(INVITED) VITAL-5G: Innovative Network Applications (NetApps) Support over 5G Connectivity for the Transport & Logistics Vertical

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Abstract—As 5G networks are being deployed across the world, more and more vertical industries are discovering the benefits of 5G connectivity and the novel business and innovation models that it has to offer. The Transport & Logistics (T&L) industry is expected to be one of the key adopters of 5G technology, where the 5G enterprise market for T&L is estimated to reach €2.7 trillion by 2026 [1]. However, the adoption and penetration of 5G-based solutions in T&L may be hindered by the knowledge/expertise gap between the vertical industry, the telecommunication experts and the application developers. 5G based Network Applications (NetApps) represent a key enabler for the adoption of 5G solutions, as they can abstract the complexity of the underlying 5G infrastructure for T&L application developers, and significantly reduce the service creation and deployment times, as well as optimize the utilization of 5G resources. The European project VITAL-5G aims to advance the offered T&L services by showcasing the benefits of 5G-based NetApps via real-life trials over state-of-the-art vertical T&L facilities and advanced European 5G-testbeds. To support both internal and 3rd-party experimentation, VITAL-5G will create an experimentation service portal and online repository to facilitate the creation, deployment, monitoring and (re)configuration of NetApps in the vertical environment.

Keywords—Transport, Logistics; NetApps; 5G-testbed; vertical experimentation; port/warehouse trials; SME;

I. INTRODUCTION

The Transport and Logistics (T&L) vertical is a major component of modern production and distribution systems and a key contributor to macroeconomic development, accounting for over 10% of Gross National Product (GNP) in most countries [2]. As 5G delivers new capabilities to vertical stakeholders, substantial commercial and innovation potential exists for software developers to provide new and innovative 5G-empowered applications for the T&L sector. The strategic objective of the European Innovation Action project VITAL-5G [3] (Vertical Innovations in Transport And Logistics over 5G experimentation facilities), which started in January 2021, is to create an open and flexible experimentation facility comprised of an intelligent virtual platform, three distributed European 5G-testbeds (Antwerp, Athens and Galati (Danube)) and associated vertical infrastructure, to enable the testing and validation of T&L Network Applications (NetApps) in real-life conditions, utilizing 5G connectivity. VITAL-5G engages significant logistics stakeholders (Sea/River port authorities, road logistics operators, warehouse/hub logistic operators, etc.), Mobile Network Operators (MNOs), and innovative SME experimenters, thus focusing on multi-modality and addressing challenges of the entire 5G-enabled T&L ecosystem.

VITAL-5G will build on top of knowledge, expertise and infrastructure provided by predecessor European projects, such as 5G-EVE [4], 5G-BLUEPRINT [5] and 5G-SOLUTIONS [6], allowing it to focus on the development of concepts such as the design and validation of Vertical T&L NetApps, their association with an open repository and the instantiation of a service orchestration platform to help accelerate the growth and adoption of 5G in the European T&L sector. The concept of NetApps, fostered by VITAL-5G, will enable experimenters to experience ultra-fast service creation, service customization, flexible adjustment to real-time conditions and more.

This paper is organized as follows. Section II presents the VITAL-5G concept and system architecture, while Section III provides the description of the experimentation facilities and their associated T&L use cases (UC). Section IV provides an overview of the project's targeted innovations and Section V concludes the paper.

II. VITAL-5G CONCEPT & SYSTEM ARCHITECTURE

A. VITAL-5G Concept: An integrated platform

The VITAL-5G platform provides a rich set of flexible and intuitive tools and APIs to facilitate the design, management, orchestration and validation of virtual services for vertical sectors in the T&L eco-system. The platform allows to share and compose production-ready NetApps, made available by multiple providers in an open repository, to build end-to-end T&L services for trials and validation over 5G network slices. VITAL-5G offers an open framework for experimental testing / validation in 5G virtual environments which are dynamically
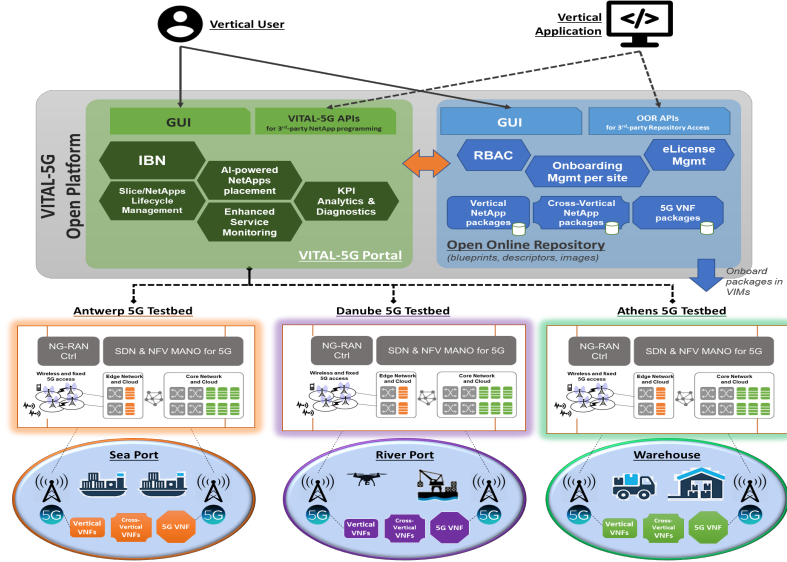
Figure 1: VITAL-5G architecture

