Defining a communication service management function for 5G network slices

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Abstract—Network slicing is an important concept for telecommunication companies for optimizing their infrastructure and providing customized services. In order to deploy them, it is necessary to fully understand the customer requirements. The Communication Service Management Function (CSMF) is an entity that has this task, acting as a gateway to translate these requirements towards the network slicing ecosystem. Even though we know the tasks for the CSMF, we find there is no complete definition of its internal elements and interactions. Our contribution is threefold: (i) we provide a comparison with current implementations and their weaknesses; (ii) we propose a complete model of the CSMF, its internal structure and its interaction with other elements of the network slicing infrastructure; and (iii) we demonstrate use case examples that show the functionality of the complete model.

Index Terms—Network slicing, 5G, CSMF, Communication Service, orchestration, FCAPS

I. Introduction

Network slicing is a key enabler for 5G networks, along with Software Defined Network (SDN), Network Functions Virtualization (NFV) and the cloud computing paradigms. It is important because it provides mechanisms to Communication Service Providers (CSP) to overcome limitations in scalability and elasticity imposed by legacy network sharing and partitioning schemes. Since the network slice is created just with the required resources, it permits the CSP to have cost-efficient operation by avoiding over-provisioning, diminishing the energy footprint of the deployment [1] and sharing resources with other operators, enabling to increase revenue [2].

There is no single and unified definition of network slicing. The reason is that each incumbent in the telecommunication industry (equipment manufacturer, CSP or Standard Developing Organization (SDO)) provides a definition according to their field of expertise, field of action and business focus.

From the definitions proposed by the Next Generation Mobile Networks (NGMN) alliance in [3], the 3rd Generation Partnership Project (3GPP) in [4], and the 5G infrastructure public-private partnership (5G-PPP) in [5], we can deduce an intuitive comprehensive definition. A network slice can be defined as: "a recursive entity, which via enabling technologies and orchestration mechanisms, provides the necessary means to realize a complete network communication service, that meets the requirements set by a concrete use case scenario powered by a business purpose, optimizing resource usage".

Network slicing enables a more service-aware system, which is defined end-to-end, and has the capacity to perform fine-tuning of the service according to the customer request (the service is born from a business purpose [5]). It is policy-driven via Key Performance Indicators (KPI), which are used to make sure that the Service Level Agreement (SLA) with the customer is fulfilled.

The interaction between Business Support System (BSS) and Operation Support System (OSS) takes a business service request and transforms it in a way that can be implemented in the network infrastructure. To aid to perform its functions, the OSS entity can leverage on *complementary frameworks* that provide the interaction towards the infrastructure and aid to perform failure management, performance management, design of network slices and configuration management. These frameworks could be Open Network Automation Platform (ONAP) [6], ETSI-MANO [7], 3GPP's NetWork Data Analytics (NWDA) [8] and fault, configuration, accounting, performance, security (FCAPS) [9], all of them supported by SDN-NFV paradigms, according to what is required.

An interesting challenge is how to capture the customer requirements for a Communication Service (CS) and provide their implementation using the available resources in the network. Inside the OSS, 3GPP in [10] defines the CSMF as an entity that will help to provide the translation of the CS request into network slicing resources. From 3GPP's technical specification, the general tasks for the CSMF are well understood, but we find there is no consensus about its internal building parts and the interactions with other components of the network slicing architecture for 5G networks.

This paper is organized as follows: Section II provides the approach and architectures for CSMF solutions, Section III enunciates the problem statement, Section IV presents the proposed software model for the CSMF for networks slicing with use case examples. Then, we end with a discussion and conclusions in Section V.

II. Approach and architectures

A. 3GPP

3GPP references the utilization of the CSMF as part of the management and orchestration domain for network slicing [10]. Figure 1 shows the management components of the NFV framework such as the NFV Orchestrator (NFVO), VNF

Manager (VNFM) and Virtualized Infrastructure Manager (VIM) and their relationship with the infrastructure (physical and virtual). Likewise, shows the considered management functions according to 3GPP, which are:

- Communication Service Management Function (CSMF): Acts as a translator from the CS related requirements to network slice related requirements.
- Network Slice Management Function (NSMF): Performs management and orchestration of the network slice instance and derives network slice subnet requirements from network slice requirements.
- Network Slice Subnet Management Function (NSSMF): Responsible for management and orchestration of network slice subnet instance.

