Deliverable D1.3

5G-enabled Living Labs infrastructure

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Meaning
FTED	Floating Truck and Emission Data
GLOSA	Green Light Optimal Speed Advisor
Living Lab	Living Lab
MANO	Management and Network Orchestration
NFV	Network Function Virtualization
NFVI	Network Function Virtualization Infrastructure
NFVO	Network Function Virtualization Orchestrator
TLF	Traffic Light Forecast
TMC	Traffic Management Centre
VIM	Virtualized Infrastructure Manager
VNF	Virtual Network Function
VNFM	Virtual Network Function Manager
vTMC	Virtual Traffic Management Centre
KVM	Kernel-based Virtual Machine
QEMU	Quick Emulator
ETSI	European Telecommunications Standards Institute
MNO	Mobile Network Operator

EXECUTIVE SUMMARY

Deliverable D1.3 aims to specify the Living Lab infrastructure requirements of the equipment to be provided for the three pilot sites, Hamburg, Luka Koper and Athens, respectively. Such infrastructure includes requirements for devices needed for the port operation, maintenance equipment, local traffic management systems, and telematics on-board-units as well as connected IoT items.

The deliverable includes the following chapters as follows:

- Chapter 1presents the deliverable approach,
- Chapter 2 describes the 5G-LOGINNOV Use Cases,
- Chapter 3 describes the infrastructure requirements for the equipment planned to be used by each Living Lab and its relationship to the Open Innovation Call.
- Chapter 4 concludes with a summary and the main conclusions.

Deliverable D1.3 is complementary to the deliverable D1.2 elaborated in task T1.2 and has as main focus the main infrastructure requirements beyond the specific characteristics and components of the 5G mobile network.

1.1 Project introduction

5G-LOGINNOV is an H2020 project running from September 2020 to August 2023 and will be deployed by a consortium of 15 partners.

The project will focus on seven 5G-PPP Thematics and support to the emergence of a European offer for new 5G core technologies in 11clusters of use cases. 5G-LOGINNOV's main aim is to design an innovative framework addressing integration and validation of Connected Automated Driving/Mobility (CAD/CAM) technologies related to the industry 4.0 and port domains by creating new opportunities for LOGistics value chain INNOVation. 5G-LOGINNOV is supported by 5G technological blocks, including new generation of 5G terminals notably for future Connected and Automated Mobility, new types of Industrial Internet of Things 5G devices, data analytics, next generation traffic management and emerging 5G network architectures, for city ports to handle upcoming and future capacity, traffic, efficiency and environmental challenges.

5G-LOGINNOV will deploy and trial 11 clusters of use cases targeting beyond TRL7, including a GREEN TRUCK INITIATIVE using CAD/CAM & automatic trucks platooning based on 5G technological blocks. Thanks to the new advanced capabilities of 5G relating to wireless connectivity and core network agility, 5G-LOGINNOV ports will not only significantly optimize their operations but also minimize their environmental footprint to the city. 5G-LOGINNOV will be also a catalyst for market opportunities built on the 5G core technologies in the logistics and port operations domains, thus being a pillar of economic development and business innovation and promoting local innovative high-tech SMEs and start-ups. 5G-LOGINNOV will open SMEs' and start-ups' door to these new markets using its three Living Labs as facilitators and ambassadors for innovation in future European ports. 5G-LOGINNOV's promising innovations are key for the major deep-sea European ports in view of the mega-vessel era (Athens, Hamburg), and are also relevant for medium sized ports with limited investment funds (Koper) for 5G.

1.2 Purpose of the deliverable

Deliverable D1.3 -Infrastructure Requirements" describes the enhanced infrastructure and the components or devices in the living labs and how will be deployed in the subsequent work package WP2 of the project.

The elements described include equipment to be provided for logistics hub and port operations, including maintenance equipment and local traffic management systems, as well as new connected and IoT devices in order to allow the development and integration of new innovative applications.

Furthermore, for each Living Lab an outline is given and further how SME could extend the planned deployment.

The objectives related to this deliverable have been achieved in full and as scheduled.

1.3 Intended audience

The dissemination level of D1.3 is public and hence will be used publicly to inform all interested parties about the 5G architecture and technologies for logistics use cases to be used in the 5G-LOGINNOV Living Labs. Especially, the deliverable is created to address the following two main audiences:

- Project partners: the deliverable creation process triggers the necessary collaboration and mutual understanding to achieve the project goals. As a result the deliverable documents the agreed architecture and serves as a basis for implementation work.

- Open call participants: the deliverable shall explain the Living Labs software and hardware components available to the participants of the open call, and how to interface with these components.

1.4 Structure of the deliverable and its relation with other work packages and deliverables

Deliverable D1.1 presented a high level description of the eleven use cases of 5G-LOGGINOV. This document describes the architecture of each Living Lab in terms of hardware and software components that will be deployed. Work package 2 “Living Labs development and deployment”, and work package 3, “Living Labs trials and evaluation” will leverage the present document for development and evaluation procedures, respectively, see Figure 1.

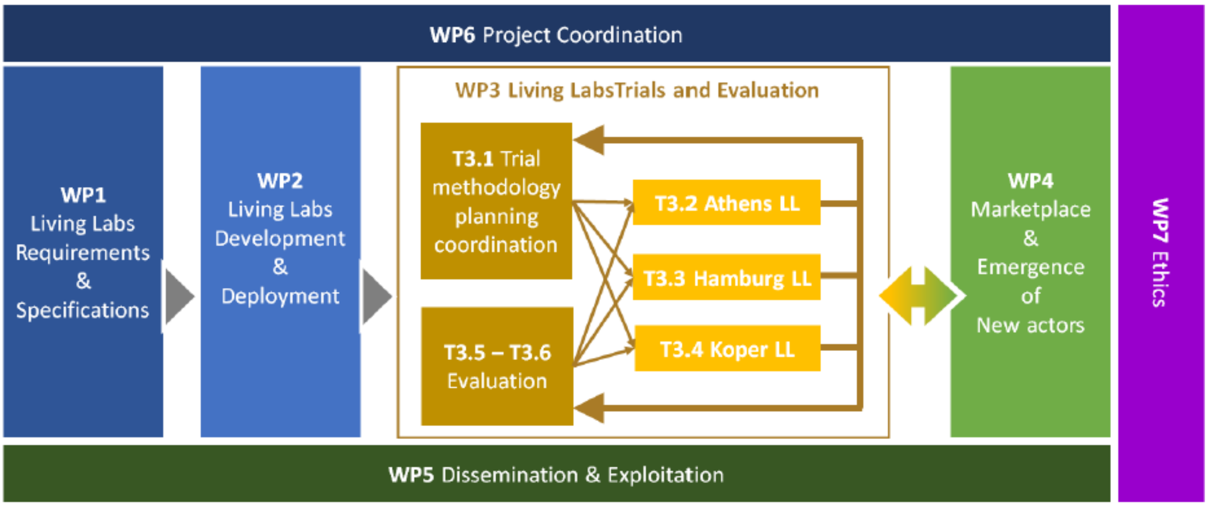


Figure 1: Relation of the 5G-LOGINNOV work packages

This deliverable contains four chapters as follows:

Chapter 1 motivates the scope of the deliverable and outlines the structure of the document.

Chapter 2 briefly recapitulates the motivation of the 5G-LOGINNOV project and introduces the reader to the eleven use cases.

Chapter 3 is dedicated to the architecture and components used to contribute to the use cases in each individual Living lab and how SME could hook in.

Chapter 4 concludes on the impact of 5G technology in port operations.

2 ACTIVITY, MOTIVATION, AND USE CASES

This chapter aims to summarize the motivation and activities or use cases of 5G-LOGINNOV for readers who are not familiar with deliverable D1.1 and functions as a foundation to chapter 3. As such, it references to deliverable D1.1 and the project's description of work.

2.1 Motivation

As it has been stated in the project's proposal, "Ports are essential for the European economy and for economic growth; 74% of goods exported or imported to the EU are transported via its seaports. At the same time, the challenges they face are only getting greater: Cargo volumes are increasingly higher – with an expected 57% rise by 2030 – while they are also arriving in a shrinking number of vessels: the next generation of Post-Panamax vessels have a capacity of more than 20k containers; 'put onto trucks, these containers would stretch in a single line from Rotterdam to Paris'. Cargo volumes not only increase, but also the types of cargo flows change due to technological trends, such as Industry 4.0. Moreover, cargo port operators need to comply with increasingly stricter environmental regulations and societal views for sustainable operations."

Therefore, 5G-LOGINOV develops and validates beyond-state-of-the-art solutions that will increase efficiency and optimize land-use, while being financially viable, respecting circular economy principles and being of service to the urban environment. Through this project, ports will minimize their environmental footprint to the city and will decrease disturbance to the local population through a significant reduction in congestion around the port. The solutions developed by the project are being deployed and validated in three Living Labs in the ports (or neighbouring city areas) of Athens (Greece), Hamburg (Germany) and Koper (Slovenia), addressing challenges taken by the mega-vessel era as well as those relevant for medium-sized ports with limited investment funds for 5G infrastructure and automation.

Activities of the Living Labs Athens and Koper are focused on the actual port areas, whereas Living Lab Hamburg operates in the hinterland area, see Figure 2.

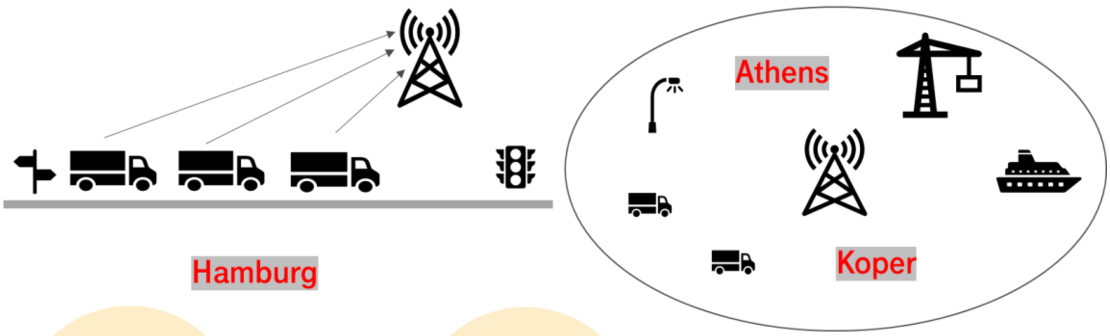


Figure 2: 5G-LOGINNOV port and hinterland use cases and cities to pilot them

2.2 Use cases

Solutions to be developed inside 5G-LOGINNOV are structured by eleven uses cases, see Table 1. The following subchapters shortly introduce these use case while the next chapter describes the technical requirements and realization details.

Use Case	Short description	Living Lab
1	Management and Network Orchestration Platform	Koper
2	Device Management Platform Ecosystem	Athens
3	Optimal Selection of Yard Trucks	Athens
4	Optimal Surveillance Cameras and Video Analytics	Athens
5	Automation for Ports: Port Control, Logistics and Remote Automation	Athens, Koper
6	Mission Critical Communications in Ports	Koper
7	Predictive Maintenance	Athens
8/9	Floating Truck & Emission Data	Hamburg
10	5G GLOSA & Automated Truck Platooning (ATP)-under 5G-LOGINNOV Green Initiative	Hamburg
11	Dynamic Control Loop for Environment Sensitive Traffic Management Actions	Hamburg

Table 1: Overview of use cases in 5G-LOGINNOV

Use case 1: Management and Network Orchestration Platform

Use case 1 will primarily address 5G-LOGINNOV MANO architecture (ETSI MAnagement and Network Orchestration) and its cloud extensions that will be used for demonstration of automated deployment and life cycle management of a network and applications operated in a 5G-enabled port environment targeting on Industrial IoT applications.

Use case 2: Device Management Platform Ecosystem

The 5G-LOGINNOV Device Management (DM) platform ecosystem aims to boost a variety of different IoT-5G devices that operate 24/7 in a two-way communication path. On top of the device data DM offers methods for device configuration via multiple paths (file upload, SMS, GPRS, etc.), tools to diagnose and debug streams of data, UI and services that allow device interactions in batch of per device. Each device must be identified and pass through the proper authentication pipeline before it can send data and interact with the platform.

Use case 3: Optimal Selection of Yard Trucks

All ports rely heavily on internal yard trucks for the horizontal movement of containers between stacking areas and loading/unloading areas for vessels and rail. The operation of those internal trucks within a port's area causes traffic jams and queues in loading places. The assignment of container jobs to yard trucks based on pool assignment and availability is not efficient since, more often than not, the trucks selected are not the ones closest to the subject container. The installation of a 5G access point on yard trucks that will be connected to the available on-truck data sources such as CAN-Bus, custom sensors (e.g., container presence sensors) and localization data will enable the maximisation of operational efficiency for the efficient coordination of the fleet of 5G connected yard trucks in port operations.

Use case 4: Optimal Surveillance Cameras and Video Analytics

Frequent incidents involving boom collisions, gantry collisions or stack collisions along with the presence of stevedoring personnel in the area make the risk for serious bodily injuries considerable. In all ports, the installation of 4K PTZ surveillance cameras is foreseen that will provide live feed over the 5G network to the current Terminal Operations Monitoring platform. The transmission of 4K resolution stream is not possible over current WiFi and LTE installations especially when the presence of multiple cameras is required in the area of coverage. The subject use case will deploy 5G-IoT devices (consisting of 4K camera, a compute node for video analytics services and a 5G interface to establish communication within the port premises) at restricted areas, that will perform video analytics tasks to determine human presence in such no admission areas. Voluminous video streams and the inference of the analytics will be transmitted to the port's management platform, triggering alerts and further actions to security patrols.

Use case 5: Automation for Ports: Port Control, Logistics and Remote Automation

A logistics support scenario will be implemented where operating port machinery (such as lifts, forklifts, terminal tractors, etc.) will be equipped with industrial cameras for capturing and transfer of UHD images to the CNS system for identification of container markers and detection of structured damage to containers using image processing techniques. In addition, transfer of remotely gathered information will be enabled to other port support systems. Secondly, port equipment monitoring and remote telemetry will be performed for operating machines (e.g. terminal tractors), by means of capturing and transferring of the key information (e.g. consumption, positions and other related telemetry information) to the port operation support system. Finally, a resilient 5G-based operational network scenario will be implemented to provide alternative 5G network capabilities to the established operational WLAN network.

Use case 6: Mission Critical Communications in Ports

Security personnel is equipped with body-worn cameras for real-time video surveillance to support their regular and mission critical operations. In addition, portable video surveillance cameras with night vision capabilities (fixed cameras covering a specific area with relocations as necessary) will be used to monitor specific port areas, and automated and coordinated drone-based surveillance will be implemented for extended ad-hoc video-surveillance support.

