Multi-Domain Orchestration for NFV: Challenges and Research Directions

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***Abstract*—In this paper we focus on the problem of multi-domain orchestration for Network Function Virtualization (NFV), over multi-technology environments. In order to facilitate service deployment in end-to-end setups, new orchestration designs are required that exploit and advance existing methodologies. We examine in detail the challenges on multi-domain NFV orchestration for the general case and we provide the current landscape and existing technologies. We also describe a reference architecture for the problem of multi-domain NFV orchestration, that also supports the concept of Network Slicing. Finally, we present a realization of the architecture proposed for the LTE network and we describe a use case with LTE-specific considerations.**

***Keywords*-NFV, SDN, Orchestration, Cloud Computing, Wireless, LTE**

I. Introduction

A great part of research activities are still ahead of us related to network and system integration towards a holistic 5G system. The reason is that despite the unprecedented advancements in new technologies like Software Defined Networks (SDN) and NFV, the actual 5G ecosystem contains numerous diverse software and hardware technologies, including a multitude of components for different Radio Access Networks (RAN). The 5G ecosystem will require the combination of various services of complex functionality, which is currently impossible to efficiently integrate.

Furthermore, instead of procedures simplification, new technologies introduced like cloud computing, SDN and NFV [1] actually exacerbate the configuration effort required. What is now happening in practice is that the software, network and IT experts are further confused with all the additional software and hardware configuration fine tuning, even when simple functionality is needed.

The goal of NFV orchestration is to meet a series of fundamental problems related to the deployment, operation and life-cycle management of network services exposed as Virtual Network Functions (VNFs). Without an orchestrator, the software tool-chain to provision resources is completely unrelated with the tools to deploy services. A specific API is used to provision resources but a completely different API is used to provision and expose services efficiently. This dramatically increases the time to deliver operational services.

In this paper we focus on the problem of multi-domain orchestration for NFV over multi-technology environments. In order to facilitate service deployment in end-to-end setups (that span both vertically and horizontally the protocol stack), new orchestration designs are required that exploit and advance existing methodologies. We examine the challenges on multi-domain NFV orchestration for the general case, according to the current landscape and the existing technologies [2]–[4]. We also propose a reference architecture, that jointly considers the challenges of NFV orchestration and supports the concept of Network Slicing. Similarly to [5] as a Network Slice, we define a composition of adequately configured network functions, network applications, and the underlying cloud infrastructure (physical, virtual or even emulated resources, Radio Access Network (RAN) resources etc.), that are bundled together to meet the requirements of a specific use case or business model. For the realization of the architecture, we provide an example use case for the LTE network and we provide an analysis for LTE-specific considerations.

The main contributions of this paper are the following:

- Using the ETSI NFV management and organization (MANO) architecture as a basis [6] [7], [8], we provide definitions of what is a domain and what is multi-domain environment in support of NFV concepts.
- We describe a number of challenges and open question for multi-domain orchestration in the general case.
- With respect to the concept of Network Slices, we propose a reference architecture that is ETSI MANO aligned and can be used to support multi-domain orchestration.
- We then provide a use case example for the LTE network and we describe additional challenges when the LTE segment is part of the design.

Note that many in the cloud community see an apparent overlap between NFV and cloud management systems like OpenStack. In that sense, many discussions exist with the questioning for the relation between OpenStack and ETSI Industry Specification Group's Management and Orchestration (MANO) architecture [6], [7]. The reason is that the ETSI MANO architecture by nature targets the data-center part and and the relevant functions there. The industry however, has not yet reached a consensus on the way the MANO architecture can be extended to support also the RAN and multi-domain/multi-technology concepts. In this context, we believe our work is among the first to position the problem of NFV orchestration and the relevant challenges in the edge network as well.

The rest of the paper is organized as follows. In Section II we present the motivation for this work, related work and the ETSI MANO architecture. In Section III we describe a number of challenges for the general case and we describe an architecture that tries to meet these challenges. In Section IV we describe an example realization of the architecture for LTE networks. We conclude the paper in Section V.

