5G Programmable Infrastructure Orchestration Using ONAP

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Abstract **- Telco operators are currently reinventing their operational model by adopting agile principles and making the shift from hardware centric towards software centric networks. 5G is not coming only with a very advanced radio layer, but also with the evolutionary concept in which the network is programmable and accessible through Application Programming Interfaces (APIs). This stands as a game changer and it will allow verticals (e.g., transport, media, energy) to seamlessly integrate their applications within the 5G ecosystem. This paper presents a programmable infrastructure leveraging Open Network Automation Platform (ONAP) capabilities developed within two European projects 5G-EVE and 5G-VICTORI. The focus is on presenting the work performed for Virtual Network Functions (VNFs) onboarding, deployment and in life management together with the 5G slicing capabilities for Radio Access and Core networks.**

Keywords-ONAP; programmable infrastructure, VNF; vRAN; vEPC; Openstack.

I. INTRODUCTION

The evolution from 4G to 5G is disruptive for the telco operators as they do not only need to embrace new concepts such as software centric networks, but also to change their operational model completely which has been effectively functional for decades.

The new software centric network model will bring two main benefits such as:

1. Being able to apply DevOps principles in the telco world, therefore facilitating a faster pace in developing and implementing new functionalities or integrating verticals.
2. End-to-end automation of day 0, 1 and 2 operations considering cognitive Artificial Intelligence (AI) enhanced capabilities, which will truly simplify operations.

In order to benefit from these advantages, the telco operator will need to adapt its operating model from the traditional one, in which engineering and operation are separated to a DevOps one. This is not simple as it will require update in all the existing processes, which will lead to a serious organizational transformation. Nevertheless, the telco operators are also aware of the high complexity of the ecosystem. Firstly, this will require more advanced skills from the network engineers and secondly, as more frequent operations will be performed, it will be more prone to errors and incidents, therefore strict control mechanism should be enforced. At the same time, the telco operator will need to adapt and evolve its infrastructure, making it fully programmable. Besides costs, this comes with a lot of technological changes, as the existing model based on monolithic equipment is disrupted.

This paper presents the technical capabilities of the programmable infrastructure deployed within 5G-EVE[1] and how it will further be utilized by the vertical use cases from 5G-VICTORI [2]. At the time of writing this paper, the programmable infrastructure allows several Virtual Network Functions (VNFs) on boarding and deployment based on ETSI specification for Network Function Virtualization Management and Orchestration (NFV-MANO) [3]. The VNFs are deployed in an OpenStack [4] environment: the Radio Access Network (RAN) VNFs are container based using Kubernetes or VM based, while the Core VNFs are only VM based. Slicing mechanism and proper radio resource allocation are also supported in the RAN through the Software Defined Network (SDN) controller Open Air Interface (OAI)-FlexRAN implementation [5], but also in the Core through proper resources and Quality of Service (QoS) assurance in the proposed communication network deployment. The programmable infrastructure is orchestrated using ONAP [6] with specific features implemented for Service Design, Service Deployment and Service Operation. The paper emphasizes the technical capabilities available at this moment, including the specific configuration needed to deploy the RAN and Core VNFs using ONAP.

The paper is organized as follows. This section is dedicated to the introduction. Section 2 relates to a previous published paper and it highlights the evolutions presented by the current paper. Section 3 summarizes the current ONAP capabilities enabled over the OpenStack infrastructure providing also a practical guide for deploying end-to-end network slices. We conclude the paper in Section 4 where we also focus on our future work from 5G-EVE and 5G-VICTORI projects.

II. RELATED WORK

In a previously published paper [8] in 2019, by one of the co-authors of this paper, the 5G ecosystem intended to be developed within 5G-EVE was presented. The work from this paper is evolutionary and it is depicting practical guidelines for orchestrating VNFs and end-to-end slices using ONAP. The related work from standards, working groups, and other 5G-PPP European projects is exhaustively presented in [8] and will not be repeated here as, from our knowledge, no major change took place.

The research for end-to-end network slicing in 5G is intensive, as this is one of the key capabilities of the new technology with major outcomes for the vertical industries. The research is not limited only to the end-to-end slicing mechanism per se (which is also documented in the 3GPP standards), but extended to the whole ecosystem/framework which enables automated and business agile provisioning and maintenance of the slices. In the following paragraphs, some related works are briefly presented. These papers help in understanding the concept of slicing and the different technical challenges that need to be overpassed in order to achieve a fully functional framework.

