5G ESSENCE: Overall System Architecture and Requirements

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20th INFOCOM World Conference – *Athens, Greece, November 21, 2018*

5G PPP PUBLIC-PRIVATE PARTNERSHIP
European Commission
Horizon 2020 European Union funding for Research & Innovation
5G ESSENCE

Introductory Framework_(1/3)

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.***

Introductory Framework_(2/3)

From "SESAME" to the "5G ESSENCE"

- *During 5G-PPP Phase-1,* **the SESAME project has evolved 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* ***provided 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 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).*

Introductory Framework_(3/3)

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).*

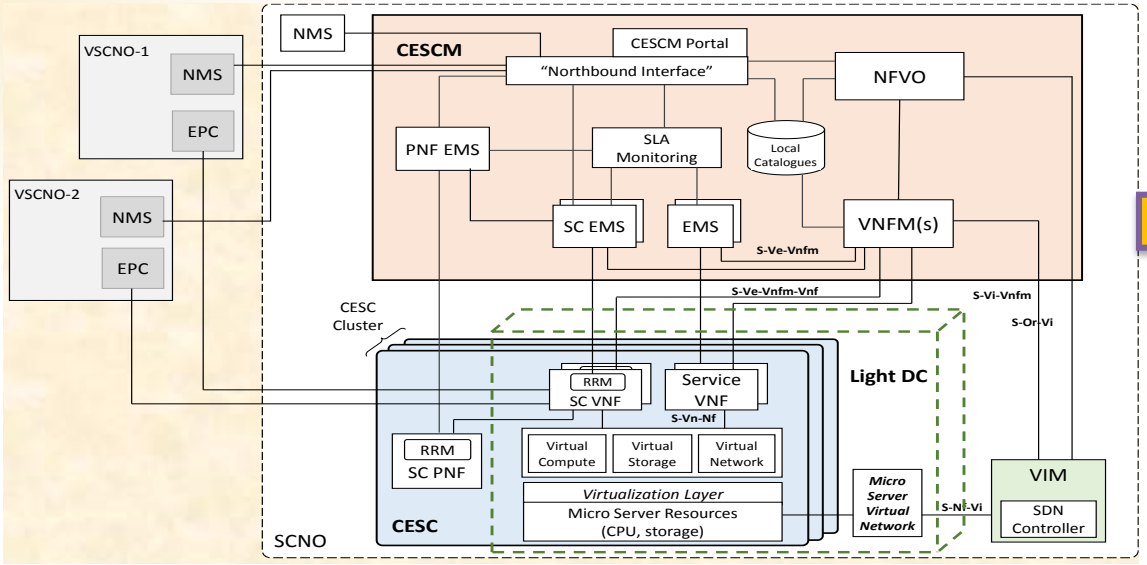
- **5G ESSENCE:**
  - ***enhances the processing capabilities** for data that have immediate value beyond locality;*
  - ***addresses the processing-intensive small cell management functions**, such as Radio Resource Management (RRM)/ Self Organising Network (SON);*
  - ***culminates with real life demonstrations**.*

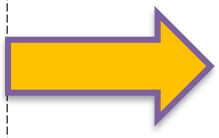
- ***5G ESSENCE suggests clear breakthroughs** in the research fields of wireless access, network virtualisation, and end-to-end (E2E) service delivery.*

- ***5G ESSENCE builds upon the SESAME project** **by developing a distributed edge cloud environment (coined as "Edge Data Centre (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.*

Process for Architectural Evolution_(1/2)

Point of departure is the 5G-PPP SESAME architecture





- *The **platform of CESCs** offers **computing, storage and radio resources.***
- *Through **virtualization**, **the CESC cluster can be "seen" as a cloud of resources which can be sliced,** so that to enable **multi-tenancy**.*
- ***Cloud-based processing and storage resources** are provided through a virtualised execution platform.*
- ***This execution platform is used to support the required Virtualized Network Functions (VNFs)** that implement the different features/capabilities of the **Small Cells** (and eventually of the core network).*

Process for Architectural Evolution_(2/2)

- **In the planned 5G ESSENCE approach, the Small Cell concept is advanced to achieve:**
  - *An increase in the capacity and the performance of current RAN infrastructures.*
  - *Extension of the "range" of the provided services.*
  - *Maintenance of its agility.*

- To achieve these ambitious goals, **the 5G ESSENCE leverages the paradigms of RAN scheduling and provides an enhanced, edge-*based*, *two-tier virtualised execution environment attached to the small cell***, *taking advantage and reinforcing the concepts of* ***MEC*** *and* ***network slicing***.

