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Network Slicing on 3GPP 5G System Architecture; An End to End Approach

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Abstract—**New emerging industries, such as vertical markets, need diverse networking requirements that the next generation mobile networks have to support effectively. Network slicing is the basic solution to meet the diverse requirements of various services over a common network infrastructure. Different network slicing architectures have been proposed; however, to the best of our knowledge, there is no unified architecture to cover all aspects of technology. In this paper, we propose a complete network slicing architecture based on 3GPP 5G system that addresses a unified end-to-end approach. We show how this architecture can create and operate various slices in the core and radio access sections using SDN controllers, virtualization, NFV MANO, and 3GPP management functions. We do compare our proposed one with some famous network-slicing architectures. The Comparison Results show that our proposed architecture is complete and covers all the aspects of network slicing. It uses NFV management and orchestration capabilities and SDN controllers while being compatible with 3GPP Service-Based architecture. It also provides life cycle management of network slices in both creation and operation phases in both core and radio access domains of the 5G network. In addition, we have included a functional RAN layer split to lay the corresponding layers in centralized or distributed units according to the requirements of each eMBB, mMTC, or URLLC slice.**

Keywords: Network Slicing, 5G, SDN, NFV, Management and Orchestration, System Architecture

Article type: Research Article

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I. Introduction

New business and vertical markets demand very diverse communication requirements. Communication services usually are classified into three main categories, enhanced mobile broadband (eMBB), massive machine-type communications (mMTC) and ultra-reliable and low-latency communications (URLLC) [1]. Legacy mobile networks are characterized by monolithic network elements that have tightly coupled hardware, software and functionality [2]. This networks, with their "one-size-fits-all" architectural approach, are unable to address the diverging performance requirements that verticals need in terms of bandwidth, latency, scalability and reliability [3]. Therefore, 5G mobile network must have enough flexibility and scalability to create and operate multiple logical networks each tailored for a specific use case running simultaneously on a common physical infrastructure in a flexible, agile, and cost-efficient manner.

Network slicing is key for this end. It is the capability that enables us to deploy multiple end-to-end

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logical networks (slices) over a common physical infrastructure each fitted for a specific use-case [4]. Network slice is a composition of adequately configured network functions, network applications, and the underlying cloud infrastructure (physical, virtual or even emulated resources, RAN resources etc.), that are bundled together to meet the requirements of a specific use case, e.g., bandwidth, latency, processing, and resiliency, coupled with a business purpose [5]. Network softwarization can provide the programmability, flexibility, and modularity that is required to create network slices. Software-Defined Networking (SDN) and Network Function Virtualization (NFV) technologies are two key enablers to achieve network slicing in 5G networks [6], [7].

Although a lot of works about network slicing and specially using SDN and NFV have been done that are reviewed in [8]–[12], but only a few of those have focused on total architectural framework that address all aspects of network slicing. In this work, we propose a complete network slicing architecture based on 3GPP 5G system. We have included 3GPP network slicing concepts as well as ETSI NFV management and orchestration (MANO) block in combination with SDN controllers. Our proposed architecture provides different functional split options for radio access stack protocol. This capability enables us to deploy RAN sub-layers in central unit (CU or BBU) or in distributed unit (DU or RRH) for any slice type based on its slice-specific requirements. We show how this architecture can create and operate various MBB, mMTC, and uRLLC slices in the core and radio access sections using SDN controllers, virtualization, NFV MANO, and 3GPP management functions.

The rest of the paper is organized as follows. In the next section, we briefly discuss related works. Then a typical mobile network is presented, and 3GPP 5G system architecture is discussed. After that, we explain the network slicing concept and network slice lifecycle management. Following that, we present a 5G network slicing architecture based on 3GPP SA and an NFV Based Network Slice Management and Orchestration architecture. Then, our proposed SDN/NFV based architecture for 5G network slicing is discussed. Finally, comparison results are presented.

II. Related Works

Network slicing is defined by multiple SDOs and Fora such as ONF, ETSI, NGMN and 3GPP. However, the meaning and understanding of the network slicing concept are different in each technology and there is no a common definition and understanding. In [7], ETSI NFV provides an insight into the different views about network slicing and describes the possible relationship with the NFV constructs. ONF in [6] presents a core concepts of the SDN Architecture that can be applied to 5G network slicing. The hart of the SDN architecture is the SDN controller. It consists of client and server contexts in addition to virtualization and orchestration functions. In [13], NGMN envisions a 5G architecture that leverages the structural separation of hardware and software, as well as the programmability offered by SDN and NFV. The architecture comprises three layers (business application layer, business enablement layer, and infrastructure resource layer) and an E2E management and orchestration entity. The concept of network slicing is described by NGMN in [4]. The network slicing concept consists of 3 layers: 1) Service Instance Layer, 2) Network Slice Instance Layer, and 3) Resource layer. 5GPPP architecture working group in [14], presented an overall 5G architecture. The recursive model is structured in three levels including service level, Network level, and resources level. A secure network and service management entity manages the total system to provide end to end services. In [2], functional perspective of the overall 5G NORMA network slicing architecture is presented. It shows the separation into four layers (service layer, management and orchestration layer, control layer, and data layer) as well as the differentiation into intra-slice and interslice functions. The Management & Orchestration (MANO) Layer realizes 5G NORMA's Software-defined Mobile network Orchestration (SDMO) concept by extending the ETSI NFV management and orchestration (NFV MANO) architecture towards multi-tenant and multi-service networks. The Control Layer accommodates the two main controllers: (1) the Software-Defined Mobile Network Coordinator (SDM-X) for the control of common (shared) NFs and (2) Software-Defined Mobile Network Controller (SDM-C) for dedicated NFs.

