Small cEllS coordinAtion for Multi-tenancy and Edge services

SESAME

White Paper

The SESAME approach for clustered Small Cell deployments: Introducing advanced coordination and service capabilities through a distributed edge data centre.

July 2016

Table of Contents

Project Positioning

The development of the 5G ecosystem involves numerous groups of industry stakeholders, research institutions, standard developing organizations, certification bodies and other institutions.

In particular, 5G-PPP is a “joint” initiative between the European Comission and the European ICT industry, intending to further reinforce the European presence in this field, at the global level. The main objective is to design and deliver appropriate solutions, architectures, technologies and standards for the next generation communication infrastructure.

Currently, the European Union (EU) funds 19 projects under the 5G-PPP Phase 1 programme. These projects work together to deliver the critical 5G technology building block.

As part of 5G-PPP Phase 1, the SESAME Project (Grant Agreement No.671596) targets innovations around three central elements in 5G: (i) the “placement” of network intelligence and applications in the network edge through Network Functions Virtualisation (NFV) and Edge Cloud Computing; (ii) the substantial evolution of the Small Cell (SC) concept, already mainstream in 4G but expected to deliver its full potential in the challenging high dense 5G scenarios, and; (iii) the consolidation of multi-tenancy in modern communications infrastructures, allowing several operators/service providers to engage in new sharing models of both access capacity and edge computing capabilities.

The SESAME project addresses the needs of future 5G mobile networks from the perspective of a scalable and flexible system, rather than focusing in new 5G waveforms or protocol stacks.

5G-PPP web site: https://5g-ppp.eu/
5G-PPP Phase 1 projects: https://5g-ppp.eu/5g-ppp-phase-1-projects/
SESAME Project web site: http://www.sesame-h2020-5g-ppp.eu/

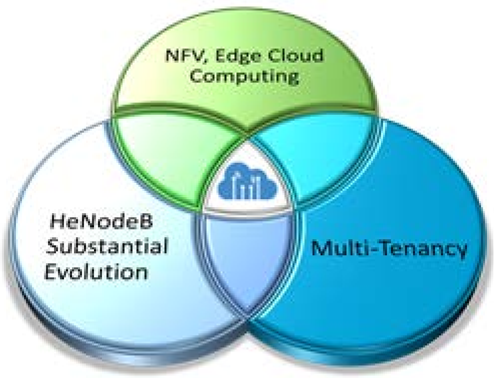
Key Concepts

The SESAME project is an innovative effort to realize multi-tenant cloud enabled Radio Access Networks (RAN) through a substantial change on the architecture of commercial Small Cells (SC), by evolving them towards the so-called Cloud Enabled Small Cell (CESC). This change paves the way towards "placing" network intelligence and applications in the network edge with the help of virtualization techniques and Network Function Virtualization (NFV).

Through the advanced coordination and orchestration realised within the SESAME concept, we propose a new architecture concept, we propose a new architecture able to attend several operators/service providers and engage them in a modern multi-tenant ecosystem.

This solution extends the "Small Cell as a Service" ("SCaaS") model, which facilitates a third-party provisioning of shared radio access capacity to mobile network operators in various localised areas, together with the provision of Mobile Edge Computing (MEC) services. Efficient management of resources, rapid introduction of new network function(s) and/or service(s), ease of upgrades and maintenance, CAPEX/OPEX reduction and encouraging openness within the ecosystem, are only few -but substantial- examples of the various benefits that the proposed solution can develop and provide. ESAME introduces:

- Cloud Enabled SC (CESC).
- Light Data Centre (DC) as geographically distributed NFV Infrastructure (NFVI) within the RAN.
- Multi-tenant over the RAN, exploiting NFV and MEC concepts.
- New business opportunities between the SC infrastructure provider and the mobile network operators.
- Use of Software Defined Networks (SDN) for managing the connections between Virtual Network Functions (VNFs) within the Light DC.
- Reuse of the current 4G architecture and protocol stack, taking in mind different possible functional splits.
- Evolution of "Self-X" properties for more enhanced network and/or service management.



SESAME Business Perspectives

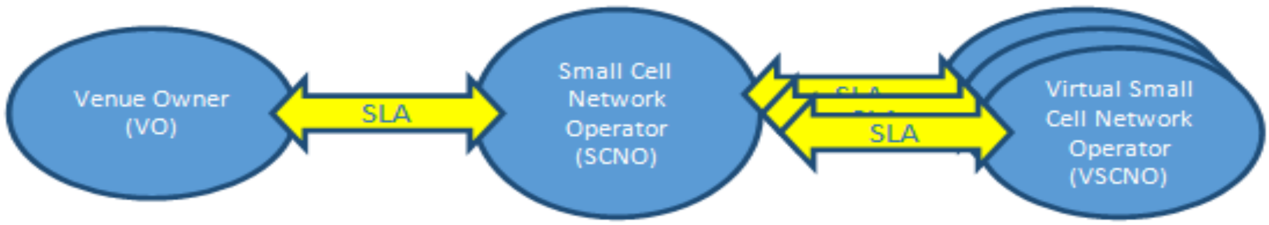
Several "actors" with different features are involved in the SESAME value chain.

The following figure illustrates the main actors related to SESAME along with their interactions in terms of services and infrastructure. It should be noticed that the SESAME value chain can be enhanced by adding general actors such as vendors, end-users etc.

Small Cell Network Operator (SCNO): These actors are owners of the telecommunication equipment (e.g. Small Cells) and are able to provide communication services both to end users and to other actors. The geographic coverage of their network is limited and complementary to that of existing mobile network operators.

Virtual Small Cell Network Operator (VSCNO): They provide communication services to end users without possessing the necessary network equipment, so they lease it from a SCNO.

Venue Owner (VO): These are actors that own the space where the telecommunication equipment can be installed. For example: a mall or a stadium owner, a municipality or a large building owner.

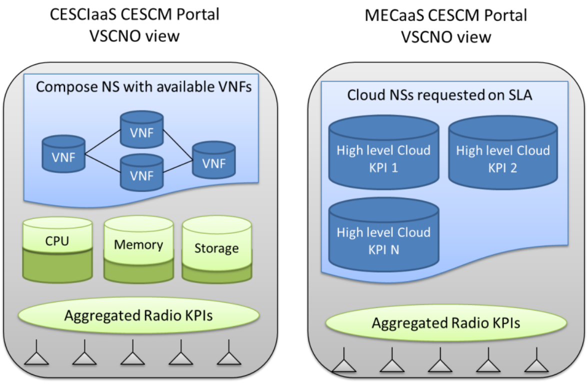


The idea of multi-tenancy has been early initiated in 3GPP and is expected to play a vital role in the forthcoming 5G networks of the future. In a multi-tenant scenario, an infrastructure provider can grant access to third parties such as network operators and service providers of Over-The-Top (OTT) players.

The resulting solution will allow VSCNOs not only to support connectivity, but also to provide added value mobile edge services.

Despite the potential technical benefits, the viability of any relevant solution strongly depends on several factors such as Service Level Agreements (SLAs) and pricing schemes. An SLA that captures the particular Key Performance Indicators (KPIs) of a delivery –i.e., scope, quality, and responsibilities– can play a significant role towards realizing business success. The critical point is that, even though there is already a good understanding and experience available on the radio access and/or cloud computing services KPIs, there is no clear vision on a "joint" radio-cloud SLA, which covers both worlds –and related concepts- simultaneously.

In multi-tenant cloud-enabled RAN, there are two main possible ways to form a joint radio-cloud service provisioning:

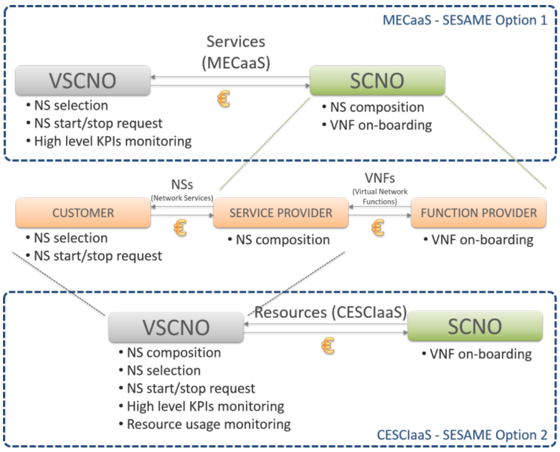


"Mobile Edge Computing as a Service" ("MECaaS") allows the Mobile Virtual Network Operator (MVNO) to rely completely upon the infrastructure and other services provided by the Mobile Network Operator (MNO). A VSCNO asks for high-level KPIs on the SLA and on the cloud. Here, a VSCNO only has an overall vision of the system and the SCNO has to provide enough support both in terms of hardware and number/composition of VNF chains to meet the agreed KPIs.

