The 5G-IANA Automotive Open Experimentation Platform: Features and Assets at the Disposal of Third Parties

Eirini Liotou
Institute of Communication & Computer Systems
Athens, Greece
eirini.liotou@iccs.gr

Dimitris Klonidis
UBITECH
Limassol, Cyprus
dklonidis@ubitech.eu

Matteo Andolfi
Nextworks
Pisa, Italy
m.andolfi@nextworks.it

Peter Schmitting
FSCOM
Sophia Antipolis, France
peter.schmitting@fscom.fr

Manuel Fuentes
Fivecomm
Valencia, Spain
manuel.fuentes@fivecomm.eu

Edoardo Bonetto
LINKS Foundation
Turin, Italy
edoardo.bonetto@linksfoundation.com

Markus Wimmer
NOKIA
Ulm, Germany
markus.wimmer@nokia.com

Konstantinos Katsarsos
Institute of Communication & Computer Systems
Athens, Greece k.katsaros@iccs.gr

Christopher Ververidis
HYPERTECH
Athens, Greece
c.ververidis@hypertech.gr

***Abstract*—5G-IANA aims at providing an open 5G experimentation platform, on top of which third-party experimenters, i.e., SMEs in the Automotive vertical sector will have the opportunity to develop, deploy and test their services. The provided Automotive Open Experimentation Platform (AOEP) is a set of hardware and software resources that provides the computational and communication/transport infrastructure. This is coupled with management and orchestration components, as well as an enhanced network application Toolkit tailored to the Automotive sector, for simplifying the design and onboarding of new network applications. 5G-IANA exposes to experimenters Application Programming Interfaces (APIs) for facilitating all the different steps towards the production stage of a new service. The platform supports different virtualization technologies integrating different Management and Orchestration (MANO) frameworks for enabling the deployment of end-to-end network services across different segments (vehicles, road infrastructure, Multi-access Edge Computing (MEC) nodes and cloud resources). The 5G-IANA network application toolkit is linked with an Automotive Networks/Application Functions Repository including an extensive portfolio of ready-to-use and openly accessible Automotive-related functions and network application templates, that are available for SMEs to use and develop new applications. Overall, 5G-IANA aspires to encourage third parties to test novel software or hardware or use cases by exploiting the platform capabilities.**

Keywords—orchestration, network applications, network platform, remote driving, 5G.

I. INTRODUCTION

Orchestration embraces automation which is critical for the commercial survival of today's Automotive Service Providers, who face rising technology complexity, increased commercial pressures, and accelerated technology refresh cycles. According to the study in [1], automation has the ability to lower the cost of operations by 60% while, at the same time, enabling the agility and innovation Service Providers need to enter and compete effectively in new markets. The global enterprise market is highly attractive for this kind of automation and its benefits and thus, seeks for new entries to compete and differentiate there. One other missing part is the capability of the Vertical Services to dynamically interact with such orchestration primitives the infrastructure exposes and provides. In that sense, a service orchestration, taking into account vertical needs, is a key factor for success in the enterprise market. The ability to orchestrate new services through the full-service life cycle of design, deployment, and operation is essential to reduce OPEX, achieving agility, reducing operational costs, and enabling new revenue generating services. However, as with the adoption of any new technology in complex legacy architecture, service providers should expect the operational overhead and complexity to increase in the short term before the long-term benefits can be realized. In consequence, the adoption of a unified programmability model and the definition of proper abstractions to constitute the creation of an open development environment that may be used by application or network functions' developers is a key point of the 5G-IANA platform, following also the example of previous works [2].

The specific benefits aspired for third parties engaging with the 5G-IANA platform concern the availability of mechanisms to easily design distributed intelligent services, which span from the remote cloud to the far-edge segment and to request their provisioning on top of 5G-enabled infrastructures. This further translates to a platform that is offered to third parties to develop, deploy and test their services, to a catalogue of available functions and network applications that are open to use, and to tools that help prepare and onboard proprietary software functions on the 5G-IANA platform, Moreover, remote accessibility to 5G resources (both spectrum and processing/computing), as well remote accessibility to OBU/RSU resources is provided. In this way, third parties can build their own 5G-centric use cases and are able to test their novel applications and services, or even test how their proprietary hardware devices behave in a real 5G environment.