built and configured over a facility comprising three T&L trial testbeds (seaport, river port and warehouse/hub). The operation of these facilities is unified through an online, centralized portal where various T&L stakeholders can evaluate and benchmark the performance of novel NetApps in the T&L area, deployed on top of configurable 5G networks.

The integrated and network-abstracted nature of the VITAL-5G platform lowers the barriers for T&L affiliated verticals, which are usually missing a specific expertise on 5G networks, to deliver 5G-enabled services in an effective and simplified manner. The virtualized 5G infrastructures with embedded resource control, orchestration and management offer the possibility to deploy complex services in short time, and with the flexibility to customize allocated resources and mobile connectivity on the basis of specific T&L service requirements. Using the embedded composition tools, T&L service providers can mix network functions and NetApps from an open catalogue, creating multi-provider service chains. The automated execution of test cases and the collection of multi-level metrics simplify the validation of the end-to-end services and the evaluation of associated business values.

B. VITAL-5G facility: distributed testbeds and open platform

The VITAL-5G architecture, shown in Figure 1, is structured in two layers: the three 5G-enabled T&L testbeds and the cross-facility open platform that implements all the tools and services for design, on-boarding, deployment, orchestration, monitoring, validation and diagnostics applied to T&L vertical services. The platform consists of an Online Portal for experimental validation and an Open Online Repository for NetApps and Virtual Network Functions (VNFs). Software providers can design their own virtual applications and on-board their packages in the VITAL-5G Repository, creating building blocks for other T&L services.

The VITAL-5G Portal offers a web graphical interface and programmable REST APIs to manage the creation, instantiation, Life-Cycle Management (LCM) and monitoring of T&L services and related 5G network slices. These procedures are facilitated through an intent-based interface that provides abstraction of the service description and transforms autonomously the application-driven service intents into 5G/NFV service descriptions and LCM actions. At its southbound, the Portal interacts with the local NFV MANO and NG-RAN control systems at the trial facilities. The primitive actions of network slice creation, resource instantiation and monitoring data collection are coordinated at the Portal level in a unified manner and executed in each site using the specific orchestrators, monitoring platforms and network controllers deployed at the facility. In this respect, the VITAL-5G Portal serves also as an abstraction and aggregation layer across different domains of a 5G facility.

The VITAL-5G Portal constitutes the centralized access point to manage the experimental testing and validation of the T&L services. In this direction, it integrates a full suite of tools to build virtualized test environment, automate the execution of test cases, collect and validate KPIs, and perform a diagnostic analysis on the experiment results. The KPI validation tools for service performance evaluation and benchmarking are designed to enable the automated verification of business SLAs and act as triggers for service automation and self-management.

The Open Online Repository manages onboarding procedures for the NetApp packages in the VITAL-5G platform. A catalogue service implements programmable APIs and a web-based graphical front-end to onboard, query, retrieve and update packages of VNFs and virtual applications, Network Slice templates [7] and Network Service descriptors [8], service and experiment blueprints [9], etc. The service also implements Role Based Access Control (RBAC) to regulate access, view, and permit actions on NetApp packages, integrating mechanisms for e-Licensing management. User profiles and additional policies can be employed to regulate user actions and the onboarding to the trial facility.

C. VITAL-5G NetApps concept

One of the major objectives of the VITAL-5G platform is to abstract the complexity of 5G/NFV service descriptors for

application developers in order to simplify service deployment for the T&L sector. This is accomplished through the concept of NetApps, virtual applications that are built and distributed through self-contained packages comprising their virtual images and metadata, descriptors and scripts that simplify their composition in service chains formed by virtualized and physical functions, as depicted in Figure 2.