"CESC Infrastructure as a Service" ("CESCIaaS"), where a VSCNO asks for connectivity in a certain coverage area and is able to compose VNF chains on demand to configure its Network Services (NS). A third party SCNO hosts hardware and other infrastructure components on behalf of its users (VSCNO). "Infrastructure as a Service" ("IaaS") providers also host users' applications and handle tasks, including system maintenance, backup and resiliency planning.

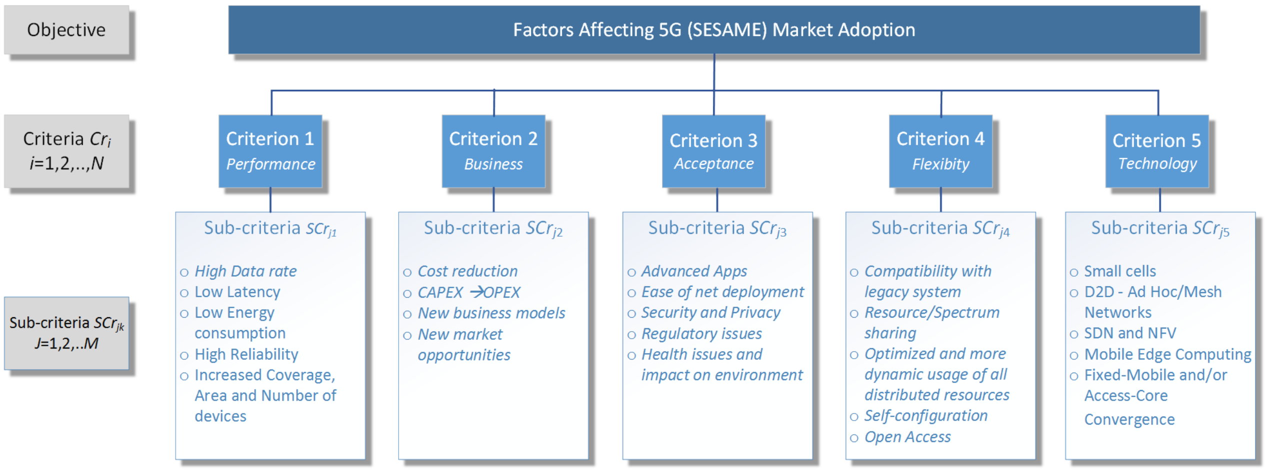
It is evident that significant changes are carried out in the mobile telecoms market, thus leading to new business models and opportunities. The bilateral relationships between mobile operators and their customers have been progressively transformed. Multi-polar decentralized value chains have been evolved, consisting of specialized (existing and/or new) legal entities providing services from different positions of the chain. New actors are expected to emerge, while Over-The-Top players, including vertical industries, may have benefits from this trend. The combined use of NFV and SDN will reduce CAPEX and OPEX thus "lowering" the barriers to entry, while optimization of operations is expected to reduce the time-to-market for new players.

However, the increased competition along with the changes introduced by the softwarization of networks, implicates for the use of new pricing schemes. Traditional models such as "flat rate" and "pay-as-you-go" (or hybrid) are no longer sufficient and should be evolved in order to take into account aspects related to the processing capability, such as memory or Central Processing Unit (CPU) (percentage or number of cores) usage by Virtual Machines (VMs) in a server etc. In addition, more dynamically- pricing schemes in which negotiations will be performed between infrastructure providers, VSCNOs and end-users, should appear.



In order to "prioritize" the various factors affecting the SESAME market adoption, a road-mapping activity will be initially conducted. Then, a techno-economic analysis will be performed assessing the viability of the proposed solution.

The first step towards "determining the critical factors that will affect the market adoption of 5G networking" is to construct the hierarchy of the problem under investigation, according to the Fuzzy Analytic Hierarchy Process (Fuzzy AHP) methodology. This hierarchy consists of the objective along with the criteria and sub-criteria describing the related problem. After interactive discussions and considerations among the SESAME partners, criteria and sub-criteria have been defined, thus forming the following hierarchy.



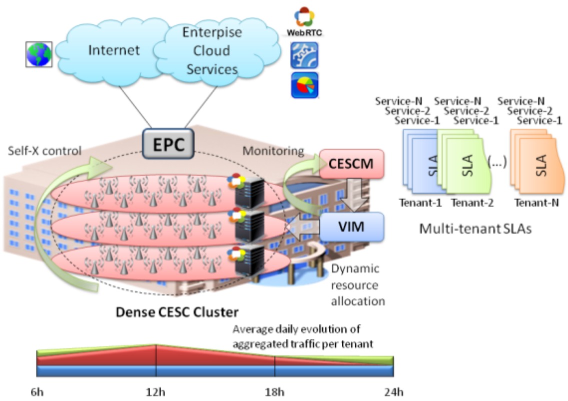
Based on the above hierarchy a questionnaire has been conducted and distributed. Next steps include the collection of the distributed questionnaire(s) and the processing of the received data in order to prioritize both criteria and sub-criteria. In a second phase, revenue streams will be identified, demand and pricing modelling and forecast will be performed thus facilitating the techno-economic analysis and leading to the financial assessment of the proposed solution. It should be noted, however, that demand modelling will be of high importance, since an explosion is expected to happen in the 5G era with billions of connected devices.

SESAME Deliverable D8.1 "Plans for Dissemination, Communication, Standardisation and Exploitation, Interaction with 5GPPP"
SESAME Deliverable D8.3 Dissemination, Communication and Standardization Report – Period 1

Scenarios

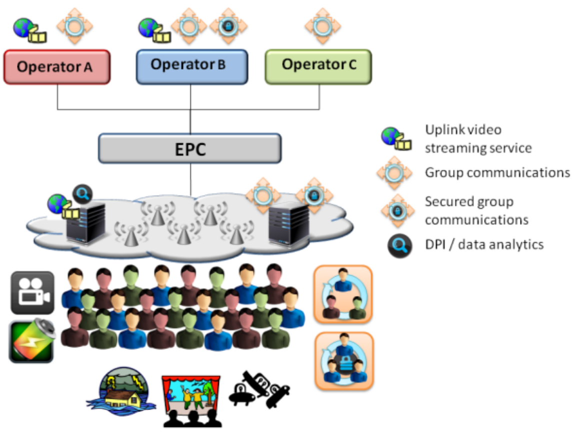
Three initial "target" scenarios have been identified as "promising fields" for the applicability of the SESAME concepts, which can be further used as the basis for the formulation of a number of specific use cases.

A description of the three scenarios, highlighting the main challenges, the applications and services in-scope as well as the respective SESAME components and capabilities is provided in *SESAME Deliverable D2.1*



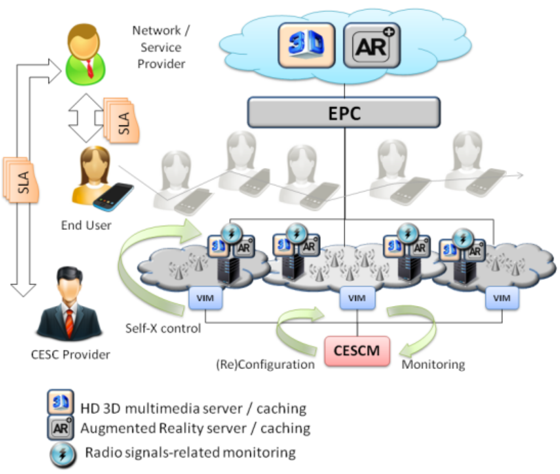
SESAME Scenario 1:
Enterprise Services in Multi-Tenant Large Business

One CESC provider owns, deploys and maintains the network infrastructure of SC and Light DC. The CESC provider establishes an SLA with each customer enterprise, to enable access to different services.



SESAME Scenario 2:
Enhanced Service Experience on the move

A CESC provider manages several geographically adjacent distributed CESC clusters and supports a single mobile network provider offering service to his end users through the CESC infrastructures.



SESAME Scenario 3:
Service Provisioning in Flash Events

This scenario is relevant to address the sudden gathering of crowds in time and space due to unexpected live events or emergency situations. The solution is to leverage the CESC cluster resources, which are essentially a collection of a number of CESCs.

Use Cases

Main focus of SESAME is the support of the identified scenarios via elaborating different use cases, in different contexts and applications, while serving a wide diversity of service provision aspect. These include, inter-alia: changes in network topology; increasing capacity requirements in dense environments, etc. Those scenarios will exploit system capabilities and solutions together with network and topology integration.

The following use cases have been identified and analysed:

SESAME Use Case1:

Elastic operator SLAs enforcement in multi-operator CESC with edge monitoring and control.

