Automated Onboarding, Testing and Validation Framework for NetApps

Andreea Bonea[1], Cristian Patachia-Sultanoiu[1;2], Marius Iordache[1], Ioan Constantin[1], Andrei Radulescu[3], Ciprian R. Comsa[2], Constantin F. Caruntu[2]
[1]Orange Romania, Bucharest, Romania
[2]Gheorghe Asachi Technical University of Iasi, Iasi, Romania
[3]Neobility, Bucharest, Romania
Email: andreea.bonea@orange.com

Abstract—This paper focuses on the development of a 5G framework used to foster the onboarding, testing and validation of new solutions closely related to the production environment. The aim is to describe the structure of the test-beds required for the full life-cycle of Netapps integration that has to allow iter-ative testing and validation. Moreover, a facility that employs an automated toolchain is introduced. The facility caters to the deployment of NetApps with very little human interaction through open source software automation tools. Furthermore, two NetApps from the automotive domain are introduced, i.e, Vehicle Route Optimizer and Road Users Interaction, which can be integrated using the provided experimental facility.

Index Terms—5G architecture, NetApps, 5G test-bed, 5G use-cases

I. INTRODUCTION

The 5G technology aims to provide higher capacity and lower latency, as well as an increased level of programmabil-ity, control and flexibility to meet the requirements stemming from innovative use cases from various vertical sectors. 5G requires dynamic allocation of resources, flexible deploy-ment of functions in distributed cloud infrastructures and, at transport level, the embedding of the end-to-end control and data plane connectivity between software peer entities and terminals, across the physical network.

There is an increased attention towards the area of 5G NetApps, where it has become necessary to shorten the cycles between development, testing and certification. The key technologies for NetApp deployment in 5G, addressed in [1], [2], are the following: Network Function Virtualization (NFV), Software Defined Networking (SDN), Cloud Com-puting and Multi-access Edge Computing (MEC).

Resource management and orchestration are also critical with the Management and Network Orchestration (MANO) framework providing coordination between available physi-cal and virtual networking, storage and computing resources. One of the goals of this paper is related to the seamless deployment against different execution environments and models, such as the open network automation platform (ONAP) [3].

*This work was partly funded by the European Commission under the European Union's Horizon 2020 program - grant agreement number 101016448 (5GASP project) and 101016567 (VITAL-5G project). The paper solely reflects the views of the authors. The Commission is not responsible for the content of this paper or any use made thereof.

This work was partially supported by a grant of the Romanian National Authority for Scientific Research and Innovation, CNCS/CCCDI - UEFIS-CDI, project number PN-III-P2-2.1-PED-2019-5296, within PNCDI III.

II. RELATED WORK

Intelligent transportation systems are one of the main ben-eficiaries of setting up MEC-enabled 5G platforms, reviewed comprehensively in [4]. The design and implementation of these platforms has to consider the interaction between core and edge tiers [5], [6] and to address the mechanism for scalable and flexible allocation of network slices.

A fully automated NetApp life-cycle from onboarding to certification will allow a massive diffusion and develop-ment of edge applications, in a "public-cloud" approach. Seamless computation and energy consumption will have to be achieved, by employing low-complexity distributed algorithms [7]. Another current challenge is addressing the cross-vertical requirements, for instance those related to mobility, which are subject to inter-domain connectivity constraints, as well as security and privacy challenges. To address these requirements, the focus needs to shift to the integration of multiple tiered-level designs, exposing and enabling automated testing and certification of key execution steps for NetApps, as addressed in [8].

A key objective to achieve this goal is to make avail-able virtual machines as well as containerized platforms. In terms of NFV, test-beds should follow the European Telecommunications Standards Institute (ETSI) NFV refer-ence architecture offering the two most-known solutions of Open Source MANO (OSM) and ONAP, while supporting both modelling and packaging according to the ETSI stan-dards OSM/SOL006 (YANG model) and ONAP/SOL001 (TOSCA) [9], [10].