The work from [9] presents a framework for automating the slicing management in the RAN part, with special attention dedicated to the functions, interfaces and information models. The theoretical framework is applied in a Proof of Concept with limited implementation of Radio Resource Management (RRM) algorithms.

In [10] the authors focus on the technical implementation of end-to-end slicing providing resource isolation and programmability on resources. The slicing is achieved by using OAI-RAN capabilities (similar with this paper) for the radio part and by introducing a deeply programmable node architecture (FLARE) for the core slicing with complete segregation among data and control plane.

The work from [11] presents the implementation of end-to-end slicing using Mosaic5G software packages [12] which are also utilized in this paper. The authors present different configuration scenarios for the Virtual Machines (VMs) in order to achieve the required performance for a certain VNF, which is also very useful for the work from this paper.

III. ORCHESTRATION OF PROGRAMMABLE INFRASTRUCTURE USING ONAP

In this paper, we are presenting a novel end-to-end network slicing mechanism implementation comprising both RAN and Core network elements using the Open Network Automation Platform (ONAP) [6] for NFV/VNFs onboarding and service deployment in 5G Non Standalone Architecture (5G NSA) [7]. The slicing mechanism is based on RAN Public Land Mobile Network (PLMN) identity (ID) techniques for the core network selection.

ONAP is an open source project developed by Linux Foundation, which allows design and creation of VNFs and network services orchestration. A set of blueprints is made available with every new platform release. ONAP Architecture provides two frameworks which enable the user to split the design and the creation phases (Design Time Framework) from the deployment phase (Run Time Framework). The ONAP implementation for 5G-EVE is depicted in Figure 1.

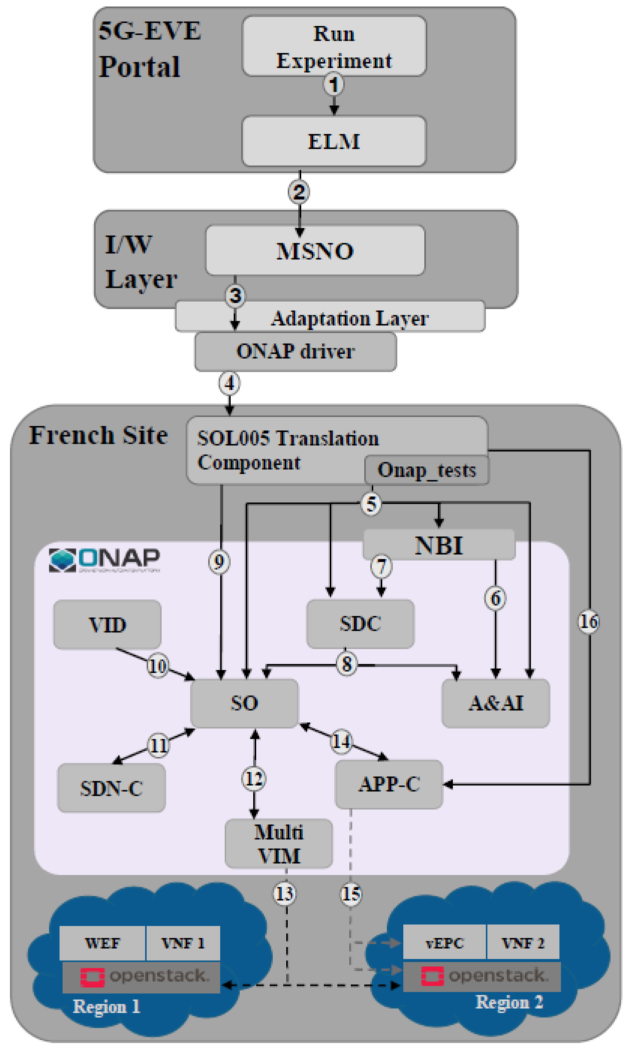

Figure 1. ONAP implementation in 5G-EVE

The main component of Design Time Framework is Software Design and Creation (SDC). Network services are represented as forwarding graphs composed of multiple VNFs. Each of them is represented in ONAP Catalog as Virtual Service Product. Deployment process begins with creation of the vendor's entitlements. In order to onboard the VNF, the user has to provide HEAT template, describing this network function, which has to meet ONAP specific requirements. The correctness of each template is checked

 ISBN: 978-1-61208-802-0

automatically during uploading. Once the template is onboarded, the certification process could be started. The above-mentioned steps, Vendor Software Product (VSP) creation, template onboarding and certification, have to be done for each VNF. The network service could be composed of the network functions stored in the catalog and afterwards it is submitted for testing before being deployed to the production environment. The service model is stored in SDC which notifies the Service Orchestrator (SO) and Active and Available Inventory (A&AI). Once onboarding steps are finished, ONAP can deploy service instance on virtualized infrastructure based on models distributed to SO. Virtual Infrastructure Deployment (VID) enables the selection of the service and the triggering of the instantiation process in SO. In order to deploy the service, a la carte flow involves performing a set of steps and actions called building blocks. Service and VNFs objects need to be created first.