Use case 7: Predictive Maintenance

Predictive maintenance is the analysis of data collected through real time monitoring of assets, and in the 5G-LOGINNOV case of yard trucks in day-to-day port operations, in order to anticipate eventual breakdowns (that lead to higher costs when handled with corrective maintenance or routine maintenance), reduce downtime for repairs and make a data driven approach for the purchasing of spare/repair parts. Therefore, 5G access point (telematics devices) will be installed on yard vehicles that will be connected to existing data sources (CAN-Bus and other custom sensors) in order to provide the data feed (from the fleet of 5G connected yard trucks) to the predictive maintenance AI algorithm.

Use case 8/9: Floating Truck & Emission Data

The overall potential of emission reduction is mainly related to vehicle type and configuration (body, mass, power train, brakes, tyres, etc.), current vehicle conditions (e.g. maintenance level, load), route characteristics, traffic management system (TMS) measures (static and dynamic), traffic flow, driver / driving profile. To synchronize TMS measures and traffic effectively it is necessary to analyse and describe the driving manoeuvres of commercial vehicles in such a detail that the influence of route, infrastructure, vehicle, use case / weight and driver (interaction with the vehicle to execute a specific manoeuvre) within a dynamic traffic environment could be isolated and assigned individually to the emission profile of the causer.

Use case 10: 5G GLOSA & Automated Truck Platooning (ATP)-under 5G-LOGINNOV Green Initiative

Whereas traditional Green Light Optimized Speed Advisory (GLOSA) technology has a focus on implementing single-vehicle speed advise, 5G GLOSA for Automated Truck Platoons goes far beyond this concept as it enables green light optimized speed advisory for a platoon of trucks emitting the possible minimum of pollutants by taking into account real-time data of the vehicles. For this purpose, 5G functionalities including the MEC server of the 5G network as well as precise positioning, the URLiving LabC, mMTC and eMBB features are needed. Only by applying these functionalities, the Automated Truck Platoons can achieve driving with optimum speed within the logistics corridor or to wait on allocated parking places and the Pre-Port Parking facilities waiting for their time slot of goods delivery to the shipping terminal.

Use case 11: Dynamic Control Loop for Environment Sensitive Traffic Management Actions

Dynamic traffic related data, like traffic volume, speed and emission (see UC 8/9), should be accessible to traffic management. By analysing those data according to the local clean air program the traffic management centre is able to initiate measures to reduce emission or improve traffic flow, e.g. by rerouting trucks.

3 INFRASTRUCTURE REQUIREMENTS OF 5G-LOGINNOV LIVING LABS

3.1 Athens Living Lab infrastructure

3.1.1 Overview of components and architecture

The Athens Living Lab at Piraeus Container Terminal (PCT) will develop a set of use cases and platforms that communicate over the deployed 5G network with different types of end devices. It includes communication with external trucks around the port (UC2: Device Management Platform Ecosystem), yard trucks dedicated to port operations (UC3: Optimal selection of yard trucks, UC7: Predictive Maintenance) as well as novel 5G-IoT devices (UC4: Optimal surveillance cameras and video analytics, UC5: Automation for ports: port control, logistics and remote automation). Figure 3 depicts the relation between the Athens Living Lab use cases (and components) with the other tasks of the project.

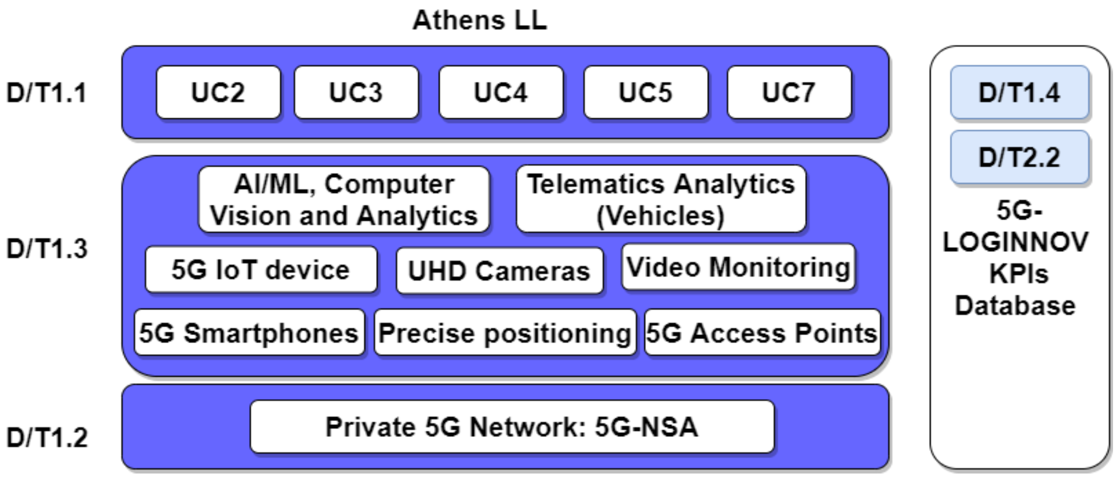


Figure 3: Hardware and Use Case Components for Athens Living Lab

In a nutshell, a MANO (ETSI MAnagement and Network Orchestration) platform will be developed by ICCS enabling service orchestration to novel 5G-IoT devices that perform locally video analytics tasks as far-edge computing services. Additionally, a MANO orchestrated aggregator platform collecting telemetry data from the fleet of 5G connected trucks will be enhanced and tailored to various scenarios and use case requirements, targeting operations optimization, improvement of personnel safety/security, as well as minimizing the environmental footprint in the area. All discussed solutions can be placed on commodity x86 servers and similar types of commercial off-the-shelf (COTS) hardware, to expedite deployment and facilitate interoperability across ports. An overview classification for the use cases that will be developed in Athens Living Lab tailored to the deployed end devices is:

5G-IoT Device

- 5G-IoT devices designed and developed tailored to the Living Lab needs.
- Centralized cloud management platform.
- Far-edge computing services.
- Computer vision and video analytics services.
- MANO enabled service orchestration.
- Video Monitoring.

5G-Trucks in port operations

- 5G enabled truck communications.
- Telematics Analytics.
- Yard Truck Precise positioning.
- Real time external truck localization.

The following sub-sections will provide more details for the use case components (categorized based on the end device type, i.e., 5G-IoT device or 5G connected truck) that will be deployed in the LL, the architecture that binds all use components with the backend system of PCT, and finally the potential extension of the LL to host interested SMEs.

3.1.2 Component specification

3.1.2.1 MANO Platform Components (UC4, UC5)

The MANO platform will initially be developed at the ICCS 5G-testbed (NSA initially and potentially SA at a later stage based on the developments of the OpenAirInterface [13] platform) and migrated to PCT premises at a later stage of the project. Particularly, the MANO platform will be based on open-source solutions and industry proven technologies ensuring ease of transferability to other ports/facilities and their operations. The proposed solution will be based on Open Source MANO (OSM) [4], an ETSI-hosted project developing an Open Source Network Function Virtualization (NFV) Management and Orchestration software stack aligned with ETSI NFV. The main platform is divided in three main components; the Virtualized Infrastructure Manager (VIM), which controls and manages the resources of an Network Function Virtualization Infrastructure (NFVI); the Virtual Network Function Manager (VNFM) taking care of the instantiation of VNFs, configuration, modification and termination of VNF instances; and the NFV Orchestrator (NFVO), which orchestrates the allocation of resources under the control of different VIMs and manages the lifecycle of network services.

The VIM that will be exploited in the 5G-LOGINNOV MANO will be based on a subset of services offered by Openstack [3] (Victoria release). OpenStack is an open source cloud operating system that controls large pools of compute, storage, and networking resources, i.e., the NFVIs, all managed and provisioned through APIs with common authentication mechanisms. The VIM orchestrator will be the interface towards the NFVI devices, i.e., the 5G-IoT nodes, that will host the VNFs (software applications that deliver network and service functions) and deliver the respective solutions for facilitating far-edge computing services in port operations. The VIM tool will be controlled by the OSM platform [4] (based on Release NINE) to facilitate the envisioned MANO system, taking care also of the VNFM and VNFO services given the pool of NFVI nodes and the set of VNFs.

3.1.2.2 MANO NFVI Pool (UC4, UC5)

NFVIs consists of remote infrastructure components—compute, storage, networking—on a platform that supports virtualization technologies like KVM/QEMU or a container management platform needed to run network apps, i.e., these will be the compute nodes of the proposed 5G-IoT devices. OSM will orchestrate the VNFs on top of the NFVIs and manage the life cycle of the service: UC4 (Optimal surveillance cameras and video analytics) and UC5 (Automation for ports: port control, logistics and remote automation).

In more detail the compute node(s) that will host the VNFs will be based on general purpose devices such as the NVIDIA Jetson Developer Kit [5]. The operating system (OS) of the host device should be supported by (and in alignment with) the VIM orchestrator based on generic Linux distributions such as SUSE, Ubuntu, RHEL and CentOS. The MANO platform of 5G-LOGINNOV will enable video analytics tasks execution locally on the compute nodes, based on computer vision techniques and/or AI based solutions necessary for the realization of UC4 and UC5, enabling far-edge computing services at the port premises. The proposed compute node will meet the service requirements with respect to GPU (e.g., 512-core Volta GPU with Tensor Cores) and CPU (e.g., 8-core ARM v8.2 64-bit

CPU, 8MB L2 + 4MB L3) specifications as well as memory (e.g., 32GB 256-Bit LPDDR4x | 137GB/s) and storage capacity (e.g., 32GB eMMC 5.1). The compute node should be able to capture live high resolution video streams from connected cameras (e.g., (16x) CSI-2 Lanes camera connectors, Ethernet) and locally process (perform analytics on) the captured UHD streams. The 5G interface that will connect the device to the 5G network at PCT premises will be a 5G modem (at least CAT-13) provided by the MNO (Vodafone) that establishes the cellular communication to the port, and will be connected via a Gigabit Ethernet link (RJ45) to the compute node.

The proposed MANO orchestrated 5G-IoT device consists of the following hardware components; a generic compute node similar to the one in [5] that will host the VNFs and analytics services, a high-resolution camera that will capture/transmit live video streams at the back-end system of PCT, and a 5G interface to establish cellular communication. A prototype version of the device is illustrated in Figure 4, where the orchestration of services is realized in-lab through the ICCS testbed and the 5G communication is facilitated through the Universal Software Radio Peripheral (USRP) B210 device [12] (Table 2) and the OpenAirInterface [13].

Figure 4: Human presence detection device (UC4), ICCS, Athens Living Lab

Feature	Capabilities
Data acquisition	USB3
Frequency range	70MHz – 6GHz
RF chip	AD9361, Full duplex, MIMO (2 Tx & 2 Rx), Supports TDD and FDD operation
ICCS tested bands	5G bands (TDD): n78, 4G bands (FDD): B7
Open source	Xilinx Spartan 6 XC6SLX150 FPGA
Output power	10dBm
Noise figure	<8dB
Operating Temperature Range	25 °C
Compatibility	4G/5G (40MHZ with ¾ sampling)

Table 2: USRP B210 specifications subset, Athens-ICCS Living Lab

The computer vision techniques that will be developed and deployed at the device include the detection of human presence (UC4) at specified risk areas, and the detection of the cargo-container seals at the loading/unloading phase of vessels (UC5) in port premises.

The layout of UC4 is shown in *Figure 5*. The device will employ (locally) AI analytics for detecting human presence in specified areas, and also transmit voluminous video streams at PCT management platform, exploiting the broadband connection of 5G technology. The inference of the module (Notifier module in *Figure 5*) will additionally be transmitted to the corresponding alert module at PCT backend system to generate respective alerts in case of incidents, i.e., human detected in risk area.

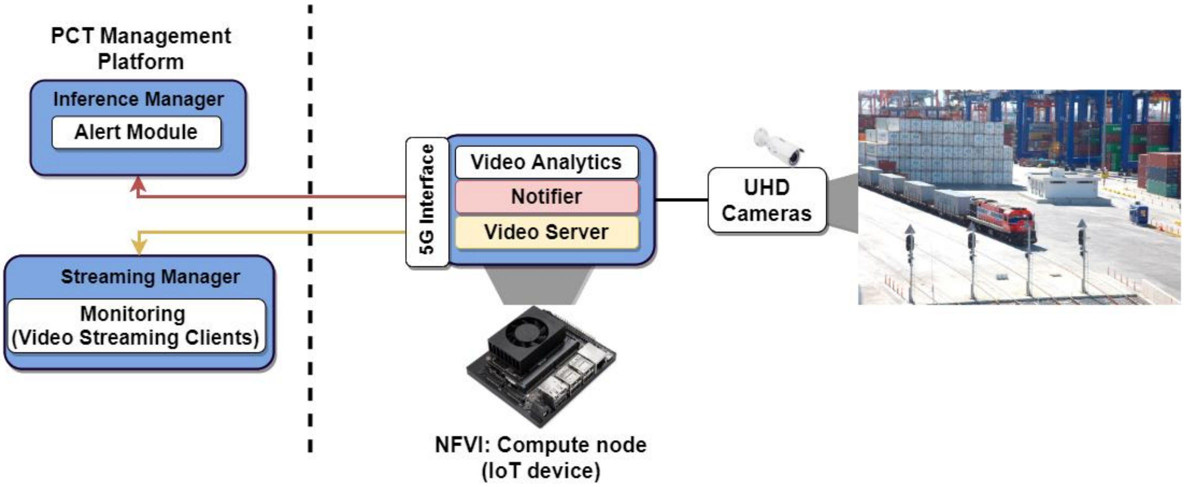


Figure 5: 5G-IoT device deployment for human presence detection, layout and architecture (UC4), Athens Living Lab

For UC5 the 5G-IoT device will be placed on quayside cranes (QC) and follows the layout depicted in Figure 6. Powered over Ethernet (PoE) camera(s) will be deployed on the crane, and connected to the compute node (IoT device) located at the cockpit. Computer vision analytics for container seal detection will be executed locally, and the inference of the model (Notifier module in Figure 6) will be transmitted to PCT backend system for visualization, database management and alerts generation (e.g., container seal missing), respectively. Additionally, 5G technology will be exploited to transmit UHD video data from the device to PCT monitoring platform.