II. Background Information in NFV Orchestration

A. Motivation, Background Information & Definitions

The need for efficient orchestration procedures in NFV environments stems directly from the Telecom provider industry and data center operations. It is the need to overcome the complexity of the underlying software and hardware components instrumentation. While there is an exponential increase in the use of cloud computing technologies and the realization of the SDN and NFV design paradigm [1], [9], [10], the target automated orchestration functions for jointly optimizing the Virtual Machines (VM) and VNF operations while also automatically reacting to events is still not mature. As we analyze in the following, although there are some efforts on the orchestration plane for the single domain case, there are still many open questions to consider. What is multi-domain orchestration and how we can achieve it? Can one multi-domain architecture fits all the technologies? What about the case of LTE and the RAN?

In order to put the problem of multi-domain orchestration in the right context, in the following we begin by describing the concept of NFV orchestration for the single domain case and we give the necessary details and definitions through the description of the ETSI NFV MANO architecture. ETSI NFV MANO is a working group (WG) of the ETSI ISG NFV [6] [7], [8]. The proposed framework is used for the management and orchestration of all physical and virtualized resources and services. According to ETSI, the NFV-MANO architectural framework is the collection of all functional blocks, data repositories used by these blocks and reference points and interfaces through which these functional blocks exchange information for the purpose of managing and orchestrating NFVI and VNFs. For ease of reading in Fig. 1 the proposed ETSI MANO architecture is presented, while in Table I, we provide a summary of definitions for the terminology used. The most important components in the ETSI MANO ecosystem are the Virtual Infrastructure Manager (VIM), that is responsible for the management of NFVI resources and the VNF Orchestrator (VNFO).

VNF Orchestrator (VNFO): An orchestrator is the software (or set of software components) responsible to automate the creation, monitoring and deployment of resources in the underlying environment (software and hardware). According to ETSI, in a NFV environment the following distinction must be considered:

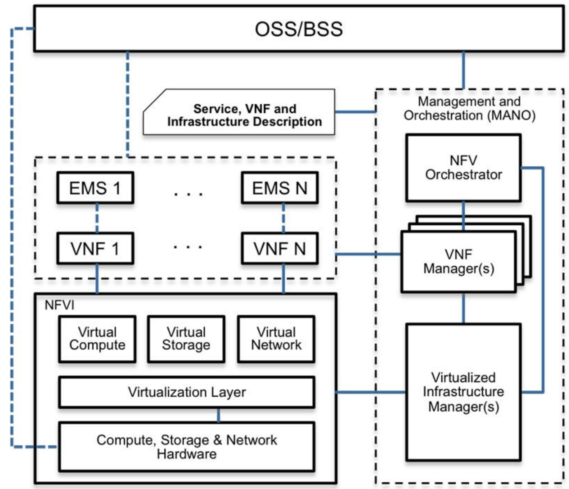


Fig. 1: ETSI MANO Architecture

TABLE I: Summary of Notation

Notation	Description
VNF	Is the virtualized network element like Router VNF, Switch VNF, Firewall etc.
VNF Catalog	A repository of all usable VNF Descriptors (VNFD). VNFD describes a VNF in terms of its deployment and operational behavior requirements
Network Services Catalog	Catalog of the usable Network services.A deployment template in terms of VNFs and description of their connectivity through virtual links.
NFVI Resources	A repository of NFVI resources utilized for the purpose of establishing NFV services.
VIM	Virtualized Infrastructure Manager (VIM), manages NFVI resources in one domain.
VNF Manager (VNFM)	Manages life cycle of VNFs. It creates, maintains and terminates VNF instances, installed on VMs which the VIM creates and manages.

- *Resource Orchestrator*: coordinates, authorizes, releases and engages NFVI resources among different Point of Presence (PoPs) or within one PoP.
- *Service Orchestrator*: Service Orchestrator overcomes the challenge of creation of end-to-end services among different VNFs (that may be managed by different VNFMs). Service Orchestration creates end-to-end service between different VNFs.

Note that the ETSI MANO architecture, only defines the building blocks by means of functionalities and provides no details regarding the technical approach to consider when it comes to the implementation of the actual end-to-end system. Furthermore, the there is no provisioning for the case where the overall system involves multiple network segments and completely diverge technologies.

B. State of the art on NFV Orchestration

In this section we present an overview of existing research activities and technologies, related to VNF orchestration. Note that towards 5G, standardization and open-source are becoming complementary allowing for fast innovation. In that context most of the solutions available are open-source. Nevertheless, existing solutions are still not mature enough and advanced orchestration systems are missing.