During the preloading phase, some VNF parameters values required during the instantiation are provided to SDN Controller (SDN-C). Once this is done, the VF modules that host VNFs could be instantiated. In fact this is triggered by the SO utilizing MultiVIM component, which is responsible for collecting information about tenants and clouds registered into ONAP. It also enables deploying VF modules in different type of infrastructure managers like OpenStack or Kubernetes. ONAP does not manage images of network functions. They have to be provided by the vendor and registered in specific cloud.

In 5G-EVE project, the operations from both Design and Run Time Framework are automated with open source *onap_tests* library [13]. The user has to provide HEAT templates for VNFs and network service composition, and requests to relevant ONAP components APIs are made in appropriate order. It is important to note that the images are previously uploaded to infrastructure managers.

The 5G-EVE Portal is the functional entity that provides access to the 5G-EVE Platform for verticals. Portal allows execution of functionalities such as instantiate, monitor KPIs and reconfigure. Each request from the Portal is passed through Experiment Lifecycle Manager (ELM) to the Interworking Layer which is composed of Multi Site Network Orchestrator (MSNO) and Adaptation Layer. MSNO decides which site should host the requested service and through the Adaptation Layer, it communicates with the specific site's orchestrator. SOL005 [14] Translation Component has been implemented on top of the ONAP instance dedicated to French site orchestration. It enables to communicate with ONAP Northbound API interface (NBI) (5) in order to perform operations ordered to execute by 5G-EVE Platform (4).

The VNF management capabilities of ONAP are assured by the joint interaction of the Service Orchestrator component with SDN-C(11) or Application Controller (APP-C)(14) components. The post instantiation configurations can have two origins. They are the result of the service reconfiguration request initiated by the end-user or the result of the control loop automation actions. The first one is triggered by SO APIs (9) or VID portal (10) where external applications or end-users can trigger orchestration workflows. Such workflows are either embedded into the orchestration logic, or they are network service and network function specific. In the latter case, the service designers can compose custom orchestration workflows with Workflow Designer capability of C portal. The standard or user-defined orchestration workflows can include day-2 reconfiguration operations or other VNF life cycle management operations into one orchestration workflow.

APP-C component is leveraged by SO for execution of selected life cycle management actions and reconfiguration actions on VNFs (14). The first includes such actions (15) like start, stop, or restart which are invoked on OpenStack directly. The reconfiguration actions can utilize NetConf configuration protocol or Ansible reconfiguration utility. For the latter one, APP-C is equipped with dedicated Ansible server which ensures communication with devices and it performs delegated reconfiguration tasks. APP-C enables also the design of configuration templates for each action with the Controller Design Tool dashboard, where the selection of communication protocol and translation of input parameters can be specified. It is worth mentioning that APP-C actions can be executed without SO and APP-C can be integrated directly with third party applications as a key functionality within 5G-EVE Portal (16).

The slicing implementation developed within the 5G-EVE project is achieved using the ONAP over the OpenStack cloud infrastructure [15]. The goal is to show the deployment of several telco VNFs - virtual Evolved Packet Core (vEPC) and virtual Radio Access Network (vRAN) for supporting different 5G use cases like Ultra Reliable Low Latency Communication (URLLC) and Massive Machine-Type Communications (mMTC), which will further be developed in the 5G- VICTORI project.

Figure 2 depicts the two end-to-end network slices (slice 1 represented in orange and slice 2 represented in green), using the described NFV/VNFs components.

