Service Provisioning and Pricing Methods in a Multi-Tenant Cloud Enabled RAN

P. S. Khodashenas, C. Ruiz, J. Ferrer Riera
I2CAT, Barcelona, Spain
pouria.khodashenas@i2cat.net

J. G. Lloreda
Atos, Madrid, Spain
javier.garcial@atos.net

J. O. Fajardo, I. Taboada
B. Blanco, F. Liberal
UPV/EHU, Bilbao, Spain
joseoscar.fajardo@ehu.eus

J. Pérez-Romero, O. Sallent
UPC, Barcelona, Spain
jorperez@tsc.upc.edu

I. Neokosmidis, T. Rokkas
INCITES Consulting S.A.R.L., Luxembourg
i.neokosmidis@incites.eu

***Abstract*—The Cloud Enabled Small Cell (CESC) concept proposed in EU funded project SESAME has emerged as a promising solution to form a multi-tenant, multi-service architecture at the network edge according to 5G needs. It allows several operators/service providers to engage in a sharing model of both radio access capacity and Mobile Edge Computing (MEC) capabilities. From a business perspective, the shared ecosystem guarantees benefits such as easy system upgrades and CAPEX/OPEX reduction. However, depending on the adapted model which is reflected at Service Level Agreement (SLA) between involved stakeholders, cost and benefit of each party are subject to change. This paper is an effort to identify and analyse different radio and cloud models and pricing schemes for the joint provisioning of radio access capacity and MEC services in a multi-tenant Radio Access Network (RAN).**

Keywords—techno-economy; service level agreement; 5G; mobile edge computing; cloud enabled small cell

I. Introduction

5G technology is a new networking paradigm to overcome the challenges of the future communication. It aims to support extraordinarily high speeds and capacity, multi-tenancy, self-X, unconventional resource virtualisation, on-demand service-oriented resource allocation and automated management and orchestration [1]. By these means, 5G paves the way for the novel vertical sectors such as Industry 4.0, Smart Grids, Smart Cities, and eHealth to enter the value chain and generate revenue. It is expected that besides improving the citizen's digital experience, such a market revelation contributes significantly to the EU economy each year and creates hundreds of thousands of new jobs mostly for the small and medium-sized businesses (SMBs) [1].

To deliver a viable solution meeting all 5G requirements, a substantial change on the network paradigm is inevitable, especially at the network edge. One of the main pillars of such revolution is the way that new network functions are introduced into the value chain. Traditionally, such a process demands deployment of specialized devices with 'hard-wired' functionalities. It implies that any adaptation to the ever increasing and heterogeneous market requirements demands a huge investment to change/deploy hardware. Thanks to the advent of cloud computing, Software Defined Networking (SDN) and Network Function Virtualisation (NFV), the idea of having general-purpose computing and storage assets at networks has been realized along with the virtualization of network functions which enables the automation of network service provisioning and management.

SESAME project [2] is an effort to realize multi-tenant cloud enabled Radio Access Network (RAN) through a substantial change on the architecture of commercial Small Cells (SC), evolving them towards the so-called Cloud Enabled Small Cell (CESC). A CESC is a new multi-operator enabled SC that integrates a virtualized execution platform equipped with, e.g., IT resources (RAM, CPU, storage) and Hardware Accelerators (HWA) such as: Graphics Processing Units (GPU), Digital Signal Processors (DSP), and/or Field-Programmable Gate Arrays (FPGA), to support the execution of novel applications and services inside the radio access network. This change paves the way to place network intelligence and applications in the network edge with the help of virtualization techniques and NFV. Through the advanced coordination and orchestration, the proposed architecture is able to attend several operators/service providers and engage them in a multi-tenant ecosystem where both radio access capacity and edge computing capabilities are shared. In this way, the proposed 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 localised areas [3], together with the provision of Mobile Edge Computing (MEC) services. Efficient management of resources, rapid introduction of new network functions and services, ease of upgrades and maintenance and CAPEX/OPEX reduction are only few examples of various benefits that the proposed solution provides.

