFV and Cloud Computing as "Enablers" of Network Intelligence_(9) – **NFV (Security and Resilience)**

- **Network operators need to be assured that the *security, resilience and availability of their networks are not reduced/harmed*, *when virtualized network functions are to be introduced.***
- ***NFV can improve network resilience and availability* by allowing *network functions to be recreated "on demand",*** *after a possible failure*.
- ***A virtual appliance should be "as secure as a physical appliance" if the infrastructure, especially the hypervisor and its configuration, is secure*.**
- *Network operators are thus seeking for tools to control and verify hypervisor configurations.*

NFV and Cloud Computing as "Enablers" of Network Intelligence_(10) – NFV (Network Stability, Simplicity and Integration)

Stability of the network should not be impacted**, **when managing and orchestrating a large number of virtual appliances between different hardware vendors and hypervisors.

This is particularly important when, for example, virtual functions are relocated, or during re-configuration events (e.g. due to hardware and software failures or due to cyber-attacks).

NFV is also beneficial for operators as it supports simplicity and integration:

- *A significant and topical focus for network operators is **simplification of the plethora of complex network platforms and support systems,** while maintaining continuity to support important revenue generating services.*
- ***Seamless integration of multiple virtual appliances onto existing industry standard high volume servers and hypervisors** is a "key challenge" for NFV.*

Network operators need to be able to "mix & match" equipment and virtual appliances from different vendors without incurring significant integration costs and avoiding undesired lock-in.

The ecosystem needs to offer integration services and maintenance**, third-party's support and **will require mechanisms to validate new NFV products.

*NFV and Cloud Computing as "Enablers" of Network Intelligence_(11) – **Edge Cloud Computing (general context)***

- ***Edge cloud computing** refers to **data processing power at the edge of a network**, instead of holding that processing power in a cloud or a central data warehouse.*

- ***Edge computing** **places** data acquisition and control functions, storage of high bandwidth content and applications **closer to the end-user.***

NFV and Cloud Computing as "Enablers" of Network Intelligence_(12) – **Edge Cloud Computing (Network Challenges)**

- A ***core (future) challenge*** is to "**guarantee and constantly improve" customer experience offered by edge cloud-*based* services**.

- ***Such experience relies on the End-to-End (E2E) QoS and, more generally, on respective SLAs in place for a given service***.

- ***This includes well-known characteristics, such as:***
  - *Latency;*
  - *throughput;*
  - *availability, and;*
  - *security.*

- ***If adopting the principles of Clouds, this also implicates for:***
  - *Elasticity;*
  - *on-demand availability;*
  - *lead- and disposal-times;*
  - *multi-tenancy;*
  - *resilience;*
  - *recovery, and;*
  - *similar characteristics.*

*NFV and Cloud Computing as "Enablers" of Network Intelligence_(13) – **Edge Cloud Computing (Market Challenges)***

- ***Edge networks are expected to create distributed environments made of clouds of virtual resources,** interconnected by a simpler and less hierarchical core network.*

- ***Some business models necessitate federation and/or orchestration capabilities**.*
  - In a ***federation context***, the stakeholders agree on jointly providing a service.
  - In an ***orchestration context***, each entity keeps its service models, interfaces and SLAs and a specific component (***called as the "broker"***), will compose services from each stakeholder to be able to provision a requested service. *The broker functionality can be implemented by one of the players or by a third party.*
  - **Both approaches can be used to extend coverage, increase capacity or enhance quality** *(e.g, for deploying functionality or locating content near by the customers).*

*NFV and Cloud Computing as "Enablers" of Network Intelligence_(14) – **Network Orchestration Issues***

- **In future ecosystems, the operator will need to efficiently orchestrate its own resources** *not only for cost reduction purposes, but also for being able to open the network capabilities to enable third party services.*

- **The single domain orchestration has many challenges** such **as *how to describe the resources and define the interfaces*.**

- ***Main components of the single domain orchestration*** **are also: Interface definition, resource/price discovery, publishing and negotiation and service level monitoring and assurance.**

- ***Key elements for the orchestration*** **are the network and service modelling and the optimization algorithms used for resource embedding.**