III. TEST-BED EXPERIMENTATION FACILITY

With the 5G service-based architecture and the separation between the control and user planes, network scalability and flexibility are enhanced. The envisioned test-bed employs NFV and SDN to allow preliminary 5G access only to Non-Stand Alone (NSA) devices. In the current setup, the user equipment (UE) connects to the Next Generation Radio Access Network (NG-RAN) only, independent from the LTE access network.

In this test-bed experimentation setup, there are three main components that are used to perform an automated deployment in the 4G or 5G network: the orchestrator, the central facility and the extension facility. At both the extension facility and the central facility, the 5G and legacy

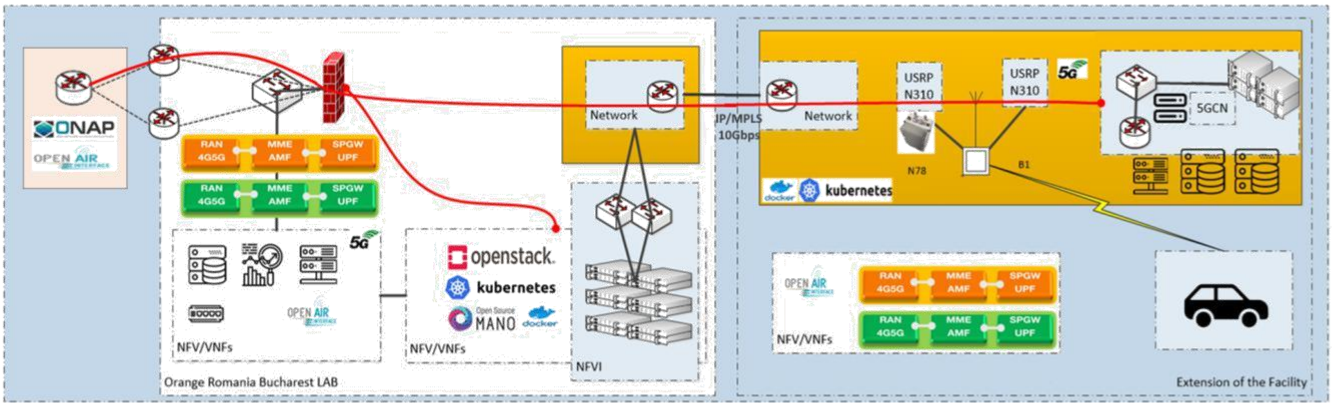

Fig. 1. End-to-end 5G reference architecture for Romanian test-bed

4G network elements are configured as two different network slices on separate logical levels, as shown in Fig. 1. On the 4G legacy side we integrate the access RAN side and core equipment, the mobility management entity (MME), service and packet data network gateway (SPGW). On the 5G slice we integrate the same functions, i.e., access and mobility management function (AMF) or user plane function (UPF). Aside from the physical elements such as servers, routers and switches that perform storage, computing and networking functions, the setup includes the radio elements. For the radio side, the USRP N310 networked software defined radio is used in combination with a N78 amplifier. These ensure reliability and fault-tolerance for deployment in wireless systems.

The extension facility is connected via the IP multi-protocol label switching (IP/MPLS) high speed technology with 10Gbps links to the central cluster which performs advanced network control functions, as well as analytics, computation and data storage. The central cluster is under on-going development and improvement over several projects [11]–[13] in accordance with ICT-17/19 5G test-bed guidance and is based on OpenAirInterface (OAI) over virtualized infrastructure for RAN and Core use case applications. Note that OAI is an open-source project that implements 3GPP technology on general purpose x86 com-puting hardware and off-the-shelf software defined radio cards like the USRP [14]. Further improvements are planned for deployment of 5G Stand Alone (SA) [15].

