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The "5G ESSENCE" Architectural Approach for the Provision of Enhanced 5G Network Facilities

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5G ESSENCE

Introductory Framework_(1/4)

Current challenges from the 5G deployment:

- Up to now, **several visions of 5G have been proposed** and their basic features converge to the idea that "*any person or item can connect at arbitrarily high data rates, from any place, and with extremely low latency*".
- The way "*how these traits can be realised*" **depends on several factors, including combinations of existing types of communication networks**, as well as ***new and ground-breaking implementations***.
- **5G solutions envisage consolidation of cellular, Internet of Things (IoT), and Wi-Fi networks**, potentially enriched with broadcast networks and automotive systems.

Options for further deployment:

- **Separate radio interfaces are required for the different solutions**, *such as cellular over IoT.*
- The **demand for extremely low latency *"drives"*** to **ultra-dense deployments** and **usage of higher frequencies.**

Introductory Framework_(2/4)

Some critical concerns:

- The **main problem of the actual 5G solutions** is that ***they neither have been "adequately tied" to a solid business case***, ***nor well integrated to the legacy infrastructure of network operators and the rest of actors,*** *within the communications ecosystem*.

- Therefore, **5G needs not only to "target" to new technological solutions**, **but should take into account current economic position of telecom operators/market actors** and **"pave the way" for producing new benefits** that will create new markets and services.

- Thus, **additional 5G actors** *-such as multimedia content providers and vendors-* **should be able to "enter the market and increase their profits"**.

Introductory Framework_(3/4)

The way forward:

- **The** second phase of 5G-PPP program activities suggests that **communication networks need to become sufficiently flexible, *to handle a range of applications/services originating from different domains/verticals.***

- **A transformation towards a significant reduction in cost** and the **optimal allocation of available resources** take the place of initial Key Performance Indicators (KPIs) **for driving capacity growth**, and "coping" with the numerous barriers on the infrastructure and management domains.

- On the users' side, **a high level of personalised services, along with edge mobile capabilities and innovative services are anticipated**, ***since customers require added-value to their choices*** *to accommodate specialised requirements with greater quality of both perception and experience.*

Introductory Framework_(4/4)

Essential Objectives of the 5G ESSENCE context

- **5G ESSENCE addresses** the **paradigms of Edge Cloud computing and Small Cell-as-a-Service (SCaaS)**, *by fuelling the drivers and removing barriers in the Small Cell (SC) market.*
  - *The SC market is expected to grow rapidly up to 2020 and beyond, and*
  - *also to play a "key-role" in the 5G ecosystem!.*

- **5G ESSENCE provides** a **highly flexible and scalable platform**, able to support:
  - **New business models & revenue streams**, ***by creating a neutral host market;***
  - **reduction of operational costs**, ***by providing new opportunities for ownership, deployment, operation and amortisation.***

- **5G ESSENCE leverages and influences knowledge**, **SW modules** and **prototypes** *from various 5G-PPP Phase-1 projects,* ***"SESAME" being particularly relevant.***

Ambitious aims are targeted,
culminating with the prototyping and demonstration of 5G ESSENCE system
in three real-life use cases, *associated to* ***vertical industries.***

Market Vision_(1/3)

From "SESAME" to the "5G ESSENCE"

- During 5G-PPP Phase-1, **the ongoing SESAME project evolves the Small Cell (SC) concept** by integrating processing power (i.e., a low-cost micro server) and by enabling the execution of applications and network services, *in accordance to the Mobile Edge Computing (MEC).*

- SESAME also **provides network intelligence and applications** by leveraging the Network Function Virtualisation (NFV) concept. *(The SESAME platform consists of one or more clusters of "Cloud – Enabled" Small Cells (CESCs), which are devices that include both the processing power platform and the small cell unit. CESCs can be deployed at low- and medium-scale venues and support multiple network operators (i.e.: multitenancy) and- further, network services and applications at the edge of the network).*

- **SESAME has developed several SC-*related* functions as Virtualised Network Functions (VNFs).**
- **SESAME has demonstrated so far that some network related functions** (*such as content caching, firewalls and monitoring*) **perform adequately well when running as VNFs** in the developed micro-server infrastructure (coined as "Light Data Centre" - Light DC).