SESAME Use Case2:

Indoor Small Cells

SESAME Use Case 3:

Managing inter-tenant smart traffic classification and network optimization and intra-tenant service¬-aware routing based on QoS differentiation

SESAME Use Case 4:

Service Function Chaining (SFC) in multi-tenant and multi-provider network

SESAME Use Case 5:

Optimized Radio Network Capacity Planning and Operation mechanisms of the Small Cell Network Operator

SESAME Use Case 6:

Blind Spot

SESAME Use Case 7:

Communications in High Density Areas

SESAME Use Case 8:

SESAME Platform Deployed for a moving hotspot

SESAME Use Case 9:

Wireless Critical lifeline communication

SESAME Use Case 10:

Sporadic Crowd Event

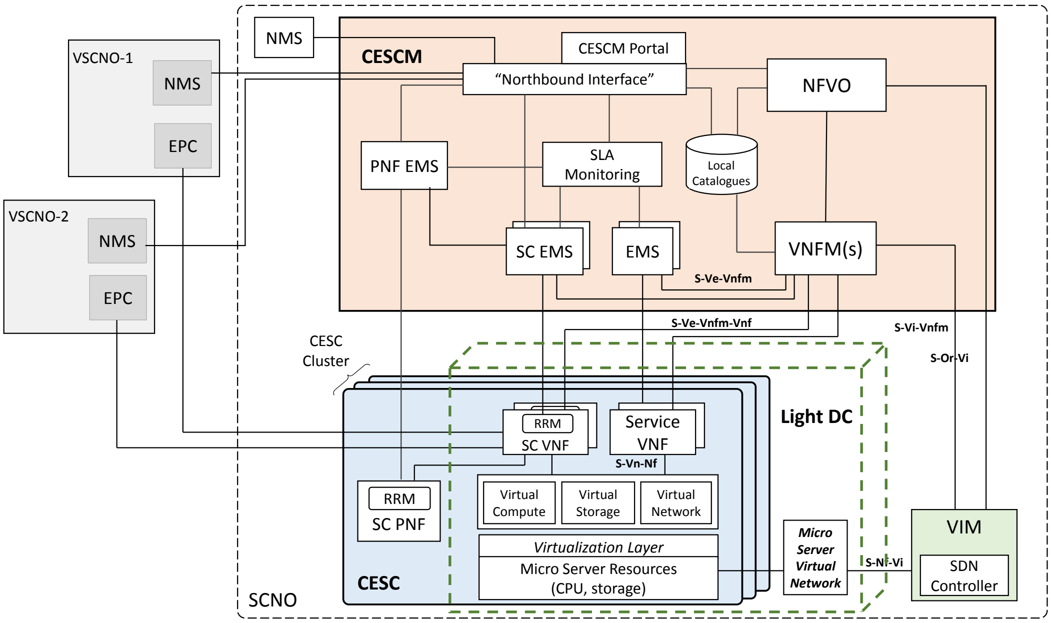
SESAME Use Case 11:

Multimedia services at the mobile edge and inter-operator edge caching.

SESAME Deliverable D2.1 "System Use Cases and Requirements"

Overall Architecture

One of the main challenges in SESAME is to form a management/orchestration system able to simultaneously control radio and cloud resources. Such system from one side should be able to support todays network providers Network Management System (NMS) interaction with the radio resources in one point of presence while, on the other side, should be able to create a platform to handle defined cloud management by the European Telecommunications Standards Institute (ETSI).



Based on the traditional mobile network architecture, SESAME comprises the following concepts:

Small Cells (SC) providing improved cellular coverage, capacity and applications for homes and enterprises as well as dense metropolitan and rural public spaces. Also known as "Home-eNB" (HeNB), in 3GPP terminology.

Radio Resource Management (RRM) including functions for managing the limited set of radio resources in the SC.

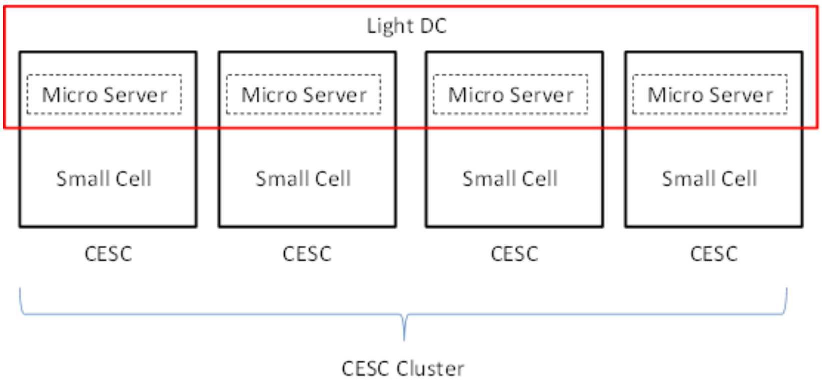
Network Management System (NMS), which is the central point for management of the operator network.

Element Management System (EMS), which is the software entity in charge of the fault, configuration, accounting, performance, security (FCAPS) operations of each Network Element.

SESAME extends the concept of SC and RAN via enabling them for NFV:

Cloud-enabled SC (CESC) is a multi-operator enabled SC that integrates a virtualized execution platform equipped with a micro-server to support the execution of VNFs inside the RAN.

Light Data Centre (Light DC) is the SESAME NFVI, made up of the aggregation of the different micro-servers of each CESC, included in a cluster. The concept of Light DC enables running VNFs of the different VSCNOs in different CESCs in a cloud computing fashion.



SC PNF (Physical Network Function) is the set of SC functions that run in the SC.

SC VNF is the set of SC functions that are deployed as VNFs in the Light DC.

Service VNFs are the edge service instances that are deployed as VNFs in the Light DC.

SESAME leverages on the ETSI architecture for NFV management:

The **CESC Manager (CESCM**) is the set of applications to manage the SESAME Network Services (NSs) and the deployment and composition of VNFs.

The **CESCM Portal** is the graphical user interface for the SCNO and VSCNOs.

The **NFV Orchestrator (NFVO)** is the entity in charge of taking the new network slice requests from the VSCNOs and mapping them to specific VNFs instances and service chaining configurations in the Light DC.

The **SLA Monitoring** beyond the basic NFV monitoring and management, is in charge of monitoring and management of some specific metrics related to the network slice in the RAN, including both radio and cloud related parameters.

The **VNF Manager (VNFM)** is the entity in charge of the lifecycle management of the VNFs.

The **Catalogues** are a repository of available SESAME VNFs, NSs and deployed instances.

The **specific EMS** for PNF, SC and Service VNFs.

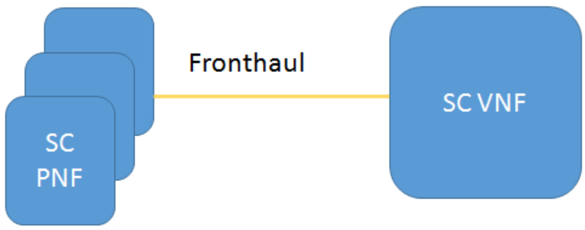
The **Virtual Infrastructure Manager (VIM)** is a software entity that monitors and manages the SESAME NFVI (i.e., Light DC) and performs the lifecycle management of the virtual units that will host the VNFs.

The **SDN Controller** takes into account the physically distributed SESAME NFVI and the stringent requirements in RAN performance metrics, SESAME uses SDN for propagating the VNF chaining requests to the NFVI in order to properly manage the networking resources within the Light DC.

SESAME Deliverable D2.2 "Overall System Architecture and Interfaces"
www.etsi.org/technologies-clusters/technologies/nfv

SC Virtualization and Functional Splits

The functional split divides the Small Cell in two main blocks, that are: the physical small cell and the virtual small cell connected together by the fronthaul link.

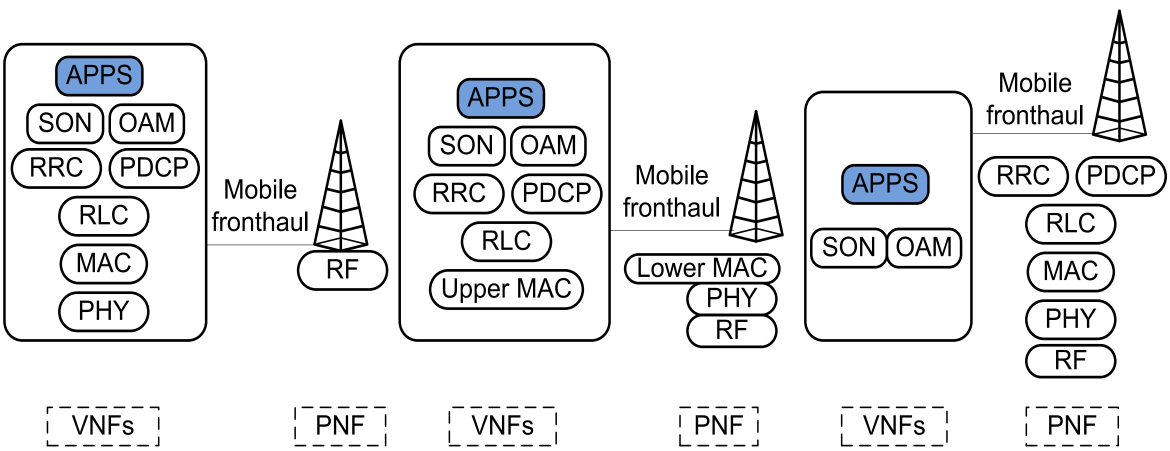


In LTE, the eNodeB is in charge of the Physical layer (PHY), Medium Access Control (MAC), Radio Link Control (RLC), Radio resource Control (RRC) and Packet Data Convergence Protocol (PDCP) functions. Typically these functionalities are split between two main components: (i) a baseband unit (BBU) usually hosted in an equipment closet, and; (ii) a remote radio head (RRH), either at the base or at the top of the tower.