Besides stating the purpose of the CSMF, 3GPP does not specify how to implement it or provide a clue about its basic building blocks to perform the envisioned task. All these details are outside of 3GPP domain.

B. European Telecommunications Standards Institute (ETSI)

ETSI does not provide a network slicing definition, but they acknowledge its importance and explore the definitions provided by NGMN, 3GPP and Open Networking Foundation (ONF) [11]. They establish a relationship between a network slice and a network service leveraging on the network slice related management functions from 3GPP and their NFV - Management and Orchestration (MANO) framework. Specifically, 3GPP's NSMF and NSSMF should be able to use the Application Programming Interface (API) that expose the NFVO via the Os-Ma-Nfvo interface (Figure 1). These two entities would rely on the information provided by the CSMF in order to trigger the required network services from the NFVO. Apart from this, ETSI does not address the functions or internals of the CSMF.
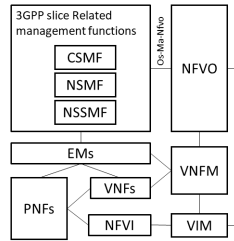

Fig. 1. Network slice management in an NFV framework [11].

C. 5G-PPP

Under the 5G-PPP umbrella, there are three projects that address the importance of the CSMF with its envisioned functionality. They are 5G-Transformer, MATILDA and 5G-MonARch.

1) 5G-Transformer: Specifies an entity called the 5GT Vertical Slicer (5GT-VS), which is part of the OSS, as the entry point for receiving service requests from all verticals [12]. Inside the 5GT-VS they specify components to perform an equivalent task to the one of the CSMF: the '*Vertical*

Service Descriptor (VSD) to Network Service Descriptor (NSD) Translator' and the '*Arbitrator*'. Specifically, the '*VSD to NSD Translator*' will perform the mapping between the requirements from the vertical customer into a network service descriptor, as can be understood by the service orchestrator in order to be deployed into service [13]. The task of the '*Arbitrator*' is to find an acceptable way to satisfy the SLA of a customer while satisfying the rest of the service requests in the slicing ecosystem. It is the entity that supports the service orchestrator to perform the deployment. Output from these two entities is used to execute the management of the network slices via a '*Vertical Service Instance (VSI) to Network Slice Instance (NSI) Coordinator and Life Cycle Management (LCM)*' who includes the NSMF and NSSMF, as specified by 3GPP in [10].

2) MATILDA: Uses the concepts of forwarding graphs and *metamodels* to (i) represent the slice towards the vertical service provider; and (ii) express the intent of the CSP to fulfill an application requirement via slices [14]. An entity as CSMF is not stated, but via these metamodels the slice manager can trigger the deployment of the network slices and integrate vertical applications into the 5G infrastructure [15].

3) 5G-MoNArch: Includes the usage of the CSMF as part of the End-to-End Service Management and Orchestration layer [16]. Their CSMF specification and functionality do not differ much from the one given by 3GPP, nonetheless they expand on the interaction with the upper layers, by stating that the CSMF "works as an intermediary function between the service layer and the NSMF within the management and orchestration layer". This project specifies internal components of the CSMF that allow, for a tenant to request a CS, translate its requirements into network terms, set up the infrastructure to create the service and provide analytics of the service. The project defines use cases related to network slice allocation and network slice congestion control, featuring the transaction and service allocation functions of the CSMF before handing out the request to the NSMF. Resource elasticity implementation is centered on the NSMF, who relies on the decisions and information sent by the CSMF [17]. The proposal by 5G-MoNArch is more elaborate and detailed, but we find some weaknesses and points that can be improved, as we will show in the next section.

III. PROBLEM STATEMENT

From the previous section we can conclude that even if there is a common understanding about the tasks that are entrusted to the CSMF, only one project provides the building blocks to implement the functionality. Anyway, there are some functions that are missing and that we consider important to perform the proper LCM of CS and its translation. Our value proposition lies on providing the minimal basic building blocks of a CSMF and depicting its relationship with other entities of the network slicing ecosystem. Together, they help to perform the required tasks in an optimal way.