Despite the potential technical benefits, viability of a solution strongly depends on several factors such as Service Level Agreements (SLAs) and pricing schemes. A SLA which captures the particular Key Performance Indicators (KPI) of a delivery –scope, quality, and responsibilities– can play a significant role towards business success. The 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 simultaneously.

This paper is an effort to look at the problem from different angles and identify different pragmatic models with a language understandable for today's telecom market. To this end, first, a brief review of the proposed concept and different stakeholders involved is presented in Section II. Next, Section III details the possible SLA models and various payment methods. Finally, section IV compares different joint radio-cloud provisioning and pricing possibilities.

II. Multi-Tenant Cloud Enabled RAN

Traditionally, actual installation of physical infrastructure is needed to provide coverage in one Point of Presence (PoP). Such an ownership increases operators' CAPEX and significantly hampers business agility, particularly when considering the high degree of cell densification needed to deal with 5G requirements. Moreover, the static nature of physical ownership makes it difficult (impossible in some cases) to handle scenarios with dynamic capacity requirements. For example, a flash crowd event at a venue (e.g., stadium, urban area, etc.) cannot be well-served without overprovisioning of the underlying physical infrastructure. That can be easily translated to more expenses for the operator, which in turn increases the service cost for end users. To address this issue, the idea of multi-tenancy has been initiated in 3GPP [4] and is expected to play a vital role in 5G networks. In a multi-tenant scenario, an infrastructure provider can grant access to third parties such as network operators, service providers or Over-The-Top (OTT) players. Sharing the physical infrastructure increases service dynamicity and reduces the overall cost and energy consumption compared to the case where parallel systems are installed in one PoP to support connectivity for different parties. Fig.1 shows an architecture to consolidate multi-tenancy in the mobile communications infrastructures based on a substantial evolution of the Small Cell (SC) towards cloud-enabled devices, as proposed in the SESAME project [2].

The key element of this architecture is the CESC, owned by a Small Cell Network Operator (SCNO), which consists of a micro server integrated with the small cell to support both radio connectivity and edge services. It foresees the split of the small cell into physical and virtual network functions [5] (namely Physical Network Functions (PNF) and Virtual Network Functions (VNF)), enabling a multi-tenant environment in support of the Multi-Operator Core Network (MOCN) requirements [4]. According to the selected functional split between physical and virtualised functionalities, a SC VNF may include several VNF components (VNFC) to carry out radio related responsibilities, such as different radio resource management (RRM) functions, Packet Data Convergence Protocol (PDCP), etc. However, in the simplest form it should include a VNFC to intercept GTP S1 tunnel and provide access to the user IP packet [6]. In the context of multi-tenant cloud enabled RAN, at minimum, a SC VNF with the mentioned functionality per tenant needs to be considered. To support multi-tenancy and the MOCN functionality, SC VNF of all tenants are connected to a common SC VNF which is responsible to appropriately establish the communication between the PNF (common to all tenants) and the SC VNF (per tenant). In addition to the virtualization enabling software set (e.g. Linux kernel, hypervisor, etc.), the mentioned components are bare minimum requirement at every CESC to have an operational radio-cloud system.

As it may be inferred, resources on a single micro server (i.e. RAM, CPU, storage, HWA) might not be enough to support the mobile edge computing services of all tenants. CESC clustering enables the creation of a micro scale virtualised execution infrastructure in the form of a distributed data centre, denominated Light Data Centre (Light DC),

