Service-Based Management Architecture for On-Demand Creation, Configuration, and Control of a Network Slice Subnet

A. Ishaq[*], D. Ronzani[*], A. Spinato[*], N. di Pietro[*], M. Centenaro[*], A. Bellin[*,†], D. Munaretto[*]

[*]*Research and Innovation Department, Athonet S.r.l.*
via Cà del Luogo 6/8, 36050, Bolzano Vicentino (VI), Italy
{arif.ishaq, daniele.ronzani, andrea.spinato, nicola.dipietro, marco.centenaro, daniele.munaretto}@athonet.com
arturo.bellin@intern.athonet.com,

[†]*Department of Information Engineering and Computer Science (DISI), University of Trento*
Via Sommarive 9, 38123, Povo (TN), Italy
arturo.bellin@unitn.it

***Abstract*—The management of a 5G system comprises Operation and Management aspects defined by 3GPP, including Network Slicing, and the Management and Orchestration aspects specified in ETSI's Network Function Virtualization framework. Our Proof-of-Concept demonstrates the implementation of an on-demand provisioning procedure of a Network Slice Subnet composed of Virtual Network Functions from potentially different vendors. The demonstration includes a Network Management System conforming to the 3GPP Service-Based Management Architecture, an ETSI MANO orchestrator, and a Network Function Virtualization Infrastructure.**

***Index Terms*—5G, 5GS, SBMA, OAM, MANO, NFV, Network Slicing, MIB, microservices, NMS, NSSMF, VNF, MOI, NRM.**

I. Introduction

The 3rd Generation Partnership Project (3GPP) has a long tradition of specifying the Operation, Administration, Maintenance and Provisioning (OAM&P) of Telecommunications Networks [1]. Management functions are separated into layers, going from the *Element Management* layer to the *Network*, *Service*, and *Business Management* layers.

Management at the *Service* and *Business Management* layers is focused on processes, and is compatible with TM Forum specifications [1]. Management in the *Network* and *Element Management* layers is specified in the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) specifications on Telecommunications Management Network (TMN), and adopted by 3GPP [2]. It takes care of the management of *Faults, Configuration, Accounting, Performance, and Security*, so-called FCAPS management.

With the advent of virtualization infrastructures for the deployment of Virtualized Network Functions (VNFs) communicating over Virtualized Networks, the model has been extended to include *Lifecycle Management*. ETSI has developed the Management and Orchestration (MANO) framework for the lifecycle management and orchestration of virtualized resources made available by a Network Function Virtualization Infrastructure (NFVI), which can abstract the functionalities provided by cloud-like infrastructure management systems [3]. 3GPP OAM adopts and integrates this framework in its own Service-Based Management Architecture (SBMA) [4].

Lastly, 5G introduces the concept of Network Slicing [5]. A Network Slice is a logical 5G System (5GS), an abstraction over the concrete network, realized by means of physical or virtualized resources. Network slicing is essentially a management concept whereby a 5GS's resources are allocated wholly or in part to logical or, in analogy to other technologies, virtual 5GSs.

The SBMA, like the 5G control plane, is service-based [6]. It makes use of so-called Management Services (MnS) and is based on the Representational State Transfer (REST) architectural style. MnSs are offered by MnS Producers, and invoked and used by MnS Consumers. There are services for lifecycle management and configuration, called Provisioning MnS - ProvMnS -, for fault supervisioning - FaultSupervisionMnS -, and for performance monitoring and reporting - StreamingDataReportingMnS, FileDataReportingMnS. These services are considered to be components of the SBMA. In particular, components of type A [6].

The management services act upon an abstract view of the 5GS's resources, which are modelled in a Network Resource Model (NRM) [7] with so-called Managed Object Instances (MOIs). Each MOI contains the essential information about the resource, modelled by an Information Object Class (IOC). The MOIs are organized in a tree structure, called the Management Information Base (MIB), similar to a Lightweight Directory Access Protocol (LDAP) tree. Each MOI is identified by a Distinguished Name (DN), which is constructed very much

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like the DNs in LDAP. The MOIs that make up the MIB are considered to be components of the SBMA, of type B [6].

Since the entities that realize the 5GS are “created” on demand through the creation of Network Slices, the relative MOIs representing those entities too are “created” on demand.

