Small Cells as a Service: From Capacity Provisioning to Full Customisation

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***Abstract*—Small Cell as a Service (SCaaS) is envisaged as a solution to facilitate the provisioning of shared radio access capacity to mobile operators in areas where dedicated per-operator deployments may be impractical, typically highly densified scenarios such as stadiums, malls, office buildings, etc. In this context, this paper analyses three different SCaaS provisioning models, which might be seen as incremental and evolutionary from one to another.**

Keywords—Small cell; SCaaS; multi-tenancy; RAN sharing; 5G networks; SON

I. INTRODUCTION

The deployment of small cells (SCs) has been considered as a means to effectively increase the available capacity in high traffic areas as well as locations with poor coverage conditions from outdoor macrocells. In this context, the so-called Small Cells as a Service (SCaaS) model is identified as an adequate solution [1] to facilitate a third-party provisioning of radio access capacity to mobile network operators (MNOs) in localised areas with capacity or coverage issues. The resulting densified network could serve multiple operators in scenarios when dedicated operator deployments are impractical. In that case, the multi-tenancy concept allows that the provisioned small cells are shared between multiple operators, denoted as "tenants", according to specific agreements between the SCaaS provider and each involved tenant.

3GPP specifications have already added some support for Radio Access Network (RAN) sharing [2]. The focus of this paper is on the Multi-Operator Core Network (MOCN) architecture, where the shared RAN is directly connected to each of the multiple operators' core networks.

The SCaaS provisioning under multi-tenancy is envisaged as a relevant component to fulfil the expected requirements of future 5G networks in highly densified scenarios. Besides, an increase in the degree of automation to carry out the different network planning, management and operation procedures - through Self-Organizing Network (SON) functions [3]- is expected to constitute a key tool in future SCaaS deployments.

In this context, this paper analyses the provision of SCaaS in multi-tenant scenarios. In particular, different incremental and evolutionary SCaaS provisioning models are considered depending on how the Service Level Agreement (SLA) between the SCaaS provider and the tenant is conceived.

The paper is organized as follows. Section II discusses the general aspects of the SLA between the SCaaS provider and a tenant, while Sections III, IV and V describe the three proposed service provisioning models. Finally, conclusions are summarized in Section VI.

II. SERVICE LEVEL AGREEMENT BETWEEN THE SCAAS PROVIDER AND THE TENANT

Legal, financial, technical and operational aspects for the implementation of a SCaaS model between a SCaaS provider and a tenant will be captured through a specific Service Level Agreement (SLA), as commonly done to formalise contractual agreements between service providers and customers. A SLA is a negotiated agreement that records a common understanding about the service and/or service behaviour offered by the SCaaS provider, together with the measurable target values characterizing the level of the offered service. An example of the attributes that could be specified within a SLA for the provisioning of SCaaS follows:

a) Service Specification

Essentially, the SCaaS provider delivers a RAN service to the tenant so that tenant's customers (e.g. mobile subscribers) can get connected through the SCaaS provider's SCs to the tenant's core network. However, different SCaaS provisioning models are envisaged in this paper, denoted as "RAN capacity", "RAN capacity with Mobility Support" and "Customised RAN service". They are further discussed in sections III, IV and V, respectively.

b) Service Scope

- Geographical scope: The area where the service is provided (e.g. an enterprise, a stadium, a mall, etc.).
- Temporal scope: The time when the service has to be provided (starting time, end time, periodicities, etc.).

c) Service Level Management aspects

- Monitoring capabilities: Performance measurements, Key Performance Indicators (KPIs) and alarms that the SCaaS provider delivers to the tenant.
- Service availability: It specifies the percentage of the time that the service should be available to the tenant
- Response to service related incidents: This specifies the response time to service related incidents notified by the tenant. Usually, incidents will be classified according to a certain priority level (High/ Medium / Low) and different time frames will be associated to each priority.
- Changes in the SLA: This specifies the procedure to request changes in the SLA, and the conditions related to these changes (e.g. time to response, etc.)
- Accounting information: the SCaaS provider needs to collect events supporting the accounting of resource usage by the User Equipments (UEs) of a tenant (e.g. start of

service by a UE of the tenant, end of service, etc.). These events may be delivered to the tenant.

III. "RAN Capacity" SCaaS Provisioning

In this model, the RAN service is just intended to provide a certain capacity to the tenant's subscribers over the temporal and geographical scope specified in the SLA. This model could fit e.g. for a MVNO or a service provider that contracts SCaaS to provide service to its users in a given area. The specification of the capacity could 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 capacity specification can be further detailed including:

- Capacity conformance: It further specifies the provisioned capacity in time and space. Constraints can be established at spatial level (i.e., maximum Mb/s over a certain area) and temporal level (i.e., maximum Mb/s that can be offered within a certain time window).
- Excess capacity treatment: It specifies how the tenant's excess capacity demand not meeting the capacity conformance will be treated.
- E-RAB attributes and Key Performance Indicators (KPIs) targets , such as:
  - E-RAB accessibility KPI: Probability that an end-user is provided with an E-RAB at request. Alternatively it can be expressed in terms of the blocking probability, which would be the complementary value to the accessibility.
  - E-RAB retainability KPI (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. It has an uplink and a downlink component.
- Dynamic capacity negotiation. The SCaaS provider can offer by automatic means spare capacity as on-demand capacity to its tenants. Specific mechanisms for querying, requesting and granting capacity based on certain policies should be in place between the SCaaS provider and tenants.

IV. "RAN Capacity with Mobility Support" SCaaS Provisioning

This provisioning model considers that the infrastructure of the SCaaS provider will supplement the tenant's own RAN (e.g. the SCaaS provider can deploy infrastructure inside a stadium, while the tenant, who in turn is a MNO, has macrocells deployed outside the stadium). In this context, and in addition to the terms already included in the case of the "RAN Capacity" model, the MNO can be interested to include in the SLA the support of mobility between the SCs of the SCaaS provider and the rest of cells of the MNO. This may involve that the SCaaS provider offers X2 interface connectivity between the SCs and the cells of the tenant, and the SLA specifies the type of services supported through this interface (e.g. exchange of load information, handover support, etc.).

V. "Customised RAN Service" SCaaS Provisioning

In this model, in addition to the provision of a certain capacity, the SCaaS provider also offers to the tenant certain capabilities for carrying out selected operations in the shared SCs. This opens the door to a much deeper involvement of the tenant in the way that the SCaaS infrastructure is managed, up to the extent that a tenant might envisage the operation of the SCaaS in harmony with its own RAN. Different aspects can be considered in this respect:

- A tenant can specify its own algorithmic solutions for some selected Radio Resource Management (RRM) and 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.).
- Certain SC parameters can be exposed to the tenant so that it can configure them (e.g. through its own SON functions running at the tenant side).

It is worth mentioning that the achievement of isolation among tenants should be implemented in a way that the customised configurations and algorithms enforced for one tenant do not affect the performance observed by the other tenants.

VI. Conclusions

This paper has analysed the provisioning of SCaaS in multi-tenant scenarios. Three models have been studied depending on the SLA between the SCaaS provider and the tenant. The first model considers just the provision of a certain capacity to the tenant over a specified temporal and geographical scope. The second model incorporates mobility support between the small cells and the rest of cells of the tenant. Finally, the third model provides the tenant with the capability to customize certain aspects of the SCaaS infrastructure.

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