Market Vision_(2/3)

From "SESAME" to the "5G ESSENCE"

- **5G ESSENCE leverages results from the SESAME project**, as well as from other 5G-PPP Phase-1 projects (COHERENT, SPEED 5G, and SONATA mainly), **to provide an evolution of the SESAME platform and to "meet" the 5G-PPP Phase-2 requirements** *(i.e., to cover the specific network needs of the vertical sectors and their interdependencies).*

- **5G ESSENCE:**
  - **enhances the processing capabilities** for data that have immediate value beyond locality;
  - **addresses the processing-intensive small cell management functions**, *such as Radio Resource Management (RRM)/ Self Organising Network (SON);*
  - **culminates with real life demonstrations**.

- 5G ESSENCE **suggests clear breakthroughs** in the research fields of wireless access, network virtualisation, and end-to-end (E2E) service delivery.

- 5G ESSENCE **will build on the SESAME project** by developing a distributed edge cloud environment (coined as "Edge Data Centre" -Edge DC-), **based on a two-tier architecture**:
  - **the first tier (i.e., Light DC) will remain distributed inside the CESCs** for providing latency-sensitive services to users directly from the network's edge;
  - **the second tier will be a more centralised, "high-scale" cloud, namely the Main Data Centre (Main DC),** which will provide high processing power for computing intensive network applications. It will also have a more centralised view so as to host efficient Quality of Service (QoS) enabled scheduling algorithms.

Market Vision_(3/3)

Challenges and Drawbacks

- **The capacity offered from small cells does not scale beyond a specific threshold, due to interference.**
- **Existing radio resource allocations remain inadequate, due to the lack of a centralised coordination**, *especially in urban areas and environments with high density of users*. **As a remedy, the Cloud-Radio Access Network (C-RAN) approach has introduced centralised BaseBand Units (BBUs)** for processing both the control and user planes, *to support flexible scaling and sophisticated interference coordination techniques*.

  - **However, the significant capacity gains proposed by C-RAN come with a high cost for the fronthaul network** *since the fronthaul requirements for C-RAN are in the order of 6 Gbps bandwidth for small cell sites and of latency less than 0.5ms Round Trip Time (RTT).*
  - **Small cells can be connected to fronthaul through a variety of technologies** (*cable, public fibre, and microwave*) and there are scenarios in which they are deployed without a central planning.
  - **SESAME applies some advantageous distributed RRM/SON techniques for managing interference and increasing capacity**. The coarse coordination achieved through X2 interface targets to reduce interference but it is less efficient for allocating resources in a unified fashion among multiple cells, in comparison with the C-RAN approach.

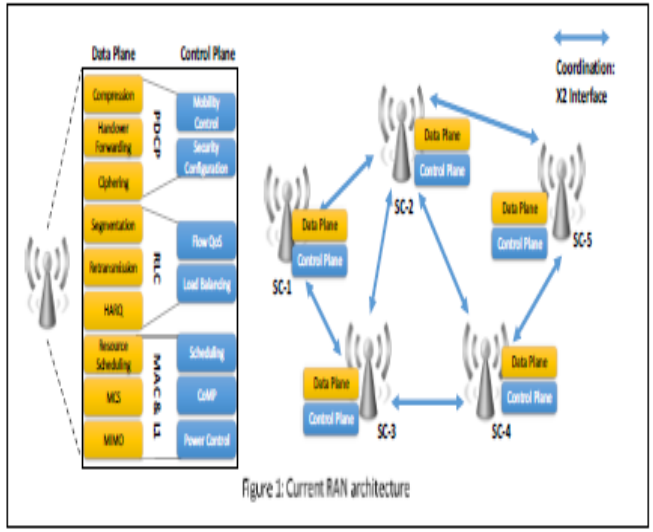


Fig. 1. Current RAN architecture

Challenges for Growth_(1/4)

- **5G ESSENCE proposes a pioneering approach to "ease" the consequences of *extreme network densification* and of the *insufficient management of the scarce network resources*.**

- 5G ESSENCE **suggests** decoupling the control and user planes for the Radio Access Network (RAN), similarly to Software Defined Networking (SDN) in data networks and claiming the benefits of C-RAN without the enormous latency restrictions in the fronthaul.