The Innovative Vision of the SESAME-based Approach_(1)

Market "Positioning" in the Modern Environment

- **The 5G scenery needs to couple fast connectivity and optimized spectrum usage with cloud networking and high processing power**, *optimally combined in a converged environment.*

- Moreover, **a critical 5G challenge is the ability to "bring intelligence" directly to underlying network's edge,** ***via the inclusion of virtual network appliances*****,** ***suitably exploiting the evolving examples of NFV and Edge Cloud Computing.***

The Innovative Vision of the SESAME-based Approach_(2)
Market "Positioning" in the Modern Environment

The future 5G network infrastructures should have the capability to provide enhanced virtualization and support multi-tenancy, not only in the scope of dividing/partitioning network capacity among multiple possible tenants, but also ***via the offering of (dynamic) processing capabilities on-demand, optimally deployed within the vicinity of the involved end-users***.

The corresponding advantages may be of prime importance for existing Communications Service Providers-CSPs (*such as Mobile Network Operators (MNOs), Mobile Virtual Network Operators (MVNOs), content and service providers, etc.*)
as these actors may have the ability to extend their business activities and acquire extra shares in the network market.

Within this scope, the use/deployment of modern businesses should produce new beneficial revenues from any sort of network infrastructure and/or facility, to be offered "*as-a-Service*".

The Innovative Vision of the SESAME-based Approach_(3)
Small Cells (SCs) as an Opportunity for Growth

- ***Although the virtualization of the network infrastructure*** *(mainly involving the core/edge segments as well as the access points/macrocells)* ***has been broadly examined*** in the framework of related market or research initiatives, ***the applicability of this conceptual view to Small Cells (SCs) infrastructures has only been the case of some independent works with limited attention.***
- However, **the SC concept has become fundamental in today's existing 4G infrastructures.**

- **SCs can bring better cellular coverage, capacity and applications** for residential and corporate uses, *along with rural public spaces and dense metropolitan areas.*
- **SCs are essential for offering services in certain domains/spaces** like shopping malls, performance venues, stadiums and, *generally speaking*, **places with (tactic or sporadic) high end-user density**.

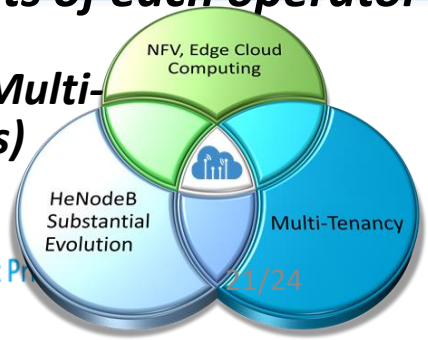
The Innovative Vision of the SESAME-based Approach_(4)

SESAME Context

SESAME targets innovations around three central elements in 5G:

- ***Placement of network intelligence and applications in the network edge*** ***through Network Functions Virtualization (NFV), Software Defined Networking (SDN) and Edge Cloud Computing.***
- ***Substantial evolution of the Small Cell concept,*** ***already mainstream in 4G but expected to deliver its full potential in the challenging high dense 5G scenarios. Provision of SC coverage as-a-Service, to multiple actors.***
- ***Consolidation of multi-tenancy in communications infrastructures,*** ***allowing several operators/service providers to engage in new sharing models of both access capacity and edge computing capabilities. Capability to accommodate multiple operators under the same infrastructure, satisfying the profile and requirements of each operator separately.***

(Small cEllS coordinAtion for Multi-tenancy and Edge services)



The Innovative Vision of the SESAME-based Approach_(5)

SESAME Benefits

The SESAME architectural framework can lead to a variety of substantial features that can be beneficial for the involved industry and end-users.