VITAL-5G NetApps are divided into two categories, vertical-agnostic NetApps (grey boxes in Fig.2) and vertical-specific NetApps (green boxes in Fig.2). They can be combined together, and/or with generalized network functions in the form of VNF or PNF (yellow boxes in Fig.2) to deliver end-to-end T&L services. Vertical agnostic NetApps are used to implement core primitives for data processing at the application layer e.g. database. They include functionalities that can be used in a variety of vertical applications and T&L services. Vertical specific NetApps address specific industry challenges for the T&L sector. They can be specific to the connectivity layer implemented at the target T&L premises.
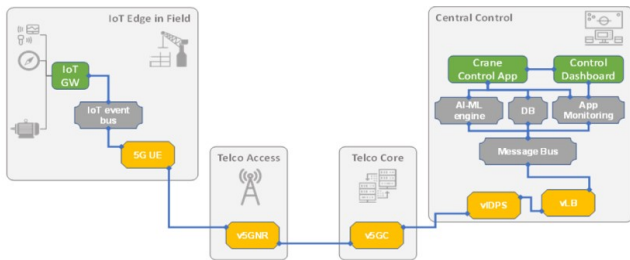

Figure 2: VITAL-5G NetApp concept

III. T&L USE CASES AND INFRASTRUCTURE ENABLERS

This section presents the VITAL-5G experimentation facilities, comprised of the respective 5G-tetbeds and vertical infrastructure, as well as the use cases (UC) to be evaluated.

A. Automated vessel transport - Antwerp facility

This UC will be validated over the Antwerp 5G testbed located at the port of Antwerp. The testbed is based on i) infrastructure of Telenet's (Belgian MNO) Innovation Centre, ii) connectivity, infrastructure and system built for the 5G-Blueprint project [5] and iii) connectivity and infrastructure built for Telenet's 5G commercial launch. The complete system will provide a fully standalone (SA) 5G network supporting 3GPP Rel.16 and will be further comprised from a virtualized 5G Core, Multi-Access Edge Computing (MEC) nodes and multiple end devices, supporting end-to-end slicing.

The aim of this UC is to remotely control semi-autonomous vessels within a mission-critical environment such as the Port of Antwerp. Slice-enabled 5G connectivity will deliver reliable and flexible communications while assuring coverage and functionality. Machine-learning techniques will be used to optimize route planning following the berthing time slots set by the Port authorities and Terminal operators. Furthermore, a real-time digital twin will be built around the vessel to support remote control of vessels. In parallel, real-time routing is foreseen to optimize the port operations and avoid idle times. The main challenges related to this UC are: 1) Remote control and autonomous navigation to reduce the number of onboard personnel, 2) Optimized navigation and speed scheduling based

on past, current and future status of port assets, and 3) Real-time port control and short-term future port status prediction assisted by Digital Twins.

B. Warehouse/freight logistics - Athens facility

The Athens experimentation facility is comprised of the 5G-testbed owned by OTE, the largest Greek MNO, and created in OTE's research labs for 5G-EVE [10], and the state-of-the-art warehouse / Logistic-hub facilities of DIAKINISIS, the largest 3rd Party Logistics (3PL) Greek operator. The 5G-testbed will be upgraded to 3GPP Rel.16 compliant Stand Alone (SA) version and will be interconnected with the DIAKINISIS facilities with fiber connectivity. 5G small cells will be deployed inside the warehouse providing indoors 5G connectivity, while the commercial OTE 5G network can be used for outdoors connectivity. Multiple end user devices will be used, such as 5G-enabled smartphones, distributed warehouse sensors and Automated Guided Vehicles (AGVs)

The Athens based UC targets the automation and remote operation of freight logistics, instantiating the concept of a *Smart Warehouse*. This UC will facilitate and optimize day-to-day warehousing operations, through an integrated operational system based on AGVs and the easy deployment and operation of such services via NetApps. The UC will address concepts such as *lean warehousing, in-warehouse route optimization* with obstacle avoidance, *remote surveillance and control, human-AGV collaboration, and intelligent product inspection.* Post-shipping truck and product monitoring and control via 5G-enabled on-board sensors will also be investigated.

C. Data-enabled assisted navigation- Galati (Danube) facility

This UC will be validated over the Romanian 5G testbed, which is based on the Orange Romania testbed platform, using parts of the commercial 5G network as well as experimental open-source components, created by the 5G-EVE project [10]. The testbed will be progressively upgraded to a Rel.16 SA, while the upgraded 5G SA infrastructure will be enhanced during the deployment process with orchestration tools, such as ONAP or OSM, automatic services and VNFs onboarding and slicing orchestration.

This UC is focused on the implementation of a data-enabled assisted navigation application using an IoT sensing system and video cameras installed in Galati port, on a ship and on barges. The implementation is focused on AI/ML mechanisms, IoT, data fusion, ingestion and post-processing which will allow the investigation of concepts, such as fraud detection and sanity checks based on the sensor data for ship insurance purposes. Through these applications, a more secure port operation will be achieved, regarding the navigation of ships with the help of assisted operation/ navigation SW, while preparations for customs operations and predictive ship/cargo checks may speed up loading/unloading operations and customs checks.

