Towards a Unified Network Slicing Model

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***Abstract*—Network Slicing (NS) is actually an ongoing standardization work, different visions and inconsistent use of terminologies are observed across Standard Developing Organizations (SDOs). In this paper, we aim at presenting and comparing most well known works about NS information models. The target is to combine major contributions from different SDOs and come out with a proposition of a unified NS model. The proposed NS model components and the way they relate to each other are then mapped to the end-to-end Management and Orchestration (MANO) reference architecture.**

***Index Terms*—network slicing, information model, data model, orchestration, network slice management**

I. Introduction

It is crucial to clarify the nuances around NS concepts from many standards associations as well as to combine and unify their works paving the way to researchers and developers for accelerating implementations and optimizing future propositions.

In this work we first overview the different NS views and terminologies as introduced by the main SDOs, e.g., ETSI, IETF, GSMA and 3GPP (Section II). In particular, we want to explain their point of view regarding the Network Slice information model and to come out with a unified NS model (Section III). Second, we map the obtained slicing model along with its contained components and the way they relate to each other to the End-to-End MANO (Management and Orchestration) reference architecture [1] [2] proposed in the context of the 5G Exchange project [3] (Section III).

II. Overview of standard Network Slice information models

A. ETSI Information Model

ETSI has identified a need for a standardized Network Slice architecture that illustrates the resource information flow over several technologies and administrative domains [4]. Then, it has provided a technology independent framework that describes the main workflow steps from the tenant service order to slice deployment, monitoring and lifecycle management. Figure 1 depicts the ETSI reference Network Slice architecture and information model that consist of three Actor types: (i) Tenants that consume a service supported by a Network Slice instance. (ii) Network Slice Providers (NSPs) that provide access to Network Slice instances, and finally (iii) the Network Slice Agents (NSAs) that have the complete view and control of their own network infrastructure also called Subnet.

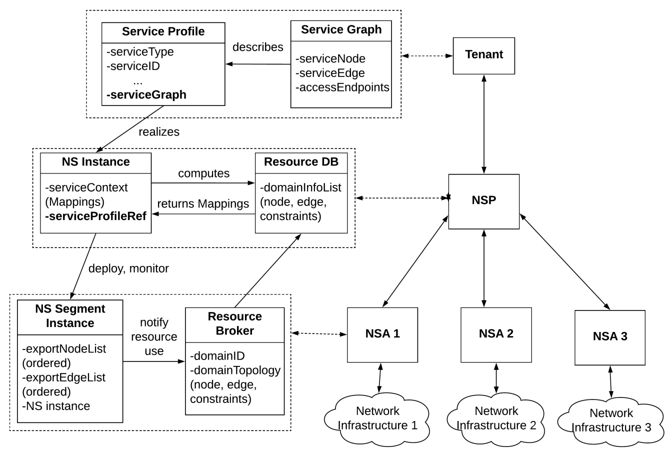

Fig. 1. ETSI NGP reference Network Slice architecture and information model.

The Network Slice deployment process begins with the tenant's service order. A Service is defined in terms of a *service profile* that comprises a *service graph* and some additional service attributes. A service graph is the part that on one hand describes the required nodes in terms of compute, storage and service instance type such as firewall, load balancer, and router. On the other hand, it defines the service connectivity resources constraints also called edges such as link bandwidth, latency, and packet loss rate. Then, at the NSA level the "resource broker" component is in charge of gathering the complete domain-specific topology information. These topological data are then abstracted and exported to the resource database at the NSP domain.

The Network Slice Instance (NSI) is an instantiation of the received service profile created by the NSP. It aims to compute the mappings of the service graph to the abstracted topological data stored in the resource database. Those mappings are then stored in the run-time service context object within the NSI. Figure 1 shows all the main information model entities involved in the Network Slice deployment process.

Given that a Network Slice may span across several NSA domains, a Segment, is the set of paths and nodes a Network Slice instance is allocating to a specific NSA. Therefore, to continue the workflow process, the NSP delegates Segments to appropriate NSAs for deployment. Segments are then concate-

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nated with each other using a Network Slice Gateway (NSG) in order to form the end-to-end slice.

B. IETF Information Model

Usually, customers do not necessarily have prior knowledge about the underlying network technology that may support a Network Slice. Hence a customer's formulated order comprises technology-agnostic service requirements. In the ongoing work [5], IETF has introduced a technology independent information model for transport NS (Figure 2). Later, a slice provider will augment the information model with technology-specific informations.