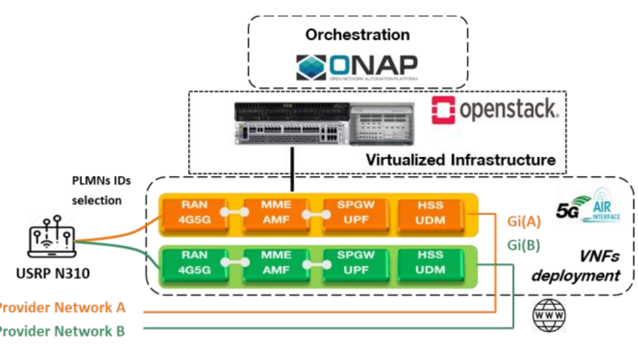

Figure 2. 5G testbed for programmable infrastructure orchestration using ONAP

The virtualized infrastructure was prepared in advance in terms of communication network, so throughout the ONAP deployment, each of the two slices are connected to its own OpenStack provider network. In this implementation, we used as Remote Radio Unit (RRU) the X310 [16] device, which is a high-performance, scalable Software Defined Radio (SDR) platform for designing and deploying next generation wireless communications systems, providing reliability and fault-tolerance for deployments, simplifying the control and the management of a network.

Based on the Mosaic5G group of software packages available [12], the vEPC core function network components – virtualized Mobility Management Entity (vMME), virtualized Serving/Packet Gateway (vS/PGW) and virtualized Home Subscriber Server (vHSS) – are deployed in a single Virtual Machine (VM), using HEAT templates. The first VM (Figure 3) deployed is a 64-bits operating system, using 4 cores Intel i7, 16GB RAM and 2 Ethernet interfaces for service connectivity and all the specific vEPC application configuration files related to: hostname, Domain Name Server (DNS), S6a diameter, S1-AP, authentication functions, Full Qualified Domain Names (FQDNs), communication networks and PLMNs.

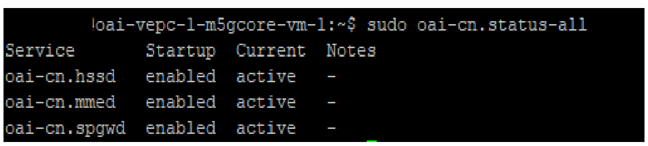

Figure 3. Mosaic 5G Core implementation

The second VNF (Figure 4) deployed through ONAP over the OpenStack infrastructure in one VM is the RAN eNodeB. The VM is using Ubuntu 18.04 LTS 64-bits as operating system and with a kernel version greater than 4.10.x, 4 cores Intel i7, 16 GB of RAM and two Ethernet interfaces.

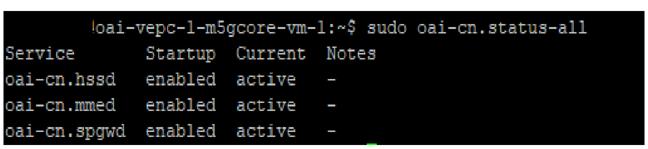

Figure 4. Mosaic 5G Core implementation

In order to be able to instantiate and run the VNF in virtualized environment, it is required to ensure several specific computing environment prerequisites configured in OpenStack infrastructure.

For the use case implementation presented, the specific infrastructure configuration was applied only on the physical host where the VM is intended to be deployed through ONAP. The physical host must have available the following special CPU flags enabled: **avx**, **avx2**.

Also, KVM mode needs to be enabled to be used in the OpenStack nova file path */etc/nova/nova.conf* for the *compute_driver* parameter *libvirt.LibvirtDriver*, setting the <u>*libvirt*</u> section configuration for virt_type to kvm and specifying the CPU model parameter cpu_mode value to host-model. An OpenStack specific flavor has been configured for this VNF as depicted in Figure 5.

```
openstack flavor create --ram 8092
                        --disk 50
                        --vcpus 8
                        --property trait:HW_CPU_X86_AVX=required
                        --property trait:HW_CPU_X86_AVX2=required
                        --property hw:cpu_cores=4
                        --property hw:cpu_sockets=1
                        --property hw:cpu_threads=1
                          oai_flavor
```

Figure 5. vRAN OpenStack special VM flavor

After the vRAN VM is running, the proper VM CPU allocation and configuration for *avx* settings were checked. In order to automatically instantiate the RAN VNF application, the script inside the VM is used (*start.mosaic5g*). This script instantiates the vRAN application after deployment, as this is not implicitly done.

Figure 6 depicts the success of this instantiation. The other specific application configurations related to hostname, S1-MME, communication networks and PLMNs, are being done through the HEAT templates.