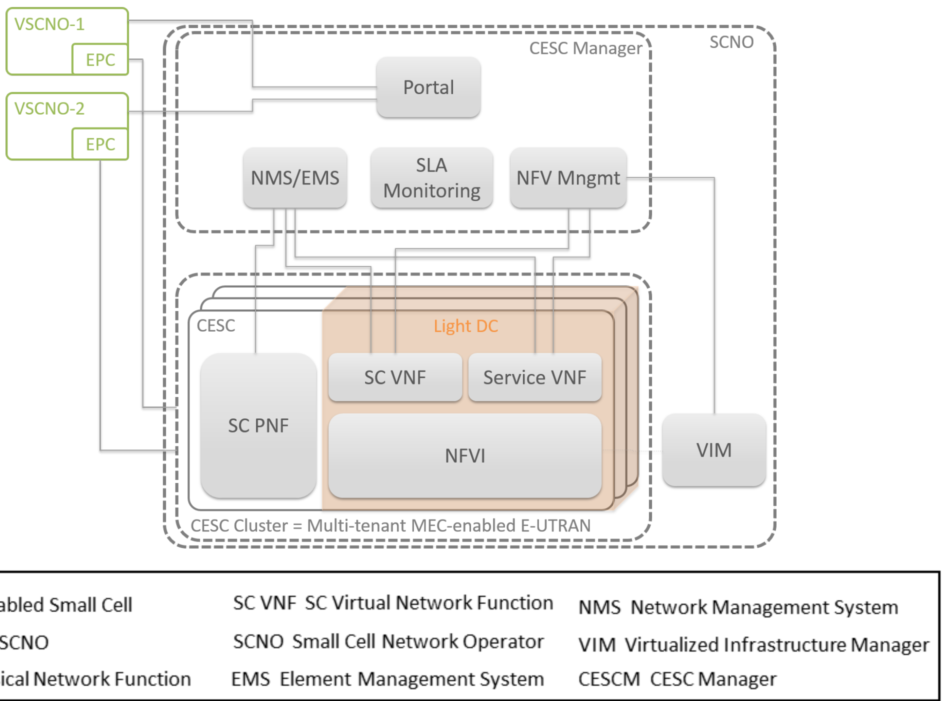

Fig. 1. Proposed archiecture for multi-tenant cloud enabled RAN using SCs.

enhancing the virtualisation capabilities and processing power at the edge. The hardware architecture of the Light DC envisages that each micro server will be able to communicate with all others via a dedicated LAN/WLAN guaranteeing the latency and bandwidth requirements needed for sharing resources. Such a clustering is achieved using for example a standard Ethernet switch, suitably configured for properly enabling the networking between CESCs (bandwidth management, VLAN separation, etc.). It provides also the backhaul connections to the operators Evolved Packet Core (EPC) and all the links to the management system. All management tasks, e.g. resource allocation and service lifecycle management over the distributed infrastructure, are carried out by a centralized unit called CESC Manager (CESCM), which incorporates Network Functions Virtualisation Orchestrator (NFVO) management capabilities.

The resulting solution will allow Virtual Small Cell Network Operators (VSCNO) not only to support connectivity but also to provide added value mobile edge services, e.g. edge caching, edge video transcoding, etc. in a PoP. Note that, in the context of multi-tenant cloud enabled RAN, a Network Service (NS) is understood as a chain of PNFs and VNFs that jointly supports data transmission between a User Equipment (UE) of an operator and the operator's EPC, with the possibility to involve one or several service VNFs in the data path. It clearly highlights that, beyond the conventional orchestration and management of the cloud resources in a virtualised environment, the proposed solution entails a series of specific challenges such as the dynamic composition of the Light DC resources based on the status of CESC cluster(s), coordination of specific type of resources (radio-related resources, service-related HWA, etc.) and isolation of dedicated network slices to each tenant.

The CESCM is the central service management and orchestration component in the architecture. Generally speaking, it integrates all the traditional 3GPP network management elements, and the novel recommended functional blocks to realize NFV [2]. A single instance of CESCM is able to operate over several CESC clusters, each constituting a Light DC, through the use of a dedicated Virtual Infrastructure Manager (VIM) per cluster. CESCM includes a portal that constitutes the main graphical frontend to access the SESAME platform for both SCNO and VSCNOs. The CESCM portal includes two login procedures. A login for the VSCNO tenants aims to provide SLA monitoring information and possibly browsing NS and VNF catalogues. Another login for the SCNO administrator is available to register extra resources and add new VNFs/NSs to the system.

For each instantiated VNF, an Element Management System (EMS), deployed in the CESCM, is responsible to carry out key management functionalities –fault monitoring, configuration, accounting, performance monitoring and security (FCAPS). The lifecycle management of deployed VNFs is carried out by the VNF Manager (VNFM). By leveraging on the monitoring mechanisms, the CESCM, in conjunction with the VNFM, is able to apply policies for NS-level rescaling and reconfiguration to achieve high resource utilization. It is worth mentioning that monitoring mechanisms are dictated by the CESCM SLA monitoring unit that allows the evaluation of SLAs between different business role players, i.e. SCNO and VSCNOs.