One of the main features of the 5G-IANA platform [3] is the integration of orchestration on top of On-Board Units (OBUs) and Road-Side Units (RSUs), based on Kubernetes, for offering a more flexible and scalable management of the so-called Network Applications. A network application is a virtual application that can be deployed in a 5G infrastructure and can use 5G services (e.g., connectivity) and that implements and exposes a specific service. A network application can be composed of one or multiple applications and/or network functionalities.

Kubernetes [4] is an open-source container orchestration system used in 5G-IANA for automating application deployment, service discovery, and scaling/load balancing/traffic distribution. For edge-based environments, Kubernetes can be useful for orchestrating and scheduling resources from cloud to edge data center workloads, and also to manage and deploy edge devices together with cloud configurations. In this way, automotive application developers can create their network applications following a conventional microservices-based approach where each component can be independently orchestrated.

The orchestration of applications on OBUs is not a common feature that is typically provided in commercial devices. A key requirement of the OBUs for enabling the orchestration of applications is to support virtualised or containerised applications. This aspect seems to not be tackled in commercial OBUs. Solutions for orchestrating applications have been instead introduced in several research projects together with different virtualisation approaches. The use of virtualization in the automotive domain and on the OBUs has been proposed in [5]. An OBU, that supports Docker containerization, is instead being introduced in [6]. This solution is in particular relevant as Kubernetes exploits containers for orchestrating the applications. The 5GinFIRE project [7] proposed an orchestration solution that is close to the 5G-IANA concept. In the 5GinFIRE project, a multi-site orchestrator was developed exploiting the functionalities provided by Open Source MANO. The orchestrator was then used to deploy automotive applications as Virtual Network Functions on real OBU hardware devices.

Since the network application concept is fairly new, there are not much research works identified in the literature, while most are driven by relative EU projects. For instance, VITAL-5G project defines the network application as a fundamental building block of the Transport & Logistics (T&L) vertical service chain, with the objective to hide the complexity beneath the application layer, while imposing service-level requirements with respect to 5G [8]. In this sense, the notion of a network application in this work is similar with the one presented in this paper. In 5G-INDUCE, a network application Orchestration component is integrated into the Operations Support System (OSS) and offers the interfacing between the network application's service requests and the actually assigned resources and network connectivity offerings [9]. At the same time, the network operator is able to apply polices and any intelligent data analytics at the service level, while the application orchestration and the pure OSS processes are clearly separated. Finally, in 5GASP, a Service Orchestrator is in charge of transforming the so-called Network Slice Template properties into network requirements that should be met by the 5G network, mainly through network slicing [10].

This paper aspires to explain the 5G-IANA platform capabilities, and to elaborate on the functionalities and the assets that are offered to third parties for experimentation on a 5G network, with the assistance of the platform. The remainder of the paper is structured as follows. Section II describes the 5G-IANA platform at a relative abstracted view, while Section III delves into more details regarding the available network application starter kits, that are at the disposal of third parties. It also provides some basic terminology used throughout the paper, and presents the identified network applications of the 5G-IANA project. Section IV describes the network and service level KPIs that 5G-IANA platform provides for the evaluation and validation of various use cases and experiments, while Section V briefly describes the project's use cases. Finally, Section VI presents the two 5G-IANA testbeds, and Section VII concludes the paper.

II. THE 5G-IANA REFERENCE PLATFORM

The 5G-IANA Automotive Open Experimentation Platform (AOEP) is specifically conceived for simplifying and automating the management of network applications onto programmable infrastructures, and particularly 5G. At a glance, the proposed platform aims to mostly hide the complexity of programmable infrastructure and 5G environment to service developers and providers, and to make the development, deployment and operation of 5G-ready applications similar to the well-known corresponding processes applied to cloud-native applications in cloud computing environments.