- The ***basic idea*** is that ***by running applications and performing related processing tasks closer to the end-user***, ***network congestion is reduced and applications perform better!***

Architectural Framework_(1/13)

The architecture combines:

- The current 3GPP framework for network management in RAN sharing scenarios (“*LTE world*”)

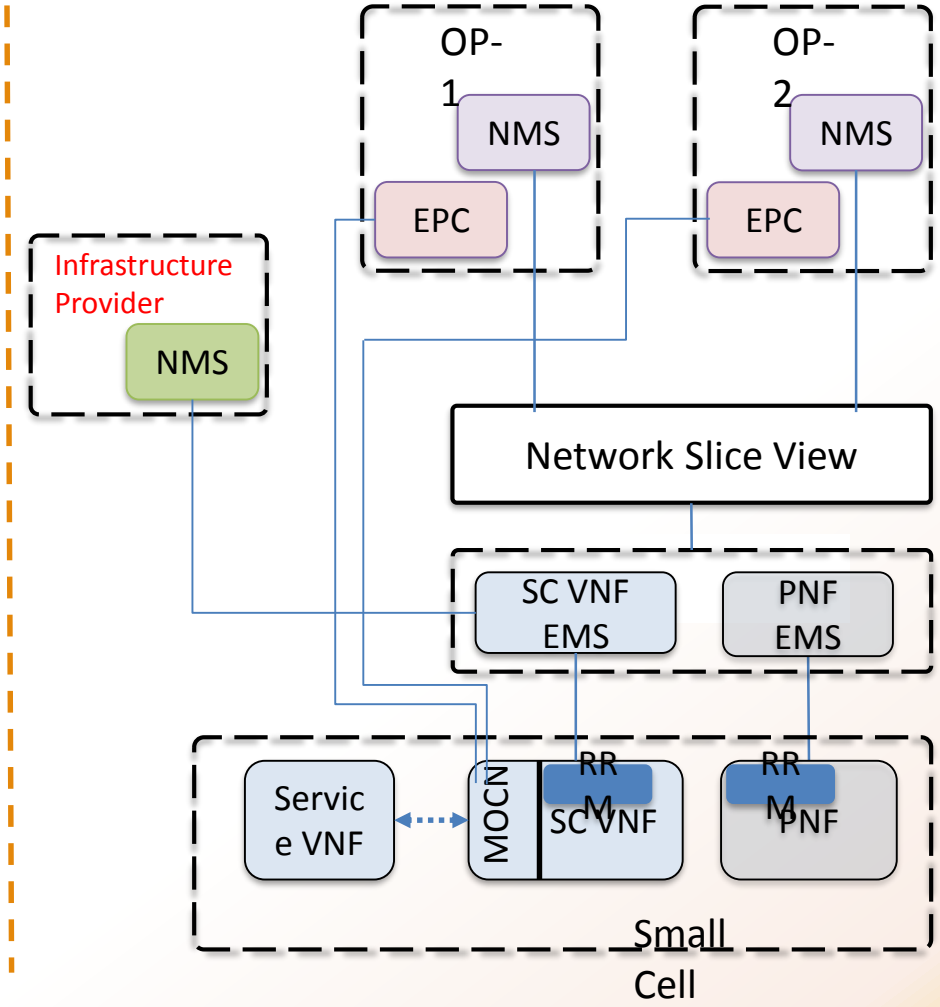
  and

- the ETSI NFV framework for managing virtualised network functions (“*NFV world*”).