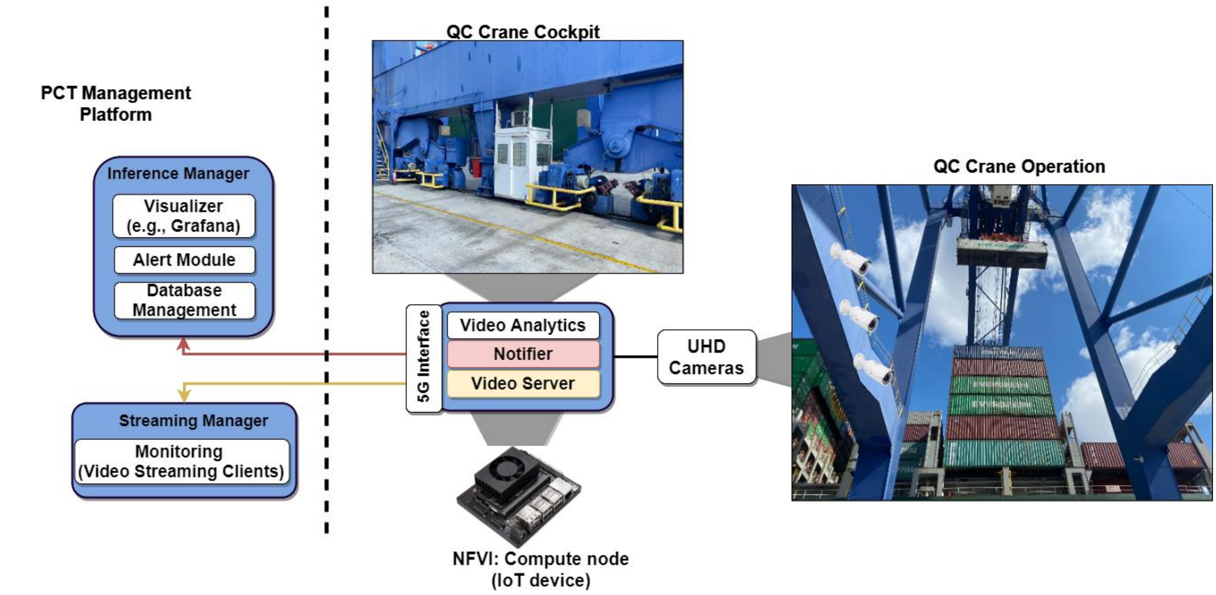


Figure 6: 5G-IoT device deployment for container seal detection, layout and architecture (UC5), Athens Living Lab

Figure 7 depicts the overall MANO layout of the envisioned 5G-LOGINNOV enabled services, components, and architecture (UC4 and UC5). The instantiation process of a set of VNFs has the following workflow. Initially the user (administrator) interfaces a User Interface (UI), where the VNFs to be deployed are selected by a catalogue of supported services. When the user instantiates the service, the VNF descriptions (that will be prepared by ICCS) are sent to the underlying VIM for preparing and configuring the physical infrastructure that will host them. These services will configure network interfaces, features regarding the virtualization technologies for the underlying physical resources (Virtual machines, Containers, Bare metal, etc.) as well as all software related services/components that need to be instantiated at the 5G-IoT devices for video analytics. Particularly, far-edge computing services need to be delivered, hence, all necessary modules for performing locally video analytics tasks following advanced computed vision techniques and AI solutions need to be triggered by the MANO platform and instantiated to all active devices. The streaming management module will handle all video data transmitted by the 5G-IoT devices at PCT backend system, whereas the inference management module will receive the inference of analytics services, interface with the database (and respective dashboards) and alert generation module. Table 3, summarizes the potential features for the analytics services, the compute node as well as camera specifications that will be evaluated for deployment.

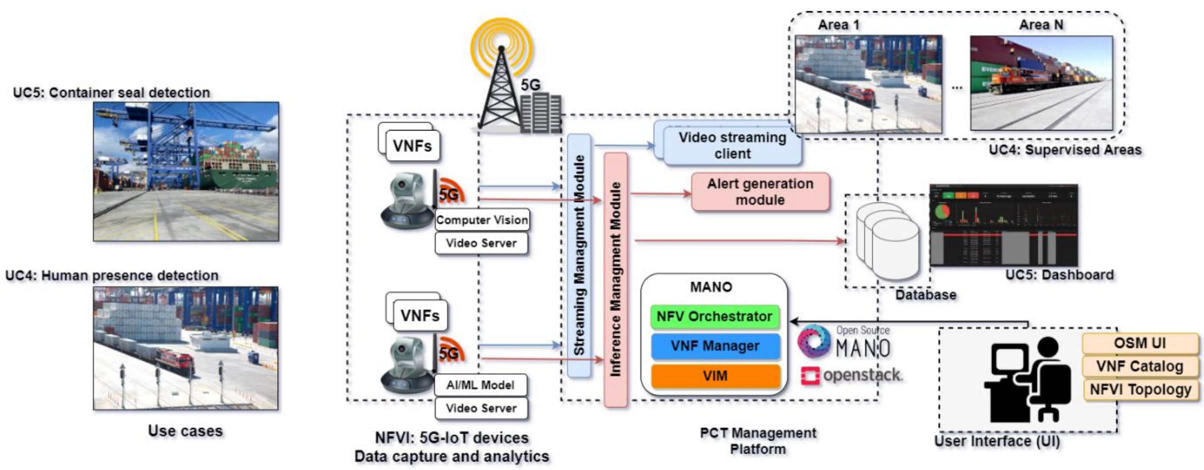


Figure 7: Architecture layout and software components of UC4 and UC5, Athens Living Lab

System Element	Feature	Requirements
Video Analytics	Computer Vision Analytics	Scanning for container images of UHD streams to detect the presence/absence of container seals from a set of camera deployments on quay cranes
	AI/ML Analytics	Processing of high-resolution video streams for human presence detection service in specified risk areas
Compute node	GPU	e.g., NVIDIA Volta architecture with 384 NVIDIA CUDA cores and 48 Tensor core
	CPU	e.g., 6-core NVIDIA Carmel ARM®v8.2 64-bit CPU 6 MB L2 + 4 MB L3
	Connectivity	e.g., Gigabit Ethernet, M.2 Key E (WiFi/BT included), M.2 Key M (NVMe)
UHD cameras	Quay crane (QC) camera requirements (UC5)	IP Camera Outdoor Camera, weatherproof, protection, e.g., IP67 Operating temperature range: -20 - 50 °C Resolution >= 4K, fps >= 24 Lossless compression formats for video and image (e.g., H.264, H.265) Wide Dynamic Range (WDR) 120dB Selected focus (Zoom in/out capability) Power of Ethernet (PoE), Gigabit Ethernet (IEEE 802.3af, IEEE 802.3at)
	Risk area camera requirements (UC4)	IP Camera Outdoor Camera, weatherproof, protection, e.g., IP67 Operating temperature range : -20 - 50 °C Resolution >= 4K, fps >= 24 Lossless compression formats for video and image (e.g., H.264, H.265) Wide Dynamic Range (WDR) 120dB Dynamic configuration of streamed video quality Selected focus (Zoom in/out capability) Power of Ethernet (PoE), Gigabit Ethernet (IEEE 802.3af, IEEE 802.3at)

Table 3: Requirements for UC4 and UC5, Athens Living Lab

3.1.2.3 5G-Yard Truck Component (UC3, UC7)

The 5th generation mobile network brings massive network capacity, increased availability and reduced transmission latency, i.e., key enabling technologies for real-time (port) asset tracking, and in particular real-time monitoring of 5G-connected trucks (equipped with various sensors), in port operations. In PCT, to facilitate 5G connectivity to/from the yard vehicles, a telematics (access point) device will be installed in the cabin of trucks, connected to several on-truck data sources. The core of the device, namely the truck controller, is a generic board connected to: CAN-Bus data (e.g., engine up-time, average speed, average throttle pedal position, consumption, etc.) utilized by the AI algorithm that provides the Predictive Maintenance service (UC7) ; GNSS coordinates enhanced with 5G localization services ; sensors for detecting the presence of containers on trucks ; a terminal operations system (TOS), e.g., tablet, relaying all relevant information to the driver such as container job assignment (UC3) ; and a gigabit Ethernet connection to the modem (at least CAT-13, provided by the MNO) that enables 5G communications. The TOS terminal and the controller device are illustrated in Figure 7.

Figure 8: Controller device and TOS terminal at PCT yard trucks, Athens Living Lab

Abovementioned telemetry data will be transmitted to PCT's management platform in real time by the 5G enabled trucks exploiting low latency transmissions and enhanced localization services, to be utilized by several algorithms that reside at PCT's management platform. Particularly, *Optimal selection of yard trucks (*UC3), will employ localization services and container presence sensor data, targeting the optimal assignment of container jobs to yard trucks for the horizontal movement of containers between stacking areas and loading/unloading areas for vessels and rail. The *Predictive Maintenance* service (UC7), will employ CAN-Bus (and other sensor/operational) data, employed by the AI algorithm, targeting the efficient operation of vehicles and reducing unplanned downtime of expensive equipment by identifying and solving problems before they occur.

Table 4 summarizes the features of the telematics device (controller, Figure 8) that will be installed on the yard vehicles for collecting and transmitting telemetry data over the 5G interface to PCT management platform.

System Element	Feature
Communication	Protocol TCP/IP, SMTP, NMEA on RS232 interface
	Wireless modem GPRS/GSM 900/1800
	Internal Sim Card Slot
	Antennas: Dual external antenna GSM/GPS active/passive
	Operating Temperature: -40° C to +85° C
I/O	three digital inputs, two serial interfaces, one USB interface, one wire interface, one Ethernet interface, ELM (J1939) interface, Ethernet Interface (Openwrt)
GPS Receiver	50 channels
	Assisted gps, GPS L1 C/A code, SBAS: WAAS, EGNOS, MSAS
	Horizontal position accuracy: 2.5m CEP
Power Supply	Internal and external battery (+8 to +40 VDC)

Table 4: Telematics device deployed on 5G yard trucks, UC3 and UC7, Athens LL

Figure 9 shows the layout for UC3 and UC7 corresponding the yard trucks in PCT, as well as UC2 (Device Management Platform Ecosystem) that will be detailed in the following subsection.

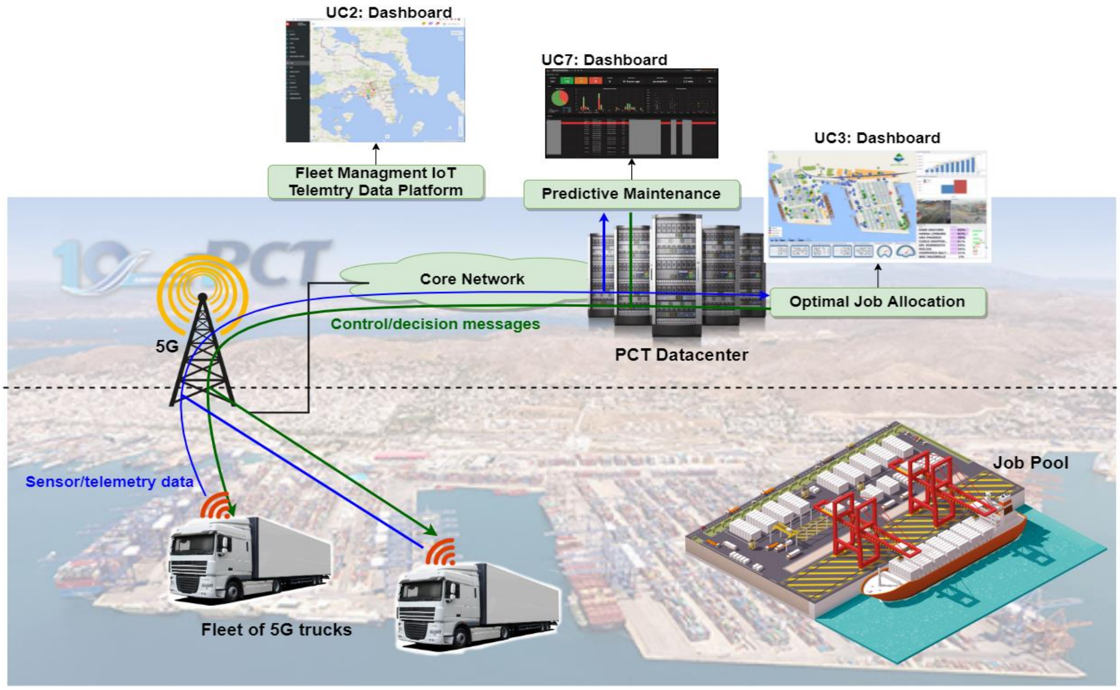


Figure 9: Layout components for UC2, UC3 and UC7, Athens Living Lab

3.1.2.4 4G/5G-External Truck (UC2)

For the external 4G/5G connected trucks (UC2) we propose a hybrid system consisting of 2 communication modules, Figure 10. Data are captured by the same mechanism and truck interconnection, but communication takes place through 2 channels. Outside of the port the 4G module will handle communications whereas in the port the 5G module will handle communications.

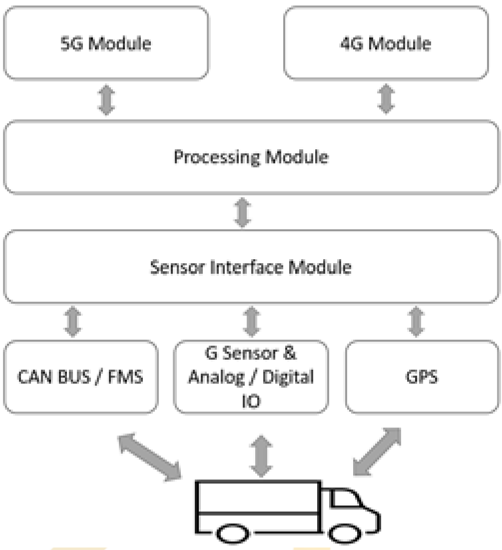


Figure 10: Overview of related components for UC2, Athens Living Lab

Data arriving from the truck are either device data or CAN BUS/FMS Truck data:

Device based data

- GPS
  - Speed
  - Geographic coordinates

  - Satellites (number of)
  - Angle
  - Odometer (point to point distance)
  - Engine status (Off, ON)
- Sensors
  - Temperature
  - Generic Analog
  - Generic Digital
  - Power sensor
  - 3 axis accelerometer events

CAN BUS data

- Total fuel consumption
- Fuel level (Dashboard)
- Vehicle mileage — Vehicle mileage from dashboard or Vehicle mileage counted (from adapter installation)
- Door status — Front left door, Front right door, Rear right door, Rear left door, Trunk cover, Engine cover (hood)
- Engine speed (RPM)
- Oil pressure/level status
- Engine temperature
- Vehicle speed
- Accelerator pedal position

The following image (Figure 11) depicts the data flow between the truck and the platform.