Some missing aspects that we found are:

1) Incomplete tasks for the LCM of the CS. In addition to the existent (requirements update, service activation, service allocation), other functions that should be considered include deactivation, commissioning and termination.
2) Specify properly the functions of the service analytics functionality. They could be complemented by supervision and intelligence entities to enable automation of management tasks and cognition-awareness mechanisms to understand the environment of the service, so better decisions are chosen.
3) Include the CS template, as a mean to inform the BSS of the service capabilities and aid the translation process of business to network requirements.
4) Include CS management capabilities into the architecture, or at least the interaction with a fault management framework.
5) Establish a link with 5G core components for analytics, performance and policy management, complementary to fault management systems.
6) Include a feedback notification mechanism to inform the BSS of important information that has to be sent to the customer, for example, changes on SLA and affectation of service because of failures.

Focusing on the CSMF is important because it is the borderline between two domains that have different languages, and deals not only with properly expressing requirements, but with making those requirements understood. It is also necessary to consider methods to transmit management information between the different layers, so all entities have up to date information about the actual situation of the provided service. On the next section, we present a proposition to overcome the identified gaps.

IV. PROPOSED ARCHITECTURE

This section is divided in two parts: the first one provides the internal elements for the CSMF; the second illustrates its most important usage examples and interactions.

A. Elements for the CSMF

According to [10], the CSMF would be the entity that knows the networking parameters to be used to deploy a network slice in compliance with the customer's specification of the CS. In Figure 2 we use an Unified Modeling Language (UML) diagram to define the building blocks of the CSMF to overcome the gaps specified in Section III. The components are:
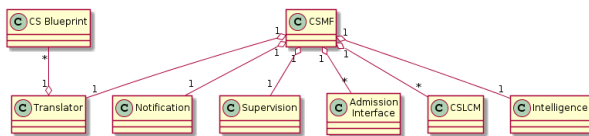

Fig. 2. Proposed UML class diagram for the CSMF

Notification: provides feedback to the user via the BSS about failures or affectation of the CS. It is useful to communicate changes on the Service Level Objective (SLO), SLA

and open trouble tickets proactively, in order to track the issue from a business point of view.

Supervision: gathers information from other frameworks, e.g. FCAPS, NWDA, and according to those inputs triggers LCM actions on the CS.

Admission Interface: receives the CS requirement with the service specification from the customer. In addition, it will receive the corresponding LCM instruction to be applied on the CS and notifies important information to the BSS regarding the CS.

CS LCM: represents the functions that can be applied to a CS. Foreseen functions are: **(i)** commissioning: creates the CS; **(ii)** activation: brings the CS into operation; **(iii)** modification: modifies parameters of the CS, due to a request of the customer or the influence of the supervision components; **(iv)** deactivation: stops the CS; **(v)** termination: erases the CS (all the non-shared resources) so they can be reused in other services.

Intelligence: performs the correlation of events reported by the FCAPS frameworks and, via a feedback loop and aided with the knowledge of the environment, it will use cognition to recommend actions, anticipate failures or detect security events.

Translator: converts the CS requirements from the customer into network slice parameters, as required by lower level management functions.

CS Blueprint: contains the configurable characteristics of the CS, then used by the Translator in order to perform its conversion tasks.

With these entities, we seek to have a complete implementation of the functions for the CSMF.

B. Examples of CSMF functionality and its interactions

It is important to visualize some usage examples of the CSMF through *use case diagrams* and *sequence diagrams*. The most relevant ones relate to **(1)** CS LCM, **(2)** CS automated management, and **(3)** NWDA actions on a CS. However, there are more use cases such as network slice LCM, management of the security of network slices aided by artificial intelligence, among others. We will focus on the first three of them.