The Network Slice data model is provided in yang language and augment the data model for network topologies developed in [6]. For the IETF, a tenant expresses its desired service as a virtual network composed of nodes and links along with connectivity constraints. A node makes references to a list of compute units, storage units and service instances (e.g.Firewall, Load balancer). As illustrated in the Figure 2, a node contains a list of "termination-points". A "termination-point" entity is described with some configuration and statistic attributes such as packet rate, packet loss probability and packet loss threshold. Last, a link is augmented with QoS attributes such as link bandwidth agreement, link throughput, link latency, and link jitter.

Network Slice Segments are not meant to be deployed separately, they are all part of the same logical End-to-End slice. Therefore, the data model is augmented again to implement the Network Slice Subnet stitching operation including informations about NSGs [7].

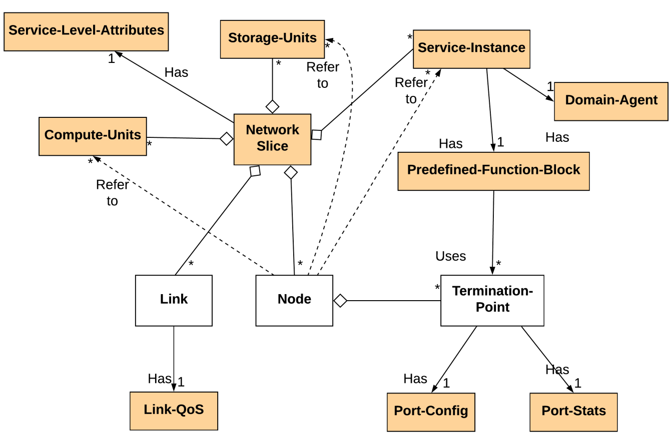

Fig. 2. IETF - Network Slice Information Model

C. 3GPP Information Model

Unlike the ETSI Network Slice architecture, 3GPP slice standards are technology-specific and it covers both the radio and the Core Networks. While a technology-agnostic Network Slice architecture is already given by the ETSI NGP group, we focus in this section on the 3GPP slice information model [8].

In 3GPP the service profile contains the list of the tenant's service requirements. A Network Slice supports a list of service profiles, each of them corresponds to a tenant service. The

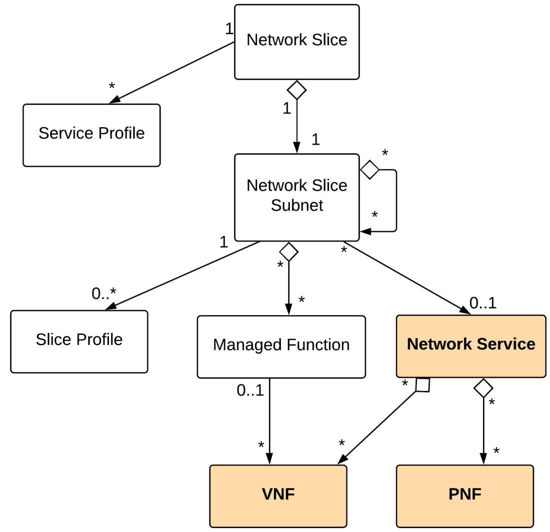

Fig. 3. 3GPP - Information model [8]

Network Slice entity also makes reference to its constituents Subnets (this term is interchangeable with Segment in 3GPP) which may recursively be composed of other Subnets. The service profile has exactly the same attributes as the slice profile, some of them has reference in GSMA's Generic Slice Template (GST) such as SST (Service/Slice type).

In addition, a Network Slice Subnet is composed of a set of managed functions and may support only one Network Service. A Managed function is realized by one or more VNFs (Virtualized Network Functions). Also the network service may comprise multiple service graphs. However, none of the dark entities in Figure 3 are described in the 3GPP yang data model. Even if the entities VNF, Network Service and PNF are part of the 3GPP Network Slice information model, their definitions are out of scope of 3GPP and are delegated to the ETSI NFV-IFA's VNF and Network Service information models [9], [10].

D. GSMA Slice Templates

GSMA has introduced the GST which contains all the potential attributes that characterize a Network Slice [11]. The later will be used as a reference by vendors, operators, providers and customers in order to identify and deploy a slice that accommodates a particular use-case.

Next, to order the deployment of a Network Slice, a customer needs to fill some or all the GST attributes with its desired values and/or ranges (i.e., service requirements) depending on the slice use-case. The filled-out GST becomes a NEST (Network Slice Type) template. The later helps the operators to select the appropriate Network Slice template (NST) to be further instantiated to a Network Slice as shown by Figure 4.