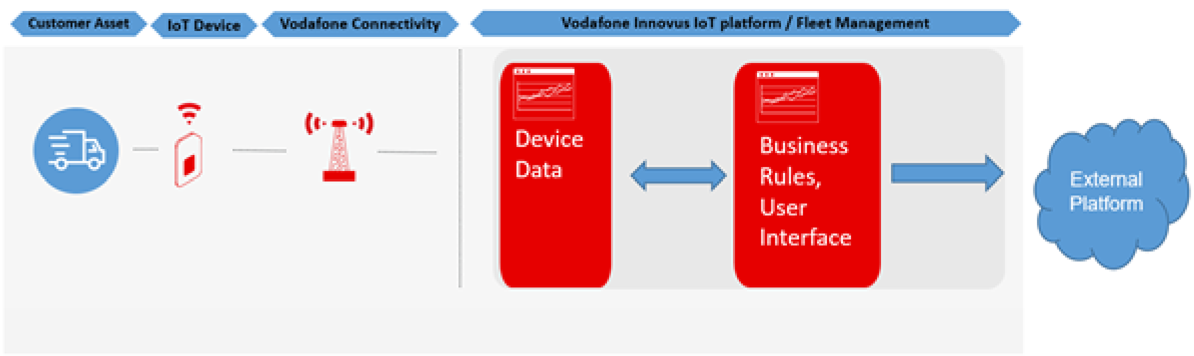


Figure 11: Vodafone Innovus IoT platform overview, Athens Living Lab

System Element	Feature	Requirements
Truck Monitor Device	Acquisition Module	DAC, to convert any relevant analogue signal from truck (e.g. battery level, cabin temperature) Digital Interfaces to capture status data from the truck (e.g. door open, cargo loaded etc) GPS antenna CAN BUS / FMS interface module G-Sensor, to detect harsh motion events
	Communications	Connectivity modules, 4G and 5G
Monitoring / Management	Cloud based platform	Device Management User management Sensor Management GIS Mapping capabilities Alerting mechanisms
	Over-the-air management	Remote configuration capabilities
Processor	Online processing	Online cluster to handle and process device data. Online alert based on dynamically set rules. Device generated events. Platform generated events
	Data fusion	Flexibility to connect to external data sources (e.g. traffic, weather) Static data fussion such as (POIs, geofences etc)
	Interconnections	Data push mechanisms to external platforms
Visualization	Real time	Real time location visualization (5G vs 4G latency) Real time sensor data visualization
	Analytics – historical data	Data aggregation per date or place Graphical UI with relevant user friendly dashboards Reporting tools by request Reporting tools with scheduled capabilities.

Table 5: UC2 components and requirements overview, Athens Living Lab

3.1.3 Interfaces and possible extensions for SME

At PCT, in Athens LL, the focus of the Open Call will be in two main areas of interest for SMEs regarding the development of:

- Pioneering Augmented Reality (AR) applications and systems to support port operations, and
- Far-edge computing enabled services for detecting distracted drivers' symptoms (e.g. drowsiness, etc.) in yard trucks.

For AR applications, PCT will provide the following equipment for the development of the pilot case:

- EPSON MOVERIO BT-350 glasses.
- Access to the Brochesia B View software.
- Virtual servers based on the ESX platform located at PCT private data centre (server specifications will be determined during the contracting phase).
- Access to the 4G/5G network (costs related to data transfer over the 4G/5G network will be assumed by PCT).

The glasses have a small camera on them to send image/video data to the support centre, while the lens can also display information (e.g. images, annotations, pdf manuals) transmitted back from the support centre. The glasses are connected via a cable to an Android device the size of a mobile phone (e.g. smartphone or tablet) through which communication is established with the support centre based on WiFi. In areas with no WiFi coverage (e.g. Quay Cranes, Rail Mounted Gantry Cranes, etc.) a mobile hotspot is deployed to establish communication over a 4G network at PCT facilities. Based on the current network type (4G or WiFi) and the channel dynamics, the transmitted image/video quality from (and back to) the AR glasses is adjusted dynamically, whereas features to annotate/mark objects in the user's field of view (by the support centre) as well as voice communications are also available for a full immersive AR experience. Suggested but not limited uses cases include:

- AR-assisted guidance to speed up repairs in port assets (e.g. trucks, lifts, cranes, etc.).
- AR-guided cargo load/unload operations (e.g. in open or closed space storehouses).
- AR-training service at port operations and related assets, with on-the-job real-time tuition.

For the driver condition use case, PCT will provide the following equipment for the development of the pilot:

- A Jetson Xavier NX Developer Kit to be used as a far-edge device.
- An HD camera installed in the yard truck cabin at a location that will not hinder operations and will not introduce security risks.
- A 10-inch tablet (Windows or Android based on use case requirements) or a Raspberry PI.
- A 4G/5G router located in the yard truck cabin.
- Virtual servers based on the ESX platform and located at PCT private data centre (server specifications will be determined during the contracting phase).
- Access to the 4G/5G network (costs related to data transfer over the 4G/5G network will be assumed by PCT).

Far-edge computing is a pioneering technology that enables the evolution to 5G and beyond architectures, designed to put applications and data closer to devices and their users in order to overcome the intrinsic problems of the traditional cloud, such as high latency and the lack of security. Applicants are invited to design and develop their innovative 5G-IoT devices (including hardware and software components) that will locally execute video analytics tasks, based e.g. on machine learning models (also developed by the applicant), to detect truck drivers' symptoms such as fatigue and drowsiness. The proposed device will be placed inside (and powered by) the yard trucks, receiving a direct video feed of the respective driver's reactions, and executing analytics locally. The inference of the model (e.g. with 90% confidence, the yard truck driver suffers from drowsiness) will be transmitted from the 5G-IoT device to the back-end application at PCT terminal, triggering the necessary actions to prevent potentially dangerous situations.

3.2 Hamburg Living Lab infrastructure

The overall business case and service architecture of the 5G-LOGINNOV project is shown in Figure 12. The red- and blue-coloured geographical boxes are in the northern and southern part of the city, all with reference to the arms of the river Elbe, which is the maritime arterial backbone of Hamburg. This Test Field for Automated and Connected Driving (TAVF) is located in the northern section of Hamburg, whereas the Kattwyk-Bridge is connecting the most important container terminals with the southern logistics hubs and warehouses including the Hinterland goods distribution centres connected to the Port of Hamburg by motorway, rail or inland waterways. In 5G-LOGINNOV, both scenarios will be studied by Living Lab pilot activities with vehicles platooning. The main difference is that the infrastructure ownership of the red-coloured geo-box lies in the hand of the city's traffic authority whereas the blue-coloured geo-box is part of the 130 km long road network of Hamburg Port Authority HPA. Both public entities are aligned within the I.T.S. policy directive to increase the attractiveness and competitiveness of the City. Further details, especially with regards to the 5G infrastructure elements planned to be used, can be found in D1.2, Living Lab Hamburg.

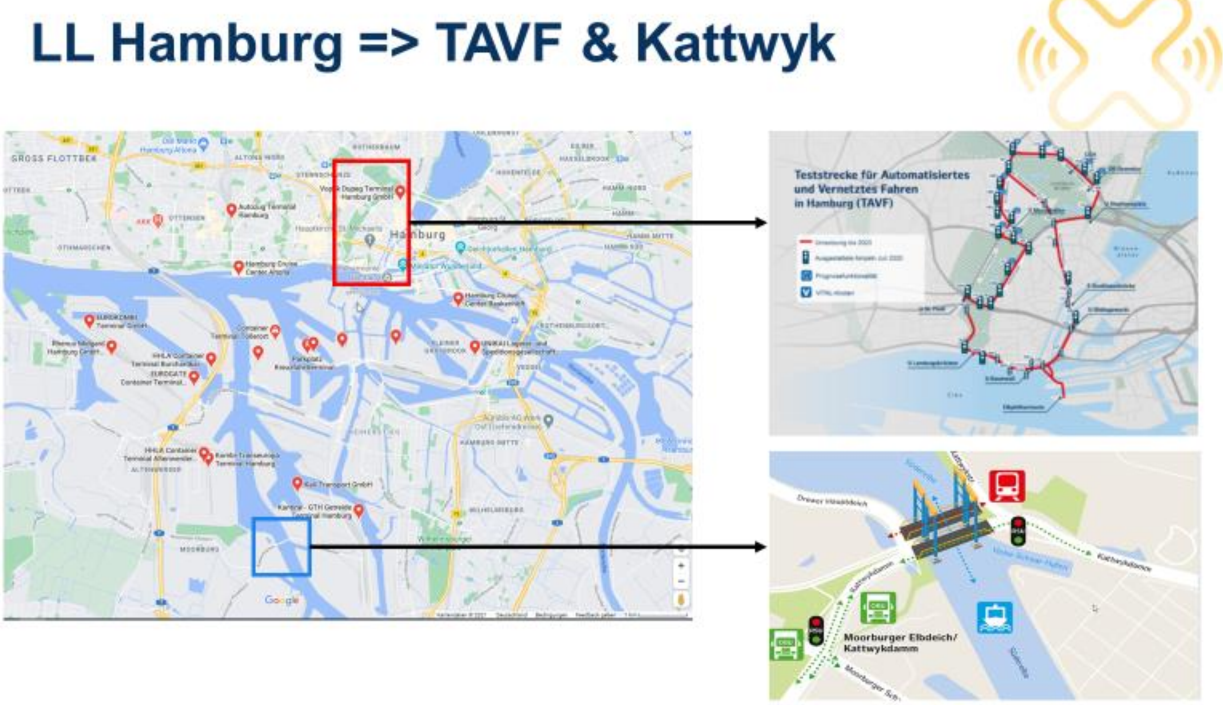


Figure 12: Geographical distribution of Container Terminals and 5G-LOGINNOV test Fields in Hamburg

3.2.1 Overview of components and architecture

In Figure 13 and Figure 14 there are depicted different components planned to be deployed. It should be noted that network centric Precise Positioning Services do not necessarily require 5G and are already available in 4G/LTE. In D1.2 reference to the 5G mobile network is analysed, compared to this, D1.3 has a focus on the service components itself showing the business logic behind the 5G technology.

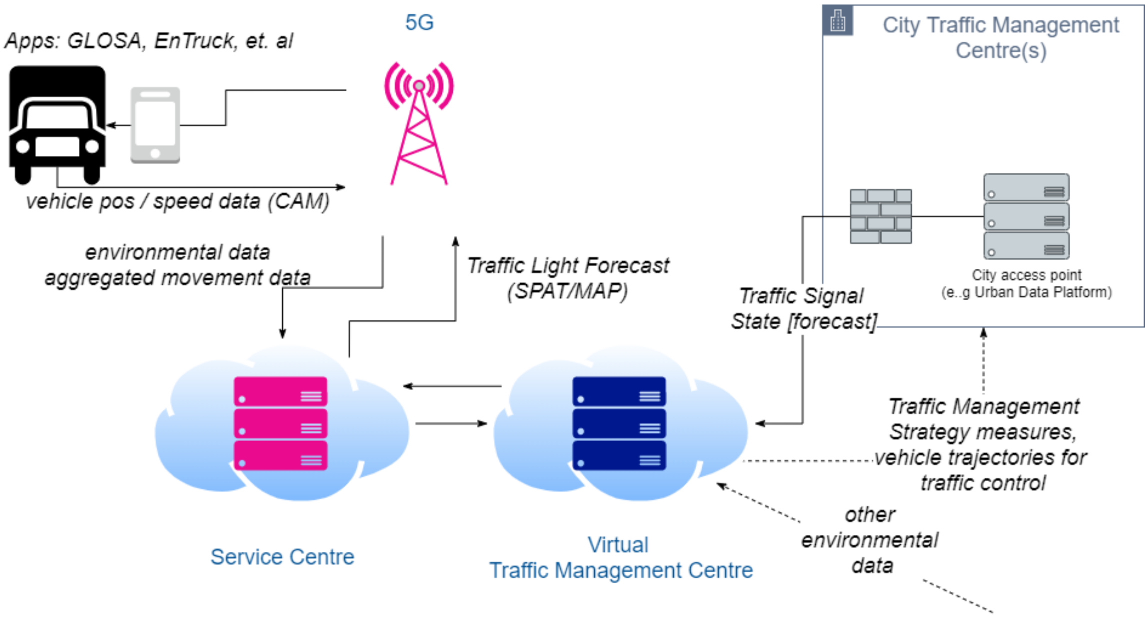


Figure 13: Service Architecture as planned for Living Lab Hamburg

In I.T.S. specifications, it is often mentioned that V2X communication has 2 different communication channels: a) classical V2X known as I.T.S. G5 using 802.11p WLAN and b) cellular V2X known as I.T.S. 5G. Both technologies are published with standardized protocol and data elements. Nevertheless, as both standards are deployed and can be found across various European pilot projects, I.T.S. experts started to discuss the use of both technologies as complementary hybrid communication, meaning that their application is use case and project driven. For 5G-LOGINNOV, this statement holds true in both test areas, the red- and the blue-coloured geo-box shown in Figure 12.

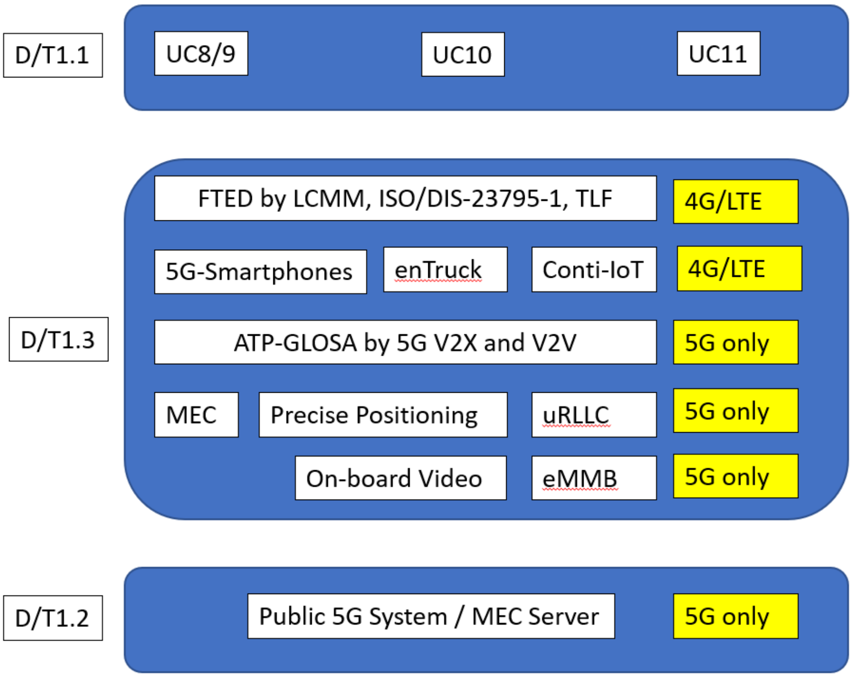


Figure 14: Hardware and Use Case Components for Living Lab Hamburg

With regards to V2X technology applied, the virtual traffic management presented in Figure 13 acts as an independent data platform with classical V2X input from RSUs and 5G infrastructure, e.g. MEC. The Signal Phase And Time information of the traffic light (SPAT/MAP) will be sent to the on-board GLOSA-Smartphone-APP installed in the lead platoon and from there via MEC to the follow vehicles. GLOSA stands for Green-Light-Optimum-Speed-Advice and will be used for Vehicle-to-Vehicle communication purposes of the vehicles platooning.