On the orchestration side, ONAP was selected to orchestrate various applications and resources, for its spe-cific functionalities, as reviewed in [16]. It connects to the computing cluster and can perform components deployment on OpenStack or Kubernetes for instantiating the required functions, as highlighted in Fig. 1. Note that, the virtual-machine based OpenStack is the open source platform for deployment and management of the cloud infrastructure as a service, and the container-based Kubernetes is the open source platform for automated management of clustered packages of executables or containers.

Collocated MEC servers and apps, with the dedicated user plane core network, bring functions closer to the end-user and are platform-independent from the rest of the network. Thus, the virtualization or containerization environment can be exposed with tools and standardized APIs for both services and life-cycle management.

A V-model methodology [17] can be used for testing. This end-to-end model demonstrates the relationships between each phase of the development and onboarding life cycle, as well as its associated phase of testing. In this manner, NetApp requirements are set up and transformed to a set of virtual functions that can have an automated repeatable deployment and testing cycle.

IV. VEHICLE ROUTE OPTIMIZER NETAPP

A NetApp addressing urban mobility is under develop-ment to be deployed in the described test-bed. Using De-mand Responsive Transportation (DRT) on 5G infrastructure MEC-enabled platforms, it can provide a near instantaneous response to the user's request. The application builds a real-time distributed vehicle route problem (VRP) optimizer engine, running on MEC servers closer to users and buses to increase processing speed. A key objective is to offload tasks to the MEC, as shown in Fig. 2.

The application can request a low latency 5G connec-tion through a wireless or radio network connection. The optimization algorithm uses as input information related to users' and drivers' location, bandwidth availability, network latency. The main constraint to be accounted is that the Vehicle Route Optimizer NetApp can provide this service but must be deployed as close as possible to the physical vehicle. As such, it must connect or migrate to the closest MEC platform. The virtual On-Board Units (vOBU) provisioning NetApp enable the possibility to implement multi-access capabilities that aim to offload tasks performed by mobile devices and ensure low latencies due to the proximity of the computing facilities to the attachment points.

For this reason, an orchestration between vOBU provi-sioning, inter-domain migration and the privacy analyser NetApp is proposed to provide a service of vOBUs that can travel close to the corresponding vehicle, switching between different virtualization and network domains seamlessly.

The vehicle route optimizer application is a 5G cloud native application and it uses the 5G infrastructure to cal-culate optimal shared routes. Using predictions, such as the

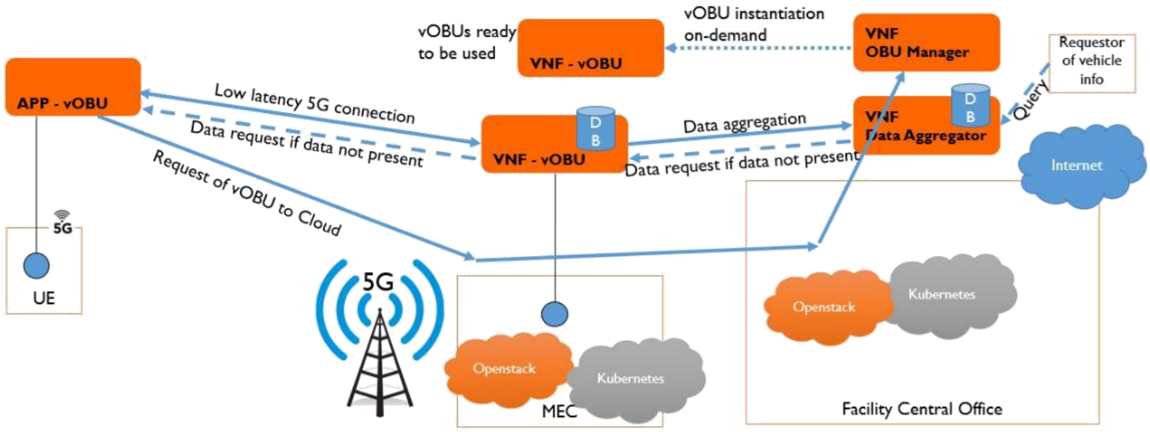

Fig. 2. 5G Virtual On-Board Units Provisioning architecture

duration of stay and next location prediction, the shared pool of potential passengers can be increased significantly. Moreover, the developed algorithms can predict the probability, time, and destination of the next travel, and use this data to contact potential travellers ahead of their travel-time and offer them the possibility to use the route.