Open Source MANO: [11] Published under Apache v2 license, includes the Service Orchestration (SO), the Resource Orchestrator (RO) and the Configuration manager (CM) and the way they interact with the VIMs and with the VNFs. In the first realization of the architecture, the Canonical's JUJU framework is used to provide the CM functionalities, Open-MANO is used for the implementation of the RO mechanism, while Riftware is used to support the SO.

Tacker [12]: Tacker is an official OpenStack project building a Generic VNF Manager (VNFM) and a NFV Orchestrator (NFVO) to deploy and operate Network Services and Virtual Network Functions (VNFs) on the OpenStack NFV infrastructure platform. It is ETSI MANO aligned and provides a functional stack to Orchestrate Network Services end-to-end using VNFs.

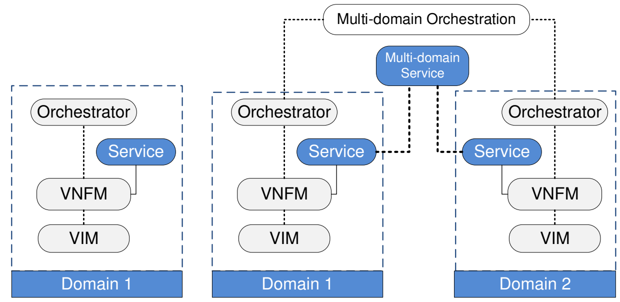
JUJU [13]: JUJU is a generic open source VNF Manager. Although in the Open Source MANO it is used as the Configuration manager, it can offer standalone functionalities of the SO and the RO as well.

Hurtle [14]: Hurtle is another open-source solution that delivers software as services and can easily compose multiple services to deliver end-to-end services. It has been used in the FP7 Mobile Cloud Networking (MCN) project to deliver and compose end-to-end services that include RAN, EPC and IMS functions including all supporting services (e.g. monitoring, DNS). It assumes multiple service providers in its architecture. Hurtle provides Service Manager (SM) that receives requests for new tenant service instances, the Service Orchestrator (SO) responsible to manage the life-cycle of a tenant service instance that is comprised of multiple components (microservices), the Cloud Controller (CC) that manages and abstracts underlying resources and SOs and a Cloud Controller SDK that provides an easy interface to the facilities of the CC.

OPNFV [15]. Another realization of the ETSI NFV ISGs architectural framework is the goal of the OPNFV activities, supported by the Linux Foundation. OPNFV integrates OpenStack as the supporting cloud management system and also considers for a number of SDN controllers and it has great industrial support. OpenStack is used in the cloud orchestrator role.

At the time of this writing, these are the most important solutions available that to some extend fulfill a number of requirements of the ETSI MANO proposal. Nevertheless as we will present in the following section, a number of challenges require for new designs in order to take into the account the multi-domain nature of the upcoming 5G ecosystem. For completeness of the state on the art, see also [4] for a review of related projects, while also we also reference other frameworks like CloudNFV, Puppet and Chef, Cloud Foundry [1] for fast applications development and deployment, ARIA[2], that provides a CLI-driven library of orchestration tools and Apache MESOS [3] that abstracts CPU, memory, storage, and other compute resources away from machines (physical or virtual), enabling fault-tolerant and elastic distributed systems to easily be built and run. We also mention the Unify solution that is presented in [16] and [17] that describe multi-layer service orchestration in a multi-domain network. There, a global orchestrator (called ESCAPE) is capable of instantiating service elements in separate domains. Dedicated local orchestrators in different infrastructure domains are responsible for setting up new VNF instances and configuring the underlying network. The implementation is based on the ESCAPE prototyping framework and an OpenStack (OS) data center with the OpenDaylight (ODL) controller. In [2] a PoC demonstration is presented on how NFV concepts can be applied to OSS/BSS. The PoC demonstration includes the Chameleon multi-domain orchestrator provided by Amartus (now owned by Huawei) and a number of PCC systems build on Red Hat Linux and OpenStack. The PoC shows how multi-vendor VNFs can be deployed in an NFVI ecosystem consisting of x86 based COTS hardware using a common VNF manager and orchestration layer.

[1] https://www.cloudfoundry.org/
[2] http://ariatosca.org/
[3] http://mesos.apache.org/



(a) Single Domain (b) Multi-Domain

Fig. 2: Single domain and multi-domain orchestration for NFV

III. Multi-domain orchestration: Challenges and a Reference Architecture

As the MANO and OSM proposal is not multi-domain, from a definition point of view, we consider the following for the terminology of the terms *domain* and *multi-domain*.