Figure 1 shows the 5G-IANA conceptual architecture at a high-level view, and highlights the two-layered Orchestration stack: the Network Application Orchestration and Development (NOD) (layer 1), the Slice Management & Multi-Domain Orchestration, the virtualized infrastructure segments (layer 2) along with the cross layer supported functionalities: The Distributed AI/ML framework (cross-layer), the Monitoring & Analytics, and the Distributed Data Collection (cross-layer).

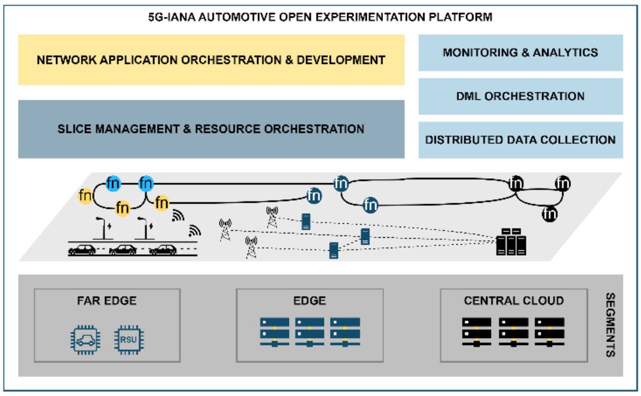

Figure 1: 5G-IANA Orchestration Layers abstraction

The separation of the 5G-IANA orchestration platform functionalities between the two aforementioned layers serves the need to operate between the following two different administrative domains: the Application Domain (in yellow) and the Infrastructure Domain (in blue). The distinction of layers targets the different "work-burden" that has to be achieved and managed. This way, the tools of the orchestration are targeting two lifecycles and specifically those: a) of the application and b) of the programmable infrastructure and network services. In this sense, the 5G-IANA Platform is comprised by a set of orchestration tools with each set devoted to its specific (applicative or network) administrative domain. Each administrative domain is mainly targeted for a specific stakeholder's needs: for the Application Domain the stakeholders are network applications developers of various automotive vertical industries, while for the Infrastructure Domain the stakeholders are programmable infrastructure owners including 5G network operators. Specifically, the Slice Management & Resource Orchestration Layer handles the communication with various edges including the on vehicle MANO. Given that the OBUs and Road Side Units (RSUs) are part of the programmable resources, the specific work described is undertaken by the Slice Management & Resource Orchestration Layer.

The 5G-IANA's network application Toolkit enables developers to create brand-new network applications and vertical automotive services which can exploit 5G services with specific requirements and functionalities, and which can be deployed over a 5G infrastructure. The goal of the Toolkit is to make it easier to chain together and customize 5G-ready vertical services with the help of functionalities provided by the Vertical App Composition & Customization as well as by the network application catalogue. This enables the on-boarding and updating of network applications Packages and related components from software providers.

The Toolkit communicates from one side with the Application Orchestrator which manages the deployment requests. On the other side, the network application Toolkit exposes its services directly to the network application and Vertical service developers providing features to:

- register Application and Network Functions (AFs/NFs) as atomic components,
- compose network applications and vertical services in a graphical, intuitive, and simple way,
- onboard network applications and vertical services for future use.

As we describe next, the Toolkit further provides support to developers in the development of their applications, in the form of "network application starter kits".

III. THE NETWORK APPLICATION STARTER KITS

For completion, we provide at this point some basic terms that are being used throughout the paper: An atomic component is a virtualizable function that is deployable in a container. In simple words, an atomic component is a docker image that runs on an executor and offers some functionalities. There are two categories of atomic components:

- Application Functions (AF) which implement the logic of the applications. Examples of application functions can be a remote driving module application function, which receives control orders: direction, angle, and speed from the actuator and moves the vehicle accordingly, or it can be a hazardous driving behaviour detection function, which is responsible for detecting and evaluating hazardous driving events (harsh braking or acceleration, speeding, mobile use).
- Network Functions (NF) that implement the communication between application functions and ensure connectivity with the 5G network. For example, a sensor's data capturing function which collects data related to the distance and angle of a vehicle to near obstacles from sensors.