- 5G ESSENCE **envisages that the Small Cell network** functions related to the user/data plane **will remain distributed**, while **the control plane functions will be disaggregated from the RAN and hosted at the Main DC**, *using Commercial-of-the-Self (COTS) hardware.*

- Although **the design of a centralised Software Defined-RAN (cSD-RAN) controller is a challenging task, the distributed and network-integrated cloud inherited by SESAME is adequate** for hosting controllers based on spatial segmentation. Moreover, **centralization brings immediate benefits for operators** seeking *to improve network efficiency and quality* as well as *coming to grips with digital convergence transformation.*

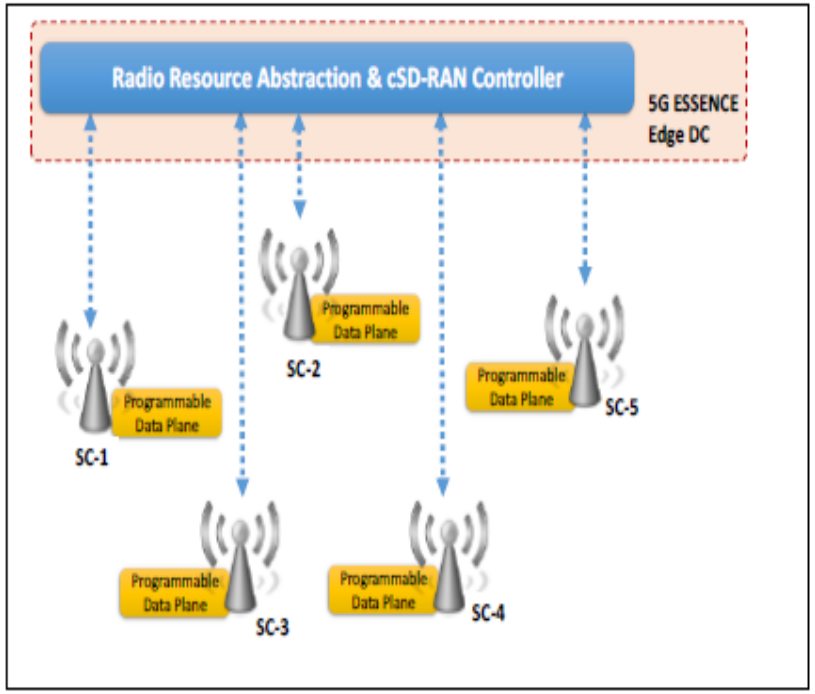


Fig. 2. 5G ESSENCE approach to radio resource abstraction

Challenges for Growth_(2/4)

- **5G ESSENCE aims to include multiple Radio Access Technologies (RAT) in its network architecture**, representing an important step towards fulfilling the vision of 5G wireless networks *(ensuring **higher performance and flexibility** and offering **more efficient spectrum utilisation**).*

- **Benefits are foreseen also in the fields of high-performance virtualisation, service delivery and resource orchestration**, targeting the ***critical issues of resource efficiency and latency reduction*.**
(*These will be achieved through the support of a converged cloud-radio environment, the orchestration of diverse types of lightweight virtual resources, and the support of live VNF migration).*

- **5G ESSENCE will provide even "tighter mapping" and closer interactions between the resource orchestration** *(i.e., deployment, placement, and scaling of VNFs)* **and service orchestration** *(i.e., building, coordinating and exposing services to upper layers).*

- On the domain of hardware technologies, **the processing power attached to small cells brings new capabilities to the network** *as well as new challenges.*

Challenges for Growth_(3/4)

- A significant part of 5G ESSENCE is devoted to the **actual demonstration of outcomes in vertical industries.**

- *In order to showcase that 5G will be able to create a whole new ecosystem for technical and business innovation*, **5G ESSENCE unifies computing and storage resources into a programmable and unified small cell infrastructure that can be provided as-a-Service,** *to all related stakeholders.*

- **5G ESSENCE provides a clear plan for real life demonstrations** in the fields of:
  - *multimedia-entertainment;*
  - *mission critical communications at emergency events, and;*
  - *in-flight connectivity and entertainment.*

Challenges for Growth_(4/4)

Innovation Framework, Impact and Market Perspectives

- **5G ESSENCE will accommodate a wide range of use cases**, *especially in terms of ameliorated latency, resilience, coverage, and bandwidth.*
  - It provides **E2E network and cloud infrastructure slices over the same physical infrastructure**, *to fulfil vertical-specific requirements as well as mobile broadband services, in parallel.*
  - **5G ESSENCE introduces innovations in the fields of network softwarisation, virtualisation, and cognitive network management.**