Another essential component at the heart of CESCM is the NFVO. Besides management and orchestration of the abovementioned functionalities, NFVO composes service chains (constituted by two or more VNFs located either in one or several CESCs) and manages the deployment of VNFs over the Light DC. This includes not only the management of a typical Network Function Virtualization Infrastructure (NFVI) (i.e. processing power, storage and networking), but also the assignment of HWAs.

The functionality of CESCM modules directly depends on the solution. Different resource sharing models are possible on a mixed radio-cloud environment. Next section moves from the radio resource options on to a joint radio-cloud scenario.

III. Service Provisioning Models and Pricing Schemes

A. *Service Provisioning Models for RAN service provisioning*

Legal, financial, technical and operational aspects between the SCNO and a VSCNO will be captured through a specific SLA as commonly done to formalise contractual agreements between service providers and customers. SLA is a negotiated agreement that records a common understanding about the service and/or service behaviour offered by the SCNO, together with the measurable target values characterizing the level of the offered service. In the context of multi-tenant cloud enabled RAN, the SLA for the RAN service can be articulated around the following categories [7]:

i) Service scope: This specifies the geographical scope (i.e. the area where the service is provided, e.g. a mall, a stadium, an enterprise etc.), and the time scope (i.e. starting time, end time, periodicities, etc.) when the service has to be provided.

ii) Service specification: The SCNO provider delivers a RAN service to the VSCNO so that VSCNO's customers (e.g. mobile subscribers) can get connected through the SCNO's CESCs to the VSCNO's EPC. In this respect, different alternative service provisioning models can be envisaged:

- RAN capacity provisioning: The service intends to provide a certain capacity to the VSCNO's subscribers over the temporal and geographical scope specified in the SLA. This model could fit e.g. for a Mobile Virtual Network Operator (MVNO) or a service provider that contracts SCaaS to provide service to its UEs in a given area. The specification of the capacity can be done in terms of aggregated global values (e.g. in Mb/s), but also limits can be put on the number and characteristics of the E-UTRAN Radio Access Bearers (E-RABs) that can be simultaneously established. The SLA can also specify different radio KPIs for the different E-RABs, such as:
    - E-RAB accessibility: Probability that an end-user is provided with an E-RAB at request.
    - E-RAB retainability (dropping ratio): Probability that an end-user abnormally loses an E-RAB during the time the E-RAB is used.

- E-RAB Quality of Service (QoS) parameters: QoS Class Identifier (QCI), Allocation and Retention Priority (ARP), Guaranteed Bit Rate (GBR) and Maximum Bit Rate (MRB) for GBR bearers.
- Per UE Aggregate Maximum Bit Rate (UE-AMBR): Limit on the aggregate bit rate that can be expected to be provided across all Non GBR bearers of a UE.

- RAN capacity with mobility support: This model assumes that the infrastructure of the SCNO will supplement the VSCNO's own RAN in a given area (e.g. the SCNO deploys CESCs inside a stadium, while the VSCNO is a Mobile Network Operator (MNO) that has deployed macro cells outside the stadium). Then, in addition to the terms already included in the case of the "RAN capacity provisioning" model discussed above, the SLA can include the support of mobility between the CESCs and the rest of cells of the MNO. This may involve that the SCNO offers X2 interface connectivity between them and that the SLA specifies the type of services supported through this interface (e.g. exchange of load information, handover support, etc.).
- Customised RAN service: In this model, in addition to the provision of a certain capacity as in the previous models, the SCNO also offers to the VSCNO certain capabilities for carrying out selected operations in the shared CESCs. This opens the door to a much deeper involvement of the VSCNO in the way that the RAN infrastructure is managed, up to the extent that a VSCNO might envisage the operation of the CESCs in harmony with its own RAN. Different aspects that can be considered in this respect include the possibility that a VSCNO specifies its own algorithmic solutions for some selected RRM and/or Self-Organizing Network (SON) functions (e.g. the tenant specifies the scheduling algorithm with corresponding automated parameter configuration through SON, the tenant specifies a certain admission control strategy, etc.), or that certain CESC parameters can be exposed to the VSCNO so that it can configure them.