5G-IANA has created network application "Starter-kits" specifically designed to aid in the development of advanced Automotive Vertical Services. These kits are intended to support the creation of Vertical Services within identified service categories by providing a baseline set of AFs/NFs (atomic components) for deployment. By utilizing these kits, service creators and providers can better leverage the resources available through the 5G infrastructure, including the ability to orchestrate and run applications on Far-edge resources like OBUs and RSUs. As each Vertical has unique needs and requirements, 5G-IANA offers a variety of such open-source network application "Starter-kits," each designed to support the roll-out of 5G-IANA and third-party UCs. These kits are available as ready-to-use network application packages that contain all the relevant information necessary for their usage in specific contexts/scenarios.

In addition to facilitating the development of advanced Automotive Vertical Services, the network application "Starter-kits" also aim to provide Verticals with the necessary knowledge to understand the specific purpose and usage of low-level functionalities. This is particularly important as the deployment of certain AFs/NFs may be required to consume and forward information on top of an OBU, such as Intelligent Transport Systems (ITS) communication functions.

For example, Figure 2 provides an illustration of network application "Starter-kits" for a manoeuvres' coordination service, highlighting two different kits, each designed to aid in the implementation of specific functionalities. The AFs highlighted in purple in Figure 2 are customizable and can be integrated by experimenters and third parties looking to provide a specific logic/algorithm for the Manoeuvres Planning functionality.

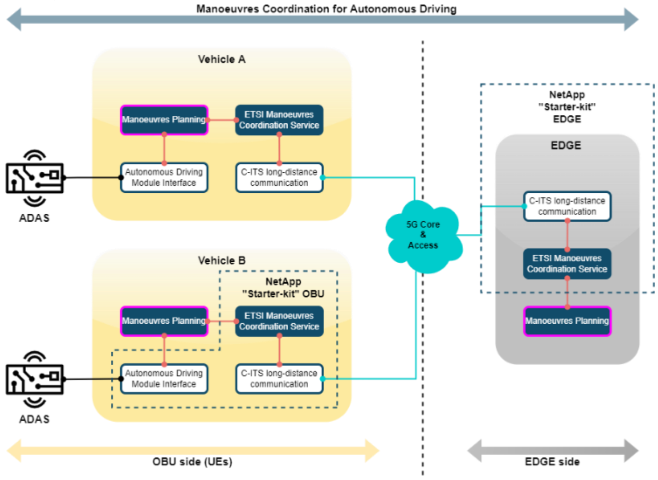

Figure 2: Manoeuvres Coordination for Autonomous Driving network application "Starter-Kits" Example

Overall, the integration of network application "Starter-kits" aims to streamline the development of advanced Automotive Vertical Services and enhance the utilization of resources available through the 5G infrastructure.

The list of the identified network applications of the 5G-IANA project is presented in Table I.

TABLE I. 5G-IANA NETWORK APPLICATIONS

Name	Description
Real Time Stream Delivery	It handles video encoding/decoding and streaming.
Object Detection Stream and Data Delivery	It applies an AI algorithm to detect objects in the video streaming.
AGV Data Processing, Communication and Control	It manages the communication with the vehicle and the processing of data from its sensors, making movement decisions.
Remote Driving	It provides a user interface that facilitates vehicle control, offering a warning system and detection of nearby objects and traffic signs to help driving task.
Manoeuvres Coordination for Autonomous Driving (MCAD) rover node	Duplex communication between MCAD Edge node and a vehicle. It manages vehicular functions so as to translate received manoeuvre coordination messages to vehicular commands and vice-versa, by transmitting vehicle pose and status.