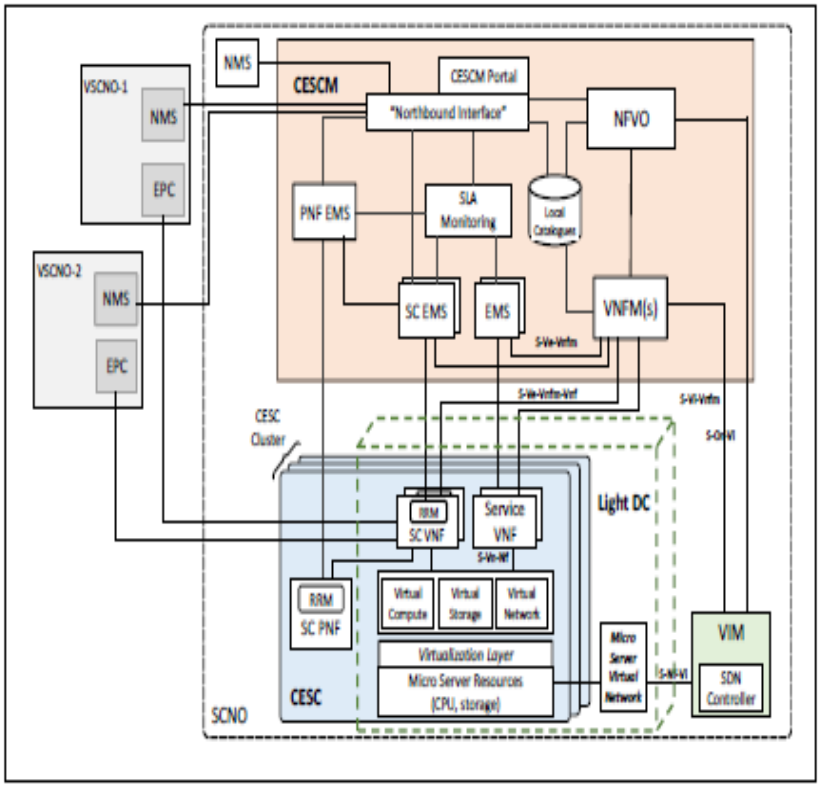
- **5G ESSENCE offers opportunities to venue owners,** *(e.g., municipalities, stadiums, site owners, and virtually anyone who manages a property and can install-and-run a local Small Cell network), to deploy a low cost infrastructure and to act as neutral host network and service provider.*

- **5G ESSENCE supports an enriched mobile users' experience**, *minimising service deployment time.*
- **5G ESSENCE enables network operators and infrastructure owners to open the radio network edge to third-party partners** *allowing them to rapidly deploy innovative applications and services.*

Architectural Framework_(1/3)

- ***The architecture provided so far by the SESAME project acts as a "solid reference point" for 5G ESSENCE***