3GPP System Architecture for 5G is defined as service-based and the interaction between network functions [15]. It is represented in two ways: service-based representation and reference point representation. As our proposed architecture is based on 3GPP SA, it is detailed in the following sections.

III. Typical Mobile Network

A mobile network consists of two parts: the core network (CN) and radio access network (RAN). Network services are implemented in the CN, and the RAN allows the user to connect to the network. The CN of 5G (5GC) functionalities are implemented as a set of virtual network functions on core cloud servers. The 5G RAN (also NG-RAN) is connected to the CN via Backhaul links. In the new radio access networks, some functional parts are separated from the base station (BS) and they are implemented in a centralized part as virtual functions on edge cloud servers. In this case, the centralized section (CU) is called baseband unit (BBU) and the distributed section (DU), which is usually the antenna and the radio side, is called the remote radio head (RRH). RRHs are connected to BBU via front haul links. Fig. 1 shows a typical mobile network.

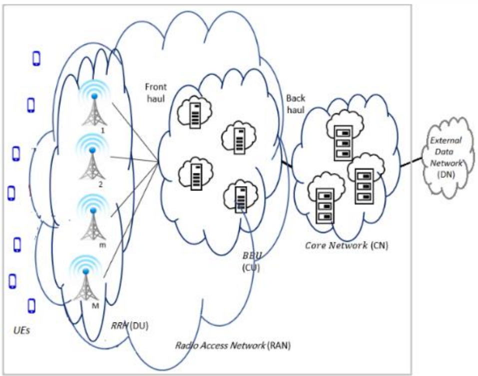

Fig. 1. Typical mobile network.

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IV. 3GPP 5G System Architecture

The 3GPP 5G System architecture is defined as Service-Based Architecture (SBA) [15]. SBA is specified by Network Function Services and Service-Based Interfaces. This architecture support data connectivity and services enabling deployments to use techniques such as Network Function Virtualization and Software Defined Networking. Network Functions provide Network Services and expose them to other Network Functions through Service-Based interfaces. The interaction between Network Functions is represented in two ways (Fig. 2):

- A service-based representation, where network functions within the Control Plane enables other authorized network functions to access their services.
- A reference point representation, shows the interaction exist between the NF services in the network functions described by point-to-point reference point between any two network functions.

The most important network functions of 5G System architecture are:

- Authentication Server Function (AUSF)
- Access and Mobility Management Function (AMF)
- Data Network (DN)
- Network Exposure Function (NEF)
- Network Repository Function (NRF)
- Network Slice Selection Function (NSSF)
- Policy Control Function (PCF)
- Session Management Function (SMF)
- Unified Data Management (UDM)
- Unified Data Repository (UDR)

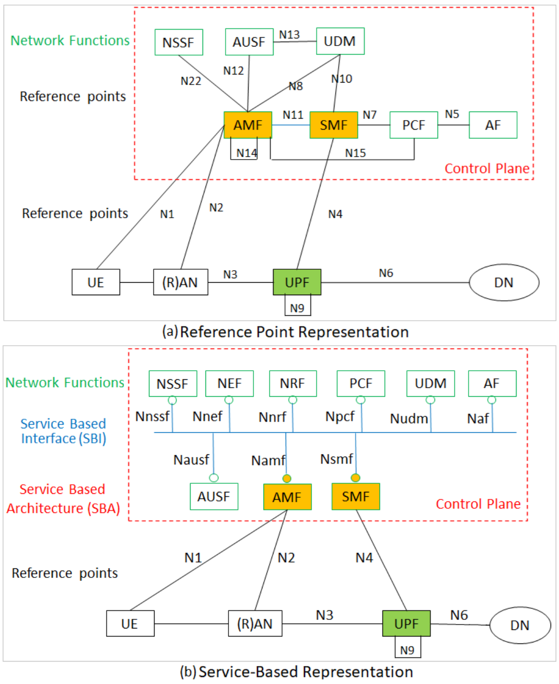

Fig. 2. 3GPP 5G SA. (a) Reference point representation. (b) Service-based representation [15]

- User Plane Function (UPF)
- Application Function (AF)
- User Equipment (UE)
- (Radio) Access Network ((R)AN
- Network Data Analytics Function (NWDAF)

A. 3GPP 5G NR

Overall description of 5G radio access network (NG-RAN or 5G-NR) is provided by 3GPP in TS 38.300 [16]. Fig. 3 shows the NG RAN architecture:

B. NG Interface

An NG-RAN node is either a gNB, providing NR user plane and control plane protocol terminations towards the UE; or an ng-eNB, providing E-UTRA user plane and control plane protocol terminations towards the UE. The gNBs and ng-eNBs are interconnected with each other by means of the Xn interface. The gNBs and ng-eNBs are also connected by means of the NG interfaces to the 5GC, more specifically to the AMF by means of the NG-C interface and to the UPF by means of the NG-U interface. Fig. 4 shows NG user plane and control plane protocol stack [16].