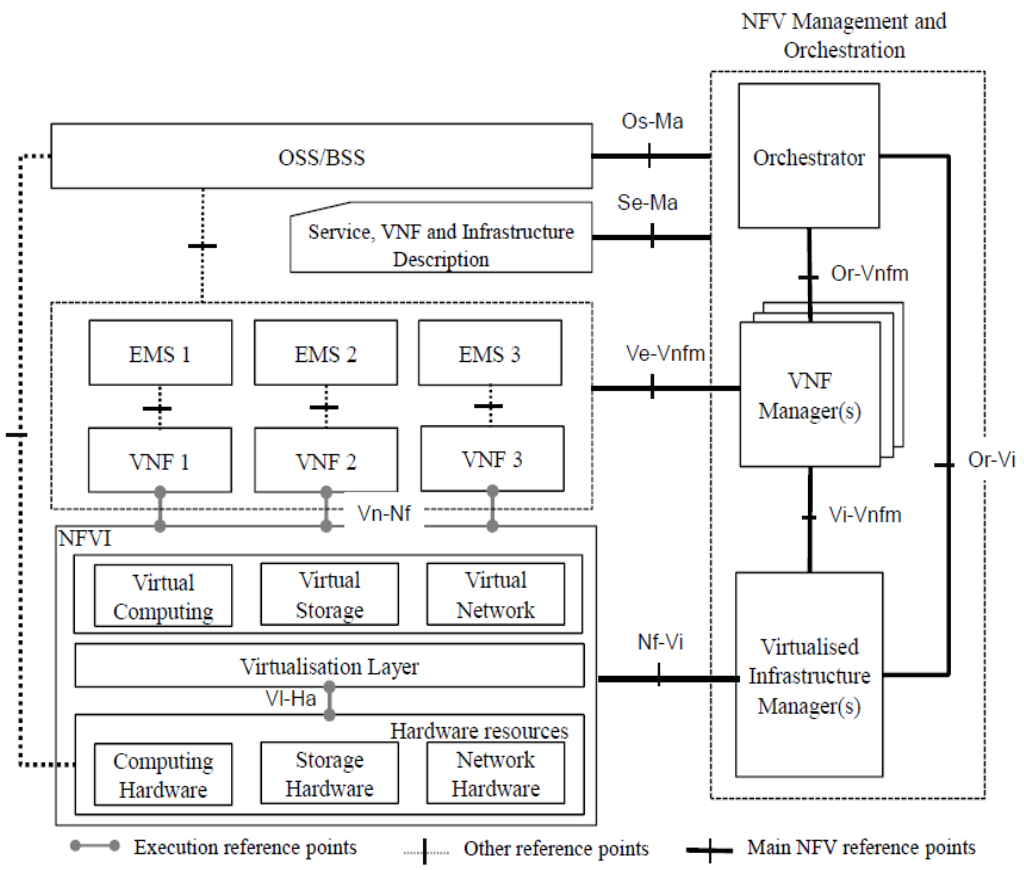
Architectural Framework_(2/13)

Concepts from the "LTE world"

- **A Small Cell network capable to support more than one network operator is envisaged.**
- **3GPP specifications have already added some support for Radio Access Network (RAN) sharing and Multi-Operator Core Network (MOCN),** where the shared RAN is directly connected to each of the multiple operator's core networks, has been identified as the exclusive enabler for multitenancy features in SESAME platform.
- **The infrastructure consists of a number of Small Cells and the corresponding SC network functions**, *such as gateways and management systems.*



Architectural Framework_(3/13)