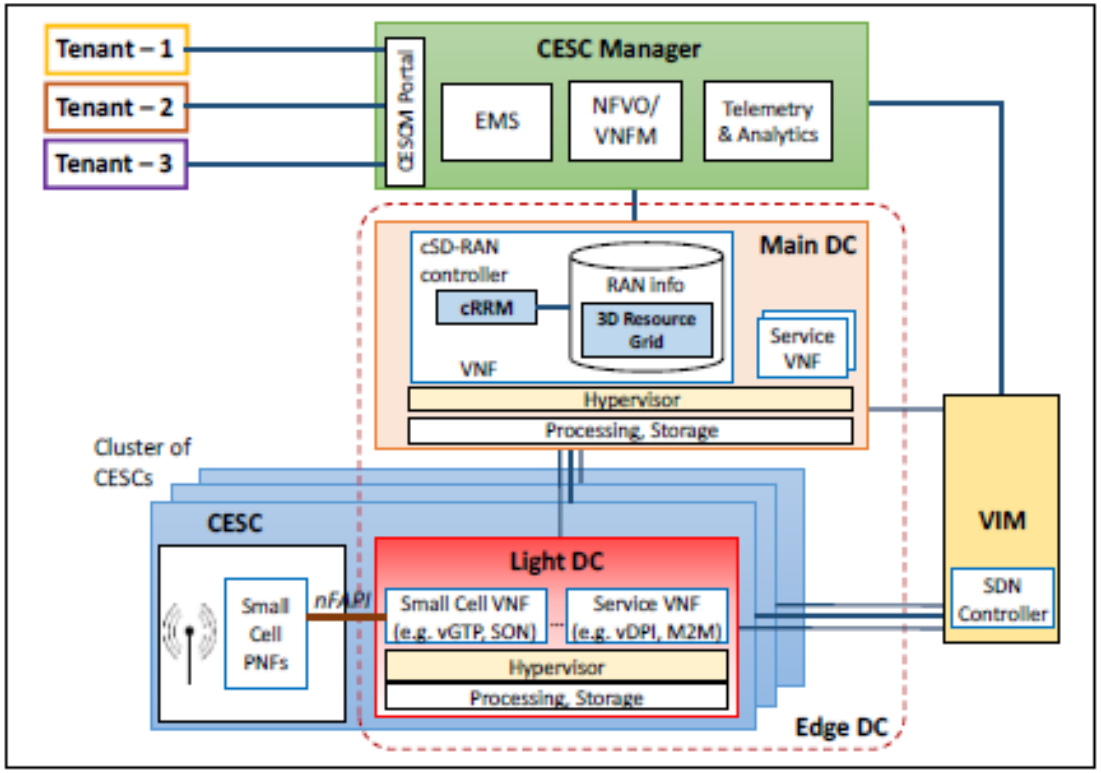
- The architecture combines ***the current 3GPP framework for network management in RAN sharing scenarios*** and ***the ETSI NFV framework for managing virtualised network functions.***
- The CESC offers virtualised computing, storage and radio resources and **the CESC cluster is considered as a cloud from the upper layer.**
- **This cloud can also be "sliced" to enable multi-tenancy.**
- **The execution platform is used to support VNFs** that implement the different features of the Small Cells as well as **to support for the mobile edge applications** of the end-users.



Architectural Framework_(2/3)

- ***The 5G ESSENCE architecture will allow multiple network operators (tenants) to provide services to their users through a set of CESCs deployed, owned and managed by a third party (i.e., the CESC provider).***

- ***Operators can extend the capacity of their own 5G RAN in areas where the deployment of their own infrastructure could be expensive and/or inefficient*** *(e.g., the case of highly dense areas where massive numbers of Small Cells would be needed to provide the expected services).*



Architectural Framework_(3/3)

Main Technical Challenges and Expected Conceptual Focus

- **Full specification of the critical architectural enhancements from 5G-PPP Phase-1 actions**, that are necessary to enable cloud-integrated multi-tenant small cell networking.
- **Definition of the baseline system architecture and interfaces** for the provisioning of a cloud-integrated multi-tenant SC network and of a programmable Radio Resources Management (RRM) controller, *both customisable on a per vertical basis*.
- **Development of the centralised SD-RAN (Software-defined Radio Access Network) controller** that will program the radio resources usage in a unified way for all CESCs (Cloud-Enabled Small Cells).
- **Exploitation of high-performance and efficient virtualisation techniques** for better resource utilisation, higher throughput and less delay at Network Services creation time.
- **Development of appropriate orchestrator enhancements**, for distributed service management.
- **Demonstration and evaluation** of the cloud-integrated multi-tenant small cell network, *via three real-life vertical industries*.
- **Conduct of a market analysis and establishment of new business models** via detailed techno-economic analysis & roadmapping towards exploitation/commercialisation by industrial partners.
- **Ensuring maximisation of 5G ESSENCE impact to the realisation of the 5G vision**, by establishing close liaison and interactive synergies with 5G-PPP Phase-1 & Phase-2 projects and the Association.
- **Pursuing extensive dissemination and communication activities**, as well as assessing the perceived impact from the stakeholders and the wider community.