1) CS LCM: Figure 3 shows the functions that are needed in the CSMF to manage a CS, being the BSS the entity that provides the initial information, and the NSMF the one that realizes the network slices after the CSMF performs its internal tasks. Leveraging on these functions, Figure 4 depicts the situation when a new CS is required. The BSS, after collecting the CS parameters from the customer (A), uses an API from the Admission Interface exposed by the CSMF to send the parameters of the CS in form of a vector (1). The Admission Interface will **(i)** parse the input to know the requirements for the CS; and **(ii)** specify the LCM action to be performed over that CS (B). Then, the CS LCM function receives the information (2) and asks the Translator function (3) for the correspondence between the CS requirements into network slice related requirements. To do so, the Translator needs three pieces of information: (i) the CS Blueprint (CSB) to know
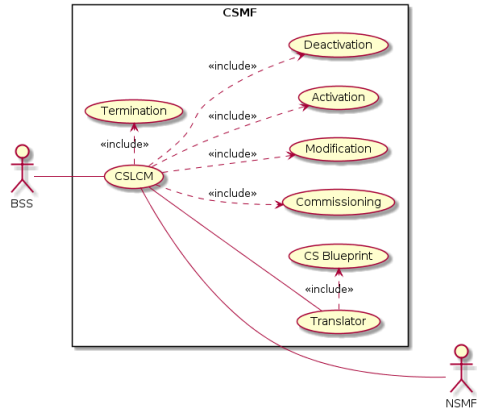
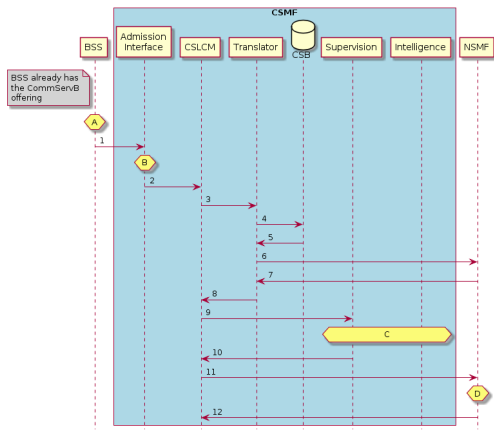Fig. 3. Use case diagram for usage *(1)*: functions in CSMF for CS LCM.

Fig. 4. Sequence diagram for usage *(1)*: new communication service.

Fig. 5. Use case diagram for usage *(2)*: CS automated management.

Fig. 6. Sequence diagram for usage *(2)*: alarm management of a CS.

the feedback loop provided by the intelligence entity is analyzed by the NWDA, who aids to perform the automated management 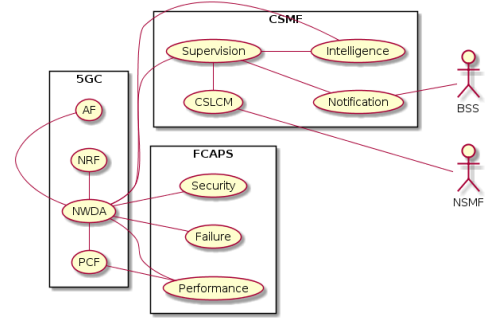of a CS. Figure 6 shows specific interactions when alarm management is needed due to a fault condition in the CS. In this case, the FCAPS can report problems to the supervision function (1). In order to have a complete picture of the environment, it can leverage on the Intelligence and NWDA entities (2) to obtain a recommended action to solve the issue (A). When the Supervision entity receives the recommended action (3), it can trigger LCM actions for the CS (4). Then the CSMF can prompt the NSMF to perform corrective actions on the network slice instances and correct the issue with the CS (5). It is always advisable to notify the customer about the problems of the service, even if it does not affect the CS. That is why the supervision function can prompt the notification function (6) to send information to the customer via the BSS (7). Information such as trouble ticket number for issue follow-up, percentage of SLA degradation, a fee discount due to the failure is considered.