The NetApp has multiple docker containers and communicates via HTTP and WebSocket. Every docker exposes a health check point and the deployment can only be finalized when all health checks are completed. The NetApp is designed such that the deployment is automated. Constraints have also been considered, hence if the NetApp is used in a region where 5G doesn't exist, or it connects via a provider that doesn't offer 5G services, it will fall back to the cloud.

A key asset for the NetApp is the usage of the 5G networks that will grant it increased capacity, security, elasticity, and adaptability. A real time planning engine takes a constant feed of GPS data both from users and vehicles and the schedule is constantly adapted. Using a real-time distributed solution, that runs closer to the user in edge computing, the algorithm will recalculate the route continuously (continuous re-optimization), while providing a near instantaneous response to the user's request.

V. ROAD USERS INTERACTION NETAPP

The architecture proposed in Section III for the 5G experimentation test-bed can accommodate the INTERACT NetApp, introduced herein, to address the topic of interac-tion between road users. This is of high interest from the perspective of connected and automated mobility (CAM), but also for traffic safety applications like vulnerable road users (VRUs) protection. This kind of safety applications have specific requirements, e.g., a maximum end-to-end latency of 100 ms, reliability higher than 95%, and data rate ranging between 5 and 10 kb/s [18], [19]. It is known that machine learning (ML) approaches can be employed in such applications, e.g., computer vision techniques to detect and classify the road users or other learning techniques to recognize different traffic situations or predict trajectories. This increases the processing power or the data throughput.

In this line, with the aim of offloading processing from vehicles and other road users' devices, virtualization of OBUs and other mobile devices have been proposed in the literature, i.e., SURROGATE [20] and MIGRATE [21], respectively. Similarly, in [22], vehicular micro clouds have been proposed to be conceptualized as a virtual cloud architecture implemented in the MEC. In this way, the virtual substitutes are maintained near or within the access network, exploiting the MEC capabilities of the 5G infrastructure.

As illustrated in Fig. 3, these concepts are employed for the proposed INTERACT virtualized architecture. As such, the MEC accommodates the virtualization of a roadside unit (vRSU), OBU, but also VRUs' mobile devices. In a typical architecture, the RSU senses and localizes the traffic participants by different kind of technologies, creating a so-called environment model (EM) [23]. Moreover, based on this EM, different kind of mobility services (MS) can be offered to the traffic participants by particular processing and communication means. As both EM and MS can be computationally intensive and bear constraints like low latency requirements for safety applications, virtualization of the RSU is the approach to offload the processing in the physical RSU and employ better algorithms, at the cost of exploiting the 5G MEC capabilities. Of course, an RSU is typically connected to the back-haul infrastructure via optical fiber and does not require a 5G connection, while it can communicate with road users by vehicle-to-everything (V2X) technologies. However, not all road users may be able to communicate via V2X, having capabilities of differ-ent radio access technologies (RAT), as in the Internet of Vehicles (IoV) [24]. The approach becomes interesting with the virtualization of the OBUs and VRUs, creating in fact a virtual micro-cloud architecture, as in [22]. The interactions between the vRSUs, vOBUs and vVRUs, respectively, can facilitate the creation of a consolidated fused EM enabling different MS paths too. Of course, for applications that are not latency critical, e.g., mapping or DRT NetApps, the slice can continue upwards to a cloud app server, offering the specific data processing and aggregation benefits.

In sum, the 5G MEC and VNF capabilities open the way for improved safety applications in different traffic scenar-ios, including in intelligent intersections enabling optimized architectures for that.