MCAD edge node	Uses ETSI manoeuvre coordination messages to manage an intersection by means of the generation of trajectories for the vehicles approaching it.
AI Enhanced Video Stream Delivery	It provides a service capable of receiving a 360° livestream and providing an Adaptive Bit Rate (ABR) stream endpoint resilient to network instability, whose bandwidth is limited via its Field of View (FOV) prediction AI mechanism.
Video enabled VR Client	It provides a VR service that can utilize a 360° live video as a background.
Active Network Monitoring Module	It monitors the network for bandwidth availability.
Virtual Bus Tour	It enables a Virtual Bus tour use case.
Augmented Reality (AR) App	It handles AR objects rendering on the mobile phone.
AR streaming application	It handles the AR objects streaming through specific AR streaming protocols and buffering.
Real-time Hazardous driving event detection	It handles real-time hazardous driving behavior detection and risk event notification. It can be easily modified to allow the addition of other AI algorithms to interact with the driving behavior data.
Aggregated Hazardous driving event detection	It handles hazardous driving behaviour detection and risk event notification based on aggregated data. It can be easily modified to allow the addition of other AI algorithms.
Real-time vehicle trajectory prediction	It provides corrections to the vehicle's current trajectory in order to accurately predict is future trajectory.
Hazardous driving event notification	It subscribes to events from ETSI decentralized environmental notification service and it identifies the appropriate hazardous events to display to the driver and also warn them when they enter a high-risk road segment.
Predictive QoS	It takes spatial and temporal data input and provides a prediction for QoS metrics such as latency and throughput. It is based on the trained distributed ML model present at the Far-Edge node.
Obtain Training Data	It collects the network status such as round-trip time, and data rate, and processes it suitable for training.
Distributed Machine Learning (DML) Training	It trains the local models of each OBU with the training data collected by the previous network application. The trained models from all the OBUs are further aggregated at the Edge to form a single Global model.
Video stream delivery	It provides a complete end-to-end video streaming service from camera on one end to UE/display on the other end (e.g., UE streams over 5G).
Environmental/IoT monitoring	End-to-end service for collecting any kind of environmental or other data via multiple IoT sensors simultaneously, storing, and representing them in multiple ways (processed by statistical methods, raw data; graphical UI, textual).
Simulator of ETSI Cooperative Awareness Service	Simulating presence of multiple vehicles by generating Cooperative Awareness Messages (CAMs) that provide information about the position and the dynamics of vehicles.
Vehicle monitoring	Collecting (via OBU), storing, and representing various vehicle parameters.

IV. KPIs FOR EXPERIMENT VALIDATION

The 5G-IANA platform provides the ready-to-use measurement of both network- and service-level KPIs at the disposal of third parties.

A. *Network level KPIs*

Network level KPIs provide information on the baseline performance requirements from the 5G network and the 5G-IANA platform, in order for a Use Case (UC) of any third party service to operate optimally. The following network level KPIs have been considered: Latency, Round-trip time (RTT), UL (DL) user data rate, Max. user data rate, UL (DL) packet loss rate, Reliability.

B. *Service level KPIs*

Service Level KPIs provide information on the baseline performance expectations of the service demonstrated. These KPIs target specific Vertical Services from a business perspective i.e., each set concerns a service focused on a specific industry or group of customers with specialized needs (e.g., automotive, entertainment etc). The following (most commonly applied) service level KPIs have been considered:

- E2E Latency is the maximum accepted latency across the entire service chain.
- E2E Reliability is defined as the percentage of correctly received packets over the total packets transmitted in the complete service chain.
- Service Availability is the percentage of time that an application is accessible and usable within a predefined QoS level e.g., the fraction of time a software component is functional (up) or the fraction of requests that are serviced correctly.
- Application Jitter is the statistical variation of the end-to-end latency for the communications across the entire service chain of the vertical service.
- Quality of Experience (QoE) is defined as the overall acceptability of an application or service, as perceived subjectively by the end-user.
- Prediction Accuracy in classification tasks is a measure of how well an algorithm correctly identifies or excludes a condition i.e., the proportion of correct predictions over the total number of cases examined.

V. AUTOMOTIVE USE CASES

The 5G-IANA platform will be evaluated against seven use cases (UC1-UC7), which are briefly presented below.

UC1 is about the integration, demonstration and validation of advanced remote driving functionalities in the open and enhanced experimentation platform developed in the 5G-IANA project. The aim is to use a vehicle connected through 5G, which is controlled remotely via a teleoperation platform.