iii) Service level management aspects: This specifies the monitoring capabilities (e.g. the KPIs and alarms that the SCNO will deliver to the VSCNO), the service availability (i.e. the percentage of time that the service should be available), the response time to service related incidents, the procedure to request changes in the SLA and the accounting information (i.e. the events supporting the accounting of resource usage by the UEs of a VSCNO that need to be delivered to this VSCNO).

B. *Service Provisioning Models for Joint Radio and Cloud Services*

From the business perspective, three major role players are identified, as depicted in Fig. 2. Function provider (FP) is the VNF developer which sells/develops VNFs. Service Provider (SP), is the one who composes NS –i.e. chain of VNFs, PNFs– with the available VNFs and offers them to the customer. Customer is the one who purchases NSs. In multi-tenant cloud enabled RAN, there are two main possible ways to form a joint radio-cloud model, as illustrated in Fig. 2.

- *Mobile Edge Computing as a Service (MECaaS):* This model (depicted as option 1 in Fig. 2) has been inspired mainly from the MNO-MVNO business relationship. Briefly, in this model, MVNO relies completely on the infrastructure and other services provided by the MNO. Bearing this in mind in the context of SESAME, VSCNO asks for high level KPIs on the SLA, e.g. on the radio aspects as discussed in section III.A and on the cloud, e.g. support for a number of caching hits, transcoding delay less than a threshold, etc. Here, VSCNO only has an overall vision of the system and SCNO has to provide enough support, i.e. both in terms of hardware and number/composition VNF chains (i.e. NS), to meet the agreed KPIs. Performance reports are provided to VSCNO on time intervals (even real time). In simple words, with this model, VSCNO does not chain VNFs to form a mobile edge service (i.e. VNF1 connected to VNF2 connected to VNF3), and a high level KPI view is enough for it to request a service without going to details.
- *CESC Infrastructure as a Service (CESCIaaS):* In this model, shown as option 2 in the Fig. 2, VSCNO on SLA asks for connectivity in a certain coverage area according to the elements discussed in Section III.A and for aggregated cloud resources on the Light DC, e.g. a certain amount of GB of storage, of RAM, etc. This model corresponds with the famous Infrastructure as a Service (IaaS) paradigm, which is one of the three fundamental service models of cloud computing [8]. In an IaaS model, a third-party provider (SCNO) hosts hardware (e.g. CESC), software (e.g. Hypervisor, VIM, CESCM, VNFs, etc.) and other required infrastructure components on behalf of its users (VSCNO). IaaS providers also host