What is a domain? A domain is the complete area of functionality that one service from one service provider offers. This domain (the service) can be potentially be divided into sub-domains, where sometimes these sub-domains are not explicitly related to one and another. How these sub-domains come together and are modeled are reflected in what is known as a bounded context [14]. It is through this bounded context that a particular service can be offered out of.

What is Multi-domain? Extending the notion of domain to multi-domain, the idea in multi-domain is that many domains that offer specific functionality are taken and composed together to deliver their functionality as a whole. See also Fig.2(b) Along with this, the provider responsible for combining the services can optionally add in value-added functionality. The value added functionality is typically the combining service providers expertise. Such providers do not have the depth of knowledge to provide all the required functionality of the complete service and this is the main motivation of such a service provider. By leveraging the services of others there is also a significant productivity gain.

As it was also pointed-out in [4] with the existing frameworks and the MANO architecture, it is impossible to chain functions offered from different operators into a single functional service that needs to operate over different and possible diverge physical or/and virtual infrastructures, owned by different providers. Service chaining and service compositions are actually ideas that stem from the Service Oriented Architecture (SOA) principles, where in our case the service is related to VNFs. Actually, a number of challenges arise on our effort to apply the SOA design paradigm in the way NFV systems are designed and implemented (see also [18] for a relevant analysis). With the existing status on state of the art, it is not possible to composite services together over multu-domain, multi-provider environments.

A. Challenges and open questions in multi-domain orchestration

An extended number of challenges exists that we need to consider towards true 5G system integration, regarding multi-domain orchestration. Furthermore, as ETSI ISG NFV mainly targets the data center side, there are many challenges and open questions on the way to apply the proposed design in the wireless domain. In this section we provide an extended analysis of the challenges of the general multi-domain orchestration problem and we describe a reference architecture for multi-domain orchestration. Note that the challenges we describe is just an indicative set. As the concept is getting more mature, new challenges and discussions on the way multi-domain orchestration can be applied will emerge.

Regarding open questions and challenges for NFV orchestration, the authors in [4] describe a number of challenges related to a) source management, b) functions placement, c) dynamic scaling, d) automation and e) self-allocation. Other dimensions of the problem are the way distributed management can be applied and issues related to the communication overhead and delay. Security considerations/isolation are also very important to consider, like also challenges related to inter-operability between different vendors. In one sense the feasibility of multi-domain orchestration (i.e., if it can be actually be applied) is rather subjective and blur, since different providers and vendors have completely different incentives and business models.

Furthermore, we identify the following open questions and challenges. The ordering does not reflect the importance of the corresponding challenge.

- Which are the domain boundaries? As true cloud federation has not yet being achieved the boundaries and responsibilities of the VNFM and VIM entities are not yet clear. Indeed, there is no clear and precise definition of what actually multi-domain means. Is the area an OpenStack controller can manage? Is the entire wireless segment or it is the set of network equipment managed and configured by a single provider? In addition many external entities and remote communities over various backhauling (optical, satellite,) exists so actually a precise definition of what even constitutes a single domain seems to be missing. Furthermore, most often there is confusion on the separation between the multi-domain and multi-layer functionalities.
- *Need for NF and VNF templates:* As ETSI does not define a data model to realize descriptors, we believe this is the most urgent problem to be solved by the community. This includes VNF templates and the selection of the appropriate modeling languages.
- A higher layer orchestrator can be centralized or distributed. In the same way a SDN controller is a logically centralized entity but physically distributed, for the design of the multi-domain orchestrator we can potentially adopt a similar approach. However, there are no studies of optimality available.
- No standard interfaces for inter and intra-orchestrator communication are defined. In fact in the MANO architecture there is no provisioning for this kind of design.
- *Challenges related to dynamicity:* Ability to change the service template definition on the fly, based on spatial temporal traffic fluctuations, on the user level, the domain level or the overall network conditions.
- *Multi-tenancy challenges:* With the emergence of NFV and SDN technologies, Telecom providers are now opening their networks. The Network Slicing concepts [5], [18] and related issues like RAN and Network sharing are open and must be also part of the overall orchestrator design.
- *Need for self-x:* The main reason for the adoption of the VNF approach is the ability to scale up and down on demand dynamics. However the mechanisms to actually react to events and the way to provide services on demand is not straightforward. The reason is that a real-time constraints require for very well designed mechanisms that are able to handle the dynamicity of the environment. Building *self-x* mechanisms as a component with whom the orchestrator can interact is extremely challenging.