The GSMA approach has several advantages. First, it permits to a customer to express its service requirements through the GST while allowing operators and service providers to

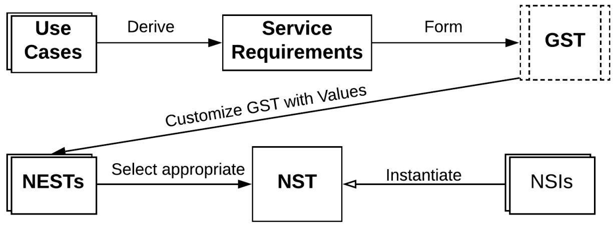

Fig. 4. GSMA - GST/NEST approach

fulfill any possible use-case. Second, standardized slice types are defined for the most popular use-cases in NEST templates (S-NEST: Standardized NEST) and are made available to all operators and concerned organizations around the world. Third, the service capabilities offered to a user inside its home operator are conserved when she/he roams to a third-party visited network. This could simply happen by exporting the NEST templates from the home network to the visited one.

III. A UNIFIED NETWORK SLICING MODEL

In this section we compare and analyze all the reviewed efforts in order to come out with a unified slicing model. Also, we map its components to the end-to-end MANO reference architecture. Even if each of the aforementioned SDOs uses its own terminologies to define slicing concepts and have different visions on how slices should be provisioned, we believe that their works have many common points and can be combined in order to converge to a standardized and unified slicing model.

In fact, we notice from Section II that some used terminologies are not consistent across all the SDOs. In addition, similar terminologies may refer to different concepts and vice versa. For example, the term ”Subnet" is used differently by the ETSI NGP . According to the later, the term is assigned to the underlying physical infrastructure owned by a NSA while in IETF and 3GPP it refers to a Segment. Also, the term ”service profile" does not refer exactly to the same concept in ETSI NGP and 3GPP. While a service profile in ETSI NGP is based on a service graph, it is defined in 3GPP as a set of slice characteristics that need to be filled by the tenant's service requirements. In the rest of this paper we use the term Subnet to refer to a segment.

The table I highlights some differences and similarities on NS standards between SDOs. In fact, given the NS provision models defined by IETF in [12] and based on the definition of service profile in each of ETSI NGP and 3GPP we conclude that currently there are two visions, across SDOs, that dictate how Network Slices are provisioned. The PaaS-like and SaaS-like provision models.

In the former, the tenant contributes to the NST creation by providing a service graph which will further be used by a NSP to design a NST and then to instantiate a Network Slice. ETSI NGP framework and IETF Network Slice information model are aligned with the PaaS-like model. In the later, NSTs are designed in advance by the NSP (predefined NSTs) and the one that best fulfill tenant requirements is selected for instantiation. In that case, the tenant makes its request using only a set of KPIs (Key Performance Indicators). GSMA's work on NS and 3GPP information model are aligned with the SaaS-like model.

TABLE I
DIFFERENCES AND SIMILARITIES ON NETWORK SLICING STANDARDS

Context	***ETSI NGP***	***GSMA***	***3GPP***	***IETF***
Provision Model	PaaS-like	SaaS-like	SaaS-like	PaaS-like
Information Model	technology agnostic	_	technology agnostic	technology agnostic
Domain	Generalized	Mobile Network	RAN and CORE	Transport
Main Contri-bution	NS Architecture	GST/NEST	Information Model	Information Model NS Subnet stitching mechanism Definition of NS provision models

The unified NS model can be derived by combining the following contributions from the SDOs' works:

1) The ETSI NGP reference architecture detailed all the functions and workflows to set up Network Slices. Also the framework is technology-agnostic and generalized to different network domains unlike the other SDOs.
2) The 3GPP information model which may be considered as a reference for the SaaS-like Network Slice provisioning on RAN and Core Network domains.
3) The GSMA GST attributes complete the 3GPP NS information model, more specifically they extend the service/slice profile with standardized slice characteristics.
4) The IETF information model which may be considered as a reference for the PaaS-like Network Slice provisioning on transport domains. In addition, the IETF has integrated a Network Slice Subnet stitching mechanism into the provided data model.

