Putting Intelligence in the Network Edge Through NFV and Cloud Computing: The SESAME Approach

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Abstract. The core challenges in the actual SESAME EU-*funded* project is to develop an ecosystem to sustain network infrastructure openness, built on the pillars of network functions virtualization (NFV), mobile-edge computing (MEC) capabilities and cognitive network management that will provide multi-tenancy and flexible cloud-network interaction with highly-predictable and flexible end-to-end performance characteristics. Based on this aspect, we discuss the potential benefits of including NFV and MEC in a modern mobile communications infrastructure, through Small Cells coordination and virtualization, also focused upon realistic 5G-*oriented* considerations. Within the proposed SESAME architecture, we also assess the various advantages coming from a more enhanced network operation and management of resources, as it appears with the incorporation of cognitive capabilities embracing knowledge and intelligence.

Keywords: 5G · Edge cloud computing · Mobile edge computing (MEC) · Network functions virtualization (NFV) · Small cell (SC) · Self-X functions · Virtual network function (VNF)

1 Towards a Modern 5G-*Based* Automated World

In our modern societies, electronic communication networks are more than "*simply fundamental*" for the adequate offering of an extended "set of services and/or related facilities", for the benefit of all involved market "actors" (i.e., corporate users, residential users, the State and local authorities, etc.). Such kind of infrastructures are able

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to 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". Moreover, apart from the well-known electronic communication networks there is also a variety of critical infrastructures (such as energy, transportation, health, water and many more) that are gradually becoming reliant upon Internet connectivity, adequacy and automation. Thus, Internet which is so correlated to an immense multiplicity of underlying networks, services and equipments 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 also implicates for an enhanced - and occasionally for an automated- use of all related available resources, of any probable origin/nature. In order to face this significant challenge, the "fifth generation" of telecommunications systems, or "5G", has been assessed as the most critical building block of our "digital society" in the next decade [1] and it has been promoted as a core strategic perspective for an effective global growth. 5G should "bring together" wired and wireless communications by providing virtually ubiquitous, ultra-high bandwidth "connectivity", including not only distinct users but also numerous (Internet-) connected objects [2]. The future 5G infrastructure is expected to support an extended variety of converged networks/infrastructures able to support a diversity of services/applications and related equipment/devices, also including professional uses (e.g., eHealth, energy management, possibly safety applications, etc.). 5G is aiming to be reasonably different compared to any prior technology. It is about more than just "*raising the bar*" on previous generations, or extending them to a certain context [3]. Thus 5G will not only be a single "progression" -or a "simple evolutionary step"- of mobile broadband networks; nevertheless, it is expected that it should "bring" innovative and exceptional network/service capabilities, in common with modern applications and related facilities and should be an "enabler" of the Internet of Things (IoT).

In addition, 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, as well as for the anticipated "convergence" of all "underlying" fixed, mobile and broadcast services. Within this scope, 5G will also support multi-tenancy models [4], thus enabling operators and other market players to collaborate in new ways, enhancing opportunities for growth and development within an intelligent network environment. Furthermore, leveraging 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 should be designed in a way to be a sustainable and fully scalable technology. In view of this aim, cost reduction through human task automation and hardware optimization will allow for supportable business models for all ICT stakeholders to be involved [5].

In this paper, we discuss the challenge of incorporating intelligence at the network edge mainly via the consideration of Network Functions Virtualization (NFV) and Edge Cloud Computing. The introductory part discusses broader challenges for network development and growth, coming from the 5G perspective. Section 2 becomes more specific and correlates actual network operations and management challenges to the NFV and edge cloud computing features, also promoting the context of cognitive features and network autonomicity. The potential benefits coming from a combined approach of network virtualization and edge computing within modern mobile (5G-*based*) infrastructures -that are now assessed via the consideration of Small Cells (SCs)- and towards fulfilling the fundamental aim of improving network management are discussed in Sect. 3; in particular, the presented context is based upon the actual SESAME 5G-PPP EU-*funded* project research effort. Section 4 realizes a step further and discusses exact ways of implementing prior considerations within the SESAME's fundamental architectural framework.