Scenarios of Use_(1/4)

Identification of 3 Main Real-Life Use Cases, *associated to Vertical Industries*

5G edge network acceleration for a stadium:

- **Demonstration of a combined 5G-*based* video production and video distribution for delivering benefits to media producers and mobile operators,** who will be able to offer enriched event experience to their subscribers.
- *The production/distribution of locally generated content through the 5G ESSENCE platform, coupled with value-added services and rich user context, **will enable secure, high-quality and resilient transmission**, in real-time and with minimal latency.*

Mission critical applications for public safety (PS):

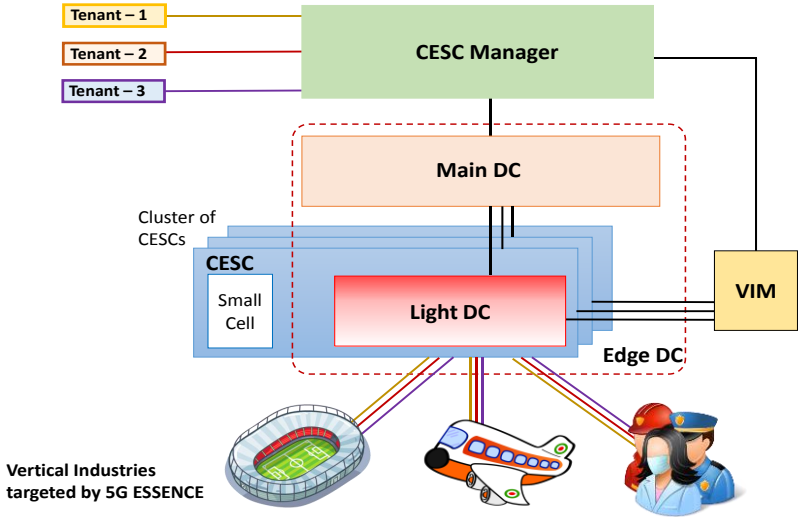
- **Involvement of one -*or more*- PS communications providers, to use the resources offered by a dedicated platform for the delivery of communication services to PS organisations in a country/region.**
- *The 5G ESSENCE platform can be owned by either a mobile (potentially virtual) network operator* or by a *venue owner*.
- *The infrastructure owner will exploit system capabilities to provide the required network/cloud slicing capabilities with dedicated SLAs to different types of tenants, by prioritising the PS communications providers.*

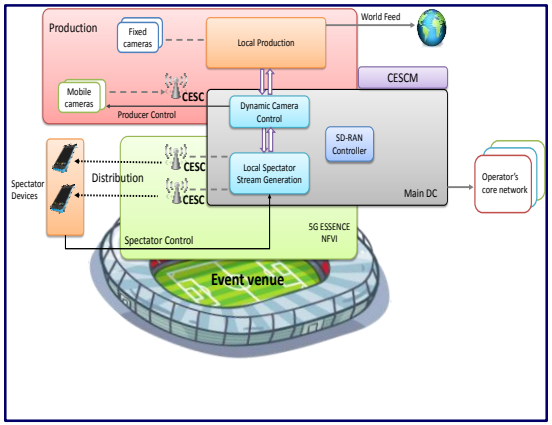
Next-Generation integrated in-flight connectivity and entertainment (IFEC) services:

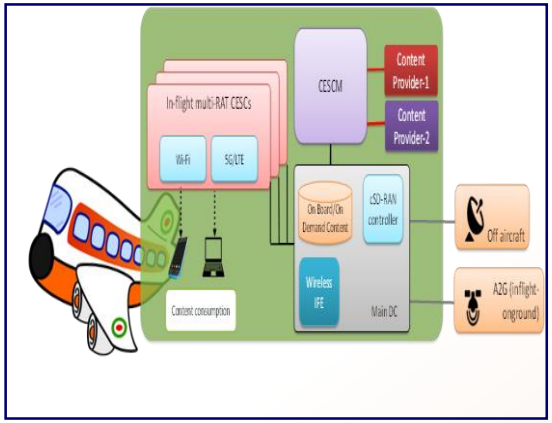
- **Testing and validation of the multi-tenancy enabled network solution for passenger connectivity and wireless broadband experience.**
- ***The multi-RAT CESCs will be implemented as a set of integrated access points to be deployed on-board.***
- Then, since IFE has to consider the explosive growth of multi-screen content consumption, the 5G ESSENCE CESCs will stream on demand multi-screen video content *(both from on-board 5G Edge DC servers and via satellite/air2ground links) to the wireless devices.*
- ***5G ESSENCE CESCs will rely on broadcast links** to optimise the bandwidth usage.*