D. Experimentation and Trials

The NetApps developed within VITAL-5G will be validated in real-life trials that will take place in the three experimentation facilities. VITAL-5G will also allow 3rd party experimenters to make use of the VITAL-5G facilities in order to test, validate

and benchmark the performance of their T&L applications. Moreover, the VITAL-5G platform will support multi-tenancy, allowing many Experimenters and/or NetApps Developers to access and use it at the same time.

IV. TARGETED INNOVATIONS

This section provides an overview of VITAL-5G's targeted innovations and ambitions. The project's innovation map is outlined in Figure 3.

A. Innovation Area 1: VITAL-5G Service Portal

VITAL-5G targets the provision of innovative platforms and services for 5G connectivity of the T&L industry, enabling vertical customers to deploy services in an automated and autonomous manner. The approach entails three main areas:

- *Enhancements to Intent-Based APIs for NetApps:* VITAL-5G will extend the work carried out in 5G-EVE on intent-based mechanisms and APIs [9] and apply it to the T&L vertical.
- *Platform-agnostic vertical slice design and control for NetApps:* VITAL-5G will enable T&L experimenters to design and manage slices transparently through its Service Portal.
- *Advanced KPI Analytics & Diagnostics tools for NetApps:* VITAL-5G will integrate KPI validation tools for service evaluation and benchmarking towards business SLA verification, specifically tailored for the project's T&L use cases.

Based on the above work, the following key innovations will be delivered: i) Flexible and powerful vertical NetApps service portal, ii) Production-ready toolkit for T&L NetApps performance evaluation and benchmarking, and iii) SME-driven 5G orchestration products and service to address the needs of T&L and other vertical markets.

B. Innovation Area 2: VITAL-5G facility at T&L sites

Several facilities are under development that are significant enablers for VITAL-5G, however, their capabilities are insufficient for the needs of the T&L use cases in terms of geographical coverage and availability of edge computing. VITAL-5G plans to reuse assets and extend the 5G-EVE and 5G-Blueprint assets for the benefit of the T&L sector. The project's ambition includes integrating non-ICT-17 5G facilities at the three facilities of Athens, Antwerp and Danube with the VITAL-5G main platform for enhanced coverage at specific T&L sites. To complement this, the project will integrate 5G-connected devices for freight logistics (vessels, robots, AGVs) to enable the targeted T&L use cases.

C. Innovation Area 3: VITAL-5G Open Online Repository

For the T&L sector, support of intelligent applications has been very sporadic, while the adoption of new technologies in terms of 5G-connectivity has been slow. VITAL-5G will implement a NetApps repository for onboarding packages, addressing specific T&L sector challenges as well as relevant generic functions. The resulting innovation is a Catalogue of NetApps that can support creation of new products and services for the T&L market and beyond.
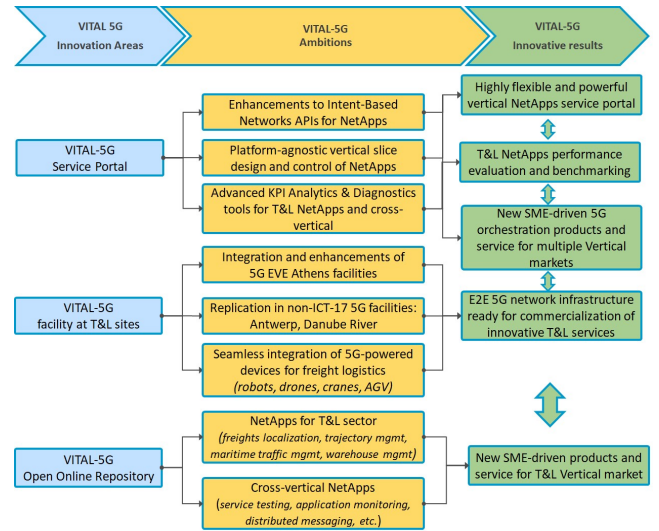

Figure 3: VITAL-5G's innovation map

V. CONCLUSIONS

This paper provided an overview of the current challenges, and obstacles that have the potential to slow down the adoption of 5G-based solutions in the T&L sector and presented the approach of the VITAL-5G project to address them. VITAL-5G aims to contribute to the minimization of the knowledge/ gap between telecom providers, vertical industries and application developers through the promotion and validation of NetApps, over its experimentation facilities, where cutting-edge technologies will be tested as part of T&L industry driven use cases. The project will contribute to the faster adoption and enhanced penetration rate of flexible, multi-modal and reconfigurable 5G-based solutions, into the T&L ecosystem.

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