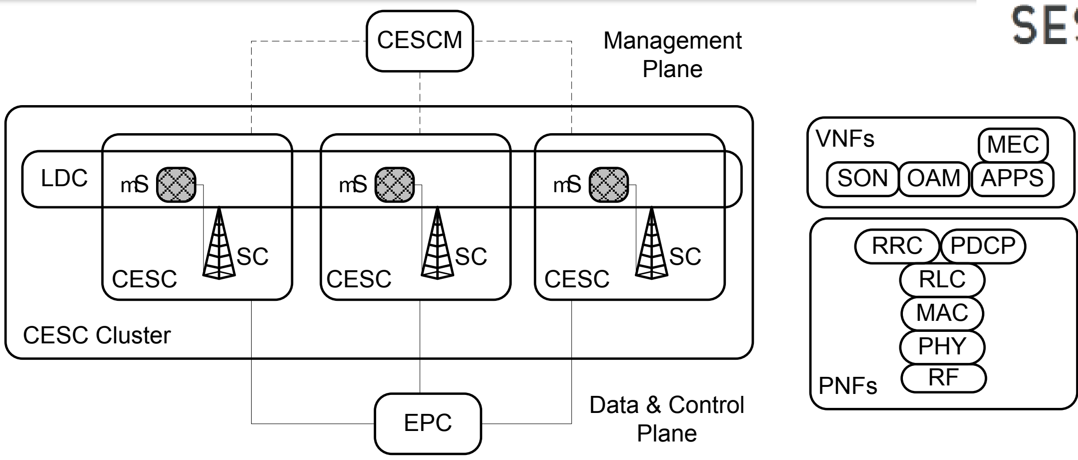
Some -or all- of the RAN functions can be virtualized and deployed as Virtual Network Functions (VNFs). The most significant change, when virtualization is applied to the RAN, is that the VNFs run in virtual machines (VMs) and they may be dynamically listed, created, queried, updated, deleted, rebooted, and resized during their lifecycle.

An extreme case is the Cloud RAN (C-RAN) scenario, where all the above functions of the BBU are virtualised and aggregated into a centralised location, thus forming a Base Band Unit (BBU) pool, where all the processing is performed. The critical point in this approach is the fronthaul, whose requirements are very strict both in terms of bitrate and latency.

Alternatively, instead of virtualising all the RAN functions, it is possible to virtualise only a subset of them. Multiple approaches for partitioning the baseband, mainly distinguished by protocol split, are currently under active discussion in technical forums. In particular, the Small Cell Forum (SCF) recently published its work on *virtualisation* of the RAN where it discusses multiple partitioning approaches for the baseband, which would be suitable for small cells.



a) fully virtualized SC b) partially virtualized SC (1) c) partially virtualized SC (2)



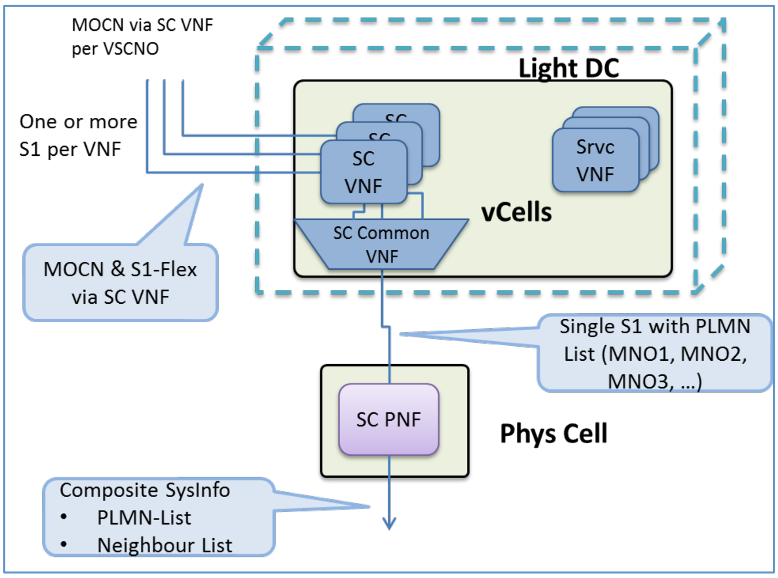
In SESAME, part of the RAN functions is deployed in the micro-server (µS in the figure above), where they are virtualised.

For the Proof-of-Concept (PoC) demonstrator of the SESAME architecture, we have chosen to investigate a functional split based on:

A **PNF**, which is a standard Multi-Operator Core Network- (MOCN-) enabled eNodeB, with an S1 interface to the VNFs in the Light DC (LDC in the figure above).

A **SC-Common VNF** which acts as the aggregation and distribution point for the S1-MME (Mobility Management Entity) links between the various tenants, and the single S1-MME link to the PNF, as well as a location for cross-tenant RRM functions and cross-tenant SLA policy enforcement features which are needed to fulfil the SESAME goals.

The **SC VNFs, one per each tenant**, which implements the SLA policy for each tenant, and has an S1-MME and S1-U link to the tenant EPC.



SESAME Deliverable D2.3 "Specification of the CESC components – First Iteration"
SESAME Deliverable D3.1 "CESC Prototype design specifications and initial studies on Self-X and virtualization aspects"

Approach for Self-X and Small Cell Coordination

Self-Organising Networks (SON), also denoted as "Self-x", functions refer to a set of features and capabilities for automating the operation of a network so that operating costs can be reduced and human errors can be minimised. In SESAME, the "Self-x" functions enable the automated and coordinated operation of the CESCs. They are in charge of tuning global operational settings of the CESCs (e.g., 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.). SESAME Self-X functions are organised around the following main categories:

- *Self-planning:* Automation of the process of deciding the need to roll out new CESCs in specific areas, identifying the adequate configurations and settings of these nodes, as well as proposing capacity extensions for already deployed nodes (e.g. by increasing channel bandwidths and/or adding new component carriers). Functions belonging to this category include the planning of a new cell and the spectrum planning.
- *Self-optimization:* Once the network is in operational state, the self-optimization includes the set of processes intended to improve -or maintain- the network performance in terms of coverage, capacity and service quality by tuning the different network settings of the CESCs. Examples include Mobility Load Balancing (MLB), Mobility Robustness Optimisation (MRO), Automated Neighbour Relation (ANR), Coverage and Capacity Optimization, optimization of admission control, optimization of packet scheduling, inter-cell interference coordination and energy saving.
- *Self-healing:* Automation of the fault management processes (i.e., fault detection, diagnosis, compensation and correction), usually associated to hardware and/or software problems, in order to "keep" the network as operational and/or prevent disruptive problems from arising. Examples include Cell Outage Detection and Cell Outage Compensation.

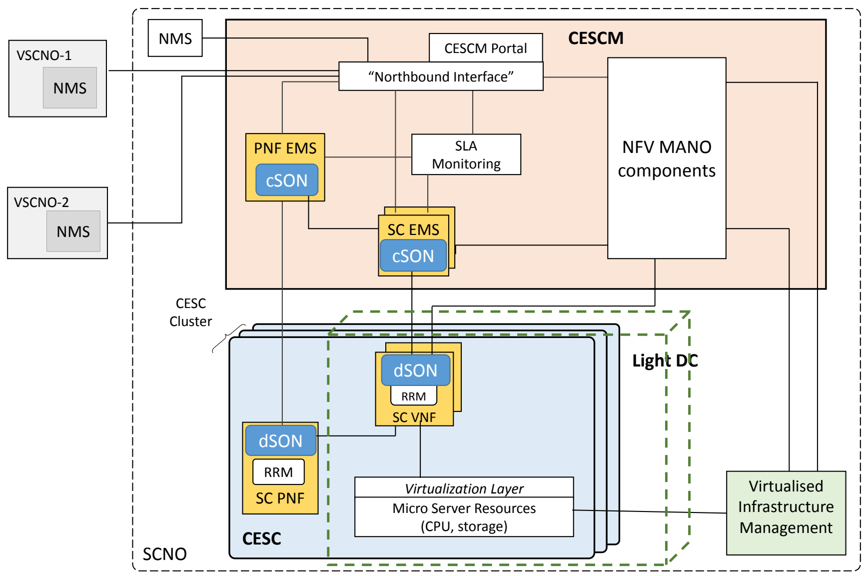
The figure below depicts a simplified view of the SESAME architecture focusing on the Self-X functionalities. As illustrated, the PNF EMS and SC EMS include the centralised SON (cSON) functions while the distributed SON (dSON) functions reside at the CESCs. The use of cSON enables the harmonized and coordinated operation of the dSON functions, by providing them with guidelines and parameters.