This list can be quite extended towards the realization of the MANO architecture. There are also many administrations issues to consider, questioning regarding openness to verticals and the way actually services composition can be achieved in the same way software service composition is managed in Service oriented Architectures (SOA). Furthermore, with existing approaches, it is not clear how to manage VNF states, especially for time-critical applications. In addition as also presented in [2] current network operations models and OSS solutions are not prepared for emerging new technologies like NFV. Furthermore, there is need for real-time processing of a huge amount of data and techniques like data analytics must be also considered.

B. A Reference Architecture: Multi-domain Orchestration in support of Network Slicing

Towards 5G communications, many architectures are already proposed. These are following either the evolutionary way with a natural and planned progression on existing

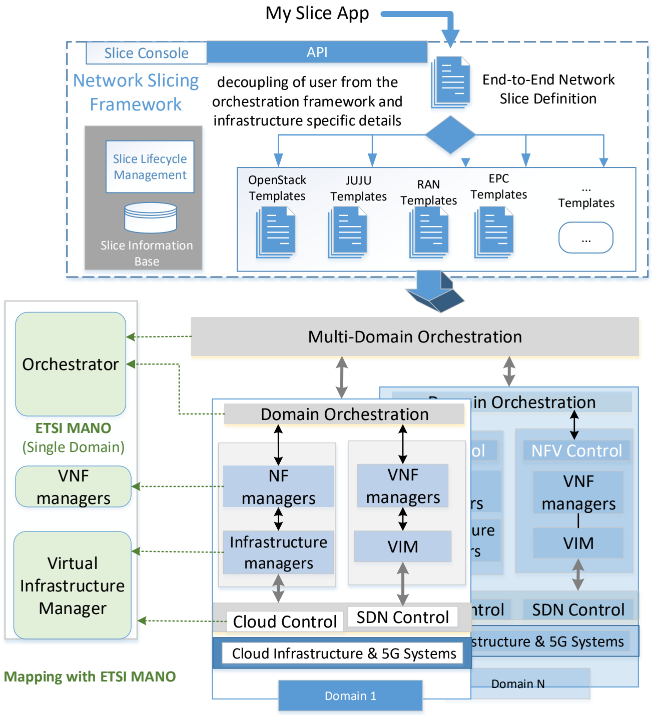


Fig. 3: A multi-domain orchestration architecture for NFV

designs or the revolutionary way with a radical rethinking and fundamental changes introduced [9], [10]. We adopt the evolutionary way, where we believe that the overall design must be able to meet the challenges described in the previous section, while it should also be build to support the concept of Network slices.

The Concept of Network Slices: The Network Slices we envision, span the whole protocol stack from the underlying hardware resources up to the abstract VNFs and applications running on top. From our point of view a 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 or business model. This approach is aligned with the industry and Telecom perspective, towards 5G [19]. See also [5] for details on the concept of Network Slices.

A high level representation of the architecture we propose can be seen in Fig.3. We believe that this design allows for backward compatibility with existing cloud systems and inherently supports SDN architectures (like the one proposed by ONF). Furthermore it is technology agnostic and flexible enough to include other design paradigms like the Mobile Edge Computing (MEC) or the Cloud-RAN.

Network Slices Framework: A Network Slices Framework is required for the creation and configuration of service bundles according to business use-case needs, described in a form of Slice manifest files. This framework needs to provide for network life-cycle service management, while its components (in some cases) must have direct access to the Infrastructure Layer. To preserve backward compatibility with existing designs and in order to facilitate the adoption of our approach from the majority of existing frameworks, its functionalities need to consider all the design elements that will constitute the future 5G ecosystem.

Network Slice Definition: A Network Slice owner must be able to provide a high level description of the environment he wants by means of: physical, virtual or emulated resources, VNFs and all the network connectivity between the components. This can be done using Network Slice Templates (manifests). Possible implementations of the template descriptor are YAML, XML, JSON, using YANG and/or TOSCA modeling languages. Note that YANG and TOSCA are interchangeable and that YAML format is preferred as recommended by OSM.