C. Radio Protocol Architecture

Fig. 5 shows the user plane and control plane 5G NR protocol stack which is used to connect UE to gNB. PHY, MAC, RLC, and PDCP sublayers are in both data and control layers. SDAP is added to user plane to control QOS. Finally, RRC and NAS are exclusive control plane sublayers. The Functionality and services of this sublayers is described in [16].

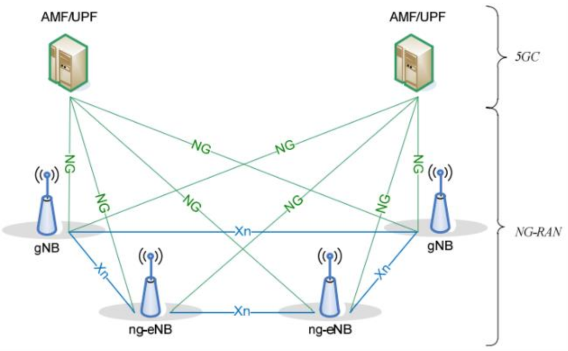

Fig. 3. NG-RAN overall architecture [16]

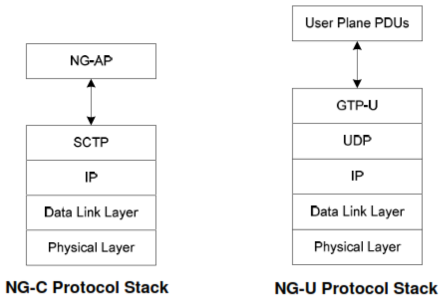

Fig. 4. NG user plane and control plane protocol stack [16]

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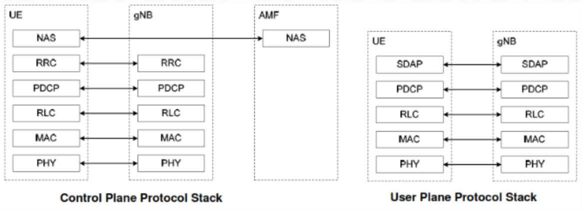

Fig. 5. 5G NR user plane and control plane protocol stack [16]

V. 5G Mobile Network Slicing

Network slicing is creating multiple end-to-end logical networks (slices) over the top of a common physical network, each tailored for a specific use case. Network slices are defined as end-to-end (E2E) logical networks running on a common underlying (physical or virtual) network, mutually isolated, with independent control and management, which can be created on demand [3]. Each network slice consists a set of resources (computing, storage, and networking) that are properly combined to satisfy service requirements.

Adopted from [17] we introduced a network slicing architecture. Fig. 6 shows this architecture that is based on 3GPP SA. Network slicing is done in both CN and RAN. A complete E2E network slice instance (NSI) is a combination of some network subnet slice instances (NSSIs). Slicing in the core network segment is straightforward due to its network function-based architecture. It is needed to create and chain a set of network function instances for each slice instance, depending on the operational and performance requirements. For overall network management, some functions on the control plane such as AMF and NSSF can be shared within all slides. Other functions that are slice-specific are deployed exclusively for each slice. Each network slice may connect to a different external data network (DN) or all connect to single one. However, this architecture covers only operation phase that network slice instances and their corresponding network slice subnet instances (Here 3 typical eMBB, uRLLC, and mMTC Slices) have been already created by the slice provider and are operating by service providers (slice operators).

The AMF instance that is serving the UE may be shared between slices. Other network functions, such as the SMF or the UPF, may be specific to each Network Slice. The Network Slice instance selection for a UE is normally triggered as part of the registration procedure by the first AMF that receives the registration request from the UE. AMF may query the UDM to retrieve UE subscription information. The AMF retrieves the slices that are allowed by the user subscription and interacts with the NSSF to select the appropriate Network Slice instance e.g., based on Allowed S-NSSAIs, PLMN ID, etc. The establishment of a PDU session within the selected instances NSSAI is triggered when the AMF receives a Session Management message from UE. The AMF discovers candidate Session Management Functions (SMF) using multiple parameters including the S-NSSAI provided in the UE request and selects the appropriate SMF. The selection of the UPF is performed by the SMF and uses the S-NSSAI. The S-NSSAI associated with a PDU Session is provided to the AN, and to the PCF entities, to apply slice specific policies.

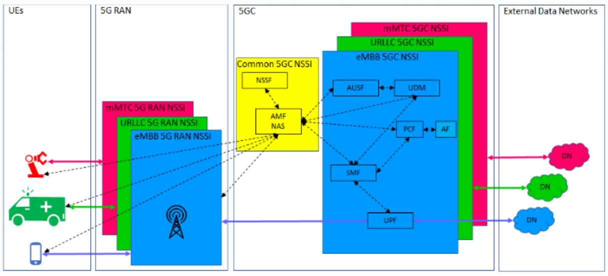

Fig. 6. 5G network slicing architecture based on 3GPP SA

A. *Network slice lifecycle management*

Management aspects of network slicing can be described by four phases shown in Fig. 7 [18]. Each phase defines high level tasks and should include appropriate verification of the output of each task.