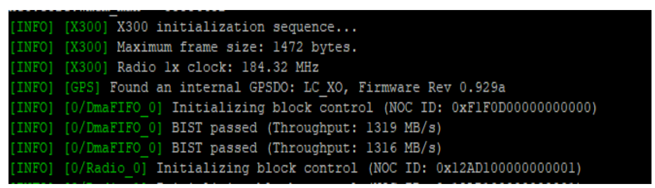

Figure 6. vRAN function running in VM

The correct functioning of the end-to-end slice is demonstrated by checking the statistics on the vMME in Figure 7.

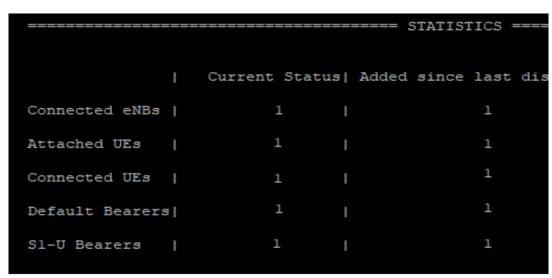

Figure 7 vMME network statistics

At this moment, our research is showing successful deployment of end-to-end slices with proper QoS enabled and automated network resource allocation leveraging ONAP capabilities over an OpenStack infrastructure.

 ISBN: 978-1-61208-802-0

IV. CONCLUSIONS

In this paper, we have exposed a programmable infrastructure leveraging ONAP capabilities, with focus on presenting the onboarding and deployment of the VNFs, showing the 5G slicing capabilities in the RAN and Core subsystems in 5G Non Standalone Architecture. The network slicing end-to-end mechanism is based on the RAN PLMN ID techniques for the selection of the Core Network. The novelty for network slicing implementation resides in using of ONAP over OpenStack cloud infrastructure. The aim is to demonstrate the deployment of a small number of telco VNFs (vEPC, vRAN) for providing services to different 5G use cases like URLLC and mMTC.

In the 5G-EVE project, a dedicated portal was developed having the functionality of providing access for verticals at 5G-EVE Platform. Through this entity, there is a possibility to instantiate, monitor KPIs or reconfigure the service. A set of information is mandatory to be fulfilled as a pre-requisite: the vendor of VNFs must provide the HEAT templates and the service graph, which are stored in a specific cloud. The requests to related ONAP components APIs are made accordingly with the network service composition.

Based on the Mosaic5G group of software packages, the vEPC, containing vMME, vPGW and vHSS, is deployed in one VM. A similar approach is used also for deploying of VNF RAN eNB. This model is capable of providing multiple e2e flexible and efficient network slices (the time of deployment is less than 1 minute), automatic network resource allocation and VNF life-cycle management (in the future). The research will be enhanced within 5G-EVE with in life management capabilities resulting in a fully functionable test bed to be further utilized for the 5G-VICTORI usecases, as described in Section 5.

V. FUTURE WORK

The work from this paper stands as basics for the future evolutions envisioned in the 5G-EVE and the 5G-VICTORI European projects. Therefore, it is important for the reader to understand the future plans as the research and development will continue for the next years.

In-life slice configuration will be performed by increasing the network compute capacity triggered by service reconfiguration request initiated by the user through the portal or as a result of control loop automation actions. In the run-time step, a set of in-life management actions are involved: upgrade, network slice instance (NSI) scaling, changes of NSI capacity, changes of NSI topology.

The entire functionality will be further evaluated on 5G-VICTORI France/Romania cross site orchestration cluster using 5G-EVE test bed facilities in two use cases: transportation and energy. The test bed physical infrastructure will contain control and compute servers, storage, eNodeB PNF, 4G/5G video cameras, radio licensed spectrum, IP/MPLS between 5G-VICTORI Bucharest facility and Alba Iulia Municipality infrastructure; L3VPNs and IPsec connectivity between 5G-VICTORI infrastructure and 5G-EVE French Cluster ONAP, MEC for video data analytics. The virtualized infrastructure will be deployed using OSMv5; Docker; ONAP and SDNC suite and Prometheus will be used for performance monitoring. NFV/VNF suite will be provided through 4G5G RAN OAI Mosaic5G for radio part, 4G5G Core OAI Mosaic5G for core part and the application software for use case application experimentation. Grafana is used for Service data visualization and KPI performance validation.

The first use case is addressing the transportation service that addresses URLLC feature requirements and pop-up network on-demand creation capabilities. Infotainment versus public safety services will be orchestrated when a threat is identified by the system, the infotainment resources are back-logged and a public safety high quality live stream is established. The use case will cover all deployment phases: infotainment and public safety application design; 5G deployment and instantiation, immediate setup time (triggered) service, service in life management and automation, service instantiation & MEC analytics function, QoS experimentation and service optimization. The creation of the slice will be triggered either manually or automatically by an external event alert, the functionality of the digital mobility use case will be assessed trough a set of tests spanning from vertical applications performance evaluation to solution functionality.