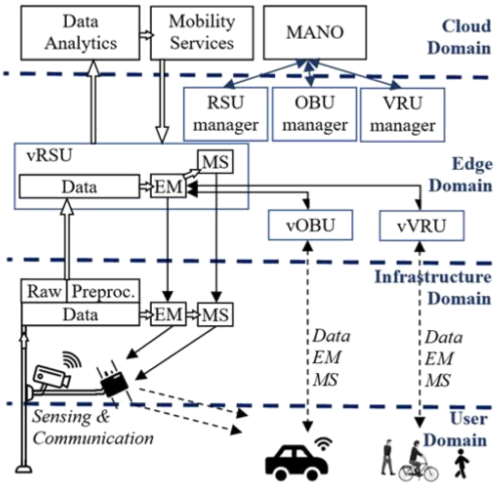

Fig. 3. INTERACT virtualized architecture

VI. CONCLUSIONS

In this paper, we proposed a framework to test and validate NetApps. The framework is based on a fully equipped test-bed experimentation facility that allows preliminary 5G access. The laboratory is fully virtualized and has MEC servers and apps collocated with a dedicated user plane core network. In this setup, iterative development, onboarding and testing can be seamlessly performed.

Further, in this paper, a vehicle route optimized NetApp is described. This NetApp builds a real-time distributed vehicle route problem optimizer engine. It can be tested and integrated in the 5G environment following the V-model for development, onboarding and testing. Moreover, a second NetApp related to the interactions between road users was introduced, in which MEC accommodates the virtualization of RSUs, OBUs and VRUs' mobile devices. Through this kind of applications, the 5G MEC and VNF capabilities enhance the development of improved safety applications tackling different mobility scenarios. The final aim is to extrapolate the iterative model to NetApps from different verticals and allow easy interfacing to production.

Future work will consider the development of a validation framework architecture. In terms of the overall 5G system, the testing facilities should offer 5G New Radio and 5G Sys-tems supporting both 5G NSA and 5G SA, while employing various MEC solutions. An improvement is related to the onboarding time of the virtual machines images or containers to a facility. This is the most time-consuming process to be reduced with pre-loading or caching mechanisms.

ACKNOWLEDGMENT

The scientific, technical, and academic activities and the testing and validation of the research results disseminated in this article have been performed in the Orange 5G Lab, an advanced experimental facility in Bucharest, created with the CAMPUS Research Center of UPB – University POLITEHNICA of Bucharest. The Orange 5G Lab supports the prototyping, testing, and validation of 5G use-cases, new applications, and new equipment within a team of industry-leading experts and academics.

REFERENCES

[1] I. Afolabi, T. Taleb, K. Samdanis, A. Ksentini, and H. Flinck, "Network Slicing and Softwarization: A Survey on Principles, En-abling Technologies, and Solutions," IEEE Communications Surveys & Tutorials, vol. 20, no. 3, p. 2429–2453, 2018.

[2] A. Esmaeily, K. Kralevska, and D. Gligoroski, "A Cloud-based SDN/NFV Testbed for End-to-End Network Slicing in 4G/5G," in 6th IEEE Conference on Network Softwarization, 2020.

[3] "ONAPArchitecture Overview." [Online]. Available: https://www.onap.org/architecture

[4] Y. Liu, M. Peng, G. Shou, Y. Chen, and S. Chen, "Toward Edge Intelligence: Multiaccess Edge Computing for 5G and Internet of Things," IEEE Internet of Things Journal, vol. 7, no. 8, pp. 6722– 6747, 2020.

[5] I. Sarrigiannis, K. Ramantas, E. Kartsakli, P.-V. Mekikis, A. Antonopoulos, and C. Verikoukis, "Online VNF lifecycle management in an MEC-enabled 5G IoT architecture," IEEE Internet of Things Journal, vol. 7, no. 5, pp. 4183–4194, 2020.

[6] L. Cominardi, T. Deiss, M. Filippou, V. Sciancalepore, F. Giust, and D. Sabella, "MEC support for network slicing: Status and limitations from a standardization viewpoint," IEEE Communications Standards Magazine, vol. 4, no. 2, pp. 22–30, 2020.