Furthermore, whatever Self-X function is considered of interest to be deployed, it can be implemented as a PNF or, if proper open control interfaces with the element controlled by the self-x function are established, it can also be implemented as a VNF running in the light DC. The implementation as VNFs provides: (i) An

inherent flexibility through easy instantiation, modification and termination procedures; (ii) an inherent efficiency in hardware utilisation, since VNFs are executed on a pool of shared NFVI resources, and; (iii) an inherent capability to "add" new functionalities and/or extend/upgrade/ evolve existing VNFs.

Different initial studies are being carried out related to Self-X in multi-tenant scenarios, as documented in SESAME Deliverable D3.1. Some examples are summarized as follows:

- Analysis of the implications of multi-tenancy, identifying which functions should be common to all the tenants and which ones can be customized on a per-tenant basis. The analysis has considered in particular the functions related with mobility control, namely ANR, MLB and MRO.
- Relationship with RAN slicing. Four RAN slicing options are presented in SESAME Deliverable D3.1 that differ on the RRM functions used as a support for splitting the radio resources between slices. They offer different degrees of customisation among tenants, because they establish the RRM and associated Self-X functions that can be implemented by following tenant-specific policies.
- A knowledge-based framework for supporting Self-X is being developed, relying upon the use of techniques from the Artificial Intelligence (AI) field. It processes input data from different sources and extracts, through learning-based classification, prediction and clustering tools, knowledge models used to drive the Self-X decisions. The applicability of the framework is studied in use cases related to energy saving, spectrum planning or mobility prediction.



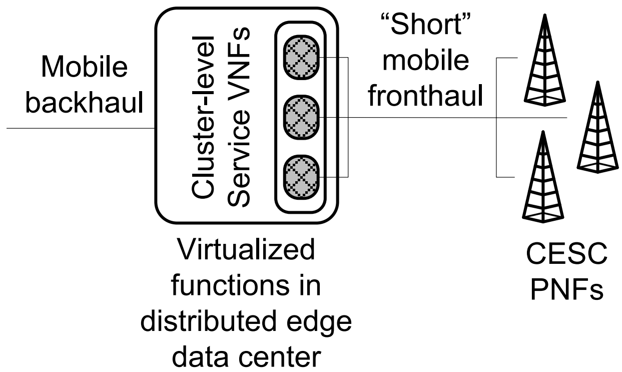
SESAME Deliverable D3.1 1 "CESC Prototype design specifications and initial studies on Self-X and virtualization aspects"

Approach for Edge Service Instantiation

The Cloud-Enabled Small Cell (CESC) infrastructure introduced by SESAME is a multi-operator enabled Small Cell with an integrated virtualised execution platform for deploying VNFs, which allows executing novel applications and services inside the access network infrastructure. Each Small Cell (SC) is enhanced with an execution infrastructure (i.e. the micro-server) that allows adding intelligence at the network's edge through the use of Network Functions Virtualisation (NFV) and Edge Cloud Computing.

The inclusion of Mobile Edge Computing (MEC) capabilities in the CESC leads to increasing responsiveness from the edge of the network, thus allowing the implementation of strategies for enriching the end users' experience. At the same time, thanks to the CESC multi-tenant built-in support, operators can open the radio network edge to third-party partners, thus allowing them to rapidly deploy innovative applications and services.

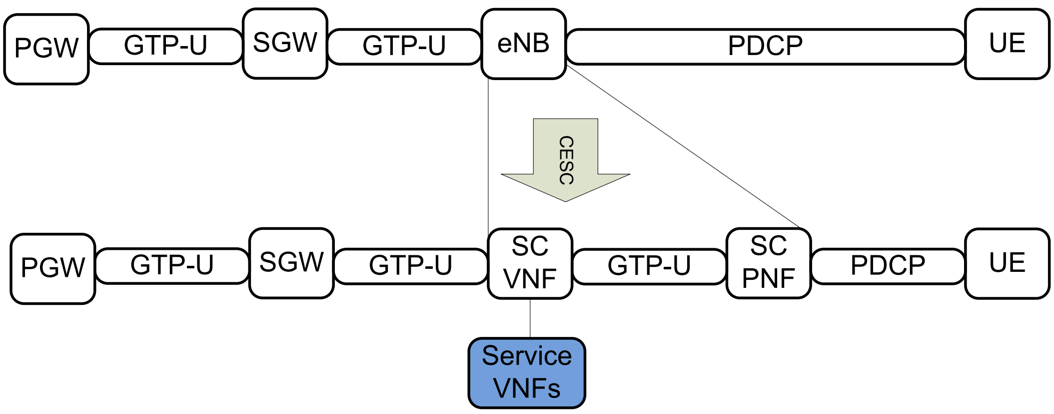
In SESAME, MEC-driven service instances are deployed over the cloud resources available at the RAN side, represented by the Light DC. In other words, part of the resources of each CESC micro-server is devoted to running the SC virtualized functions (SC VNFs in SESAME terminology), while the remaining resources are made available for running mobile edge service instances (Service VNFs in SESAME terminology) devoted to deploy shared service-level functions within the CESC cluster.

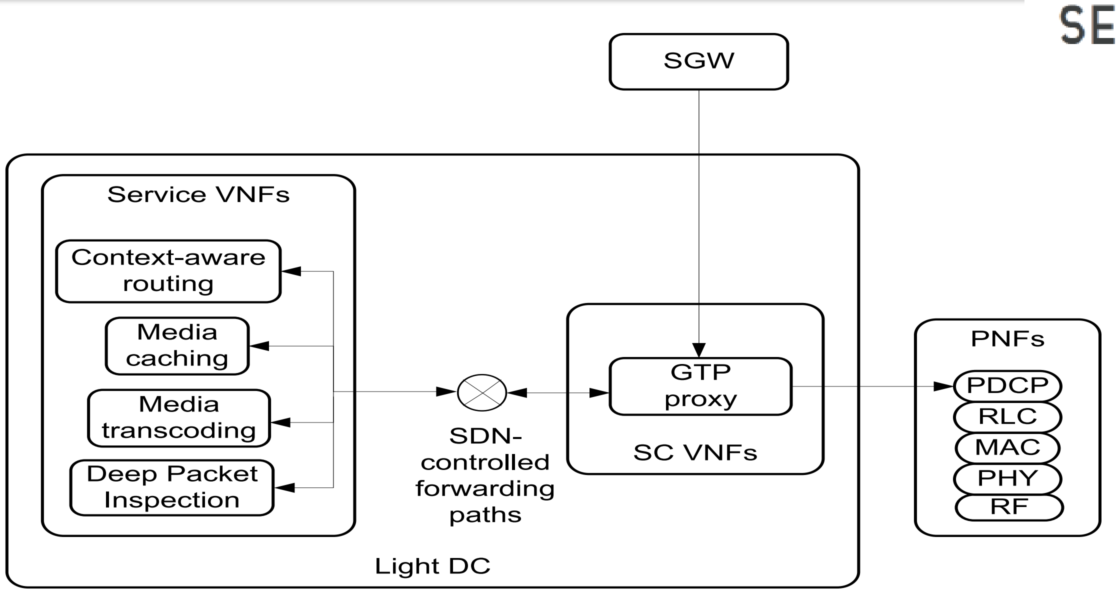


From the Service VNF standpoint, the service instances are orchestrated at cluster level to be deployed in the distributed micro-servers of the Light DC.

SESAME PoC analyses the inclusion of four different Service VNFs:

- vCaching
- vTu
- vCAR
- VDPI





In SESAME four different cases of service provisioning are considered:

SESAME legacy 3GPP control plane and data plane

For the C-Plane and typical U-Plane traffic, all the user packets are encapsulated at the SC PNF with GTP-U and transported over IP towards the specific VSCNO Service Gateway (SGW). In this case, the data packets arrive at the SC VNF and are not forwarded to the Service VNFs.

SESAME data plane with external services with edge content modification

This type of service also requires the connection with external servers for the service provision, but the data packets can be forwarded to a local Service VNF for its further processing. An example would be the use of a transcoding VNF for the Uplink (UL) or Downlink (DL) streams. The associated traffic needs to be handled forward and back to the SC VNF in the transit.