2 NFV and Cloud Computing as "Enablers" of Network Intelligence in 5G Infrastructures

Future networks will need to be deployed much more densely than today's networks and, due to the economic constraints and the availability of sites, will need to become significantly "more heterogeneous" and use multi Radio Access Technologies (RATs). A network needs to be able to scale its operation, even for short time-periods, depending on the widely varying traffic capacity requirements, while it should also remain energy-efficient. Furthermore, in modern (5G) networks, devices are no longer connected to just one single access node; on the contrary, the full picture consists of a combination of multiple physical interfaces based on the same -or different- radio technologies. Fast selection and combination of most -if not of all- of the available interfaces can support an adaptive set of virtual interfaces and functions, subsequently depending on respective applications. SCs can contribute to the effort of making "best use" of novel applications offered by "denser" and more heterogeneous RATs while, *in parallel*, being able to efficiently support several widely varying traffic needs. Furthermore, SCs also support scalability issues ([6, 7]).

In addition, future network deployments have to allow for network/infrastructure/resource sharing and potential re-utilization on all levels, so that to "fulfil" the fast growing demands on network resources management and operation. This is to take place simultaneously with the proper inclusion of cognitive capabilities in the network design on all layers, able to support a flexible network adaptation at low operational costs, towards providing 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 optimisation, fast failure recovery, and fast adaptations to changes in network loads, architecture, infrastructure and technology. 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. In brief, SON is a collection of procedures -or functions- for automatic configuration, optimization, diagnostication and healing of cellular networks [8]. 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.

SON functionalities are also referred to as “Self-x” functionalities and 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 [9]. With the introduction of “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 (e.g., 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.).

On the other hand, today’s networks are populated with a great and growing diversity of proprietary hardware appliances. Launching a new network service often requires yet another variety of appliance, thus increasing the overall complexity of the network and causing a number of issues to be addressed. The shortage of skills necessary to design, integrate and operate increasingly complex hardware-*based* appliances, poses supplementary challenges. Moreover, hardware-*based* appliances rapidly reach their “end-of-life”, requiring much of the procure-, design-, integrate- and deploy-cycle to be repeated with little or no revenue benefit. Worse, hardware lifecycles are becoming shorter as technology and services innovation accelerates, inhibiting the roll-out of new revenue earning network services and constraining innovation in an increasingly network-centric connected world [10].

Network Functions Virtualization aims to “address” these critical problems 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 [11]. Actually, NFV is applicable to any data plane packet processing and control plane function both in fixed and mobile network infrastructures [12]. There are various challenges to implement NFV that need to be examined by the community interested in accelerating technological progress. Based on the original context of the SESAME 5G-PPP project [13] - which is also discussed in more details, in Sects. 3 and 4- we can, *among others*, identify the following meaningful cases: (i) Management and orchestration; (ii) the perspective of automation, *and*; (iii) the options of security and resilience. As of the former case, 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 [14]; 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 [15]. The orchestration and federation of network resources as “network functions” is an important aspect of the future network ecosystem. As such, research is relevant on the way in which resources and functions are described, 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, under the management and orchestration domain. Regarding the option of automation that has been identified in the second case, above, NFV will only scale if all of functions can be automated, while automation of processes is paramount towards improving OAM. As of the latter case (i.e., the third case) which is about security and resilience, it is assumed that network operators need to be assured that the security, resilience and availability of their networks are not reduced -or not 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. In fact, 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 [16].

In addition to the above, ensuring stability of the network is not 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: For the first case, a significant and topical focus for network operators is simplification of the plethora of complex network platforms and support systems, which have evolved over decades of network technology evolution, while maintaining continuity to support important revenue generating services. Regarding the second one, 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. Therefore, the ecosystem needs to offer integration services and maintenance, third-parties support and will require mechanisms to validate new NFV products.

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 [17]. A fundamental 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, but by adopting the principles of Clouds, also elasticity, on-demand availability, lead- and disposal-times, multi-tenancy, resilience, recovery, and similar characteristics important especially in case of cloud-*based* services [18]. However, in order to guarantee this kind of service level, network-*based* service qualities may not be enough, but need to be aligned with platform-level and Cloud specific tenets, like dynamic discovery, replication, and on-demand sizing of Virtual Machines (VMs), since previous over-provisioning best-practices inherent to hosted and managed execution environments are no longer applicable [19].