Network Slice Template Processing: The Network Slice Template actually needs to be processed by an entity that we name as Network Slice Template Processor. The processor template analyzes (dissects) the high level description into a number of sub-templates that are orchestrator specific. This is a major innovation that offers for advanced research and innovation potential. Template processing also considers that in the template processing process the Framework can make the system dynamics sustainable by identifying possible missing resources and providing full guidance based on the use case needs. Actually the Network Slice template processing output is the input to the multi-domain, end-to-end orchestrator. In order to support the concept of Network Slices we need to consider for a number of new features like configuration of service bundles on per tenant basis, while also for slice orchestration and slice service management. This discussion however is out of the scope of this paper.

Multi-domain Orchestration: The multi-domain orchestrator is the entity that is responsible for the composition of all the services, while also for all the coordination of the resources in all the available domains. In order to create a service, it must be possible to do this in an automated, programmable way otherwise the time to deliver a working service will be high. A programmatic interface (API) to automate the creation of services is absolutely essential, while an additional challenge derives when different APIs, protocols and/or data models are used to express service requests. There are two approaches for solving this challenge. The first approach considers that all service providers adopt a standard; however this is very difficult to achieve. In the SOA word, it was attempted through the web services standards initiative out of OASIS through the attempted introduction of WSDL. The other approach is more engineering intensive. The orchestrator maintains adaptation modules that translate the requests from the orchestration engine to the specific target service.

In addition, from our point of view the cloud-based infrastructure provides all the resources as also the Network and Cloud control and management components. These can be layered internally according to existing designs. The orchestration layer actually interacts with VIM and VNFAM, where the virtualized infrastructure includes all types of physical and virtual resources (server, storage etc., virtual resources, software resources (hypervisor), RAN resources etc. that are

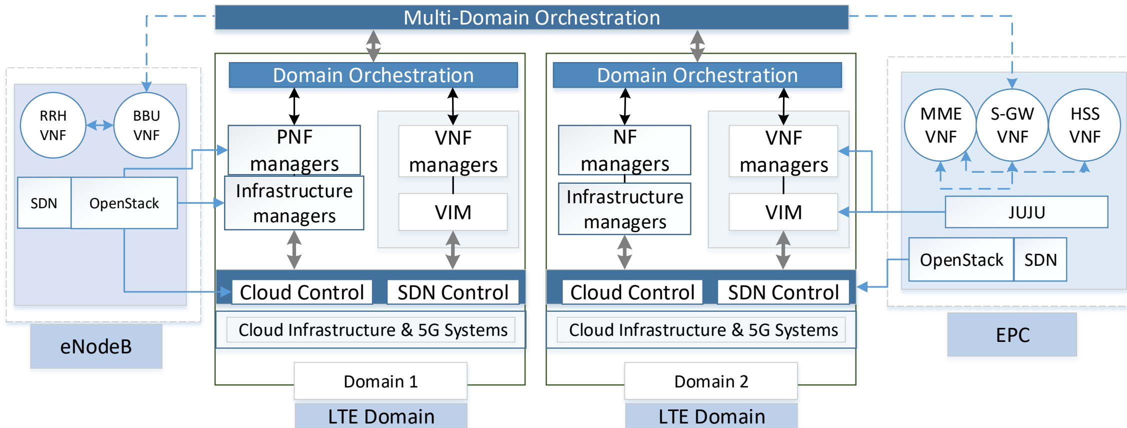


Fig. 4: Multi-domain NFV for LTE networks

exposed by the cloud systems. The VNFAM creates, maintains and terminates service instances and VNFs. These can be installed on Virtual Machines (VMs) which the VIM creates and manages, while it also includes other types of management functionalities related to services that are not deployed in VMs.

Note that Orchestration procedures run on top of VNF-enabled environments or non VNF-enabled environments. Integrated network programmability is a vital gear to support efficiently the concepts we describe and let the orchestrator to actually operate in a way that inter-operability is promoted and the NFV are truly independent from the actual hardware. Integrated network programmability is utilized by the orchestrators where in this process, all technologies are combined together, towards delivering transparent network services.

IV. Multi-domain orchestration: The LTE Use case

We stress the fact that the ETSI MANO architecture (although generic to some extend), mainly targets the data-center part and the relevant operations. The challenges described in the previous section are important for any type of network; however, the way multi-domain orchestration can be realized when the LTE network segment is also part of the design imposes a number of additional issues to investigate.