The second use case is a Low Voltage (LV) smart energy metering use case addressing mMTC capabilities to show that 5G mMTC services can be used for an advanced energy metering deployment. It will be demonstrated using the same 5G-EVE test bed facilities to provide energy metering services for energy consumers like public buildings and street lighting in the Alba Iulia Smart City environment and for energy sources like photovoltaic panel or national grid. Smart Energy metering use case demands advanced requests of high data processing capacities, flexible provisioning capabilities and service customization to create automated capabilities for deployment and in-life management over network virtualized infrastructures. The scenario assumes metering data collection from endpoints scattered across a city and requires scalability of network slice from get-go. The collected measurements will be transferred to the central cloud facilities where they will be stored, processed and analyzed by the telemetry platform. Advanced analytics will be used to predict future power demands.

 ISBN: 978-1-61208-802-0

Acknowledgment

This work was partly funded by the European Commission under the European Union's Horizon 2020 program - grant agreement number 815074 (5G-EVE project) and 857201 (5G-VICTORI). The paper solely reflects the views of the authors. The Commission is not responsible for the contents of this paper or any use made thereof.

References

[1] 5G-PPP Phase 3 Project 5G-EVE. [Online]. Available from: https://www.5g-eve.eu/ 2020.06.12

[2] 5G-PPP Phase 3 Project 5G-VICTORI. [Online]. Available from: https://www.5g-victori-project.eu/ 2020.06.12

[3] Network Functions Virtualisation (NFV); Management and Orchestration, Group Specification, Dec. 2014.

[4] Openstack framework. [Online]. Available from https://www.openstack.org/ 2020.06.12

[5] OAI-FlexRAN. [Online]. Available from: https://gitlab.eurecom.fr/mosaic5g/mosaic5g/wikis/tutorials/oai-ran?fbclid=IwAR3V__MC60MMPV6KqFIJpOox0EnUphKgeH0hApCGiIsSDs3NwVNe70oBAZ8 2020.06.12

[6] ONAP Architecture Overview. [Online]. Available from: https://www.onap.org /architecture 2020.06.12

[7] 5G NSA: Universal Mobile Telecommunications System (UMTS); LTE; 5G; NR; Multi-connectivity; Overall description; Stage-2 (3GPP TS 37.340 version 15.5.0 Release 15.

[8] L. Yala, M. Iordache, A. Bousselmi, S. Imadali, "5G mobile network orchestration and management using open-Source", 2019 IEEE 2nd 5G World Forum (5GWF), doi: 10.1109/5GWF.2019.8911690

[9] R. Ferrús, O. Sallent, J. Pérez-Romero and R. Agustí, "On the automation of RAN slicing provisioning: solution framework and applicability examples", Eurasip journal on wireless communication and networking, Dec. 2019, pp. 1-12, doi: 10.1186/s13638-019-1486-1.

[10] A. Nakao et al.," End-to-end network slicing for 5G mobile networks", Journal of Information Processing 25, Feb. 2017, pp. 153-163, doi: 10.2197/ipsjjip.25.153

[11] I. Afolabi et al., "End-to-end network slicing enabled through network function virtualization", 2017 IEEE Conference on Standards for Communications and Networking (CSCN), Sep. 2017, doi: 10.1109/CSCN.2017.8088594

[12] Mosaic5G, https://gitlab.eurecom.fr/mosaic5g/mosaic5g/-/wikis/tutorials

[13] Orange Opensource onap-tests library. [Online]. Available from: https://gitlab.com/ Orange-OpenSource/lfn/onap/onap-tests/-/tree/dublin/onaptests 2020.06.12

[14] ETSI GS NFV-SOL 005. [Online]. Available from: https://www.etsi.org/deliver /etsigs/NFV-SOL/001099/005/02.04.0160/gsNFV-SOL005v020401p.pdf 2020.06.12

[15] Openstack Infra: OpenStack installation tutorial for Ubuntu. [Online]. Available from: https://docs.openstack.org/newton/install-guide-ubuntu/overview.html 2020.06.12

[16] x310 RRU USRP. [Online]. Available from: https://www.ettus.com/all-products/x310-kit/ 2020.06.12

 ISBN: 978-1-61208-802-0