SESAME data plane with external services with edge transparent caching

This type of service generally requires the connection with external servers for the service provision, but the data packets can be derived to a local Service VNF acting as a transparent cache of contents. Therefore, the data packets need to be moved forward and back to the SC VNF for caching in the first request, and forwarded or not to the Evolved Packet Core (EPC) based on its local availability in subsequent requests.

SESAME data plane with local services

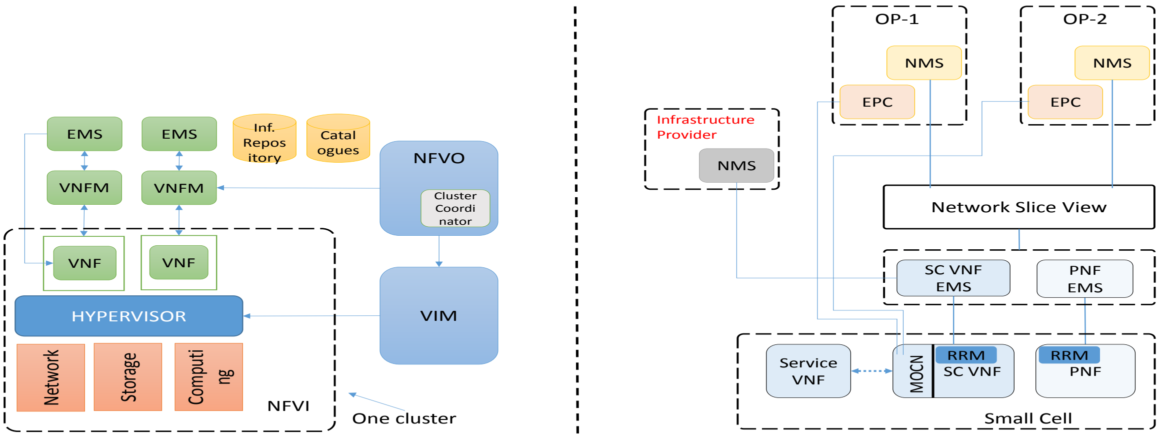
The last example network service involves the deployment of local services, e.g. enterprise services, which do not require traversing the VSCNO EPC for their provisioning. In order to implement these services , the traffic needs to be forwarded between the SC VNF and Service VNFs without going out to the VSCNO EPC.

SESAME Deliverable D2.2 "Overall System Architecture and Interfaces – First Iteration"
SESAME Deliverable D2.3 "Specification of the CESC components – First Iteration"

SESAME

Approach for Multi-Tenancy

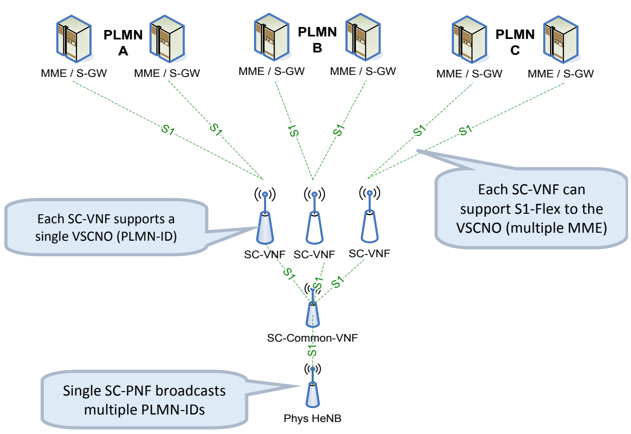
Multi-tenant RAN through MOCN and use of S1-Flex



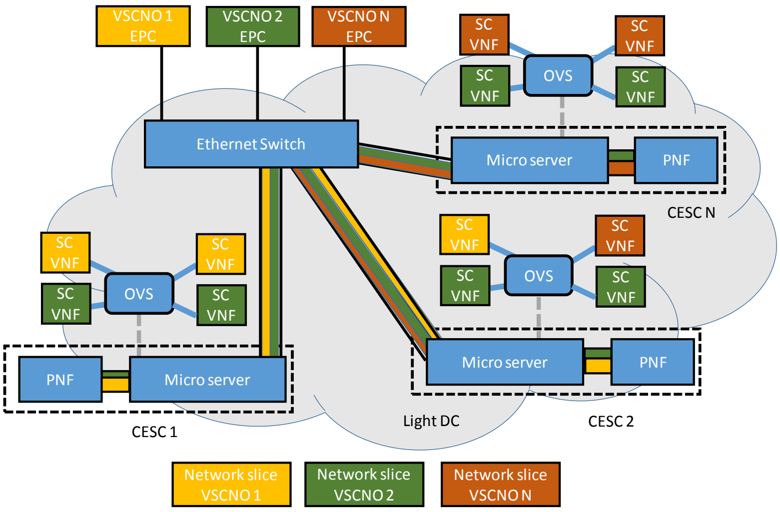
A Small Cell network capable to support more than one network operator is envisaged (right-hand side of the figure). 3GPP specifications have already added some support for Radio Access Network (RAN) sharing. Although two main architectures are identified, namely Multi-Operator Core Network (MOCN), where the shared RAN is directly connected to each of the multiple operator's core networks, and Gateway Core Network (GWCN), where a shared core network is deployed so that the interconnection of the multiple operator's core networks is done at core network level, the MOCN case has been identified as the exclusive enabler for multi-tenancy features in SESAME platform.

S1-Flex is a separate but related feature to MOCN. In a non-MOCN S1-Flex deployment, an eNodeB has multiple S1 connections serving a single Public Land Mobile Network (PLMN) -or a set of PLMNs- and uses them for the purpose of load-sharing and resilience. If the User Equipment (UE) has not provided a Registered MME identity, the eNodeB selects an S1 connection for the UE, using a weighted random mechanism based on relative MME capacity. When MOCN is added to the mix, the eNodeB must also consider which PLMNs are served by each S1 connection and eliminate from the selection those that do not serve the UE's Selected PLMN.

Each CESC supports up to 6 PLMN IDs, but the CESCs in a Cluster are not required to support the same PLMN IDs, so more VSCNOs may be supported by a Cluster



Deployment of multi-tenant VNFs through NFV support



that includes the VNF instances supporting the different KPIs required by the VSCNO.

The following two concepts are the main building blocks in SESAME NSs.

The **VSCNO Network Connectivity Topology (NCT)** determines the complete list of VNFs and their **Connection Points (CPs)**, as well as the possible interconnections through a series of **Virtual Links (VLs)**. In this sense, the VSCNO NCT can be seen as the virtual network slice assigned to that VSCNO in the CESC Cluster.

SESAME Network Service (NS) is a collection of VNFs that includes all the network and service instances required to deploy a complete mobile service for the end users of the VSCNO. Therefore, a SESAME NS can be characterized through a series of radio-level and service-level KPIs that are captured in the SLA between the SCNO owning the NFVO and the interested VSCNO. These KPIs may include bare network parameters (e.g., aggregated uplink (UL) / downlink (DL) bitrate in a certain coverage area for a percentage of time) or more complex service-level KPIs (e.g., a number of supported video sessions with edge caching / edge transcoding features).

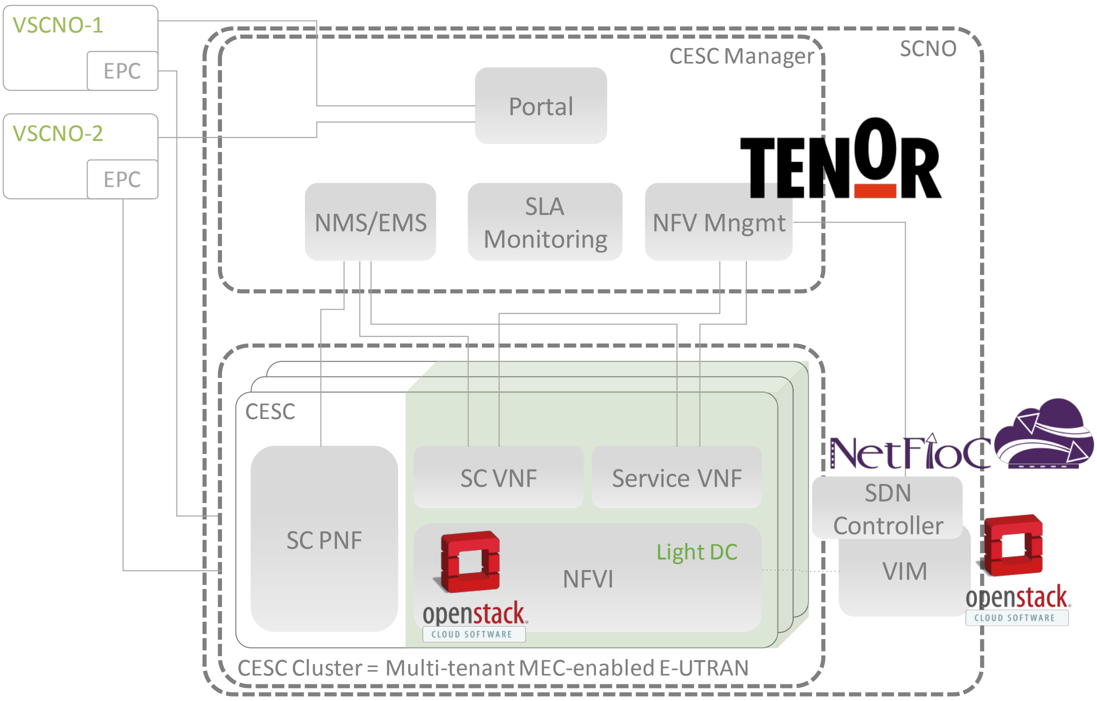
Every SESAME NS is defined through its associated Network Service Descriptor (NSD). In SESAME, the NSD is deployed by the SCNO through its NFVO, and every VSCNO is provided with at least one NS