Edge networks are expected to create distributed environments made of clouds of virtual resources (even operated by diverse players) interconnected by a simpler and less hierarchical core network [17]. 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. Both approaches can be used to extend coverage, increase capacity or enhance quality (for example deploying functionality or locating content near by the customers). The broker functionality can be implemented by one of the players or by a third party. It, *therefore*, represents by itself a business opportunity. 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* in such a way that the network capabilities are exposed to third parties or partners without exposing the level of detail that constitutes the operator's know-how and hence its market differentiation. Interface definition, resource/price discovery, publishing and negotiation and service level monitoring and assurance are also main components of the single domain orchestration. Key elements for the orchestration are the network and service modelling and key optimization algorithms used for resource embedding. The orchestration needs of the future network will involve not only connectivity (and its associated functions) but also computing resources enabling complex network functions ranging from platform to applications.

3 The Innovative Vision of the SESAME-*Based* Research

It is now widely accepted that both mobile data traffic and services have reached to a "critical" level of penetration to our daily activities [1], mainly due to the extreme adoption and use of a great variety of (personalized) applications, serving not only communication and information purposes but also those related to work, leisure, etc. For most -if not for all of these- the requirement is always to "preserve" an acceptable level of the quality of services (QoS) offered, together with the user experience and satisfaction. The evolution of previous technological frameworks (such as 3G and/or 4G) has mainly focused upon the support of network aspects, such as via the promotion of network coverage and capacity, in parallel with improved resource usage [10]. The strategic challenge for 5G, *however*, is not just to create a new paradigm shift via the establishment -and the validation- of a next generation network framework attaining consistent, omnipresent, ultra-low latency, broadband connectivity, able of offering and/or managing critical and highly demanding applications and services [20]. Apart from these explicit and useful aims, 5G intends to enact fundamental changes in network infrastructure management, in particular by supporting the ability to deal with a wide set of miscellaneous use cases and related scenarios. For these purposes, 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. Precisely, a critical challenge among the essential ones in the 5G technological context 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 [12] and Edge Cloud Computing [17]. 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 (MNO), Mobile Virtual Network Operators (MVNO), Over-The-Top (OTT) content and service providers, as these actors -via a respective implementation- can 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, able to be offered "*as-a-Service*".

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 SC 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 [21]; in fact, 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 domains/spaces like shopping malls, performance venues, stadiums and, generally speaking, places with (tactic or sporadic) high end-user density. For the above use cases it is expected that each separate telecom operator should deploy his dedicated infrastructure, as a "complement" to the macro-cell network. The usual SC provisioning implicates for certain time- and money-consuming procedures (such as the provisioning of installation site, power supply, etc.). Involved operators also have to take care of costs of launching committed, high-capacity backhaul connections, as well as those relevant to radio resource management and interference mitigation, thus increasing their operational expenses. This sort of approach is based on the possession of the physical SC infrastructure and becomes "impractical", due to a variety of reasons; it usually results to increase of network CAPEX and sets obstacles to business agility, while it cannot support active scenarios of use. With the intention of responding to such sort of challenges, network operators can alternatively install, and for a certain period of time, a SC network to serve a related event/case, without necessarily owing the related infrastructure. Underlying facilities could be provided by a third party (such as, for example, the owner/operator of the venue). Such shared uses are expected to "play an important role" in 5G networks [21], following to related policy challenges.

Towards covering this high-demanding request and via the conceptual consideration of several fundamental features such as network functions virtualization, mobile-edge computing (MEC) and cognitive management [22], the actual SESAME's EU-funded research effort is the development and demonstration of modern architecture, able to provide SC coverage to multiple operators "*as-a-Service*". SESAME considers the logical partitioning of the localized SC network to several isolated slices as well as their delivery to some tenants. Apart from virtualizing and partitioning SC capacity, the SESAME-*based* effort supports enriched multi-tenant edge cloud services via the by upgrading of SCs with micro-servers [23]. SESAME develops a framework to perform multi-tenant cloud-*enabled* Radio Access Network(s) - RAN(s), via a major conceptual modification of the architecture of commercially offered SCs; it is realized by evolving SCs to the "Cloud-*Enabled* Small Cell" ("CESC"). This modification implicates for "placing" enhanced network intelligence and/or applications in the network edge, with the fundamental support of virtualization techniques and Network Function Virtualization (NFV). Therefore, an innovative architectural framework has been proposed with the aim of attracting network operators/service providers and "engaging" these in a modern multi-tenant ecosystem, able to fulfill 5G visions. The CESC concept is a new multi-operator enabled SC, able to integrate a virtualized execution platform (i.e., the so-called Light Data Centre (Light DC) for deploying Virtual Network Functions (VNFs), supporting strong "Self-x" management and performing innovative applications and services inside the access network infrastructure. The Light DC should feature low-power processors and hardware accelerators for time-critical operations; furthermore, it should structure a highly manageable clustered edge computing infrastructure, with may advantages. This concept allows new market actors to "get stakes" of the value chain as they can operate as "neutral host providers" in high traffic domains where densification of multiple networks is not technically or economically practical. The optimal management of a CESC deployment becomes a core issue for SESAME, implying for further evolution and development of new orchestration, NFV management, virtualization of management views per tenant, "Self-x" features and radio access management techniques.