- Preparation: In the preparation phase the Network Slice instance does not exist. The preparation phase includes network slice design, network slice capacity planning, on-boarding and evaluation of the network functions, preparing the network environment and other necessary preparations required to be done before the creation of a Network Slice instance.
- Commissioning: Network Slice instance provisioning in the commissioning phase includes creation of the Network Slice instance. During Network Slice instance creation all needed resources are allocated and configured to satisfy the network slice requirements. The creation of a Network Slice instance can include creation and/or modification of the Network Slice instance constituents.
- Operation: The Operation phase includes the activation, supervision, performance reporting (e.g. for KPI monitoring), resource capacity planning, modification, and de-activation of a Network Slice instance. Activation makes the Network Slice instance ready to support communication services. Resource capacity planning includes any actions that calculates resource usage based on a Network Slice instance provisioning, and performance monitoring and generates modification polices as a result of the calculation. Network Slice instance modification could be including e.g. capacity or topology changes. The modification can include creation or modification of Network Slice instance constituents. Network Slice instance modification can be triggered by receiving new network slice requirements or as the result of supervision/reporting. The deactivation includes actions that make the Network Slice instance inactive and stops the communication services. Network slice provisioning actions in the operation phase involves activation, modification and de-activation of a Network Slice instance.
- Decommissioning: Network Slice instance provisioning in the decommissioning phase includes decommissioning of non-shared constituents if required and removing the Network Slice instance specific configuration from the shared constituents. After the decommissioning phase, the Network Slice instance is terminated and does not exist anymore.

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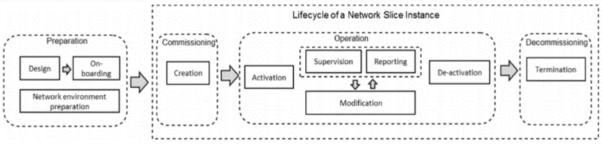

Fig. 7. Management aspects of network slicing [18]

B. 3GPP Management and Orchestration for Network Slicing

Network function virtualization (NFV) is based on decoupling of network functionality from hardware infrastructure. Instead of network equipment (NE), its Functional task is considered as network function (NF). Multiple instances of network functions can be created and deployed as VNFs on a cloud platform and then network services could be provided by chaining these network functions. A framework is needed to manage the life cycle of NFV-based network services. To this end, the *European Telecommunications Standards Institute* (ETSI) has presented the ETSI NFV architecture [19]. A set of SDN applications and controllers can be added to the standard NFV architecture to support network slicing [20]. Three main working domains are identified in NFV: (1) Virtualized Network Functions, (2) NFV Infrastructure (NFVI), (3) NFV Management and Orchestration (MANO). MANO covers the orchestration and lifecycle management of physical and/or software resources that support the infrastructure virtualization, and the lifecycle management of VNFs. It focuses on all virtualization-specific management tasks necessary in the NFV framework. MANO includes three functional blocks:

- Virtualized Infrastructure Manager (VIM): comprises the functionalities that are used to control and manage the interaction of a VNF with computing, storage and network resources under its authority, as well as their virtualization.
- NFV Orchestrator (NFVO): is in charge of the orchestration and management of NFV infrastructure and software resources, and realizing network services on NFVI.
- VNF Manager (VNFM): is responsible for VNF lifecycle management (e.g. instantiation, update, query, scaling, and termination).

Network slicing, especially in cases where the number of network slices is large, increases the complexity of network management. Therefore, it is vital to find solutions for automated slice management and orchestration. To provide the capability of automated and flexible slice management, the concept of Communication Service (CS) introduced by 3GPP, could be used. A CS is provided by the network operator and is presented to a service operator or a business owner. The service operator uses this CS either for its own communication requirements or to provide services to its users. Such a CS requires an E2E network to be run on it. Indeed, a CS uses a Network Slice Instance (NSI) to provide its service. Different aspects of managing network slices is defined by 3GPP in TR28.801 [21]. Complete management of a NSI includes managing all its operational functions as well as resources needed for supporting its communication services. An NSI may be a combination of network slice subnets consisting of physical and or virtual network functions in both CN and RAN sections. It also includes connectivity between NFs.

3GPP TR 28.801 [21] describes an information model where a network slice contains one or more network slice subnets, each of which in turn contains one or more network functions and can also contain other network slice subnets. These network functions can be managed as VNFs and/or PNFs. To address management and orchestration of communication services, 3GPP introduces Management Function (MF) and Management Service (MS) concepts in [22]. A management service offers management capabilities. In the service-based management architecture, Management Function plays the role of either Management Service producer or Management Service consumer. The management system shall be capable to consume NFV MANO interface (e.g. Os-Ma-nfvo, Ve-Vnfm-em and Ve-Vnfm-vnf reference points). Producer of management services can consume management interfaces provided by NFV MANO for following purposes:

- Network Service Lifecycle Management (NS LCM), Performance Management (PM), Fault Management (FM), Configuration Management (CM) on VNF supporting NS
- VNF Lifecycle Management (VNF LCM), Performance Management (PM), Fault Management (FM), Configuration Management (CM) on resources supporting VNF

3Gpp identifies some management functions related to network slicing management, each provides some management services and may consume some management services produced by other functional blocks [22]:

- Communication Service Management Function (CSMF): this function is responsible for translating the communication service-related requirement to network slice related requirements. The CSMF communicates with the Network Slice Management Function (NSMF)
- Network Slice Management Function (NSMF): this function is responsible for the management (including lifecycle) of NSIs. It derives network slice subnet related requirements from the network slice related requirements. NSMF communicates with the NSSMF and the CSMF. It provides the management services for one or more NSI and may consume some management services produced by other functional blocks.
- Network Slice Subnet Management Function (NSSMF): This function is responsible for the management (including lifecycle) of NSSIs. The NSSMF communicates with the NSMF. It provides the management services for one or more NSSI and may consume some management services produced by other functional blocks.
- Network Function Management Function (NFMF): Provides the management services for managing one or more Network Functions (NF) and may consume some management services produced by other functional blocks.
- Management Data Analytics Function (MDAF): Provides the Management Data Analytics Service

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for one or more NF, NSSI and/or NSI, and may consume some management services produced by other functional blocks.

Fig. 8 shows 3GPP Management Functions and a deployment scenario for NSSI management with interface to NFV-MANO [22]. The entity denoted as NSSMF (NSS Management Function), is capable of consuming the VNF LCM and NS LCM related services provided by the NFV-MANO (NFVO). Same entity is also a provider of the NSS related management services. The entity denoted as NFMF (NF Management Function), is capable of application level management of VNFs and PNFs and is a producer of the NF Provisioning service that includes Configuration Management (CM), Fault Management (FM) and Performance Management. Same entity is consumer of the NF Provisioning service produced by VNFs and PNFs.

Using 3GPP slice management functions and including them in ETSI NFV basic architecture as described in [7] and considering slice management and orchestration architecture presented in [17] , we have introduced an extended architecture for slice management and orchestration based on NFV MANO framework which is expected to support network slicing for different eMBB, URLLC, and mMTC slices. Fig. 9 shows this architecture that is in accordance with NGMN conceptual network slicing model [4] where business layer is added on top. Hence, the layered architecture consists of 4 layers: (1) Business layer, (2) Communication Service Instance layer, (3) Network Slice Instance layer, and (4) Resource layer. The OSS/BSS domain is enhanced with 3 management functions including Communication Service Management Function (CSMF), Network Slice Management function (NSMF), and Network Slice Subnet Management Function (NSSMF). As shown in Fig. 10, the Os-Ma reference point can be used for the interaction between 3GPP slicing related management functions and NFV-MANO to manage NSI lifecycle management as well as fault, configuration, accounting, performance, and security management (FCAPS). To properly interface with NFV-MANO, the NSMF and/or NSSMF need to determine the type of Network Services (NSs) or set of NSs, VNF and PNF that can support the resource requirements for a NSI or NSSI, and whether new instances of these NSs, VNFs and the connectivity to the PNFs need to be created or existing instances can be re-used.

VI. Proposed Network Slicing Architectural (NSA) Framework

In this section, an SDN/NFV based architecture for 5G network slicing is proposed. We have included 3GPP network slicing concepts as well as ETSI NFV management and orchestration (MANO) block. This architecture provides different functional split options for radio access stack protocol [23], [24], [25]. This capability enables us to deploy RAN sub-layers in central unit (CU or BBU) or in distributed unit (DU or RRH) for any slice type based on its slice-specific requirements. Fig. 10 shows proposed architecture. It covers all three network domains including core network, transport network, and radio access network.

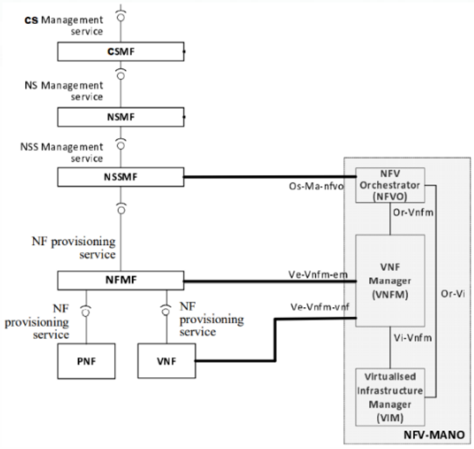

Fig. 8. 3GPP Management Functions and a deployment scenario for NSSI management with interface to NFV-MANO [22]

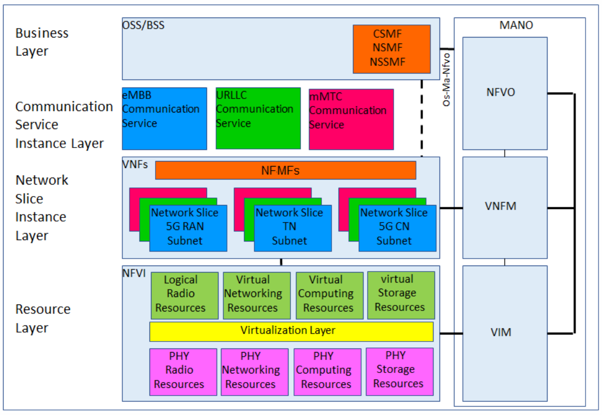

Fig. 9. NFV Based Network Slice Management and Orchestration architecture

A. Architectural Functional Blocks description

The architectural framework (Fig. 10) specifies functional blocks and the main reference points between such blocks. The functional blocks are:

Virtualized Network Function (VNF): A VNF is a virtualization (software-based) of a network function. Examples of NFs are 3GPP 5GC network elements, e.g., AMF, NSSF, UPF, SMF; conventional network functions, e.g., Dynamic Host Configuration Protocol (DHCP) servers, firewalls; and RAN layer functionality and protocols s, e.g., NAS, RRC, SDAP, PDCP, RLC, MAC, and also some functionalities of PHY as well as MEC applications and cache servers.

Element Management (EM): The Element Management performs the typical management functionality (fault, configuration, accounting, performance, and security) for one or several VNFs. An EM itself may be implemented as a VNF. For compatibility with 3GPP network slicing concepts, we use NFMF instead of EM.

NFV Infrastructure (NFVI): The NFV Infrastructure is the totality of all hardware and software components which build up the environment in which VNFs are deployed, managed and executed [19]. In NFV, the physical hardware resources consist of computing, storage and network that provide processing, storage and connectivity to VNFs through

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the virtualizati on layer. The virtualization layer abstracts the hardware resources and decouples the VNF software from the underlying hardware, thus ensuring a hardware independent lifecycle for the VNFs. The use of hypervisors is one of the present typical solutions for the deployment of VNFs [26]. When virtualization is used in the network resource domain, network hardware is abstracted by the virtualization layer to realize virtualized network paths that provide connectivity between VMs of a VNF and/or between different VNF instances [27]. RAN virtualization due to limited radio resources and time varying channels is more complicated [28]. However, RAN slicing has been emerged as a solution [29]–[33].

The NFV Infrastructure can span across several domains and locations. As shown in Fig. 10, there is five different domains in accordance with 5G mobile network architecture (Fig. 1) including 5G Core Virtualization Infrastructure (5GC NFVI), Backhaul Link's vitalization infrastructure (BHLVI), RAN Central Unit Virtualization Infrastructure (CU NFVI), Fronthaul Link's vitalization infrastructure (FHLVI), and Distributed Unit RAN slicing Infrastructure (RANSI). The 5GC NFVI and CU NFVI are cloud-based and deployed in the form of datacenters (DCs).

Management and Orchestration (MANO): Performs all the virtualization-specific management, coordination, and automation tasks in the NFV architecture.

Virtualized Infrastructure Manager (VIM): Functional block that is responsible for controlling and managing the NFVI compute, storage and network resources**.** To manage the resources and their connectivity of a single PoP within its administrative domain, the infrastructure provider exposes a Virtualized Infrastructure Manager (VIM). However, to control connectivity between different PoPs as well as backhaul and fronthaul links, SDN controllers at the position of VIMs are used [20]. Therefore, we have evolved the VIM entity with 6 sub-blocks: Core Network VIM (CN VIM), Core Network SDN Controller (CN SDN-C), Backhaul SDN Controller (BH SDN-C), RAN Central Unit VIM (CU VIM), Fronthaul SDN Controller (FH SDN-C), and Radio Resource Controller (RRC). Note that CU-RAN SDN Controller is not considered because different BBUs are not connected to each other and each of their VIMs manages its internal connectivity.

Virtualized Network Function Manager (VNFM): functional block that is responsible for the lifecycle management of VNF. For this end, it uses VNF Descriptor (VNFD). Each PoP Provides a VIM

Network Functions Virtualization Orchestrator (NFVO): Functional block that manages the Network Service (NS) lifecycle based on Network Service Descriptor (NSD). It coordinates the management of NS lifecycle, VNF lifecycle (supported by the VNFM) and NFVI resources (supported by the VIM) to ensure an optimized allocation of the necessary resources and connectivity**.** It has two set of functions performed by the Resource Orchestrator (RO) and Network Service Orchestrator (NSO)**.**

Communication Service (CS): communication service Instances are laid at service instance layer. We consider a communication service instance as an end-to-end NFV composite Network Service Instance that spans over all administrative domains. A CS matches an NSI which may be consisted of one or some NSSI which in turn correspond to an NFV Network Service. Three different type of communication services i.e., eMBB, uRLLC, and mMTC are considered.