In the next chapter, this will be described in more detail.

3.2.2 Component specification

3.2.2.1 GLOSA, FTED and Truck Platooning

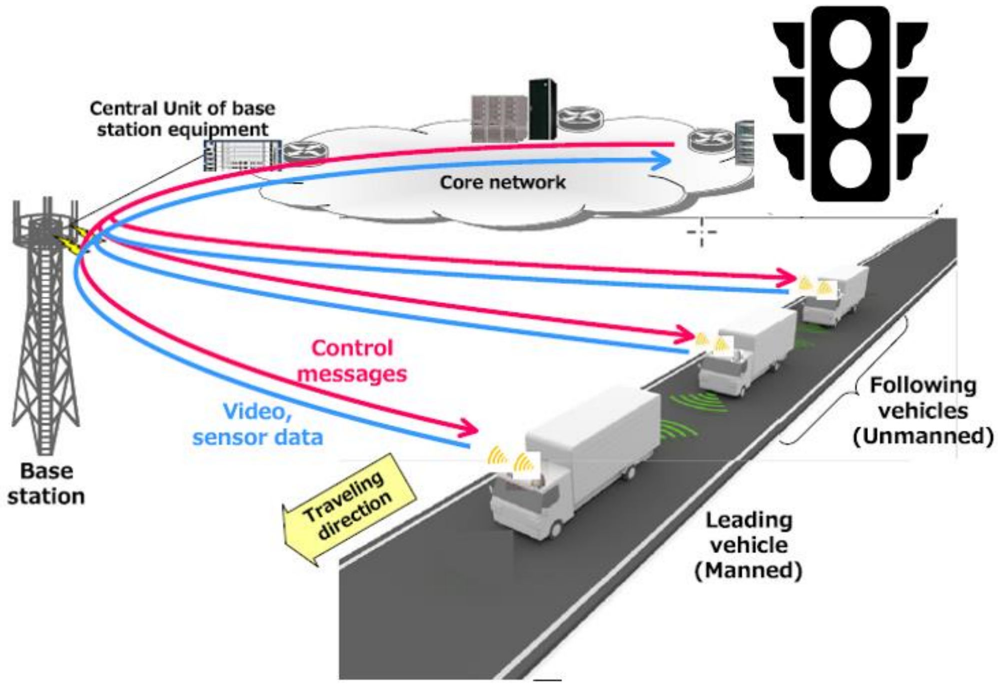


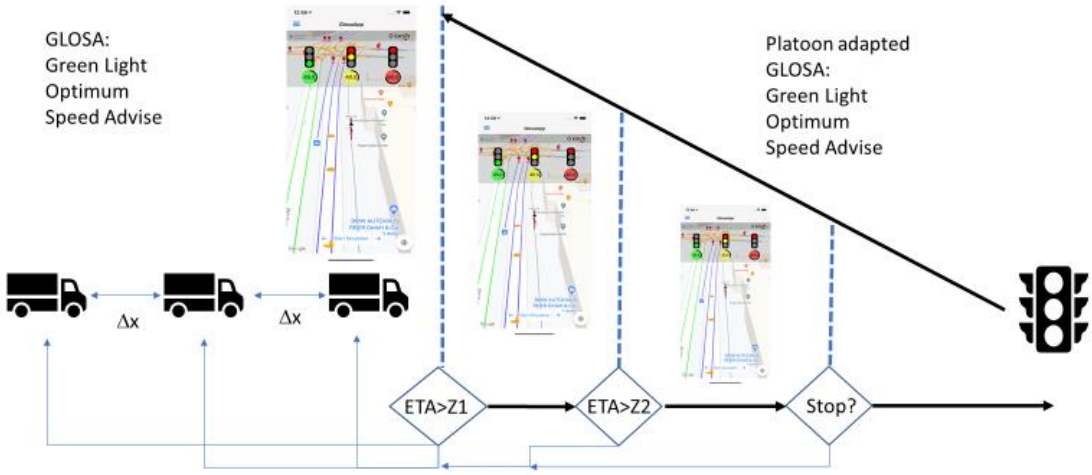
Figure 15: Hardware and Use Case Components for Living Lab Hamburg

Functional components of GLOSA based Truck Platooning as planned for the City of Hamburg are shown in Figure 15. The Truck Platoon with 3 different Telematic On-Board Units (Conti, enTruck and LCMM) is travelling in the indicated direction exchanging sensor data and video control data with the Mobile Base Station, in this case the Deutsche Telekom mobile network. Video data exchange is optional for the purpose of control messages to keep the platooning at distances required for stability and safety.

Complementary to this, Figure 16 presents decision gates to operate trucks platooning safe and driving at constant distances. Control messages also refer to the different roles of the lead platoon with a driver on board and the follow platoons which will be operated in the long-term (beyond project duration) driverless SAE-level 5. The GLOSA APP analyses the lead vehicle and its driver behaviour to adapt the GLOSA speed advice for the follow vehicles of the platoon.

Figure 16 also shows how the GLOSA enabled Truck Platooning could be operated by applying state of the art traffic light priority technology. First, it is needed to keep a minimum distance Δx between Lead and Follow platoon vehicles. From the Physics of Driving aspect, the minimum distance should lie in the range of 3 to 5 meters balancing safety and stability of the platoon’s operation.

Then, Figure 17 depicts the acceleration interval for harsh braking emergency events which might take place along the urban path of the platoon. Here an urban speed up to 30 km/h was assumed with regards to approaching traffic light-controlled intersections, see Figure 16. Additionally, the equation used in Figure 17 assumes run-times between Lead Truck to base station to Follow Truck of <25 ms as already published in [1] and other research papers, e.g. [2] where truck platooning was analysed with reference to 5G technology components.



ETA: estimated time of arrival / Z: threshold trigger to stop Truck Platoon

Figure 16: Truck Platooning with 5G-GLOSA – Decision Gates

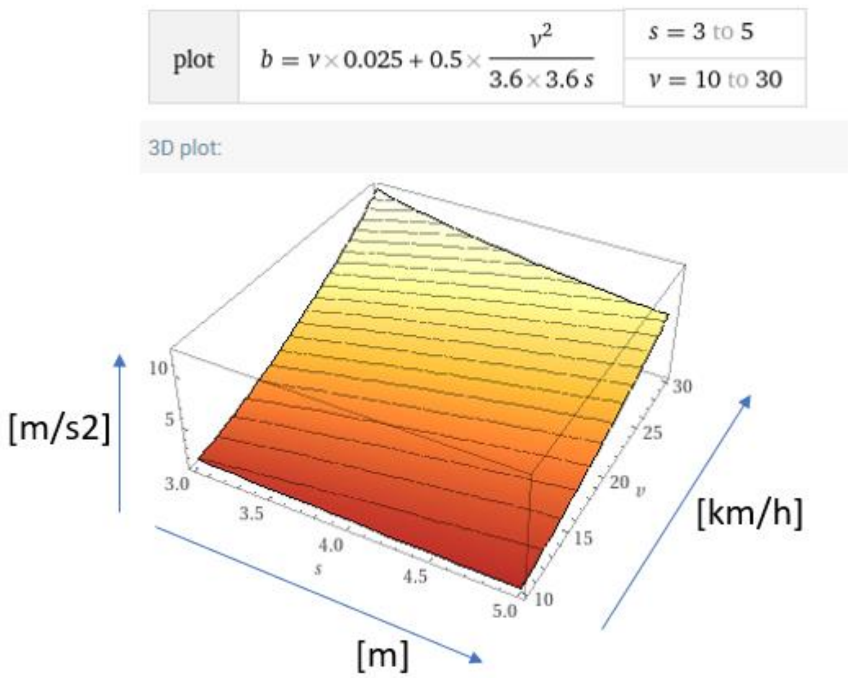


Figure 17: Mathematical relationship of distance, acceleration, and speed in urban traffic conditions

The use cases UC8-11 are linked to the red and blue coloured boxes indicated in the map of Hamburg, see Figure 12. From the overall accessibility of container logistics to and from terminals located in different parts of the southern part of Hamburg (relative to the river Elbe), the box shows a typical bottleneck in the road network: Kattwyk bridge and its connecting road feeder system. Complementary to the I.T.S. directive of the City, Hamburg Port Authority started to implement Road Side Units (RSU) to give optimized Green for trucks equipped with an On-Board-Unit. The objective is to give longer Green time to trucks which otherwise might be blocked until a container ship has passed the uplifted bridge. The current OBU offered by HPA to logistics service providers uses classical V2X, but has so far no V2V communication module as required by truck platoons and even more for future automated trucks platooning. Besides this planned 5G-LOGINNOV innovation complementing HPA's strategic approach to improve traffic flow, 5G-LOGINNOV's use cases 8 and 9 with components for CO2 emission monitoring will be deployed in both test Fields of the Living Lab. From previous research projects it was found that coordination of Green Light Signal Phase and Time (SPAT) has a significant potential in GHG savings for both fuel and emissions, which will be quantified on vehicle platoon level

3.2.2.2 Local traffic management system

In a nutshell, the local traffic management system provides online traffic light data enhanced with a centralized traffic light forecast (UC 10) to enable a green light optimal speed advisor (GLOSA) application, visualizes floating truck emission data (FTED) (UC 8/9) and derives a strategy to avoid pollution hotspots based on the emission data (UC 11), see Figure 18.

As it is not part of the traffic management centre of the city of Hamburg, it will be deployed on a virtual machine in the cloud.

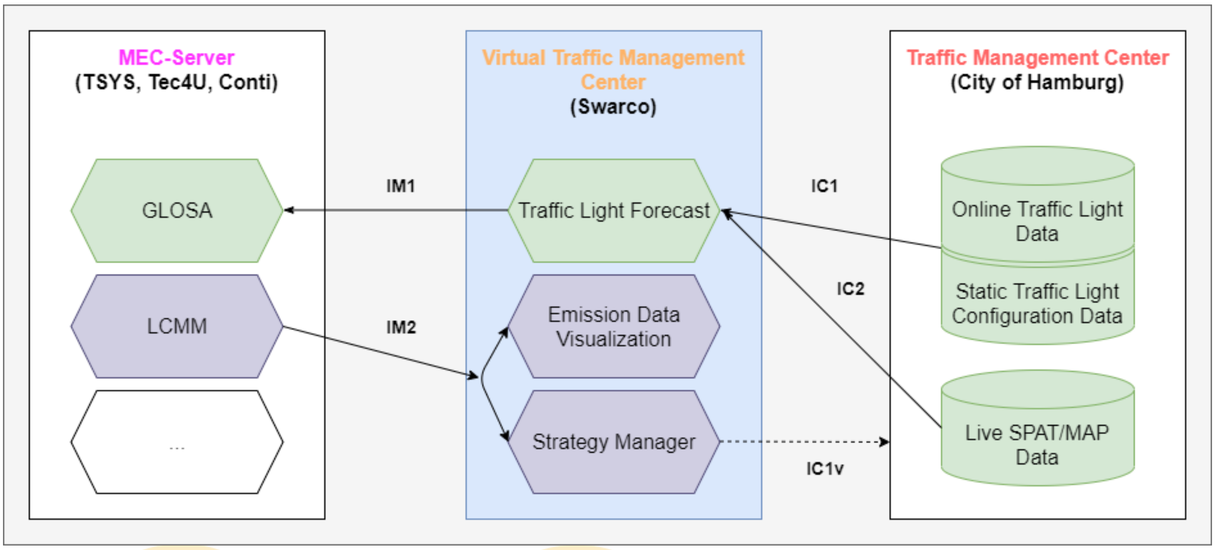


Figure 18: Architecture and interfaces of the Virtual Traffic Management Centre (vTMC)

In 5G-LOGINNOV, there are two live streams of traffic light data, which will be provided by the traffic management centre of the city of Hamburg. For the first stream (IC1 in Figure 18) a definition of an appropriate truck route is needed beforehand. The stream itself consists of online traffic light and detection data as well as configuration information for the individual intersections along the route. Detection data are needed to forecast at intersections with a traffic dependent, i.e. reacting on the current traffic situation, control logic. In addition, the configuration of the traffic control logic for each intersection is mandatory, since it describes the schedule of the traffic logic during the day and maps the detection data to their relevant detectors and traffic signs. Based on this data the TLF module calculates continuously the forecast and itself generates a stream of present and forecasted traffic light states (IM1).

The second stream (IC2 in Figure 18) consists of data generated at intersections alongside the TAVF testbed. Data are delivered in an XML-encoded version of the ETSI C-ITS messages MAP (intersection topology) and SPAT (signal phase and timing). The SPAT data already includes prediction data based on a local forecast performed inside the individual traffic light controller. The TLF module will convert these data and streams them through interface IM1.

Obviously, to produce a meaningful GLOSA application, it is required, that the traffic light data has very low latency and the forecast is performed with lowest delay possible. In Germany, traffic light control logic usually has a stroke of one second, so the delay from the local controller to IM1 should be much less than a second.

FTED are provided by the LCMM module on the MEC-server via interface IM2 for both the route of the TAVF testbed and the selected appropriate truck route. They are consumed by the visualization module, which shows the emission data with and without the influence of GLOSA on truck driving.

In addition, IM2 data are used to evaluate the current emission situation. In case of high emissions, a strategy to decrease emission values will be suggested. This could be an alternative routing for trucks or an adapted traffic control scheme. Since this module is a first prototype, it will not influence the real traffic management, so interface IC1v is a virtual one.

3.2.2.3 Entruck, open telematics and telemetry platform

Entruck is a vendor independent telematics platform with enhanced analytical capabilities that connects assets (e.g. vehicles, trailers, containers, machinery) with their asset management. Entruck is used in logistics and R&D applications by e.g.