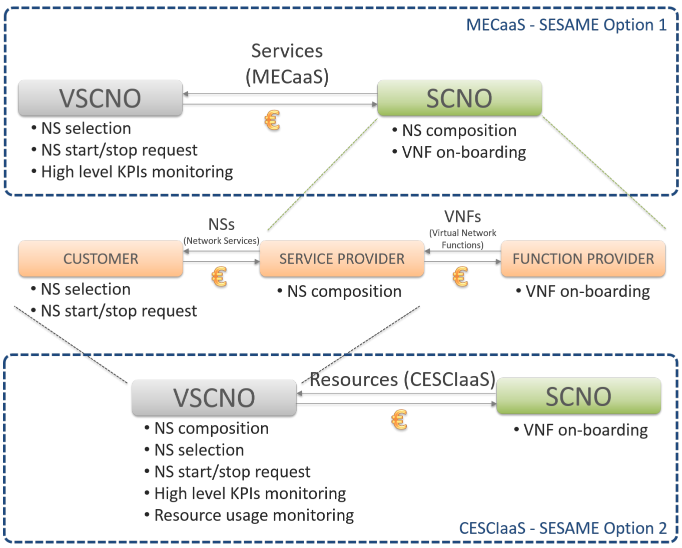

Fig. 2. Role players and possible Service provisioning schemes

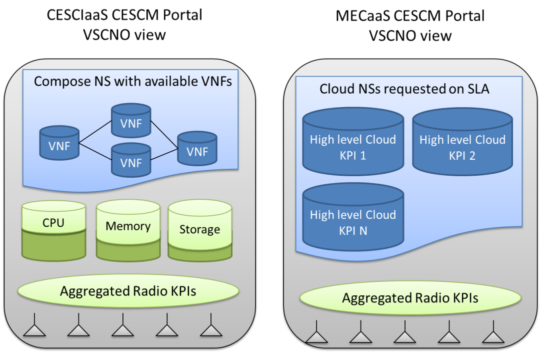

Fig. 3. VSCNO's CESCM portal view on the multi-tenant cloud enabled RAN.

users' applications (i.e. edge/cloud service) and handle tasks including system maintenance, backup and resiliency planning. In the context of SESAME, with this model in place VSCNO can compose VNF chains on demand, i.e. VSCNO decides to have VNF1 connected to VNF2 connected to VNF3. As a consequence, any VNF instantiation (depending on the used hardware resources) consumes a portion of available VSCNO's aggregated resources. Therefore, the deployment of VNF chains is conditioned to the amount of requested resources by the VSCNO. Note that VNF (e.g. vCaching, vTranscoding) hardware resources are fixed and determined by the VNF developer (e.g. 2 GB of storage and 2 GB of RAM). Although, it is possible to have different flavours of one VNF in place, e.g. vCaching with extra/less storage capabilities, etc. In this case, VSCNO has more choices among one family of VNF.

Fig. 3 shows the dashboard view of VSCNO based on the two mentioned joint cloud-radio service provisioning models.

C. Pricing Schemes

Based on what we have discussed so far, three charging scenarios seem possible:

- *Flat rate:* In this scenario, SCNO and VSCNO agree on KPIs on a business negotiation (e.g. in person). KPIs involve radio aspects as noted in Section III.A and service-level parameters as discussed in Section III.B. Charging is for a long period, for example 2 years, and may also include temporal profiles based on daily / weekly / monthly characteristics. The SCNO is responsible to ensure KPIs by all means, otherwise there will be a penalty associated to the severity of the SLA violation. CESCM portal in this case is only used to provide VSCNO with high level monitoring information.
- *Pay as you go:* In this scenario, after agreeing on the radio aspects as noted in Section III.A, VSCNO purchases network services (i.e. chain of SC VNF and service VNF) on the CESCM portal from the list of available ones (composed by SCNO). In this sense, there is no charging for NS unless it gets instantiated. As long as the service is up and running VSCNO pays for it. This model gives the full flexibility to VSCNO to start and stop added value edge services on demand. The main problem with this scenario is that instantiation of network services depends on the availability of hardware resources. Since network services are deployed in the first come first serve manner, there will be no penalty for service instantiation failure because of resource shortage. Note that VSCNO can set performance metrics for the requested NS, e.g. number of caching hits or transcoding delay. Monitoring information will be provided to VSCNO via the CESCM portal.
- *Hybrid:* This scenario is a mix of the previous two and it is possible to see it as an intermediate solution. SCNO and VSCNO agree on the required day by day network service, e.g. the radio aspects as noted in Section III.A and number of caching hits, maximum transcoding delays for a number of flows, etc. SCNO is responsible to keep these KPIs by all means. Besides that, as explained on *"pay as you go"*, in case of e.g. flash events, VSCNO can purchase extra services via the CESCM portal. Like above, these extra services will be served in the first come first served fashion. Again monitoring information will be provided to VSCNO via the CESCM portal.