The scope of this demo is a Proof-of-Concept (PoC) Network Management System (NMS) for the creation and configuration of a Network Slice Subnet (NSS), constituent part of a Network Slice, composed of VNFs from potentially different vendors [8]. The 3GPP SBMA-compliant NMS is integrated with OSM (Open Source MANO), an open-source implementation of the ETSI MANO framework [9], using OpenStack [10] as the NFVI.

A. *Our contribution*

3GPP SBMA specifications are neither stable nor complete, with many aspects left to vendor/developer-specific implementation. Further, OSM, despite being an ETSI initiative, is not fully compliant to ETSI NFV MANO specifications, and in certain aspects it even deviates from the very integration points with the 3GPP OAM framework.

Nevertheless, given the importance of a standardized operation and management solution, and the guarantee of a well-thought-out solution based on a long tradition, we have endeavoured to undertake the realization of a 3GPP Management Framework. We employ vendor-specific Management Nodes to cater for the vendor-specific differences in VNF implementation. For VNFs that employ specific techniques, such as e.g. microservices, the vendor-specific Management Node fetches VNF instance information from ETSI MANO and passes it to the VNF in dedicated Vendor-Specific Data Container MOIs.

Since Management Nodes and Vendor-Specific Data Containers are abstractions in the SBMA, we achieve the goal of constructing a multi-vendor Management System in which Network Slice Subnets can be provisioned and managed.

II. Demonstration Use Case

A. *Hardware and Software Setup*

The demonstration main setup is hosted at Athonet’s Research and Innovation (R&I) labs, remotely accessible via VPN connection. Users will interact with the test-bed via a Graphical User Interface or Command Line Interface on a PC at the conference venue.

The PoC is deployed in a virtualization infrastructure installed on a Dell R640 server system. OpenStack (release Victoria) [10] has been adopted for providing an open-source NFVI as private cloud. It manages hardware pools and provides a virtual infrastructure for service or network deployments. Finally, it operates as a Virtual Infrastructure Manager (VIM) in the NFV MANO framework and orchestrates NFVI resources, instantiating Virtual Machines (VMs), virtual networks, and providing an internal gateway. Some instances can have a port attached to the internal OpenStack network for external connectivity.

OSM was chosen as the NFV MANO system because it is a fairly stable open-source implementation, with support for various NFVIs, including OpenStack, and promises alignment with ETSI NFV MANO specifications. Further, OSM allows to model and automatize the complete lifecycle of virtual, physical, or hybrid Network Functions (NFs) and Network Services (NSs). In our prototype, OSM Release Ten is installed and deployed into a VM managed by OpenStack itself.

Both OSM and the OpenStack NFVI are located in Athonet’s R&I testbed. The PoC’s NMS, instead, is deployed in a PC in the conference venue.

The NMS hosts the root SubNetwork MOI, which name-contains the other Managed Entities. It also exposes a Notification Endpoint which captures notifications from the Managed Entities as they get created.

B. *Demonstration Steps*

The creation and operation of the Network Slice Subnet follows the phases described in [8] and implements the three phases of Preparation, Commissioning, and Operation.

1) Network Slice Design and Preparation Phase: In this step [8], the Network Slice Subnet, including its networking, is designed, and that information is provided to the NMS and NFV MANO.

As depicted in Fig. 1, the exemplary NSS that we are considering in this demo is composed of two Network Functions of the 5G core network: the Unified Data Management (UDM), and the Network Repository Function (NRF) [5]. The two NFs are implemented by different developers, mimicking vendor-independence. One, the UDM, is implemented as an agglomeration of independent microservices and is SBMA-aware, exposing SBMA-compliant management services. The other, the NRF, is monolithic and does not expose SBMA-compliant management services.

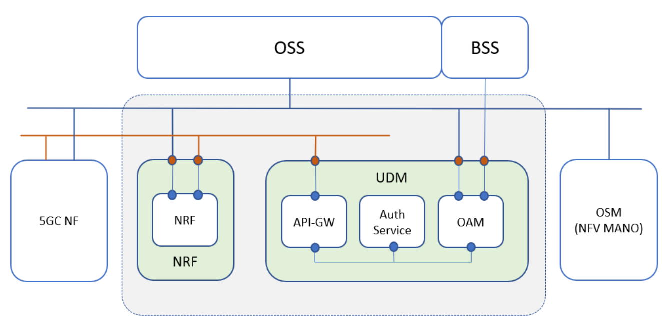

Fig. 1. Demo Network Slice Subnet configuration.