By following the definition of the domain and multi-domain architecture provided earlier, we describe a number of open issues in the case of LTE systems. In Fig. 4 a realization of the architecture is depicted for LTE, where we consider the offering of end-to-end services, using multi-domain orchestration. For example as shown in the figure, the eNodeB resides in domain 1, orchestrated by domain's 1 orchestrator that is different entity than the one responsible for domain 2, where the EPC resides. In the eNodeB case we assume that there are no NFV mechanics used and services are exposed in the form of Physical Network Functions (PNFs), while for the EPC we consider that system components like MME or S-GW are exposed as VNFs. In the later case the open source JUJU framework is depicted as the VNFM entity and OpenStack with SDN support offers the necessary VIM functionalities.

To begin with, the main difficulty arises from the fact that both the EPC and the eNodeB need to harmonically operate in order to offer integrated services. Thus it is not just about a single hardware or software component that needs fine-tuning. Also in the LTE network, there is no single flat network. There is a clear separation of the User Plane and the Control Plane layering structure and the protocols used in each case. For example in the Packet Data Convergence Protocol (PDCP) for the User Plane GTP tunneling is used, while for the same layer for the Control Plane SCTP is used, with the Resource Control Layer (RRC) on top, responsible for the configuration of the lower layers. These are related to the way Non-Access Stratum and Access Stratum functionalities are actually performed.

We identify the following challenges as critical towards the adoption of the MANO design, when the LTE segment is part of the integrated system. The ordering does not reflect the importance of the corresponding challenge.

- *Understand and realize the role of NFV in LTE:* With adoption of NFV by the telecom provider, actually all the elements of the 3GPP architectures can be exposed as VNFs (S/P-GW, HSS, MME, PCRF VNFs). More recently other VNF like analytics come into the picture [2]. Which are the VNFs for the Radio Part, VNFs to logical and transport channels mapping and issues like Service Function Chaining are still open.
- *How to distribute EPC functionality:* Exposing EPC functionalities in VNFs can solve scalability issues however specific scenarios might require different locations of EPC elements. Furthermore, different schemes where S/P GW-U are managed by different SGW-C, require for advance S/P GW-U placement algorithms. Advanced orchestration procedures and appropriate interfaces must be used to facilitate for this flexibility (see also [3] for the general VNF placement problem).
- *Role of SDN and Integrated network programmability:* Although there is a lot of research activity on applying the SDN approach inside the EPC and more recently in the virtualized eNodeB [20], a lot of work needs to be done especially in the eNodeB side, since the way SDN control can interacts with an integrated orchestration system is not straightforward.

- *Need for LTE NF and VNF templates:* As ETSI does not define a data model to realize descriptors, we believe this is the most urgent problem to be solved by the community. This includes VNF templates for LTE especially for the Radio part and the selection of the appropriate modeling languages.
- *Multi-technology RAN:* There is no denying that the RAN segment is radically changing not only from the technology perspective (i.e. evolution of LTE, WiFi, and New Radio for mmWave) but also from the deployment scenarios (e.g. Cloud-RAN, Distributed-RAN, Ultra Dense Networks) and particular techniques (e.g. Inter-cell coordination technologies, Interference management, Dual Connectivity, Flexible UL/DL TDD). Actually what we witness is the transformation of the RAN using multi-technology convergence. Since many of these technologies are in their infancy and has not reached a sufficient Technology Readiness level (TRL) level, building multi-domain or even single orchestration procedures over multi-technology environments is expected to be a field of very active research.

V. Conclusions & Future Work

In this paper we focused on the problem of multi-domain orchestration over multi-technologies environments. We examined in detail the challenges on multi-domain NFV orchestration for the general case, according to the current landscape and the existing technologies. We also proposed a reference architecture, that jointly considers the problems of NFV orchestration and the Network Slicing, while focusing on the LTE network side we provide a note for LTE-specific considerations. Our future plans include the realization of the system architecture proposed using the JUJU framework [13] working in parallel with the Hurtle orchestrator [14] in order to provide a multi-domain orchestration solution. This will be used to demonstrate an integrated NFV use case, that jointly considers the operation of a LTE network based on the open-source OpenAirInterface (OAI) and an IP Multimedia Subsystem (IMS).

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