Besides the mentioned pricing schemes defining a single SCNO – VSCNO relationship, in the case of multi-tenant scenarios (multiple infrastructure providers or / and multiple virtual operators) more dynamic pricing schemes should be used due to competition. In such a scenario, negotiations should be performed between the interesting parties. Recently, dynamic pricing has attracted an increased attention in revenue management literature from travel industry [9] to cloud computing [10] and multi-domain virtual networks [11]. In a 5G multi-tenant environment customers (VSCNO) will have a set of resource requirements, the number of customers and the duration of usage are unknown while both the pricing and the willingness to pay strategy of competitors should be taken into account. The main objective of all parties is to maximize their own profit. Requests from VSCNOs are sent to one or multiple SCNOs. To do so, VSCNOs use cost information of SCNOs and send requirements regarding the needed resources and the duration. In each request, SCNOs provide an offer while VSCNOs have a willingness to pay strategy. Unit price of resources of SCNOs can vary depending on the utilization. Prices are initial low to attract customers. As utilization is increasing, resources are protected and only virtual requests with high potential revenue are preferred or priced attractively. The ratio of the requests that will be priced attractively to those that will be priced with a premium should be carefully evaluated / optimized.

IV. Final Discussion and Conclusion

The above discussion shows the wide range of choices for the service provisioning and pricing scheme in a joint radio-cloud scenario. The similarities with the existing solutions of the individual radio and cloud systems can facilitate the establishment of a mixed environments. Table I summarizes possible service provisioning and pricing models.

Based on this information and depending on the use case, VSCNO can decide to select one or another option. The

CESCIaaS model allows a better understanding of the use of NFVI resources to the VSCNO, but requires specialized VSCNO staff and systems. The MECaaS model hides the low level details of the NFVI to the VSCNO, which only need to care about the outcomes of the process at service level.

In multi-tenant environments with more than one SCNOs or/and VSCNOs more complex solutions (especially pricing schemes) should be adopted. Due to competition in such cases and in order to maximize the profit of all interested parties, negotiations are performed and VSCNOs with higher potential revenue are preferred. Attractive prices to premium prices ratio is subject to optimization. A possible direction for further work would be to derive the complete business model of SESAME solution illustrating participant actors and describing their interaction and revenue streams. A pricing scheme per stream could be identified. In such a model, an agreement between SCNO and VSCNO will also be considered and described. In addition, a more detailed description of SLA parameters should be provided in conjunction with the monitored parameters and the pricing models. As one step further, we introduce the concept of a broker and the interaction with SCNOs/VSCNOs. Using mathematical representation, numerical simulations will be performed in order to assess the impact of several parameters.

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TABLE I. POSSIBLE SERVICE PROVISIONING AND PRICING MODELS

Radio-cloud SLA / Payment method	MECaaS	CESCIaaS
Flat rate	• Compliance with conventional MNO/MVNO relationship. • Support for the cloud services on the network edge without worrying about the service composition and availability of cloud resources. • No support for dynamic NS changes, e.g. on a flashy event. • SCNO is the only actor with specialized staff / SW for managing the NFVI • VSCNO only cares about high level KPIs, regardless the required underlying resources. • Long term contract with penalty for the service deployment failure.	• Compliance with IaaS. • Payment is to reserve the cloud resources even if they remain unutilized. • Guarantee for the service deployment over the rented cloud resources. • VSCNO is in able to deploy the desired VNFs over the NFVI, and has the control of the resource usage. VSCNO can dynamically modify the edge services overtime for the assigned resources. • VSCNO needs specialized staff. • Long term contract with penalty for the service deployment failure.
Pay as you go	• The VSCNO requests to deploy a new edge service or to extend a running edge service, without the knowledge of the used / available NFVI resources. • The SCNO checks the feasibility of the request and progress the request if possible; otherwise, the request is rejected. No penalty for the service deployment failure.	• The VSCNO requests new or additional NFVI resources to deploy a new edge service or to extend a running edge service. • The SCNO checks the feasibility of the request and progress the request if possible; otherwise, the request is rejected. No penalty for the service deployment failure.
Hybrid	• Compliance with conventional MNO/MVNO relationship. • Support for a basic cloud services on the network edge without worrying about the service composition and availability of cloud resources. • Support for introduction of added value services, e.g. on a flashy event, always subject to the acceptance by the SCNO based on the available NFVI resources. No penalty for failure in the added value service deployment.	• Compliance with IaaS • Basic payment to guarantee a minimum cloud resources. • Extra payment in a pay as use fashion for added value services, e.g. in case of a flashy event. No guarantee for the added value services deployment (i.e. it is subject to the NFVI resource availability). No penalty for failure in the added value service deployment.