- freight forwarders for order planning and scheduling
- approval associations for enhanced tyre / component testing
- Fleet operators for vehicle management, monitoring and maintenance
- OEMs for R&D related testing and benchmarks

Figure 19: Entruck, Overview and main application areas

Within the Living Lab Hamburg, Entruck will be used to connect vehicles with the infrastructure and enable a two-channel communication between vehicle and infrastructure by 5G. The collected vehicle data will be enriched by third party data as e.g. infrastructure and weather information, analysed on manoeuvre level and fed back to other stakeholder as LCMM and traffic management. The results will be inter alia the

- segmentation of the route into manoeuvres forced by the infrastructure
- segmentation of the route into manoeuvres forced by the traffic
- influence of the infrastructure to fuel consumption, emissions and wear
- influence of the traffic to fuel consumption, emissions and wear
- influence of the driver to fuel consumption, emissions and wear
- influence of the logistics operation (eg. load, task, etc..) to fuel consumption, emissions and wear
- influence of the used vehicle and components (e.g. hp, tyres, power train) to fuel consumption, emissions and wear

This analysis and information will be fed back and provided in various indicators as e.g. active acceleration, active deceleration, constant driving, coasting, and speed and route classes.

The data collection on the vehicle will be done by the Entruck OBU with CAN bus / FMS access. The Entruck OBU is a full spec. vehicle pc for various mobility application and interfaces to

- 2G / 3G / 4G and 5G communications networks
- GNSS
- CAN bus / FMS
- TPMS
- display for driver or service / maintenance
- RFID network and applications (e.g. driver license verification, container management)
- Remote load room monitoring by camera
- Other sensors, as e.g. door, temperature, flow sensors, et…

Figure 20 : Entruck OBU

In addition to the EnTruck OBU, the IoT-box of Conti will be used in Living Labs Hamburg and Koper, see chapter 3.3.2.2.

For the four Living Lab Hamburg uses cases, the Entruck OBU will collect - besides GNSS information - following data in a frequency of 2 Hz from the vehicle for further analysis:

Parameter	Unit
odometer	km
actual vehicle speed	km/h
actual engine speed	RPM
actual engine torque	%
kick down switch	0 / 1
accelerator pedal position	%
brake switch	0 / 1
clutch switch	0 / 1
cruise switch	0 / 1
PTO	0 / 1
fuel level	%
actual fuel consumption	l
engine temperature	°C
turbo pressure	bar
axle weight (per axle)	kg

Table 6 : Vehicle raw data used for Living Lab Hamburg

3.2.3 Interfaces and possible extensions for SME

3.2.3.1 GLOSA, FTED and Truck Platooning

The overall service architecture as planned for Living Lab Hamburg is shown in Figure 13. On the right, one can see soft- and hardware systems linked to the city traffic management centre, from where traffic signal states (including forecast) are exchanged with the platoon. Additionally, external environmental data will be collected and made available for the virtual traffic management centre. On the left side, data is transferred from the floating vehicles equipped with telematics devices.

All telematics devices use the public 5G mobile network as available in inner urban area in the city of Hamburg. The foreseen telematics devices are:

1. Tec4U Entruck CarPC collecting raw CAN-Bus data and aggregating them as calculated data.
2. Continental IoT box selecting CAN-Bus data plus additional IoT devices.
3. T-Systems Smartphone LCMM App collecting GPS speed profiles for pre-configured vehicle parameters.

All of these data sets are transferred via the Telekom 5G public network to the service centre in charge of the use cases. For UC8 and UC9, the Living Lab partners are focusing on floating vehicle emission data collection, evaluated by the three telematics devices running inside the platoon. The devices transmit detailed data sets of single vehicles and platoons including taxi fleet data. The data of UC8 and UC9 helps traffic managers to evaluate emissions along the road network and to help developing strategies for clean air policy measure (short-term and mid-term). Compared to this, UC10 evaluates traffic signal forecast data within the GLOSA APP sent previously from the virtual traffic centre. Additionally, 5G based precise positioning technology will be used to improve the accuracy of all calculations executed within the uses cases.

Use case 10 has the objective to implement 5G-enabled truck platoons, including the lead platoon vehicle and the following vehicles. To keep the platoon safe and distance stable, the speed range of the lead vehicle has to be transferred to the platoon followers. For this purpose, vehicle-to-vehicle communication (V2V) with low latency run times (<50 ms), a feature of the 5G mobile network, is foreseen and helps to guarantee the operation of the truck platoon, especially in urban traffic conditions where platooning is challenging. For this, the traffic signal forecast is sent to the vehicle and drivers can adopt their speed to optimum according to road and traffic conditions.

SMEs and Start-Ups are welcome to design convincing business cases with the technical requirements for business implementation to attract fleet and traffic managers. Solutions should take features of telematics, IoT and 5G into their consideration and convince the Living Lab partners about their innovative go-to-market strategy.

3.2.3.2 Local traffic management system

The TLF module in Figure 18 could be extended to support intersections in the area of the city of Hamburg which are not part of the 5G-LOGINNOV truck test route. Then, by consuming the data stream of interface IM1, an external partner could implement further GLOSA applications, e.g. for cyclists or other vehicles distributed to handhelds, smartphones or navigation solutions.

In a city there are several sources of emission which add to air pollution, traffic related, like trucks or normal vehicles, or even static ones, like heating. These data could be fed via interface IM2 in Figure 18 to the (virtual) traffic centre in order to visualize their effects or let them influence the strategy managers' decisions.

3.3 Koper Living Lab infrastructure

3.3.1 Overview of components and architecture

Koper Living Lab targets implementation of novel 5G technologies such as MANO-based services and network orchestration, Industrial IoT, AI/ML based video analytics, drone-based security monitoring and cutting-edge prototypes tailored to be operated in European port environments. Use cases (UC 1 - Management and Network Orchestration platform (MANO), UC 5 - Automation for Ports: Port Control, Logistics and Remote Automation and UC 6 - Mission Critical Communications in Ports) that will be supported are primarily targeting Industry 4.0 scenarios and include activities related to port control, logistics and remote automation. More specifically, the following 5G-enabled logistics support activities will be implemented and verified at the port area:

- Operating port STS (Ship to Shore) cranes will be equipped with industrial cameras connected to 5G network for capturing and transfer of UHD streams to cloud-based analytics for identification of container markers and detection of possible structural damage of containers using advanced video analytics based on AI/ML techniques.
- Port equipment monitoring and remote telemetry will be performed for operating machines (e.g. terminal tractors), by means of capturing and transferring of the key information (e.g. consumption, positions and other related telemetry information) to the port operation support system.
- Drone-based and portable night vision cameras connected to 5G network will be used to support real-time video surveillance and other security related port activities.
- Finally, a resilient 5G-based network scenarios over public and private 5G infrastructure will be implemented to provide alternative 5G-enabled network capabilities to the established operational WLAN network.

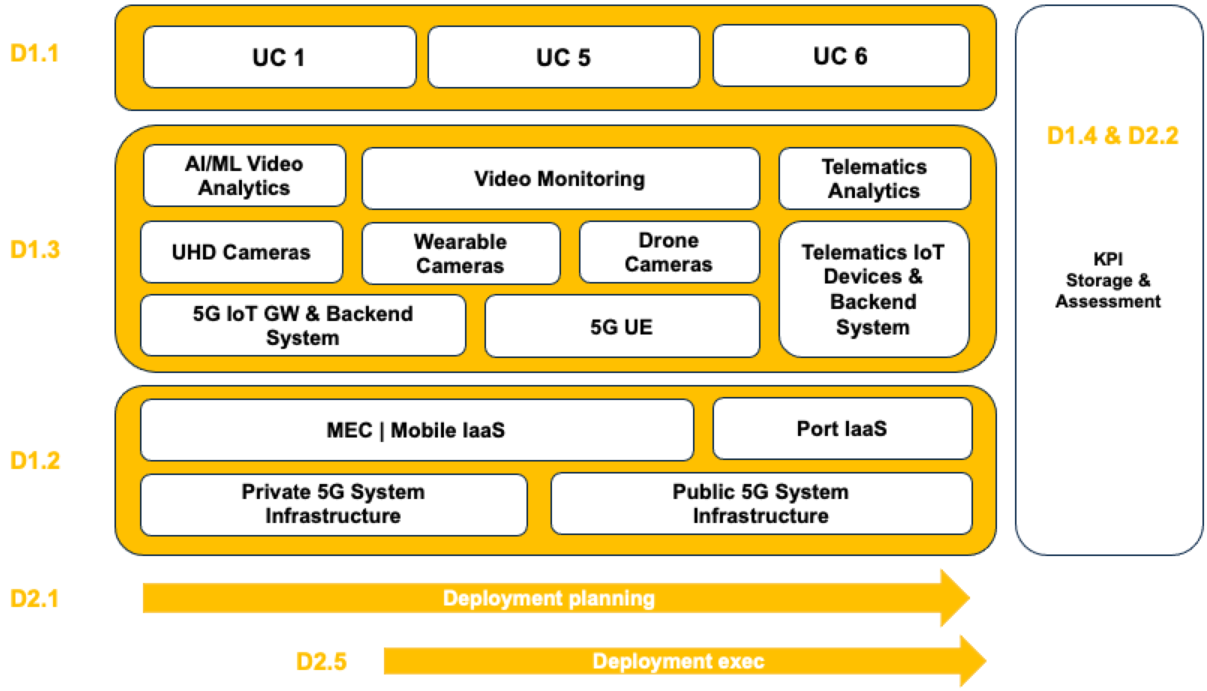


Figure 21: Hardware and Use Case Components for Living Lab Koper

In Figure 21 relations between the Living Lab Koper use cases, 5G mobile network capabilities and other Living Lab infrastructure components with respect to the 5G-LOGINNOV deliverables (D1.1, D1.2, D1.4. D2.1, D2.2 and D2.5) and other project tasks are presented. To assure needed infrastructure required to support targeted use cases deployment, testing and verification activities and to provide capabilities for the engagement of the innovative start-ups and SMEs, Living Lab Koper infrastructure will be composed of 5G mobile network services, mobile IaaS capabilities and additional services and applications components. From technical perspective and as depicted on the Figure 21 two distinctive domains can be identified in the Koper Living Lab:

Mobile network and cloud/IaaS domain[1]:

- Public 5G System Infrastructure provided by the TSLO
- Private 5G System Infrastructure provided by the ININ
- Port IaaS provided by LK
- MEC | Mobile IaaS assured by TSLO and ININ

Application and services domain:

- 5G IoT Gateway and Backend System
- Telematics IoT Devices
- AI/ML Video Analytics
- Telematics Analytics
- Other supportive devices such as 5G UE, Drone, industrial UHD and wearable cameras

Based on the supported network, cloud, services and application capabilities all targeted use cases can be deployed, tested and verified. Living Lab Koper architecture is generic enough to host various other use cases targeting port operations, logistics and private security services which will be

[1] Detailed 5G architecture with system elements and supported functionalities is provided in the deliverable D1.2.

exploited and showcased as part of 5G-LOGINNOV open call. In the following section application and services domain components will be presented and explained in more detail.

3.3.2 Component specification

3.3.2.1 5G IoT GW and Backend System (ININ)

5G IoT GW and Backend System is a distributed solution with 5G and MANO-ready capabilities designed for the deployment of Industrial IoT/M2M based remote sensing and monitoring services and applications in port and industrial environments. It features a distributed system architecture and comprises a cloud-based back-end system to assure remote gateway control, upgrades and system autonomous operation. Industrial gateway supports various communication modules (3G/4G/5G and Ethernet) to enable integration with external devices (e.g. Industrial UHD cameras) and to provide backhaul connectivity over 5G mobile system to port IaaS and other port operation and support system. As part of a IoT backend system a cloud-based measurement collectors and analytics will also be available to visualize IoT and 5G system performance metrics and to provide notification and alerting services.

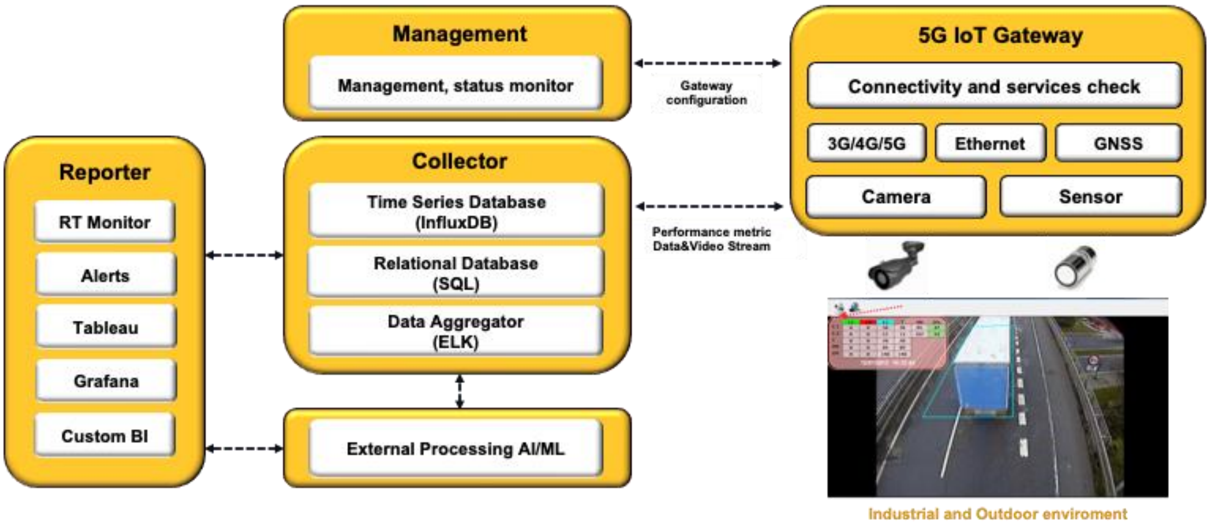


Figure 22: Hardware and Use Case Components for Living Lab Koper

Architecture of the industry grade 5G IoT system has the following components:

- Management – Centralized cloud-based management system.
- 5G IoT Gateway – Autonomous 5G enabled IoT/M2M gateway used to connect external devices e.g. industrial cameras.
- Collector – Cloud-based storage with flexible data collection and exporting options (My/MS SQL and time series DB).
- Reporter – Cloud based Real-time monitoring, notification and alerting dashboard.

Detailed analyses of the supported functionalities and its capabilities are presented in Table 77.