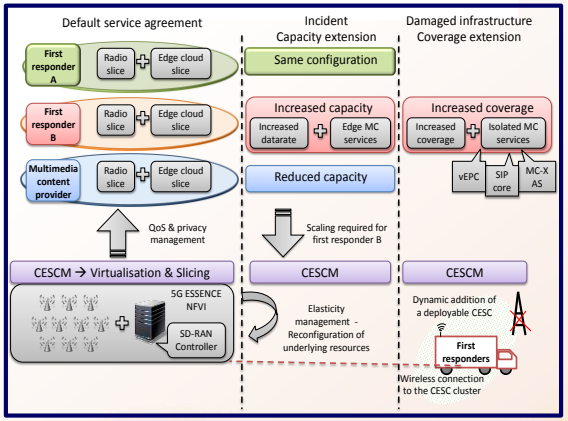
Scenarios of Use_(2/4)

Identification of 3 Main Real-Life Use Cases (cont.)





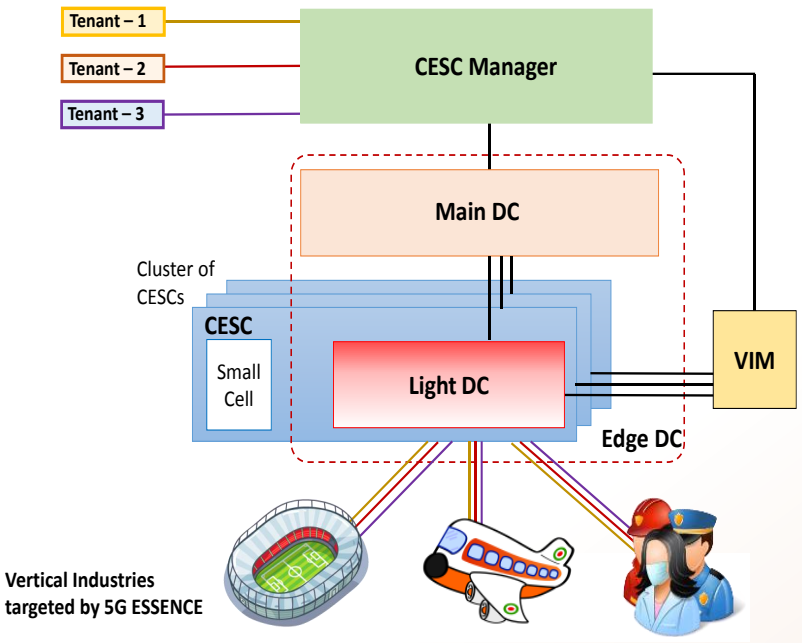




Scenarios of Use_(3/4)

- **At the network's edge, each CESC is able to host one or more service VNFs**, directly applying to the users of a specific operator.
- **VNFs can be instantiated inside the Main DC *and be parts of a Service Function Chaining (SFC) procedure***.
- **The Light DC can be used to "implement different functional splits of the Small Cells *as well as to support the mobile edge applications of the end-users.***

5G ESSENCE proposes the development of small cell management functions as VNFs, which run in the Main DC and coordinate a fixed "pool" of shared radio resources, *instead of considering that each small cell station has its own set* of resources.



- ***The CESC Manager (CESCM) is responsible for coordinating and supervising the use, the performance, and the delivery of both radio resources and services***. It controls the interactions between the infrastructure (CESCs, Edge DC) and the network operators.
- The ***CESCM handles Service Level Agreements (SLAs)***, while on an architectural basis it encompasses telemetry and analytics as fundamental tools for efficiently managing the overall network.
- ***The Virtualised Infrastructure Manager (VIM) is responsible for controlling the NFV Infrastructure (NFVI)***, which includes the computing, storage and network resources of the Edge DC.

Scenarios of Use_(4/4)

5G ESSENCE will explore the means to deliver its achievements to the market, with emphasis in the **quantification of benefits**, especially in terms of total cost of ownership, revenues and profits.