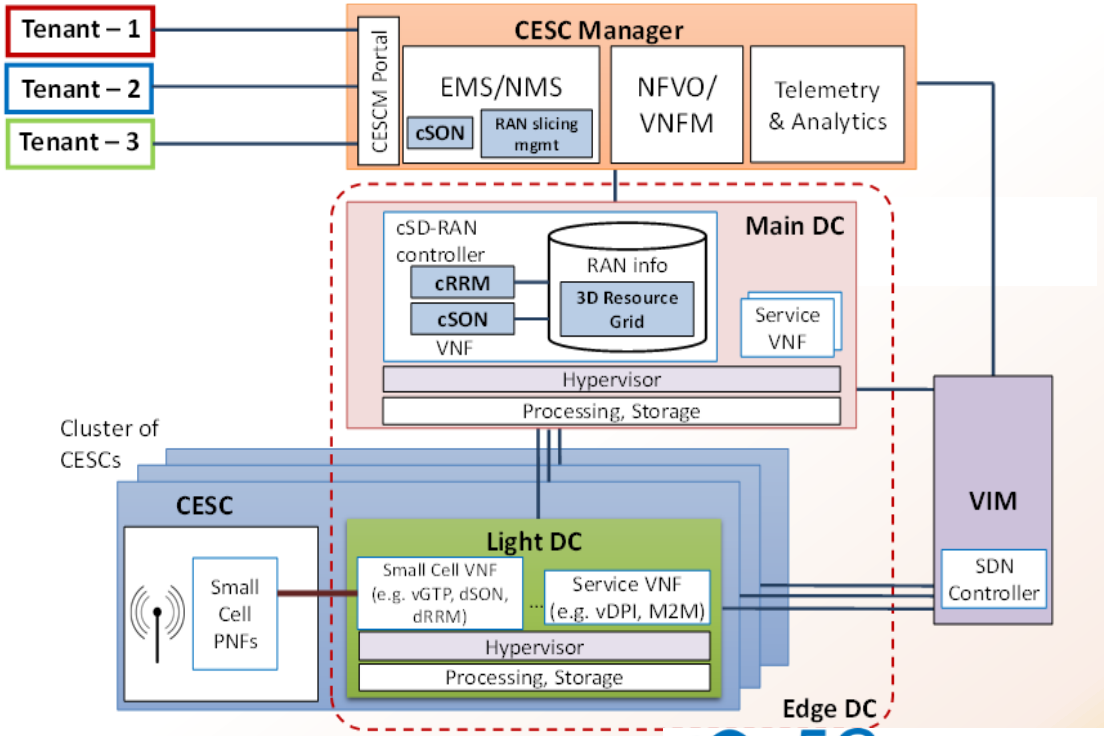
Concepts from the "NFV world"

- The **NFV concept** is used as an enabler that **offers a virtualisation platform** and "meet" related requirements as of NFV-*driven* small cell functions and NFV-*based* network services.
- **The figure presents the MANO framework for the NFV part**

Architectural Framework_(4/13)

- ***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).***

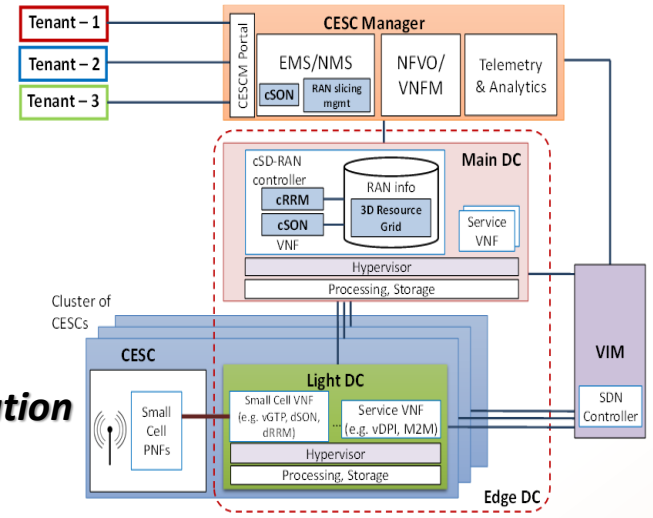
- ***Operators can extend the capacity of their own 5G RAN in areas where the deployment of their own infrastructure could be expensive and/or inefficient*** *(e.g., the case of highly dense areas where massive numbers of Small Cells would be needed to provide the expected services).*



Architectural Framework_(5/13)

A CESC consists of a Multi-RAT 5G SC with its standard backhaul interface, standard management connection *(TR069 interface for remote management)* and with necessary modifications to the data model *(TR196 data model)* **to allow Multi-Operator Core Network (MOCN) radio resource sharing.**

The CESC will be composed by a physical SC unit attached to an execution platform, based on one of x86, ARMv8, MIPS64 architectures.