System Element	Feature	Requirements
5G IoT Gateway	Operational environment	Industrial -20 °C ~ 60 °C IP40 Fan-less design
	Mounting	Rack Mount or Wall Mount
	Supported technologies	5G NR Sub-6, BW per CC (Up to 100 Mhz), SCS 15 Khz (FDD), SCS 30 Khz (TDD),

System Element	Feature	Requirements
		NSA mode, 3GPP R15, EN-DC, Option 3/3a SA mode, 3GPP R15, Option 2
		5G Sub-6 bands SA (TDD): n78 5G Sub-6 bands SA (FDD/TDD) with future SW extensions: n1, n2, n3, n7, n28 (optional), 5G Sub-6 bands NSA (TDD&FDD): n1, n2, n3, n5, n7, n20, n28, n78
		4G LTE: CA, Cat-20 LTE-A Pro, up to 7CC DL and up to 2CC UL
		4G/LTE bands (FDD&TDD): B1, B2, B3, B7, B8, B20, B42, B28,
		Ethernet interfaces with RJ-45 or SFP+ connector 1GE
	Protocols	TCP/IP, PAP/CHAP
	Positioning	GNSS: Galileo, GPS, GLONASS
	Network connectivity and services check/testing	Data based: DNS, PING, FTP UL, FTP/HTTP DL, Web services Synthetic traffic: IPERF UDP/TCP
	RAN check/testing	4G&5G: RSSI, RSRP, RSRQ, SINR, Tx Power PLMN ID/name, EARFCN, Band, BW, Cell ID, PCI, Carrier Aggregation, RRC state
Management	Cloud-based management	IoT GW status monitoring Multiple user profiles Remote control option: APN setting, reboot, GIS Maps
	Over-the-air upgrades	“Live” system upgrades Autonomous operation, zero data loss
Collector	Storage	Centralized check/testing KPI collector DB deployed in IaaS environments as single or multiple instances (redundancy scenarios)
	External output connectors	Multiple enterprise and data streaming DB outputs: My/MS-SQL, influxDB, Elastic, Prometheus
Reporter	Analytics	Flexible cloud-based analytics options E2E Real-time network and application monitoring Advanced post analytics with data enrichment and KPI visualization
	SLA/SLS Monitoring	Visualisation of combined active testing and passive KPI collection from the 5G IoT GW

Table 7: 5G IoT System requirements overview

Figure 23: 5G IoT GW prototype with external 5G modem development board

5G IoT System will be designed, build, tested and verified as part of UC 1 in the Living Lab Koper and will be also available as a distinctive Living Lab Koper component to support other Living Lab use cases e.g. UC 5 and UC 6.

3.3.2.2 Telematics IoT Devices (CONTI)

With high bandwidth and reduced latency, the new mobile network standard 5G offers all pre-requisites to connect vehicles in real-time. To assure remote telemetry monitoring of the operating machines in the port, some of the terminal tractors will be equipped with telematics IoT devices provided by the Continental. They will enable continuous capturing and monitoring of a key vehicle information such as operating machines consumption, positions and other related telemetry data. The Continental 5G IoT device has the following features:

- Based on Continental's Open Telematics Platform
- Continental designed NAD based on Qualcomm
- Powerful Application Processor w/ Linux OS
- HSM (Hardware Security Module)
- High Speed Vehicle Interface with 1000BaseT1 Ethernet
- Hybrid V2X Technology (DSRC and/or C-V2X)
- Bluetooth/WIFI Interface

This brings the following benefits:

- Customized software solutions for telematics use cases
- Software development kit (SDK) for more flexibility
- Lower latencies for V2X Real-Time Communication
- Enhanced security
- Localization – Vehicle tracking by GNSS
- Scalability – Enables future services and features

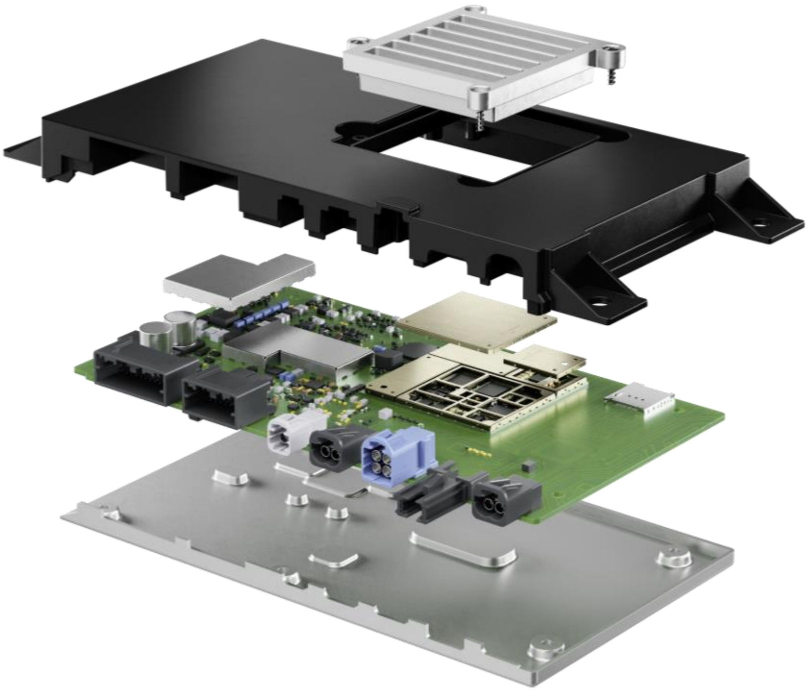


Figure 24: Continental IoT device - mechanical design

The Continental 5G IoT device collects information from the vehicle CAN bus, as well as from the internal GNSS sensor, and transmits this information to the Continental backend via 5G mobile system. This information will be used as part of UC 5, in the Luka Koper Living Lab.

System Element	Feature	Requirements
Continental 5G IoT device	Wireless	Cellular 5G - release 15 (> 3Gbps) Sub-6GHz Band Support LTE-A Pro CAT 19 Opportunistic ULCA
		eUICC – 1 embedded SIM. For development phase a SIM holder placed on PCB should available
		V2X – C-V2X (R14 for 4.5G and R15 for 5G), DSRC (optional)
		Positioning - L1/2/5, DR, PPP/RTK
	Main HW features	App µP – iMx8 (ARM A35) Modem – ARM A7 Vehicle µController : Cortex M4, integrated in Application Processor
		Memory: App µP: 512 MB LPDDR4 Modem: 512 MB LPDDR4
		Vehicle interfaces: • Gigabit ethernet • CAN HS/FD • USB 2.0 (for development purposes)
		Back-up battery included

Table 8: Continental IoT device requirements overview

Telematics 5G IoT device provided by Continental will be integrated tested and verified as part of UC5.

3.3.2.3 AI/ML Video Analytics (VICOM)

One of the components of the Living Lab in Luka Koper is AI/ML-based Video Analytics platform, which makes use of the underlying 5G infrastructure for the video streaming to the platform. These computer vision capabilities will be used for the detection of several events both in logistics and risk environments, with the objective of performance and security improvement, respectively.

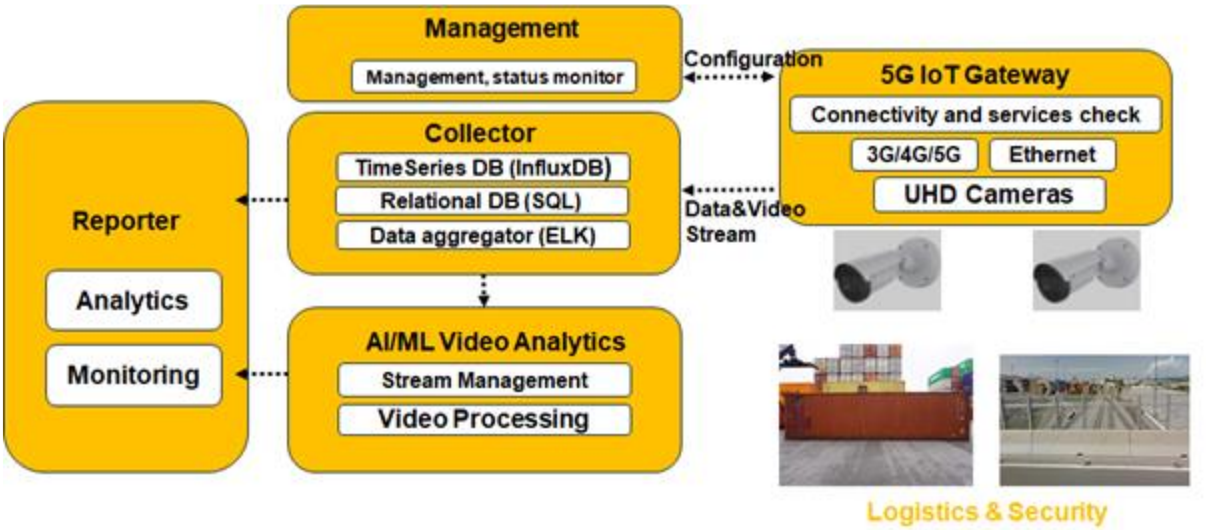


Figure 25: Components for the AI/ML Video Analytics

Within this platform, UHD cameras will be the main sensors that collect the video stream from the environment (containers in UC5 or risk areas and vehicle/train gates in UC6). These sensors will be connected through the 5G IoT GW to the cloud-based data collector. The video analytics component will extract the images from the collector and generate information (about identification marker and damages in containers, presence detection in risk areas, and classification of vehicles) that will be sent to the Reporter component.

Architecture of the AI/ML video analytics has the following components:

- 5G IoT Gateway – in this case, UHD cameras located in cranes and in risk areas will be the sensors
- Collector – Cloud-based storage and stream management
- AI/ML Video analytics – video processing techniques for events detection (damages, identifications)
- Reporter – Cloud based Real-time monitoring dashboard.

Detailed analyses of the supported functionalities and its capabilities are presented in Table 9.

System Element	Feature	Requirements
Video Analytics	External input connectors	Multiple enterprise and data streaming inputs
	Data stream management	Analysis and filtering of the incoming data Pre-process of the filtered data and sending to the different analytics component
	AI/ML container analytics component	Analysis of the container images to detect damages and text identifiers.
	AI/ML road analytics component	Analysis of the images for presence detection in risk areas and classification of vehicles
	External output connectors	Multiple enterprise and data streaming outputs
	Computing features	RAM DDR4 >= 16GB NVIDIA GPU COMPUTE CAPABILITY >= 7.5, RAM >= 10GB, e.g. RTX >=2080 or Tesla T4
IoT – UHD cameras	Crane cameras requirements	Resolution >= 4K Lossless compression formats for video and image
	Road cameras requirements	Resolution for people >= 100x100 pixels Lossless compression formats for video and image

Table 9: AI/ML based video analytics system requirements overview

The Video Analytics component will be designed, built, tested and verified as part of both UC 5 and UC 6 in the Koper Living Lab.

3.3.2.4 Telematics Analytics (CONTI)

Analytics provided by Continental represents an integral part of a 5G IoT telematics solution presented in previous sections. Information collected by the Continental 5G IoT devices will be sent via 5G mobile system to the MQTT broker located in the Continental backend (installed in the port IaaS). Its architecture is presented in a Figure 26.

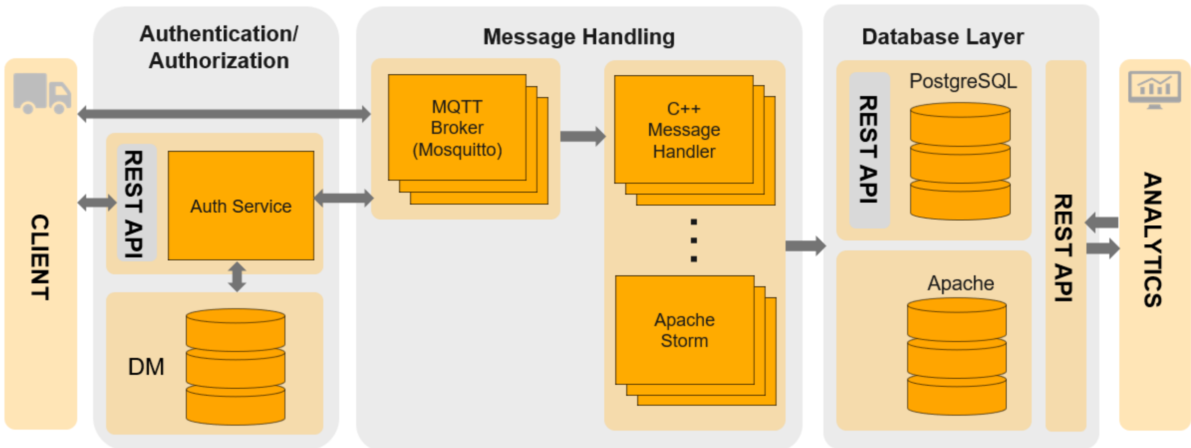


Figure 26: Continental backend architecture

The main roles of the backend are as follows:

- Device management
- TLS encryption
- Data handling via MQTT protocol
- Storage of data collected from the IoT devices

* Scalable / load-balancing
* configuration download
* Security
    * Certificate handling and generation
    * Authentication and authorization

5G IoT telematics solution provided by Continental will be integrated tested and verified as part of UC5.

3.3.2.5 Supportive devices and base-line port infrastructure (LK, ININ)

To complement main Living Lab components presented in previous sections several other system elements, such as UHD cameras, drones, industrial 5G UE handheld terminals etc., will be provide by the Koper Living Lab. Detailed system elements requirements presented in the Table 10 were prepared based on the targeted use cases (UC1, UC5 and UC6) and envisioned deployment, testing and verification scenarios that are planned to be run during the 5G-LOGINNOV project time span. Availability of the elements will rely on the availability of commercial 5G components and products, especially those related to the support of 5G eMBB features (e.g. 5G support on industrial UE and drones). In case of delays in the commercial rollout on the part of 5G vendors (especially industrial editions) and consequently unavailability of some elements/functionalities, these will be replaced with the most suitable prototypes and open-source implementations already available in the 5G ecosystem.

Finally, several other base-line infrastructure elements such as STS cranes, optical fibres, server rooms etc. are needed to build and operate 5G-enabled port-based living lab as envisioned in the Port of Koper. Detailed information on supportive devices and other infrastructure in Luka Koper / Port of Koper is presented in Table 10.