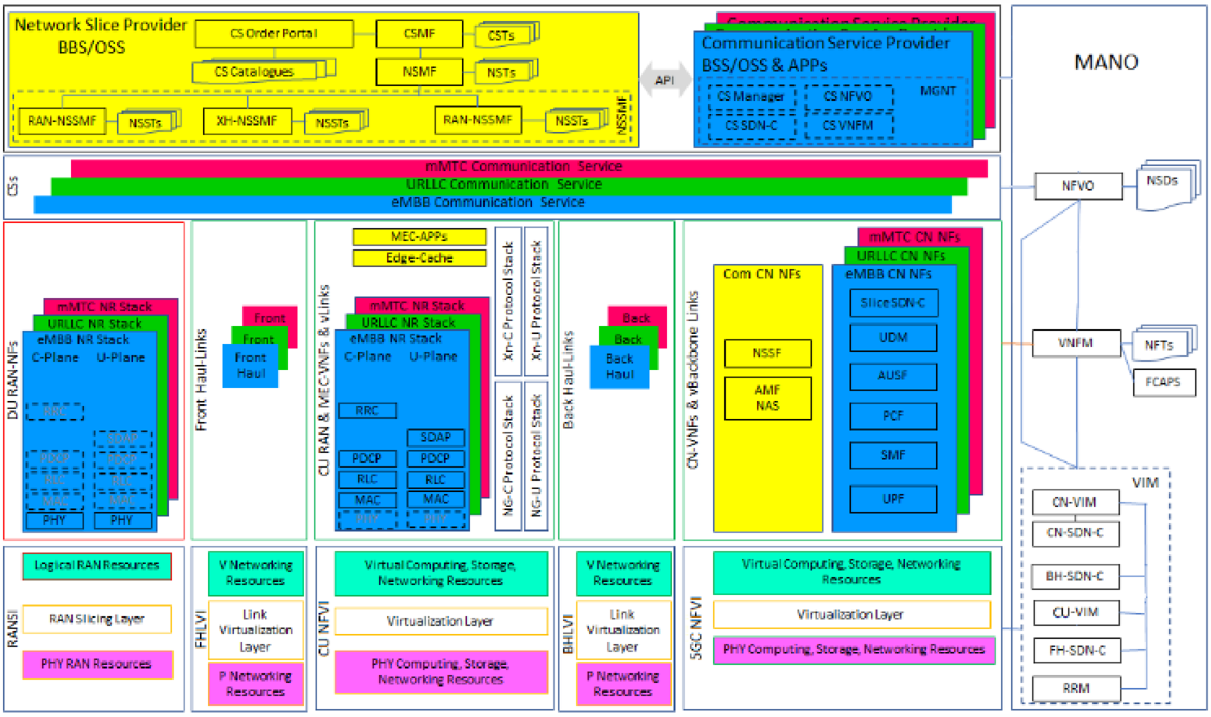

Fig. 10. Proposed 5G Mobile network slicing architecture

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Oper ation Support System/Business Support System (OSS/BSS): a variety of software systems and management applications used to provide and operate network services. In our view to OSS/BSS, all players involved in creation, provision, and operation of a communication services such as infrastructure provider, network slice provider, and network service provider use their specific OSS/BSS applications at different administrative level to perform infrastructure, network, and service-related management tasks. However, we didn't show the infrastructure provider OSS/BSS in Fig. 10.

B. Network slice Creation

A complete study on network slice creation phase is presented in [34]. Authors introduce Instantiation Level concept for Network Service and Network Slice. They also include two functional blocks, Network Slice Orchestrator and Resource Orchestrator in their architecture. However, we focus on 3GPP management services and management functions to provide network slice instances.

Network slices are created by Network Slice (Communication service) provider. The network slice provider uses infrastructure resource to provision network slice instances. To this end, Network Slice Provider uses three management functions including CSMF, NSMF, and NSSMF and a set of Communication Service Templates (CST), Network Slice templates (NST), and Network Slice Subnet Templates (NSST) in its OSS/BSS domain. CST, NST, and NSST are descriptions of the structure (and contained components) and configurations of CSI, NSI, and NSSI respectively. The creation and modification of these templates are out of the scope of this work.

Communication Service Customer (CSC) requests a CS from Communication Service Provider (CSP). CSMF adapts the requested CS with existing CSTs and selects the closest CST and customizes it to satisfy CS requirements (such as network type, network capacity, QoS requirements, etc.). Then, based on this CST, translates the CS requirement to network slice requirements. NSMF receives NS requirements from CSMF and derives network slice subnet(s) requirements from network slice requirements using NST. NSMF is responsible for management and orchestration of NSI. NSSMF receives NSS requirements from NSMF and defines NFV network service(s) requirements from network slice subnet requirements using NSSTs and send it to NFV-MANO to deploy NSSIs. NSSMF is responsible for management and orchestration of NSSI.

C. Operation Phase

NSMF and NSSMF use NFV-MANO management services to manage and orchestrate available resources between network slice instances and network slice subnet instances, respectively. The NFVO as a Resource Orchestrator uses the finite set of resources that are exposed by the underlying VIMs/SDN-Cs and dispatches them to the network slice instances in an optimal way. This optimization means that all the NSIs are simultaneously provided with the resources needed to meet their requirements, while preserving their performance isolation. The resource requirements of each NSI are stated by its NST.

An NSI uses its assigned resources to run instances of VNFs. These VNF instances are chained to build up the required network service instances, following the specificities given in the NSSMF. At infrastructure level, VNF instances are executed on virtualization containers. These virtualization containers are deployed inside one or more PoPs, according to the geo-location requirements of the VNFs.