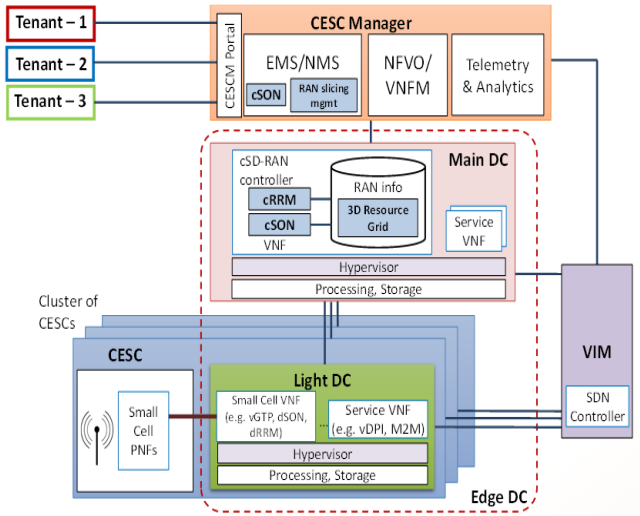
Edge cloud computing and networking are realised through the sharing of computation, storage and network resources of those micro-servers present in each CESC and ***these form the Light DC,*** *for implementing different features/capabilities of the SC.*
Therefore, ***the CESCs becomes a "neutral host"*** ***for network operators or virtual network operators*** *that want to "share" IT and network resources at the edge of the mobile network.*

The CESC is meant to accommodate multiple operators (tenants) by design, offering Platform-as-a-Service (PaaS), capable of providing the deployed physical infrastructure among multiple network operators. Different VNFs can be hosted in the CESC environment for different tenants. This also provides the support for mobile edge computing applications deployed for each tenant that, operating very near to the end-users, may significantly reduce the service delivery time and deliver composite services in an automated manner.

Architectural Framework_(6/13)

The CESC is the termination point of the GTP-User Plane (GTP-U) tunnelling which encapsulates user IP packets from the core network entities (e.g., the Evolved Packet Core (EPC) Serving Gateway (SGW) in LTE) destined to the User Equipment (UE), and vice versa.

The CESC exposes different views of the network resources: *per-tenant small cell view and physical small cell substrate, which is managed by the network operator, decoupling the management of the virtual small cells from the platform itself.*



In the CESC, *rather than providing multiple S1 (or Iu-h interface) connections from the physical SC to different operators' EPC network elements such as Mobility Management Entity (MME) and SGW,* ***such fan-out is done at the Light DC.***
The CESC is further the termination of multiple S1 interfaces connecting the CESC to multiple MME/SGW entities as in S1-Flex.

The interconnection of many CESCs forms a "cluster" *which can facilitate access to a broader geographical area with one or more operators (even virtual ones)* ***extends the range of their provided services, while maintaining the required agility*** *so that to be able to provide these extensions on demand.*

GTP: GPRS Tunneling Protocol

Architectural Framework_(7/13)

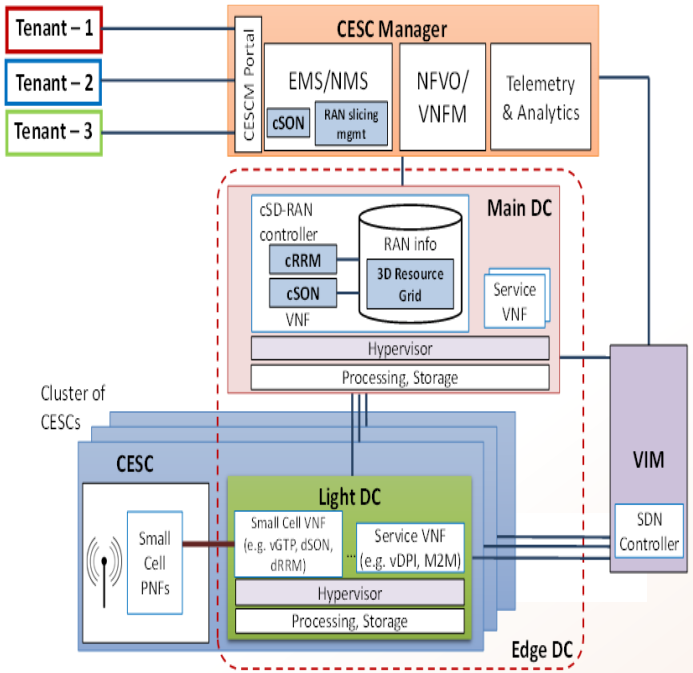
The Edge DC encompassing Main DC and Light DC:

- ***5G ESSENCE envisages combining the MEC and NFV concepts with SC virtualisation*** *in 5G networks and enhancing them for supporting multi-tenancy .*

The purpose of the Edge DC is to provide Cloud services within the network infrastructure and also to facilitate, by promoting and assisting the exploitation of network resource information.

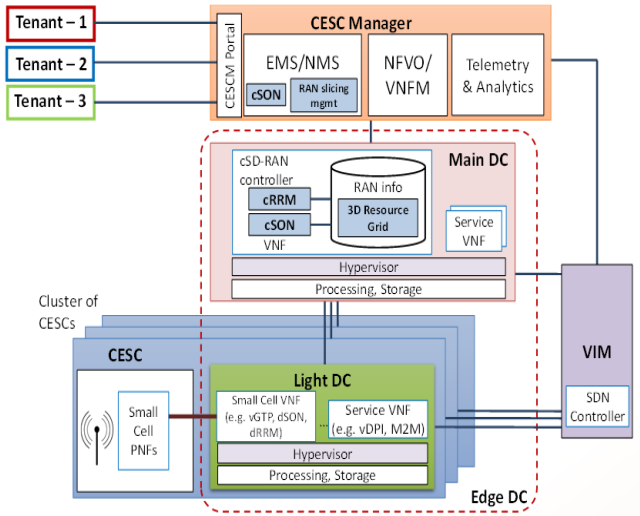
All the normally hardware located modules of the Light DC and the Main DC will be delivered as "resources using novel virtualisation techniques".

Both networking and computing virtualisation extensions will be developed by using open frameworks such as OPNFV.



The combination of the proposed Edge DC architecture with the concepts of NFV and SDN, ***will facilitate achieving higher levels of flexibility and scalability*****.**

Architectural Framework_(8/13)



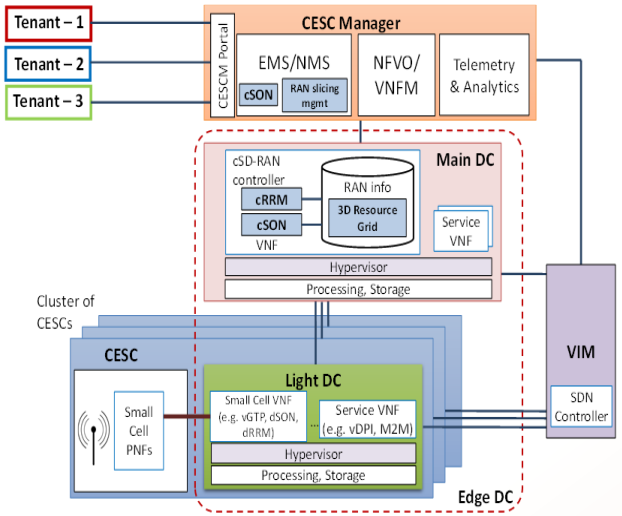
The Main DC:

- ***is able to execute different SC and Service VNFs under the control of the CESCM;***
- ***hosts the cSD-RAN controller which performs cRRM decisions for handling efficiently the heterogeneous access network environment*** *composed of different access technologies (such as 5G RAN, LTE, and Wi-Fi).*

- ***These radio access networks can be programmable and under the supervision of the centralised controller.***
- **The cSD-RAN controller updates and maintains the global network state in the form of a database called as "RAN Information",** which includes, *among other* elements, an abstraction of the available radio resources in the CESC cluster.
- ***The RAN Information will be used by the cRRM to perform the resource allocation decisions*** *(e.g., scheduling).*