In addition, the SESAME context with its anticipated distinct innovations manages to extend the "*Small Cell-as-a-Service*" ("*SCaaS*") model [24]; this, *in turn*, enables a the provisioning of shared radio access capacity by a third-party -or entity- to MNOs in certain localized areas, and this is conceived in parallel with the delivery of Mobile Edge Computing (MEC) services. MEC, also known as "*Fog computing*", is an innovative concept that extends the services, typically provided by the Cloud, to the network edge [25]. (In case of 5G wireless networks, the term "edge" usually means the RAN, while some part of the Cloud services is provided by cognitive base stations). Potential facilities to be offered may include storage, computing, data, and application services. Available MEC infrastructure permits running of applications closer to the end-user so that to reduce the E2E network latency as well as the backhaul capacity requirements. MEC also allows for more enhanced quality of experience (QoE) of fast moving end-users and enables highly-interactive real-time applications. Our architectural assumptions are based upon the *SESAME architecture*, as discussed in Sect. 4. Our analysis can be easily extended to "alternative" network architectures and even in the cases of macro-cells or combinations of macro- and small-cells. 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, *inter-alia*, 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. Following to the design and related upgrades of the relevant architecture and of all the involved CESC modules, the SESAME framework will conclude with a prototype with all corresponding functionalities.

4 The Fundamental SESAME Architectural Context

The architecture provided so far by the SESAME project (Fig. 1), acts as a "*solid reference point*" for 5G multi-tenant small cell infrastructures with mobile edge computing capabilities [26]. It combines the current 3GPP framework for network management in RAN sharing scenarios and the ETSI NFV framework for managing virtualized network functions [27]. The CESC offers virtualized computing, storage and radio resources and the CESC cluster is considered as a cloud from the upper layers. This cloud can also be "sliced" to enable multi-tenancy [28]. The execution platform is used to support VNFs that implement the different features of the SCs, as well as to support the mobile edge applications of the end-users.

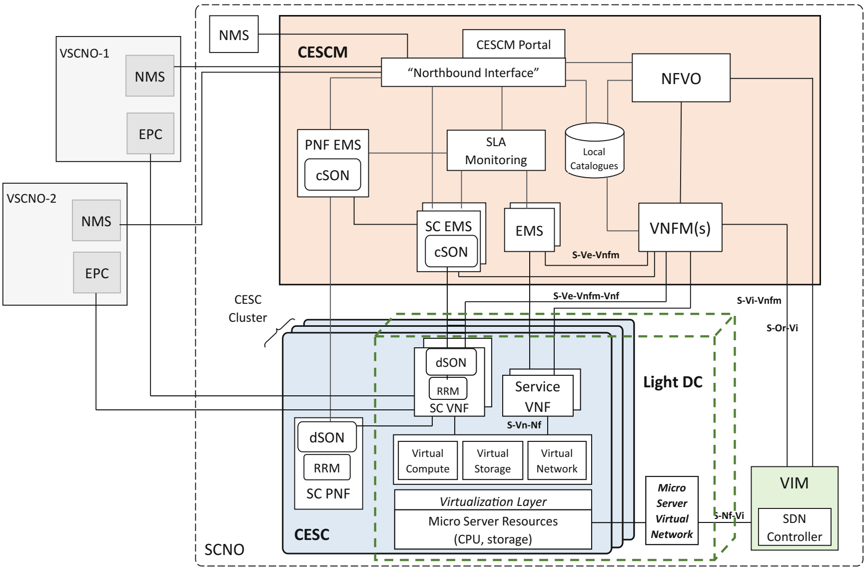

Fig. 1. The SESAME essential architecture.