The choice of these two NFs for our demo is based on the consideration that two NFs are enough to demonstrate a NSS, all the more so because these NFs do not depend on the functionality of other NFs in the 5G core network [5]. In addition, in the implemented service-based architecture of the UDM, each microservice is considered a VNF component, thus permitting the demonstration of the instantiation of a VNF with multiple VNF Components (VNFCs).

The NSS corresponds to a Network Service (NS) in NFV MANO [7], and is described in an Network Service Descriptor (NSD) [11]. The NSD specifies the required VNFs - described in VNF Descriptors (VNFDs) - and their networking requirements. Each VNF is made up of one or more VNFCs - described as Virtual Deployment Units (VDUs) in the VNFD [15] - and specify the component's *Compute*, *Storage*, and *Network* resource requirements. The NSD and the constituent VNFDs are defined in *yaml* files and can be on-boarded in OSM by means of its GUI or CLI.

From the SBMA point of view, the NSS and the constituent NFs are all part of a SubNetwork [7]. The NSS is associated with a Slice Profile, which specifies the characteristics of the NSS, including the PLMN and the Slice Service Type (SST). The characteristics and their exact meaning are specified by Global System for Mobile Communications Association (GSMA) [13].

We register vendor-specific Management Nodes in the NMS as well as Slice Profiles with their corresponding NSD identifiers in the Network Slice Subnet Management Function (NSSMF) component of the NMS. This interface is not subject to standardization.

2) Network Slice Commissioning Phase: In the Commissioning phase, the NSS is created by invoking the *AllocateNssi* operation of the NSSMF ProvMnS service [12]. The NSSMF requests the OSM to create an NS instance based on the specified NSD and then to instantiate it [14]. OSM sets up the required virtualized network resources and instantiates the constituent VNFs.

The NSSMF fetches the information on the instantiated NS from OSM and determines the VNFs that have been instantiated, together with the virtualized resources, including networking resources, that have been allocated, and requests the Management Nodes of the VNFs to create the required MOIs for the virtualized resources. The request includes the Notification Endpoint of the NMS to enable the VNFs to send notifications of the creation of the relative MOIs.

Finally, the NSSMF creates an NSS MOI for the instantiated Slice Subnet and notifies the NMS. A fragment of the resulting MIB is represented in Fig. 2.

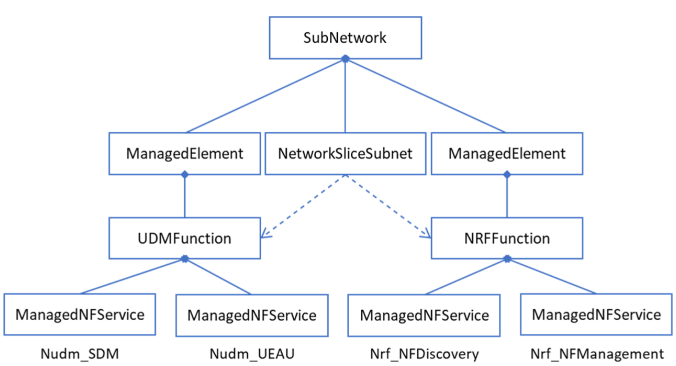

Fig. 2. MIB fragment created for the demonstrated NSS.

The 5G services provided by the VNFs are initially unavailable, with *administrativeState* set to "locked". Through the GUI, or via HTTP client tools such as *curl*, it will be possible to invoke *ProvMnS* operations on the MOIs to inspect the MIB. In particular, it will be possible to see which NFs make up the NSS, which 5G services they offer and the relative Service Access Points (SAPs), what the state of those services is, and whether the UDM is registered in the NRF or not.

3) Network Slice Operation Phase: In the Operation phase, the NSS is activated by setting the NSS MOI's *administrativeState* to "unlocked". The NSSMF then unlocks the constituent VNFs, enabling their produced 5G services. It will be possible to see the changed state of the ManagedFunctions, that the 5G services produced by the UDM are registered in the NRF, and to invoke those services.

III. Conclusions and Future Work

Adherence to standards is essential in a multi-vendor world. This PoC demonstrates how it is possible to implement a standard-compliant system to manage a 5GS, and in particular to manage its network slicing aspects, with relatively little system integration effort, and compatible with the combination of components from different vendors into an open environment (i.e., not subject to vendor lock-in).

The PoC was limited to the configuration aspects, but fault supervision and performance monitoring are other essential functions of a management system, and we are experimenting with their implementation following the 3GPP SBMA framework in our test-bed.

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