- ***The cSD-RAN controller can also host centralised SON (cSON) functionalities that need to coordinate multiple small cells, so they are not appropriate for running at the Light DC*** *(for example, this could be the case of InterCell Interference Coordination (ICIC) functions).*
- ***Other distributed (dSON) functions and/or distributed RRM (dRRM) functions that are of low complexity and that do not involve the coordination of multiple small cells will run at the Light DC.*** *For example, this could be the case of an admission control function that only takes decisions based on the current load existing at a given cell.*

Architectural Framework_(9/13)



Actions for the CESCM:

- ***Management and orchestration of the proposed uniform virtualised environment,*** *able to support both radio connectivity and edge services,* ***is a challenging task.***
- ***The management of diverse lightweight virtual resources is of primary importance****, enabling a converged cloud-radio environment and efficient placement of services.*

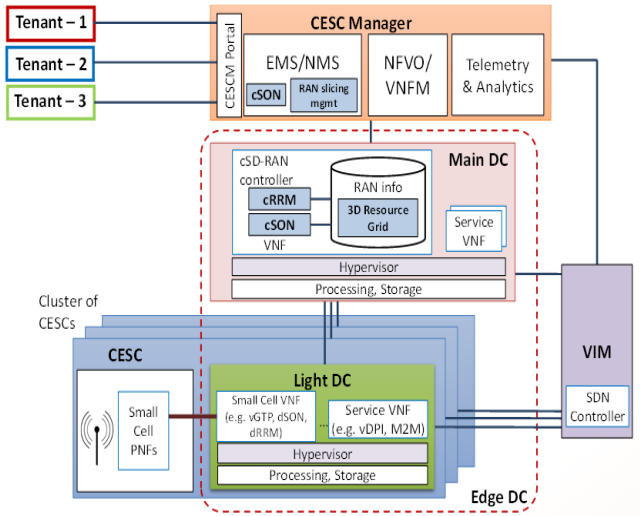
- ***The CESCM is the central service management and orchestration component in the related architecture.***
- ***It integrates all the traditional network management elements and the novel recommended functional blocks to realise NFV operations.***
- ***A single instance of CESCM is able to operate over several CESC clusters at different Points of Presence (PoPs)****, each constituting an Edge DC through the use of a dedicated VIM (Virtualised Infrastructure Manager) per cluster.*

Architectural Framework_(10/13)

An essential component at the heart of CESCM is the Network Functions Virtualisation Orchestrator (NFVO), *being in charge of* ***realising network services on the virtualised infrastructure*** *and including interfaces to* ***interact with the CESC provider for high-level service management*** *(e.g., exchange of network service descriptors and Service level agreements (SLAs) for each tenant).*

The NFVO composes service chains *(constituted by two or more VNF instances located either in one or several CESCs that "jointly" realise a more complex function)* ***and manages the deployment of VNFs over the Edge DC.***

The NFVO uses the services exposed by the VNF Manager (VNFM), *which will be in charge of the instantiation, update, query, scaling and termination of the VNFs. Also, the NFVO may include features to enhance the overall system performance, e.g., to improve energy efficiency.*



The CESCM hosts also the Element Management System (EMS), which provides a package of end-user functions for the management of both the PNFs and VNFs at the CESCs.

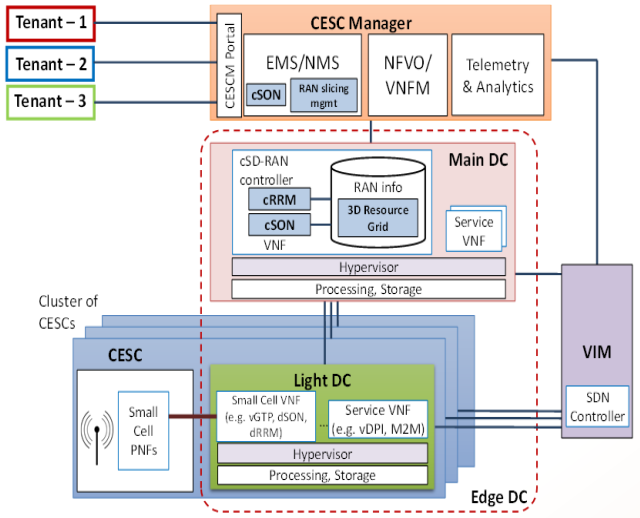
The EMS carries out "key" management functionalities such as Fault, Configuration, Accounting, Performance, Security (FCAPS) operations. The EMS will be responsible for partitioning the single whole-cell management view into multiple virtual-cell management views, one per tenant.