[7] I. Labriji, F. Meneghello, D. Cecchinato, S. Sesia, E. Perraud, E. C. Strinati, and M. Rossi, "Mobility aware and dynamic migration of MEC services for the Internet of Vehicles," IEEE Transactions on Network and Service Management, vol. 18, no. 1, pp. 570–584, 2021.

[8] "5G ASP: 5G Application & Services experimentation and certification Platform." [Online]. Available: https://5g-ppp.eu/5gasp/

[9] "5G Implementation Guidelines: SA Option 2." [Online]. Available: www.gsma.com/ futurenetworks

[10] "Open Source MANO." [Online]. Available: http://osm.etsi.org

[11] "5G EVE: 5G European Validation platform for Extensive trials." [Online]. Available: https://5G-ppp.eu/5g-eve/

[12] "MATILDA: A holistic, innovative framework for the design, development and orchestration of 5G-ready applications and network services over sliced programmable." [Online]. Available: https://5g-ppp.eu/matilda/

[13] "SLICENET: End-to-End Cognitive Network Slicing and Slice Management Framework in Virtualised Multi-Domain, Multi-Tenant 5G Networks." [Online]. Available: https://5g-ppp.eu/slicenet/

[14] F. Kaltenberger, G. d. Souza, R. Knopp, and H. Wang, "The OpenAir-Interface 5G new radio implementation: Current status and roadmap," in 23rd International ITG Workshop on Smart Antennas, 2019.

[15] "VITAL-5G: Vertical Innovations in Transport And Logistics over 5G experimentations facilities." [Online]. Available: https://5g-ppp.eu/vital-5g/

[16] G. M. Yilma, Z. F. Yousaf, V. Sciancalepore, and X. Costa-Perez, "Benchmarking open source NFV MANO systems: OSM and ONAP," Computer Communications, vol. 161, p. 86–98, 2020.

[17] S. Mathur and S. Malik, "Advancements in the V-Model," Interna-tional Journal of Computer Applications, vol. 1, no. 12, pp. 30–35, 2010.

[18] S. Barmpounakis, G. Tsiatsios, M. Papadakis, E. Mitsianis, N. Kour-sioumpas, and N. Alonistioti, "Collision avoidance in 5G using MEC and NFV: The vulnerable road user safety use case," Computer Networks, vol. 172, p. 107150, 2020.

[19] M. Emara, M. C. Filippou, and D. Sabella, "MEC-assisted end-to-end latency evaluations for C-V2X communications," in European Conference on Networks and Communications, Jun 2018.

[20] J. Santa, P. Fernandez,´ J. Ortiz, R. Sanchez-Iborra, and A. Skarmeta, "SURROGATES: Virtual OBUs to foster 5G vehicular services," Electronics, vol. 8, no. 2, p. 117, 2019.

[21] J. Santa, A. F. Skarmeta, J. Ortiz, P. J. Fernandez, M. Luis, C. Gomes, J. Oliveira, D. Gomes, R. Sanchez-Iborra, and S. Sargento, "MI-GRATE: Mobile device virtualisation through state transfer," IEEE Access, vol. 8, pp. 25 848–25 862, 2020.

[22] F. Dressler, G. S. Pannu, F. Hagenauer, M. Gerla, T. Higuchi, and O. Altintas, "Virtual edge computing using vehicular micro clouds," in International Conference on Computing, Networking and Commu-nications, 2019.

[23] O. Grembek, A. Kurzhanskiy, A. Medury, P. Varaiya, and M. Yu, "Making intersections safer with I2V communication," Transportation Research Part C: Emerging Technologies, vol. 102, pp. 396–410, 2019.

[24] R. Sanchez-Iborra, J. Santa, J. Gallego-Madrid, S. Covaci, and A. Skarmeta, "Empowering the Internet of Vehicles with Multi-RAT 5G Network Slicing," Sensors, vol. 19, no. 14, p. 3107, 2019.