The overall SESAME system architecture is shown in Fig. 1. The SESAME architecture foresees the split of the small cell physical and virtual network functions [29], respectively Physical Network Function (PNF) and VNF, based on the Multi-Operator Core Network (MOCN) requirements and associated RRM and OAM features, which need to be supported.

The Cloud Enabled Small Cell (CESC) is a complete Small Cell with necessary modifications to the data model to allow MOCN radio resource sharing. The CESC is composed by a Physical SC unit and a micro-server. The physical aggregation of a set of CESCs (i.e.: CESCs cluster) provides a virtualized execution infrastructure, denoted as the "Light DC" [30], enhancing the virtualization capabilities and process power at the network edge. The functionalities of the CESC are split between SC PNFs and SC VNFs; the latter are hosted in the environment provided by the Light DC.

The Light DC encompasses the micro-servers of the different CESCs in a cluster and provides a high manageable architecture optimized to reduce power consumption, cabling, space and cost. To achieve these requirements, it relies upon an infrastructure that aggregates and enables sharing of computing, networking and storage resources available in each micro-server belonging to the CESC cluster. The Light DC infrastructure provides also the backhaul and fronthaul resources for guaranteeing the requirements for connectivity in case of multi-operator (multi-tenancy) scenarios. The hypervisor computing virtualization extensions enable access of virtual machines to the hardware accelerators for providing an execution platform that can support the deployment of VNFs. Different types of VNFs can be deployed through the Virtual Infrastructure Manager (VIM), for carrying out the virtualization of the SC, for running the cognitive/"Self-x" ([9, 31]) management operations and for supporting computing needs for the mobile edge applications of the end-users. The combination of the proposed architecture allows achieving an adequate level of flexibility and scalability in the edge cloud infrastructure [32].

The CESC Manager (CESCM) is the central service management component in the architecture that integrates the traditional 3GPP network management elements and the novel functional blocks of the NFV-MANO (Network Functions Virtualization - Management and Orchestration) framework. Configuration, Fault and Performance management of the SC PNFs is performed through the PNF Element Management System (EMS), while the management of the SC VNFs is carried out through the SC EMS. The EMSs provide performance measurements to the SLA Monitoring module that assesses the conformance with the agreed SLAs. EMSs are connected through the northbound interface with the Network Management Systems (NMS) of the Small Cell Network Operator (SCNO) and the different tenants, denoted as Virtual Small Cell Network Operators (VSCNOs), providing each VSCNO with a consolidated view of the portion of the network that they are able to manage. Finally, the CESCM includes a portal that constitutes the main graphical frontend to access the SESAME platform for both SCNO and VSCNOs.

Automated operation of CESCs is made possible by different SON functions that will tune global operational settings of the SC (e.g., transmit power, channel bandwidth, electrical antenna tilt) as well as specific parameters corresponding to RRM functions (e.g., admission control threshold, handover offsets, packet scheduling weights, etc.). As shown in Fig. 1, the PNF EMS and SC EMS include the centralized "Self-x" functions (cSON) and the centralized components of the hybrid SON functions. In turn, the decentralized (dSON) functions - or the decentralized components of the hybrid functions - reside at the CESCs. The dSON functions can be implemented as PNFs or, if proper open control interfaces with the element (e.g. the RRM function) controlled by the SON function are established, they can also be implemented as VNFs running at the Light DC. The mapping of the specific RRM and SON functions in the different components of the architecture depends in general on the selected functional split between the physical and virtualized functions.

By summarizing, the SESAME project has proposed a detailed architectural framework to implement NFV and Edge Cloud Computing with the pure aim of providing intelligence at the network edge for modern 5G mobile networks that have currently been examined under the SC context [33]. In particular and within certain priorities, 5G also targets at offering rich virtualization and multi-tenant capabilities, not only in term of partitioning network capacity among multiple tenants, but also by offering dynamic processing capabilities on-demand, optimally deployed close to the end-user or the end-device. Furthermore, the SC concept, is expected to be enriched within 5G via the incorporation of virtualization and edge computing capabilities, aiming to provide better cellular coverage, capacity and applications for homes and enterprises, at various public spaces (both rural and urban). The potential benefits from such a combined approach of NFV, Edge Computing and SCs and with the aim of improving network management and operations are critical for most involved market players, as the latter may access new revenue streams. Such a conceptual framework as actually proposed in SESAME may be the "key" for promoting relevant 5G aspects in the market.

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