In this way, ***a virtualised SC with a set of (limited) management functionalities can be made visible to, e.g., the Network Management System (NMS) of each tenant*** *in order to, for example, collect performance counters, configure neighbour lists for a proper mobility management, etc.*

Architectural Framework_11/13)

In addition to the NMSs of each tenant, in a general situation, ***the CESCM can also incorporate a NMS for managing the whole set of CESCs deployed by an operator****. This can be appropriate, for example in case that there exist CESCs belonging to different vendors in the same deployment, each one with its own EMS.*

The EMS/NMS will also host the cSON functionalities ***(e.g. self-planning, Coverage and Capacity Optimisation (CCO), etc.)*** ***and the functionalities for the lifecycle management of RAN slicing (i.e. for the creation, modification or termination of RAN slices).***



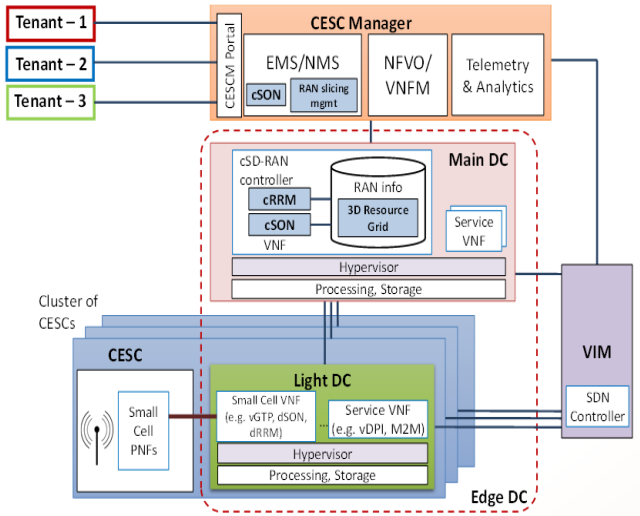
The CESCM also encompasses a telemetry and analytics module that captures and analyses relevant indicators of the network operation. *This will provide the CESCM with accurate knowledge models that characterise the behaviour of the network and its users in relation to the utilisation of both cloud and radio resources.*
This will facilitate the realisation of effective optimisation approaches *based on, for example, machine learning (ML) techniques for service placement, which can dynamically adapt to the context of the provided services and their execution environment and to enable automated enforcement of SLAs.*

Finally, the CESCM also incorporates the CESCM portal.
It is a control panel with web Graphical User Interface (GUI) that serves as the "entry point" for the users, both the CESC provider and the tenants, to the CESCM functionalities and constitutes the main graphical frontend to access the 5G ESSENCE platform.
The CESCM Portal provides visual monitoring information of the platform, the agreed SLAs, and the available network services/VNFs, allowing parameters' configuration.

Architectural Framework_(12/13)

The VIM:

The CESCM functions will be built upon the services provided by the VIM for appropriately managing, monitoring and optimising the overall operation of the NFVI *(NFV Infrastructure)* ***resources*** *(i.e.: computing, storage and network resources)* ***at the Edge DC.***



- ***The role of VIM is essential for the deployment of NFV services and to form and provide a layer of NFV resources to be made available to the CESCM functions.***
- *The NFV resources will be ultimately offered as a set of application programming interfaces (APIs) that will allow the execution of network services over the decentralised CESCs, located at the edge of the network.*
- ***The VIM relies on an SDN controller for interconnecting the VNFs and for offering SFC on the data-plane*** *by establishing the path for the physical connections.*

Architectural Framework_(13/13)

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.

For further communication…

http://www.5g-essence-h2020.eu

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