3) NWDA actions on a CS: Figure 7 shows the use case diagram when the NWDA, thanks to input received from FCAPS and other AF, can influence changes on a CS via the CSMF. Changes are triggered via internal actions such as determination of policy, Quality of Service (QoS) adjustment, SLA guarantee, predictable network performance, among others [18]. These actions seek to lead the CS to a desired state. For the interaction, the service-based interface *Nnwdaf* [4] is used for the exchange of information. Figure 8 addresses the situation when there is a deviation from the policy established for a CS: the NWDA receives from AF and

the service offering (4,5); (ii) the Network Slice Template, held by the NSMF, to know the network slice offering and capabilities (6,7); and (iii) the requirements from the customer. With this information, the Translator provides the network slice related information to the CS LCM (8). The CS LCM function asks the Supervision and Intelligence entities for information about the current state of the network and its future behavior (according to cognitive tools), in order to supply correct configuration parameters for a communication service (9,C). It is envision that information from these two entities can be used also for the management of isolation and other security requirements. As soon as the CS LCM receives the data (10), it is ready to instruct the NSMF to perform the required LCM action focused on network slices (11). After the NSMF performs its duties in relation to the orchestrator (D), it sends the status of the task to the CSMF (12).

2) CS Automated management: Figure 5 shows the representative entities and internal functions for the FCAPS, the 5G Core (5GC) and CSMF for this use case. Information gathered from FCAPS (service-related alarms, performance related data like SLA, SLO, KPI, and security-related alarms), from Application Function (AF) of the 5GC [8] and from

FCAPS entities information regarding the ongoing services, alarms, and performance indicators (1). It executes calculations and analytic functions (A) that lead to a suggested action (2) to enforce a desired policy. The action is received by the supervision and intelligence entities which, with knowledge of the environment and cognition properties, will prompt the CS LCM function (3) to perform management of the CS. This will be executed further by the NSMF (4) over the network services and infrastructure by subsequent entities.
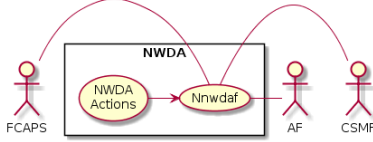

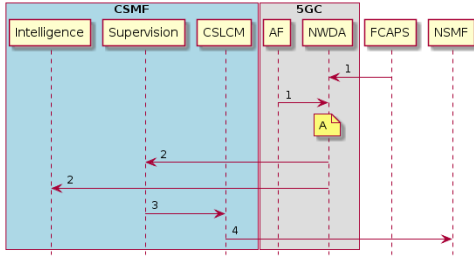Fig. 7. Use case diagram for usage *(3)*: NWDA actions on a CS.

Fig. 8. Sequence diagram for usage *(3)*: NWDA actions to correct a CS according to policy.

C. Final remarks

The proposed CSMF model provides the missing features named in Section III and, via these enhancements, we achieve to describe its interactions and the needed parameters to fulfill its purpose. We named and specified several use cases, being the ones addressed in this section the initial steps to build more advanced use cases. Our future work involves the implementation of the proposed CSMF model to verify its performance and use it to capture the security conditions that a customer requires for its CS. To this end, the challenge at CSMF level is related to the translation of these requirements expressed in business language, into parameters that the network infrastructure can understand. The proposed model helps to go towards this objective.

V. CONCLUSIONS

The network slicing concept is an important foundation for the CS that will be deployed over 5G networks. One essential component in the architecture is the CSMF, as an entity that performs the mapping from customer requirements into network slicing capabilities for a desired CS. We pointed out that associated entities like FCAPS, intelligence, and NWDA are needed as support systems to ensure the correct LCM and operation of CS. For example, without an FCAPS

framework, we would be lacking of failure management, performance measuring and basic security supervision. Without the intelligence entity, decisions to solve service issues via automatization would be lacking of the understanding of the environment and use of cognition to convert information into knowledge. Without NWDA, we would lack of the interaction with the 5GC functions with respect to policy, access to application functions and the analytics of network slice load, user authentication attempts and traffic analysis. We proposed the internal functions for the CSMF that are necessary for performing its duties and described the interactions with other entities of the network slicing architecture. Our proposition enhances the current approaches from existing projects and helps to pave the way to further specify its internal functions, their implementation, and ease the interaction between the customer and the operations and support frameworks of the architecture. Our approach is extensible to connect to the 5GC network and use its analytics and policy functions. This will be helpful in our envisioned implementation of the model and application to security use cases. The whole ecosystem helps to build synergies and overcome challenges about the implementation of communication services.

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