5G ESSENCE will allow the sharing of existing and new infrastructure by many operators in a multitenant environment, *thus* ***enabling new business models*** *that will help new entrant market players to develop and analyse the perspectives of potential win-win strategies based on the developed solutions.*

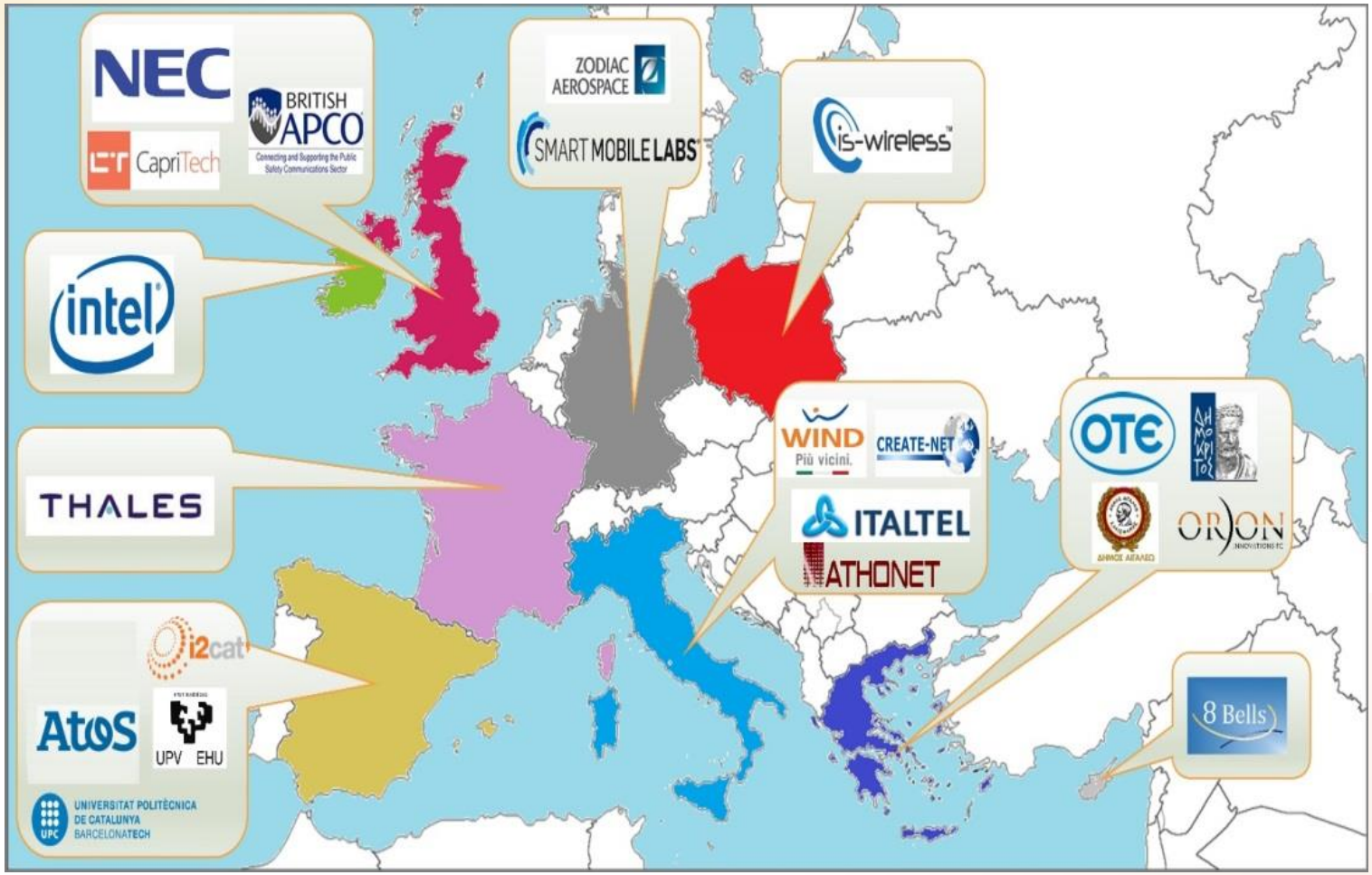
Key actors, revenue streams, and cost/performance drivers ***of the various RAN partitioning options*** ***will be identified.***

The main benefits of 5G ESSENCE include

- the **maximisation of resource usage**,
- the **reduction of equipment and management costs**, and
- the **QoS improvement**,

thus encouraging ***network innovation*** *and* ***deployment of distinct network services***.

5G ESSENCE Consortium



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