To preserve management isolation across NSIs, each NSI must have its own management plane. This plane consists of four functional blocks: VNF Manager (VNFM), NS Orchestrator, Tenant SDN Controller, and Network Slice Manager [34]. According to the one-to-one correspondence between each network slice and the communication service, in Fig. 10, we have presented a limited level of this management blocks in the form of dotted boxes in the communication service provider application. The management plane of CS consists of four functional blocks: CS NFVM, CS NFVO, CS SDN-C, and CS Manager. Indeed, the CS provider could control, manage, and orchestrate its own CS-related NSI, NSSIs, VNFs, NSs, and SDN controller in a limited level through APIs exposed by network slice provider.

VII. PROPOSED NSA COMPARISION

In this section, we have compared some famous network-slicing architectures. These architectures are discussed in the Related Works section. Comparison criteria are enabling technologies (SDN/NFV), Service Based Architecture (SBA), Network domain (Core/Radio Access), Network Slice Creation /Operation Phases, and RAN Split Capability. Results are presented in Table 1. As shown in the last row of Table 1 and discussed in the previous section, our proposed network slicing architecture is complete. It uses NFV management and orchestration capabilities and SDN controllers while being compatible with 3GPP Service-Based architecture. It also provides life cycle management of network slices in both creation and operation phases in both core and radio access domains of the 5G network. In addition, we have included a functional RAN layer split to lay the corresponding layers in centralized or distributed units according to the requirements of each eMBB, mMTC, or URLLC slice. Performance evaluation of the presented model in different domains, including Network Slice Management and Orchestration, Admission control, RAN Resource Allocation, and 5G RAN Functional Layer Split based on this model, are the subject of our current studies and will be published soon.

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TABLE I. NETWORK SLICING ARCHITECTURES COMPARISON

NS Architecture	SDN	NFV	SBA	RAN Split	CN/RAN	NSI Creation/Operation
ONF [6]	Yes	No	No	No	CN	Operation
ETSI NFV [7]	No	Yes	No	No	CN	Creation/Operation
NGMN [13]	No	Yes	No	Yes	CN/RAN	Operation
5GNORMA [2]	Yes	No	No	Yes	CN/RAN	Operation
5GPPP [14]	No	Yes	Yes	No	CN/RAN	Creation/Operation
3GPP SA [15]	No	Yes	Yes	No	CN/RAN	Creation/Operation
Proposed NSA	Yes	Yes	Yes	Yes	CN/RAN	Creation/Operation

VIII. FUTURE WORKS

This presented architecture is an overall 5G mobile network slicing framework. It provides network slicing capability in both creation and operation phases. Based on this framework, the following works are being done:

- *Multi SLA Network Slice Management and Orchestration* that is a network slice creation algorithm based on tenant's SLA.
- *Multi-Level Admission control for 5G Network Slicing* that is a two-level admission control algorithm in operation (run time) phase.
- *Hierarchical OMA/NOMA RAN Resource Allocation for 5G Network Slicing.* In this work a two-level resource allocation algorithm is being presented. At the first level (Slice Provider level), resources are pre-allocated to tenants based on their SLAs. Then in the second level (Slice Operator level), slice's pre-allocated resources are allocated to users based on the user priority.
- *5G RAN Functional Layer Split to serve eMBB, uRLLC, and mMTC slices.* Based on the RAN functional layer split capability of the proposed framework, we are working on a model to deploy RAN sub-layers in central unit (CU or BBU) or in distributed unit (DU or RRH) for any slice type based on its slice-specific requirements

IX. CONCLUSION

Network slicing is a basic requirement in new mobile networks. Although many steps have been taken in this regard, and some frameworks have been proposed for network slicing, but as far as we have studied, there is a lack of general architectural framework both about enabling technologies and diversity of provided services, as well as compatibility with the 3GPP 5G system architecture.

In this paper, we have introduced the concept of network slicing as well as enabling technologies including SDN and NFV. We also reviewed 3GPP 5G service-based architecture and present two representation of this architecture, namely Service-Based representation and Reference-Point representation, as well as description of 5G network functions. In addition, 3GPP 5G NR is introduced along with description of NG interface and 5G NR protocol stacks. Next, we expressed the concept of 5G mobile network slicing and presented a 5G network slicing architecture based on 3GPP 5G system architecture to support various eMBB, mMTC and uRLLC slices while separating the radio access network and core network segments focusing on shared network functions and dedicated network functions for each slice. Then the network slice lifecycle management was explained and 3GPP management and orchestration functions for network slicing were introduced, and based on this we presented an NFV based slice management and orchestration architecture using 3GPP CSMF, NSMF and NSSMF management functions. Finally, an SDN/NFV based architecture for 5G network slicing is proposed. We have included 3GPP network slicing concepts as well as ETSI NFV management and orchestration (MANO) block in combination with SDN controllers. Our proposed architecture provides different functional split options for radio access stack protocol. This capability enables us to deploy RAN sub-layers in central unit (CU or BBU) or in distributed unit (DU or RRH) for any slice type based on its slice-specific requirements. It covers all three network domains including core network, transport network, and radio access network. In the following, we explained the operational blocks of the proposed architecture and showed how this architecture can create and operate various MBB, mMTC and uRLLC slices in the core and radio access sections using SDN controllers, virtualization, NFV orchestrator and 3GPP management functions.

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