UC2 aims to showcase a manoeuvre coordination service, capable of lowering the risk of collision in complex junction scenarios by describing suitable paths and priorities for connected, eventually automated, vehicles directed by a shared coordination system. It facilitates AVs and human driven cars interaction at gatherings, complex intersections, and clogged traffic. The use case will include autonomous and traditional cars together with Virtual Vehicles that can be put in at will to recreate realistic traffic conditions. Virtual simulated vehicles, fully integrated into the AOEP, will also serve as a powerful tool to facilitate experimentation throughout the 5G-IANA platform ecosystem.

UC3 corresponds to a virtual tour, where virtual reality users will be joining a tour guide in a virtual environment of a double decker bus and will be represented in the VR space with their avatars. Users will be able to receive to their HMD (Head Mounted Display) the video of the tour surroundings streamed by a high resolution 360º camera mounted to a vehicle taking the real tour, along with GPS-driven landmark indicators providing information about the attractions. The users, via their avatars will be able to gesture, speak and listen to one another, from their dedicated virtual bus seats, which will be determined during their entry.

UC4 aims at providing “high-quality AR content streaming” taking advantage of the future web AR applications, the MEC and 5G connectivity. For a UE entering a 5G network, the respective network application will provide information in the form of “high-quality” virtual 3D objects embedded on the user’s 3D map on his mobile device (e.g., iPhone/iPad). This is a characteristic example of convergence of edge computing, the ARCore Geospatial API and 5G networking that will give users the ability to interact with content, digital character displays, virtual experiences and outdoor navigation. Instead of using cloud, we will leverage MEC server so that the experience is rendered on powerful, edge-based GPUs and then streamed to any mobile device.

UC5 aims to develop a feature that will be integrated in the 5G-IANA platform, which will detect aggressive and distracted driving (hazardous events), and transmit warning notifications on road risk-level to other vehicles. The two kinds of risky behaviour the UC5 novel network application aims to detect are: a) aggressive driving via harsh braking, harsh acceleration, speeding, crashes, and b) distracted driving via mobile use.

UC6 provides an overview of the status of network components or virtual network functions and draws conclusions and predictions with respect to the performance of the monitored components. It utilizes network communications to deliver predictions of the network quality to a central computation entity at the MEC server. This network application has the goal to minimize the data collection effort through utilizing a distributed Machine Learning (ML) approach, i.e., instead of collecting large amounts of network monitoring data to be centrally analysed, the ML analysis/prediction model is distributed on the NFs/AFs located at the RSUs and the vehicle OBUs. The goal of the ML model is (1) to learn data traffic patterns for data traffic prediction, (2) to learn network condition models to provide QoS predictions, and (3) to learn to distinguish between normal and abnormal network behaviours to detect and predict faults.

UC 7 aims to develop and integrate necessary components (e.g., NF/AFs, RSU, OBUs, sensors and cameras, 5G SA network, 5G MEC) to provide situational awareness for first responders. In case of an accident in a road tunnel, situational awareness systems enable first responders to understand the exact location of the incident, number of involved vehicles and people and other critical situational information, such as temperature, smoke, and CO level status in the tunnel. RSU and sensors connected to it, as well as OBUs, will provide environmental data sensed in a tunnel, including real-time video-stream. NFs/AFs deployed in RSU and OBUs will take care of initial processing of collected data and will provide data transmission to the MEC where monitoring NF/AF will collect them.

VI. REAL-TIME USE CASE DEMONSTRATION

An excellent example of how a use case can be implemented, onboarded, and deployed using the 5G-IANA reference platform and orchestrator is UC1. The particular network application is formed by 4 NFs, i.e., video server (NF#1); AI object detection and processing (NF#2); AGV communication API (NF#3); and remote driving web server (NF#4). Figure 2 shows the UC service chain (network app.).

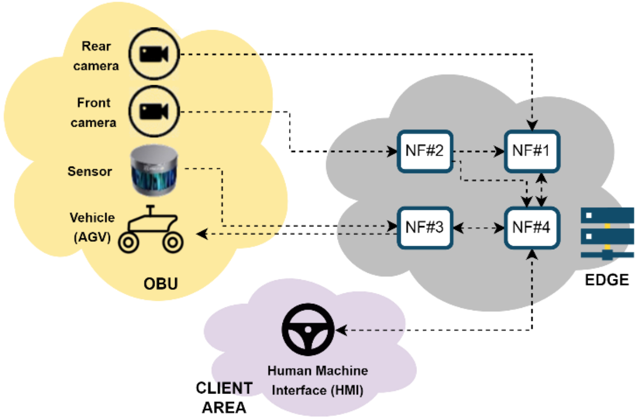

Figure 2: UC1 service chain.