A VNF Forwarding Graph (VNF-FG) describes the possible paths that data packets can follow within the VSCNO NCT. Generally speaking, a VNF-FG determines the possible data paths for a specific type of service. Depending on the complexity of the considered service, the VNF-FG can be a simple chain of VNFs determining the data path from the entry to the exit point, or a more complex VNF chain with alternative paths that requires decision-making functions within the VNFs. In these cases, the VNF-FG needs to include a specific **Network Forwarding Path (NFP)** for each well-known type of traffic. A NFP is an ordered list of CPs that determines a chain of VNFs from entry to exit.

SESAME Deliverable D2.3 "Specification of the CESC components – First Iteration"
SESAME Deliverable D2.4 "Specification of the Infrastructure Virtualisation, Orchestration and Management – First Iteration"
SESAME Deliverable D6.1 "Orchestrator Architecture Design and Interfaces Specification"

Implementation Details

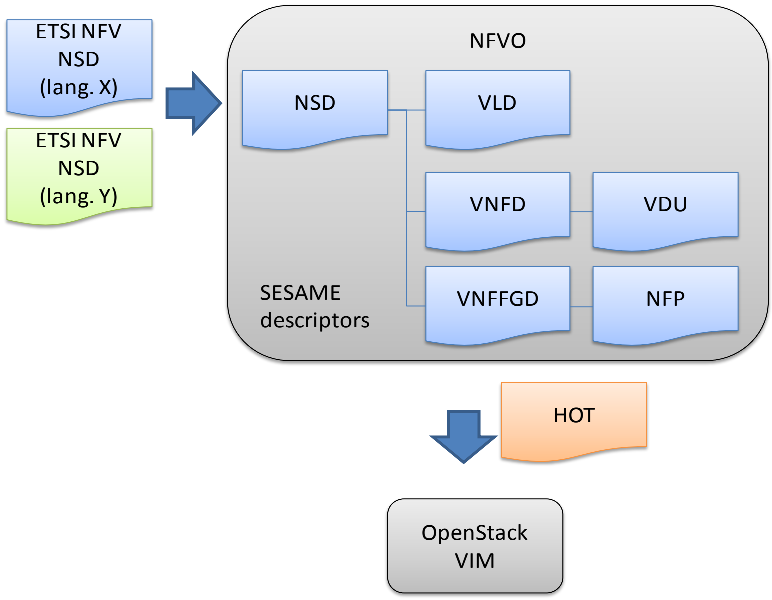
The choice of the CESC model descriptors is mainly driven by two implementation decisions, namely the adoption of TeNOR, i.e. the T-NOVA orchestrator, as a starting point to develop the SESAME orchestration functionality, and of OpenStack as the Virtual Infrastructure Manager.



Based on such choices, the descriptor schemas will be ETSI-compliant based on the ones from T-NOVA as the initial version of SESAME descriptors, slightly modified to adapt them to the SESAME characteristics. Such descriptors will thus be used as the SESAME "internal" data structure, and will be used and processed by the SESAME orchestrator. Furthermore, the orchestrator will translate them into Heat OpenStack Templates, in order to forward the necessary information from/to the VIM.

A Network Service Descriptor, in the SESAME-specific approach, can be created and sent in an NFVO from two different sources. These sources can be either an NMS or a CESCM Portal. After receiving the NSD descriptor, the NFVO component starts the process of "translating" the relevant information from the descriptor into a template.

The main responsibility of NFVO is to perform lifecycle management of network services. On the NS instantiation phase, the NFVO needs to digest the logical view of network service (provided in NSD) into something understandable for VIM (OpenStack). This implicates translation of NSD into an understandable VIM template (Heat). This sort of file will include information such as how many VMs are needed to form NS, what images needs to be placed on each VM, how the internal communication is between internal VNF



components (VNFCs) and one VMF as a whole with another.

To enhance the VIM performance on the networking aspect, Netfloc is used. It is a SDN component build on the top of the OpenDaylight controller.

NETwork FLOws for Clouds (Netfloc) is an SDN-based Software Defined Kit (SDK) for datacentre network programming. Netfloc exposes Representational State Transfer) REST Application Programming Interface (API) abstractions and Java interfaces to enable optimal integration in cloud datacentres and fully SDN-enabled end-to-end management of OpenFlow enabled switches. It is built as modular component aimed for network developers and cloud data-centre administrators. The work in the T-NOVA project related to this component has included the development of two libraries: (i) multi-tenant isolated slices in OpenStack based on SDN (ODL) and; (ii) Service function chaining for deploying orchestrated network service among VNFs deployed in OpenStack cloud. Incremental work on Netfloc will address the requirements of the SESAME SDN control module specificities. Netfloc support for NSD and VNFDs will leverage the NFVO service deployment.

After the NS instantiation, though out communication with VNF manager (which is the responsible element for the lifecycle management of a single VNF) and other CESCM components such as SLA monitoring, the NFVO takes care of its other relevant responsibilities, such as network service monitoring (in terms of service continuity) or network service scaling.

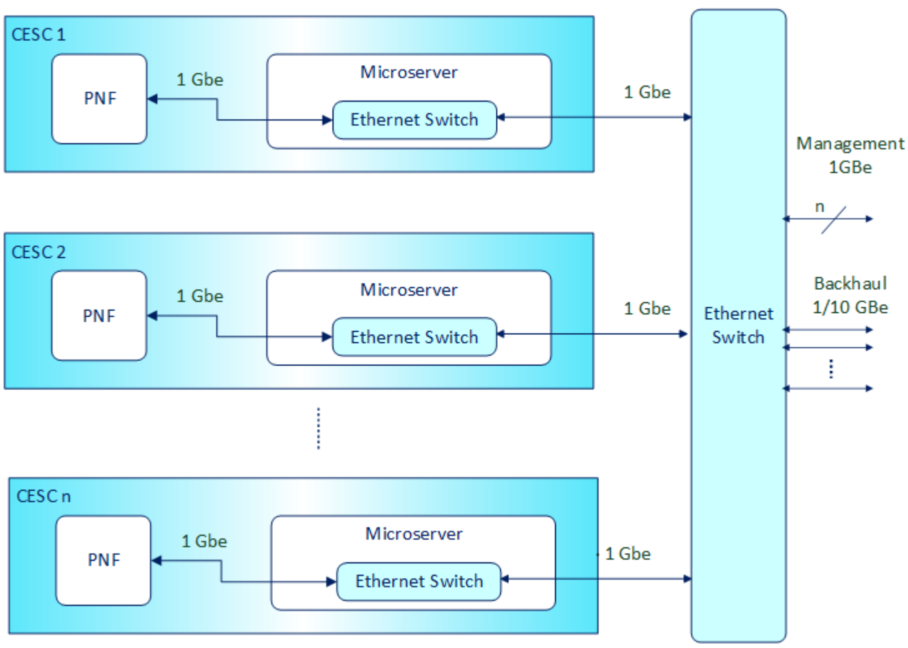
SESAME Deliverable D5.1 "Description of CESC abstraction model"
SESAME Deliverable D6.1"Orchestrator Architecture Design and Interfaces Specification"
www.t-nova.eu

Micro-server HW Architecture

The SESAME Light DC architecture is designed to enhance the virtualization capabilities of the Small Cell deployment, providing high processing power at the network edge. The architecture is optimized to reduce power consumption, cabling, space and cost. To achieve these requirements, the design envisages an infrastructure that aggregates and enables sharing of computing, networking and storage resources, leveraging on the design of a dedicated micro server. The processor chosen as host for the micro server is a System on Chip (SoC) that includes a multi core ARMv8 64-bit CPU and has maximum efficiency as main target. In fact, the ARMv8 architecture introduces the 64-bit support to ARM, providing backward compatibility for the 32-bit software and low power consumption as well. The selected SoC also includes HW accelerators and interfaces dedicated to networking and packet processing.