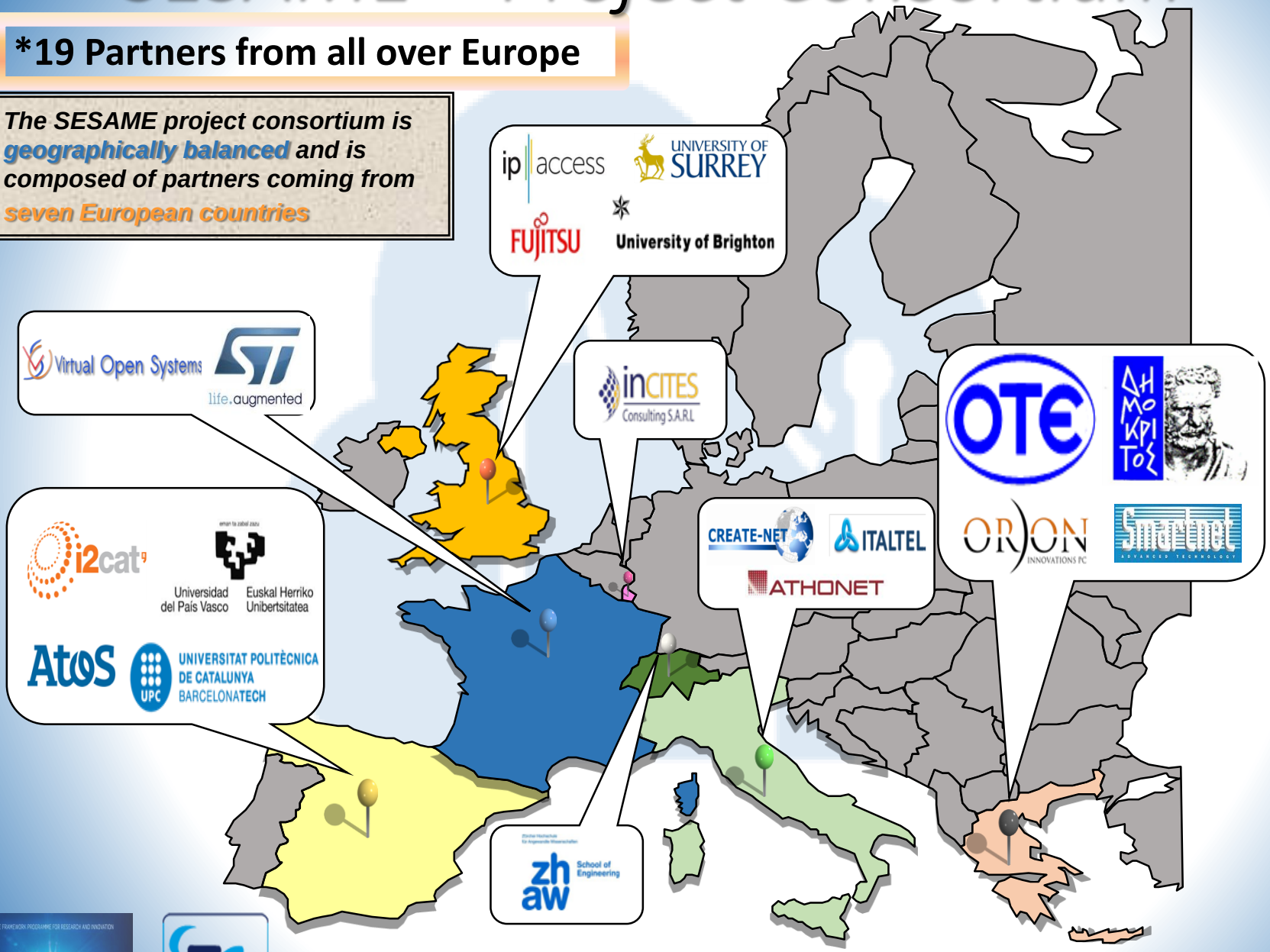
These could be relevant to:

- a ***more efficient management of involved (network) resources***;
- the ***fast inclusion of modern network function(s) and/or service(s)***;
- the ***ease and simplicity of network upgrades and maintenance***;
- ***CAPEX/OPEX reduction***, and;
- ***inclusion of openness*** **within the corresponding ecosystem.**

SESAME – Project Consortium

***19 Partners from all over Europe**

The SESAME project consortium is geographically balanced and is composed of partners coming from seven European countries



Thank you for your attention!

For Further Communication

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