After a successful onboarding of the end-to-end application in the platform, a real-time demonstration of a remote driving service with 360º lidar information and ML video-based object detection was deployed by the platform orchestrator and demonstrated in the 5G testbed located in Ulm (Germany), in June 2023. In this demonstration, an AGV equipped with an OBU was controlled via 5G by a remote driver, also connected through 5G to the platform, which received the processed video and warning alerts, and provided the orders to move the vehicle with a wheel and pedals. The particular setup can be observed in Figure 3.

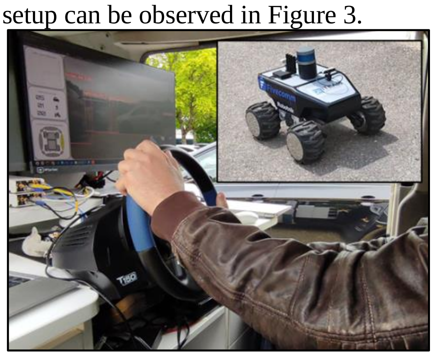

Figure 3: Real-time end-to-end demonstration performed in Ulm: remote driving cockpit and vehicle employed.

VII. 5G TESTBEDS

The 5G-IANA platform will be available via two 5G testbeds, one operated by Nokia (Germany) and one operated by Telecom Slovenia, and will be available for remote access through secure connection.

Nokia operates an LTE/5G test network in Ulm, Germany. Four antenna sites are connected with optical cables to the 5G base station (gNB) located in the Nokia laboratory. The 5G core’s User Plane Functions (UPFs), which are responsible for routing and forwarding user data between the gNBs and the external Data Networks (DN), are also located in the Nokia laboratory. So is the EDGE Server, on which Data Networks (DNs) for 5G-IANA are hosted. The EDGE Server provides computing resources at the “edge” of the mobile network and close to the mobile user.

Network Slicing is used to allocate network resources to fulfil the requirements of specific services. Nokia provides two preconfigured network slices – one low priority Enhanced Mobile Broadband (eMBB) with 5GI 7 and one high priority Vehicular to Everything (V2X) with properties similar to 5GI 79. In high load scenarios, the V2X slice gets approximately 75% of the radio resources allocated and the eMBB slice the remaining 25%. In scenarios, in which only one slice is used, up to 100% of a cell capacity can be allocated to this slice.

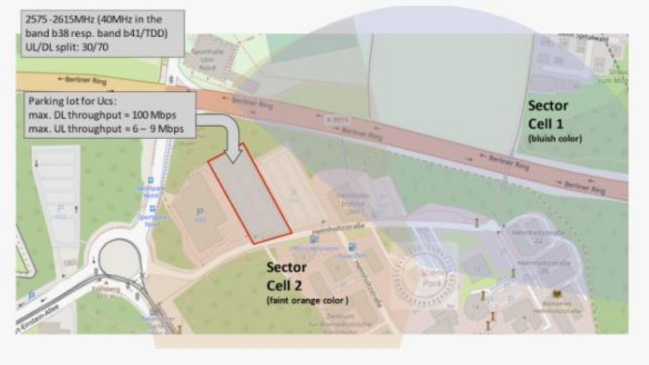

Figure 5: Sector cells at antenna site DRK and the cell capacities at the parking lot for UC testing. (map picture source: OpenStreetMap)

The area at antenna site “DRK Ulm” is predominately used for the 5G-IANA use case testing. Figure 5 indicates the two of the three available sector cells of this site, and the enclosed parking area near this antenna site, which can be reserved for use case testing. Each cell sector operates in the frequency range from 2575-2615MHz (band b38 resp. band b41/TDD) with an UL/DL radio resource split of 30/70, providing in areas of goad signal reception a maximum cell UL throughput rate of approximately 100Mbps and a maximum cell DL throughput capacity of approximately 9Mbps. The average round-trip-time (RTT) between a UE and the EDGE-Server is below 20ms. The cell range is approximately 2km.