Additional computational requirements (e.g. for audio and video transcoding, security features, crypto engines) are implemented within the SoC or, hosting standard Peripheral Component Interconnect (PCI) Express (PCIe) cards, equipped with different types of hardware accelerators (Filed Programmable Gate Arrays (FPGAs), Digital Signal Processors (DSPs), Graphic Processing Units (GPUs)). HW Accelerators are hardware components able to perform some *specific* functions faster and more efficiently than possible on general-purpose CPUs. By specializing for a specific workload, accelerators can realize orders-of-magnitude performance improvements. The main task of hardware accelerators is to offload workloads from the host CPU increasing performance. Their use also enables the reduction of the number of physical servers, footprint, network appliances and overall power consumption.

The micro server provides also the HW resources needed for the virtualization of the hardware accelerators, thus enabling the VNFs to increase their performance. The micro server can host, optionally, one or two storage devices, attached via Serial Advanced Technology Attachment (SATA) interfaces, enabling the possibility to realize a distributed architecture for the storage system



of the Light DC.

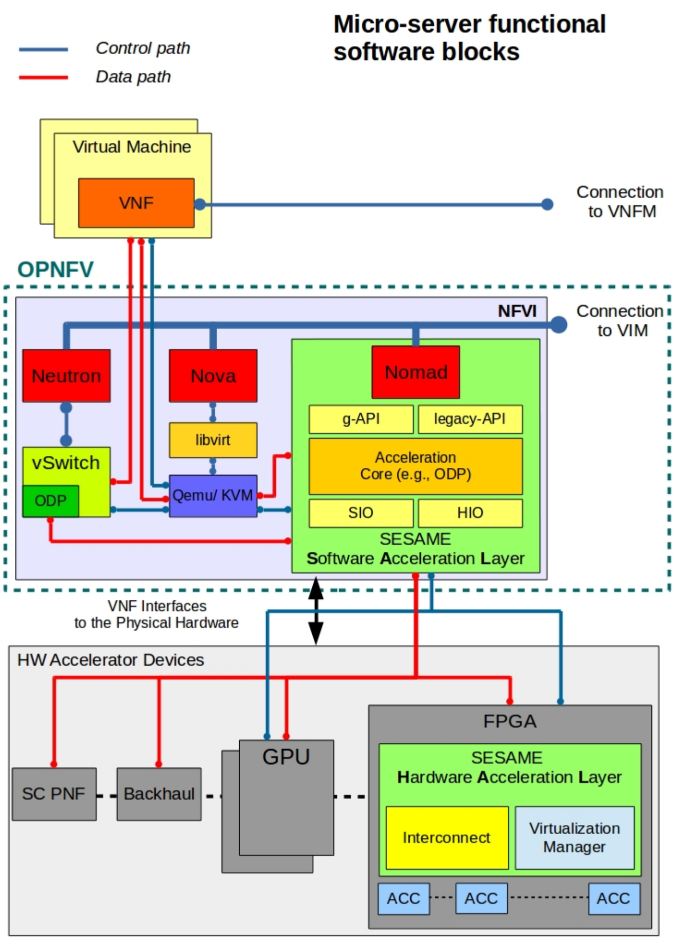
The main goals obtained by the adoption of this architecture are reliability and easy scalability in capacity, thus reducing the cost of the infrastructure.

Two types of hardware platforms have been chosen for the implementation of the SESAME micro-server. One is low performance with lower power consumption, while the second offers more resources at a higher energy consumption cost.

Both platforms share common software blocks. Essential components are Qemu, an ARMv8 KVM enabled Linux kernel, libvirt. Furthermore, with OpenStack being the VIM of choice for SESAME, its agents are also part of the micro-server software baseline. On top of this, the virtual L2 network switch VOSYSwitch and the SESAME Software Acceleration Layer (SAL) provide accelerated networking and computing at the network edge, which is one of the outstanding aspects of the SESAME project. The software baseline of the micro-server is Open Platform for NFV (OPNFV) compliant. In fact, the work on SESAME leads to contributions to the OPNFV Data Plane Acceleration (DPACC) architecture document and the GAP analysis for OpenStack.

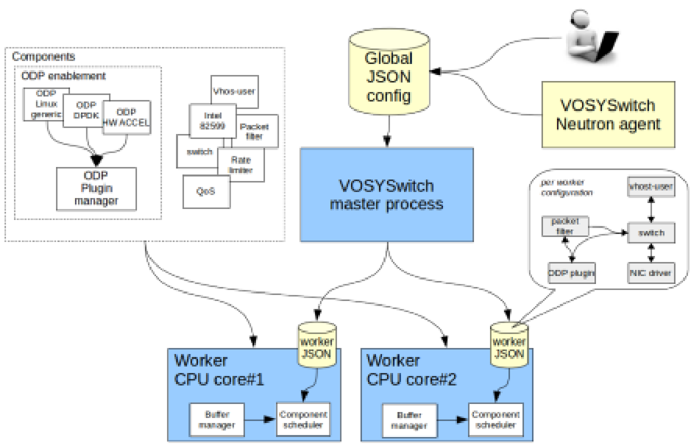
An important component of the software architecture are OpenStack agents, such as Nova, Neutron and Nomad. They assure management communication between the micro-server and the VIM. One of them, introduced in SESAME, is Nomad. It is an OPNFV DPACC initiative that aims to provide a standard interface to manipulate hardware accelerators. Nomad is the component that interacts with the SESAME SAL in order to configure available hardware accelerators for use by virtual machines. Moreover, it makes possible live migration of virtual machines using accelerators.

Another essential software block is the accelerated NFV virtual switch developed in the scope of SESAME, named VOSYSwitch. Several approaches have been implemented in order to be able to process the traffic at rates close to those of high-performance Network Interface Cards (NICs), therefore improving connectivity between VNFs at the



SESAME network edge and also to the backhaul. One of the most important techniques is running VOSYSwitch completely in user-space, hence avoiding performance penalty related to context switching. Furthermore, the switch makes use of zero-copy mechanisms via shared memory segments to improve speed of VM-to-VM communication. VOSYSwitch also leverages Open Data Plane (ODP) via a plugin system, allowing native use of a large number of different types of NICs and offloading specific operations to underlying hardware accelerators such as cryptochips. Additionally it supports VLAN (802.1ad), IGMP spoofing and OpenFlow. Indeed, OpenFlow is an essential feature that enables the SDN controller to compose service function chains and perform certain actions on the network packets.

One more outstanding software component is the SESAME Software Acceleration Layer. It manages concurrent access of virtual machines to underlying hardware accelerator resources. Besides access multiplexing of hardware accelerators such as GPUs and cryptochips, an outstanding feature of the SESAME SAL is the ability to provide partitions of FPGA, loaded with specific acceleration code, to different Virtual Machines for use as hardware accelerators. Moreover, those partitions can be reconfigured without need to restart or reconfigure the FPGA. To achieve this, the SESAME SAL interacts with the Hardware Accelerator Layer (HAL), which is a collection of hardware extensions to enable virtualization of hardware acceleration resources. The HAL is composed of a Virtualization Manager, in charge with management and reconfiguration of the hardware accelerator partitions of the FPGA and a Virtualization Layer, exposing the partitions as independent devices to the host platform.



SESAME Deliverable D4.1 "Light DC architecture design"
http://www.virtualopensystems.com/en/products/vosyswitch-nfv-virtual-switch/

MAIN EDITORS

Begoña Blanco (University of the Basque Country UPV/EHU)
Jose Oscar Fajardo (University of the Basque Country UPV/EHU)
Fidel Liberal (University of the Basque Country UPV/EHU)

CONTRIBUTORS

Cristina Costa (CREATE-NET)
Leonardo Goratti (CREATE-NET)
Cristina Ruiz (Fundació i2CAT)
Pouria S. Khodashenas (Fundació i2CAT)
Ioannis Chochliouros (Hellenic Telecommunications Organization S.A. - OTE)
Ioannis Neokosmidis (INCITES Consulting S.A.R.L.)
Theodoros Rokkas (INCITES Consulting S.A.R.L.)
Alan Whitehead (ip.access Limited)
David C Brock (ip.access Limited)
Antonino Albanese (ITALTEL)
Paolo Secondo Crosta (ITALTEL)
Ioannis Giannoulakis (N.C.S.R. "Demokritos")
Jordi Perez-Romero (Universitat Politecnica de Catalunya - UPC)
Pavel Bliznakov (Virtual Open Systems)
Michele Paolino (Virtual Open Systems)
Irena Trajkovska (Zurich University of Applied Sciences - ZHAW)

SESAME
Small cEllS coordinAtion for
Multi-tenancy and Edge services

http://www.sesame-h2020-5g-ppp.eu/
http://www.sesame-h2020-5g-ppp.eu/Dissemination.aspx

Grant Agreement: 671596

SESAME