Without a doubt, orchestration, SDN and NFV technologies are the key enabler for NS. Therefore, we map the current slicing model to the E2E MANO reference architecture as depicted in Figure 5. We chose this architecture among others because of its generality. For example, multi-domain orchestration may involve resource and/or service orchestration using several Domain orchestrators (DOs) belonging to either the same operator (multi-technology) or different operators (multi-operator). Furthermore, each of the Multi-domain orchestrator (MDO) and the DO may perform resource orchestration only, service orchestration only or both. The NFV orchestrator (NFVO) of the NFV-MANO Framework [13] is considered as a service orchestrator (but also includes a resource orchestrator) and can be placed at both the domain and multi-domain orchestration layers [14].

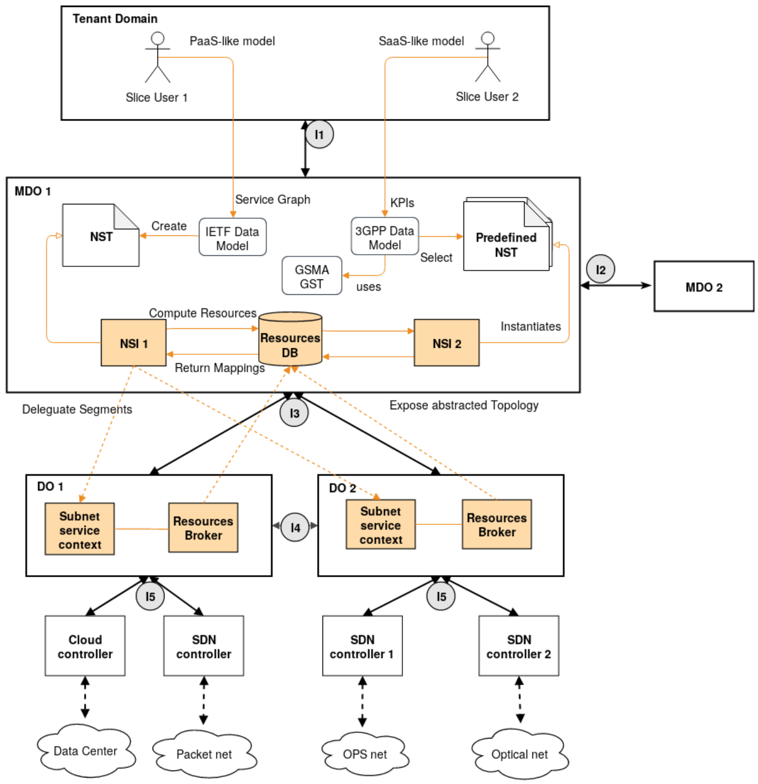

Fig. 5. The unified NS model mapped to the reference E2E MANO architecture

We map the NSA and the NSP from the ETSI NGP architecture to respectively the DO and the MDO of the E2E MANO architecture. Consequently, all the NSA and NSP components illustrated earlier in Figure 1 are now mapped to the DO and the MDO. This mapping is obvious since the DO has a unified control of the underlying cloud and network domains over interface 5. Likewise, the MDO receives customer orders at interface 1 and formalize its request to each one of the DOs, over interface 3, in order to provide Network Slice services. The resource layer comprises several technology-domains such as cloud, and optical packet switching network, etc. Each domain has its own controller. Open Daylight (ODL) and Open Networking Operating System (ONOS) are examples of the most known SDN controllers. Openstack and Kubernetes are the most popular infrastructure controllers for data centers.

The unified NS model illustrated in Figure 5 supports two Network Slice provision models. Tenant's SaaS-like requests carries the NEST template defined by GSMA and its contained service requirements (KPIs) are captured by 3GPP Network Slice data model. Next, an appropriate predefined NST is selected for instantiation. Tenant's PaaS-like requests carries a service graph captured by the IETF data model. This model leads to the creation of a new NST. All the remaining workflows from the NSI creation to Network Slice Subnets delegation are from the ETSI NGP work group and are explained in section (II).

IV. Conclusion and Future Work

The NS technology is witnessing a tremendous standardization wave driven by many SDOs mainly ETSI, 3GPP, GSMA and IETF. This article surveyed their work having in mind the combination of their major contributions in order to propose a unified network slicing model. This will enrich the research community by an in-depth view on network slicing and clarify all the nuances resulting from the SDOs' different visions and terminologies.

Since orchestration and automation are the main enabler of NS we mapped the obtained model to the End-to-End MANO reference architecture.

As future work, we aim at developing a prototype of the unified proposed slicing model including a protocol specification for both the interface 3 and 5 relying on the surveyed SDOs' data models.

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