Figure 6: Outdoor coverage near Vojkova 78 location in Ljubljana

Moreover, Telekom Slovenije provides a second testbed, which is located at Telekom premises in Ljubljana (Figure 6). The 5G infrastructure consists of Cloud and virtualization environment, Centralized Edge, Network connectivity, 2 dedicated indoor 5G NR micro cells, 5G ready core network based on EPC extensions, 5G SA Core, and 4G – LTE radio access network (CA, Nb-IoT, VoLTE).

The cloud and virtualization infrastructure is the main compute, storage and network power of the facility. It serves as a container for deployment of AFs/NFs. The mobile core is deployed on top of the cloud virtualization platform, with all virtual packet core functions. The Radio Access Network (RAN) is connected to the mobile core network, residing in the cloud/virtualization environment.

VIII. CONCLUSIONS

The 5G-IANA platform has been designed and developed in order to offer service providers the mechanisms to easily design distributed intelligent services, which span from the remote cloud to the far-edge segment, and to request their provisioning on top of 5G-enabled infrastructures. Except for offering such a platform to third parties to develop, deploy and test their services, a catalogue of available ready-to-use AFs/NFs (~70) and network applications (~25) is provided, together with network applications starter kits, while friendly-to-use interfaces and tools to prepare and onboard AFs, NFs or network applications on the 5G-IANA platform are given. Therefore, the 5G-IANA platform, along with the provisioning of remote accessibility to 5G resources, the accessibility to OBU/RSU resources, and the anticipated support to AI/ML-oriented services, is expected to become a valuable asset in the era of future networks for Connected and Automated Mobility.

ACKNOWLEDGEMENT

This research was performed in the context of the 5G-IANA project, co-funded by the European Commission under the Horizon 2020 Research and Innovation Programme (grant agreement No 101016427).

REFERENCES

[1] M. Liyanage, et al., “A survey on Zero touch network and Service Management (ZSM) for 5G and beyond networks,” Journal of Network and Computer Applications, vol. 203, p. 103362, Jul. 2022.

[2] P. Gouvas, et al., “Separation of concerns among application and network services orchestration in a 5G ecosystem,” European Conference on Networks and Communications (EuCNC) 2018, Ljubljana, Slovenia.

[3] K. V. Katsaros, et al., “Enabling far-edge intelligent services with NetApps: the Automotive Case,” IEEE Internet of Things Magazine - Network Application Software for Vertical IoT Industry special issue, December 2022.

[4] https://kubernetes.io/ (Accessed September 24, 2023).

[5] M. Zhu, et al., “Providing flexible services for heterogeneous vehicles: an NFV-based approach,” in IEEE Network, vol. 30, no. 3, pp. 64-71, May-June 2016.

[6] R. Morabito, et al., “Lightweight virtualization as enabling technology for future smart cars,” 2017 IFIP/IEEE Symposium on Integrated Network and Service Management (IM), Lisbon, Portugal, 2017, pp. 1238-1245.

[7] 5GinFIRE project, https://5ginfire.eu/ (Accessed September 24, 2023).

[8] N. Slamnik-Krijestorac, et al., “Network Applications (NetApps) as a 5G booster for Transport & Logistics (T&L) Services: The VITAL-5G approach,” 2022 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit), Grenoble, France, 2022, pp. 279-284.

[9] I. Martinez-Alpiste, et al., “NetApps Approach for Accelerating Vertical Adoption of 5G Networks: A UAV Case,” 2022 International Conference on Software, Telecommunications and Computer Networks (SoftCOM), Split, Croatia, 2022, pp. 1-6.

[10] R. Direito, et al., “5GASP’s approach to the onboarding, deployment and validation of 5G NetApps,” 2022 IEEE International Mediterranean Conference on Communications and Networking (MeditCom), Athens, Greece, 2022, pp. 78-81.