System Element	Feature	Requirements
UHD Cameras	Operational environment	Industrial -20 °C ~ 50 °C IP40 Fan-less design
	Mounting	Mounting on the horizontal crane construction
	Requirement	Resolution >= 4K Lossless compression formats for video and image IR illumination Ethernet interface 10/100/1000Base-TX Cellular 5G interface
5G UE Handheld terminals	Operational environment	Industrial -20 °C ~ 50 °C
	Wireless	Cellular with 5G NSA and SA, LTE-A Pro
		5G Sub-6 bands SA (TDD): n78 optional 5G Sub-6 bands SA (FDD/TDD) with future SW extensions: n1, n2, n3, n7, n28 5G Sub-6 bands NSA (TDD&FDD): n1, n2, n3, n5, n7, n20, n28, n78
		4G/LTE bands (FDD&TDD): B1, B2, B3, B7, B8, B20, B42, B28,
		eUICC – 1 embedded SIM. For development phase with USIM holder
		Positioning – GNSS, GPS, Galileo
	Main HW features	CPU: Qualcomm Snapdragon™ 660 octa-core, 2.2 GHz or similar
		Memory: 4 GB RAM/32 GB Flash pSLC or similar
		Corning Gorilla Glass or similar
		Back-up battery included
		1D/2D extended range imager scanner

System Element	Feature	Requirements
		Camera: Front: Resolution >= 5MP Rear: Resolution >= 10MP
Drones	Main HW features	Operating Frequency (remote control): 2.400-2.483 GHz; 5.725-5.825 GHz
		Drone remote controller connected to 5G UE
		Camera resolution >= 4K
		Lossless compression formats for video and image
Cranes and other prefabricated columns for assembly of cameras	Rail distance	30 m
	Horizontal sill beam height	5,5 m
	Hoisting speed	3 to 5 m/s
	Mounting	Mounting on the crane sill beam
Server room	Operational environment	21 °C air-conditioned room
	Rack enclosure	2000 x 700 x 1200 cm (h x w x d)
Optical infrastructure	Type	Single mode 9/125um with LC, FC connectors
Power	Server room	UPS, diesel generator, 230V
	Cranes	24VDC, 230VAC
	Vehicles	24VDC

Table 10: Supportive devices and other infrastructure

As part of 5G-LOGINNOV open call it is expected that engaged start-ups and SMEs will additionally extend the Koper Living Lab capabilities with innovative port- and 5G-related elements and functionalities required to support novel use cases targeting future port operation and control.

3.3.2.6 Koper Living Lab components used in UC 1

Mapping of the UC1 elements to the Koper Living Lab is presented in Figure 27. UC1 will be built on the basis of Industrial IoT platform provided by ININ and will be extended with 5G and cloud-native principles and other mechanisms required to support onboarding and automated deployment of the 5G-enabled IoT services (5G Industrial IoT System) into the MANO-controlled cloud environment in the Koper Living Lab.

As presented in Figure 27 the following components from the Koper Living Lab will be exploited to deploy and operated services and applications from UC1:

- ***Mobile and port IaaS system components*** to be used for the deployment of the 5G IoT backend elements.
- ***Private and public 5G system*** infrastructure to provide backhaul connectivity to 5G IoT gateways and connected devices

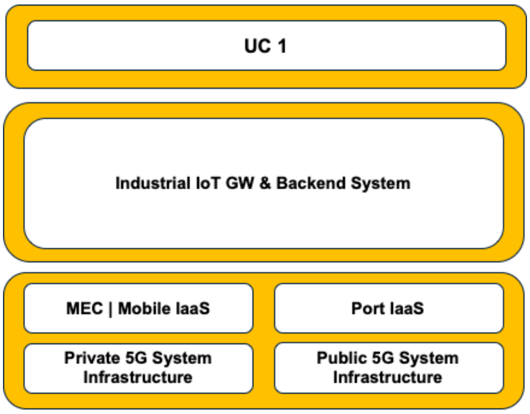


Figure 27: UC1 components mapping to the Koper Living Lab infrastructure

5G IoT system elements will be prepared as Cloud-Native Functions (CNF) and extended with the support of MANO-based orchestration on the Kubernetes and OpenStack infrastructure. Therefore, to assure the 5G IoT system operation in the Koper Living Lab, the currently monolithically-built server elements will be split and prepared as distributed and modular application components. The following 5G IoT system components are foreseen:

- MBL – Management Business Logic
- DB – Database
- CBL – Collector Business Logics
- TSDB – Time Series Database
- DEXT – Data Extractor
- RTAA – Real Time Advanced Analytics

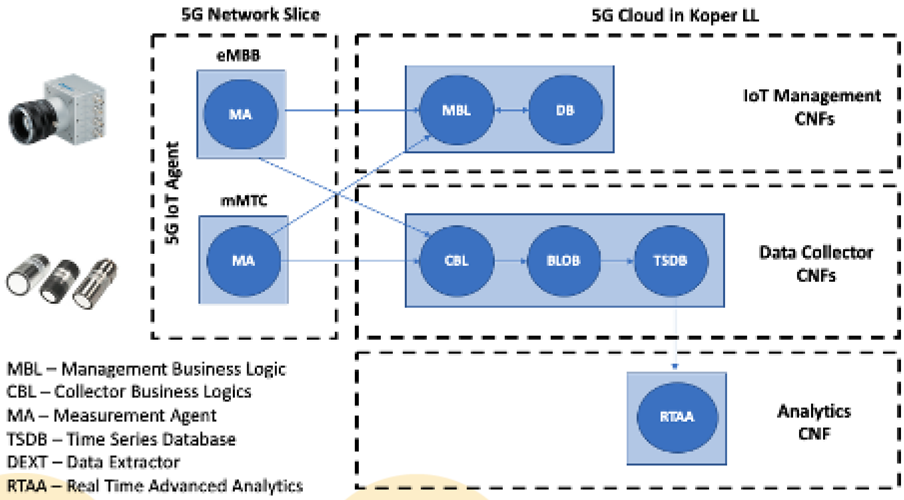


Figure 28: 5G IoT system deployment diagram

The relevant 5G IoT system deployment diagram, including component interdependency and interactions, is presented on the Figure 28. The diagram will be used to develop the required MANO descriptors used by the orchestrator for the 5G IoT system initial deployment and run-time scaling automation.

More detailed information about UC1, with detailed description and operational flows is provided in the 5G-LOGINNOV deliverable D1.1 5G-enabled logistics use cases.

3.3.2.7 Koper Living Lab components used in UC 5 (CONTI, VICOM, LK, TSLO, ININ)

To automate STS crane logistics process and to assure port equipment monitoring and remote telemetry operation several components and supportive elements from the Koper Living Lab will be exploited. UC5 will be built as an extension of prepared communication and cloud infrastructure of UC1 provided by ININ and TSLO, where UC1 components (5G network and services, 5G IoT GW, IaaS infrastructure) will be extended with additional sensor-based elements and cloud-assured analytics:

- **External sensors** such as UHD cameras will provide real-time video streaming from the STS crane area and Telematics IoT Devices will support capturing and transferring of key telematics information from operating terminal vehicles.
- **Analytic components** (AI/ML Video and Telematics analytics) will be provided to extract the information regarding the control, logistics and remote automation in port operation.

Detailed mapping of the UC5 elements to the Koper Living Lab is presented on the Figure 29.

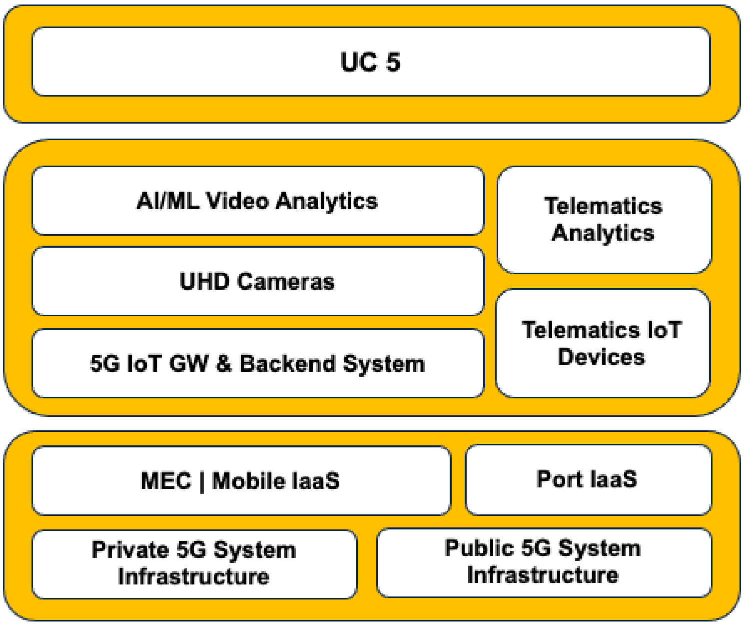


Figure 29: UC5 components mapping to the Koper Living Lab infrastructure

Purposely build AI/ML Video Analytics system will make use of the real-time video streaming captured by the UHD cameras located on STS cranes or in dedicated structures or prefabricated columns for assembly of cameras, in order to extract:

- Marker identification of the containers
- Damages in the containers

Video Analytics system elements will be prepared as Cloud-Native Functions (CNF) and deployed on top of the Kubernetes provided by the UC1. Therefore, to assure the Video Analytics system deployment in the Koper Living Lab, the current elements will be split and prepared as distributed and modular application components. The relevant Video Analytics system deployment diagram, including component interdependency and interactions, is presented on the Figure 30.

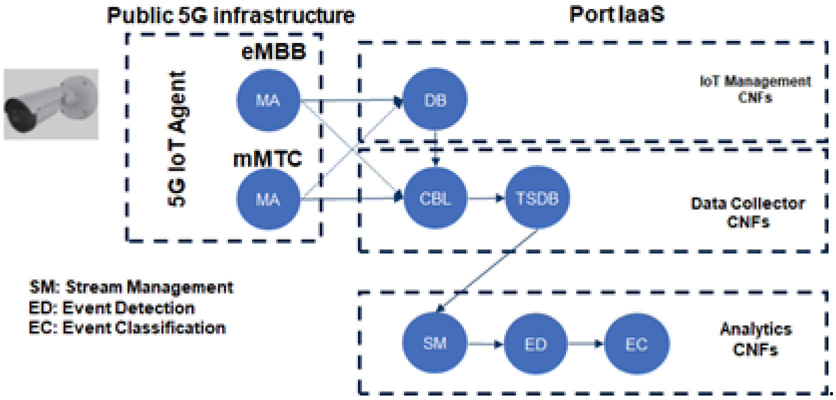


Figure 30: Video Analytics deployment diagram in UC5

In addition, to provide authenticated, secure and reliable reception, storage and processing of vehicle telemetry data, dedicated telematics backend and analytics infrastructure (e.g. MQTT broker, Apache storm, PostgreSQL database) provided by Continental will be deployed and operated in the private port IaaS infrastructure assured by the Koper Living Lab.

More detailed information about UC5, with detailed description and operational flows, is provided in the 5G-LOGINNOV deliverable D1.1 5G-enabled logistics use cases.

3.3.2.8 Koper Living Lab components used in UC 6 (VICOM, LK, TSLO, ININ)

In the UC6, where port security operation is targeted, real-time video surveillance will be implemented using several video sensors such as body-worn cameras carried by security personnel and portable video surveillance cameras with night vision capabilities to monitor specific port area (e.g. railway entrance). In addition, automated and coordinated drone-based surveillance will be implemented for extended ad-hoc video surveillance support, where 5G network will be used to transfer video streams in real time into the port Security Operation Centre.

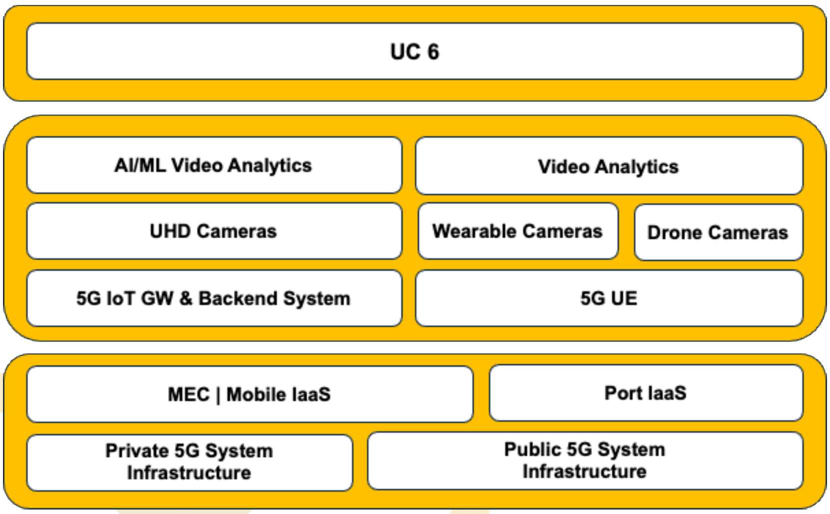


Figure 31: UC6 components mapping to the Koper Living Lab infrastructure

UC6 deployment will be leveraged on the prepared communication and cloud infrastructure from the UC1 where network and cloud components (5G network and services, 5G IoT GW, IaaS infrastructure) will be extended with the additional sensor-based elements and purposely built cloud-assured analytics:

- **External sensors** (UHD cameras, Wearable- and Drone-base Cameras) to capture data from the monitored environment.

- **Analytic components** (Video analytics) to extract the information regarding both video surveillance and private security operations in port.

Concretely, the information captured by UHD cameras allocated in high-risk areas, will be analysed by the ML/AI analytics component in order to detect human presence or any type of vehicles not allowed in that area. On the other hand, analytics about the number and classification of vehicles in some hot points in the port will be also performed. Elements from Video Analytics system will be prepared as Cloud-Native Functions (CNF) and deployed on top of the Kubernetes infrastructure provided by the UC1. To enable deployment of the system the currently elements will be split and prepared as distributed and modular application components.

More detailed information about UC6, with detailed description and operational flows, is provided in the 5G-LOGINNOV deliverable D1.1 5G-enabled logistics use cases.

3.3.3 Interfaces and possible extensions for SME

5G combined with the emerging technologies, such as UAVs (Unmanned Aerial Vehicles, e.g. drones) and AI-assisted video analytics deployed in cloud, presents immense potential for the development of innovative applications targeting services for the established vertical industries such as logistics, industry 4.0 and security.

As part of 5G-LOGINNOV Open Call, innovative SMEs will be invited to develop beyond-state-of-the-art solutions and applications addressing security and environmental aspects of port operation, to be integrated, tested and showcased in live port theatre. Special attention will be given to the following supportive services and use cases:

4. Providing autonomous operation of UAVs (e.g. drones without human pilots) in harsh industrial and port environment, targeting technologies and applications for supporting automated charging of UAV, self-flying and self-piloting actions, scheduled and event triggered UAV take offs, mission control planning, head back to the landing/charging station and finally receiving mission data in real and non-real time as part of fully automated process.
5. AI- and ML-based applications for cloud environments targeting support services for the port security operation, based on the exploitation of real-time video streams from moving and stationary drones to recognize security-related events and to identify objects of interest in real time.
6. AI- and ML-based applications for cloud environments targeting port safety and environment monitoring on the land and sea, based on the exploitation of UHD video streams from moving and stationary drones and other supportive sensors to identify environmental, safety and other hazardous events that may present damage to the health of people and other organisms. These events can be oil and chemical spill and other maritime pollutants coming from the cargo ships and open cargo already stored in the port area.

For the realization of the open call activities and to support innovations of the engaged start-ups and SMEs, Living Lab Koper will provide the following Living Lab system capabilities in a standardized manner:

- Commercial mobile network
  - 5G NSA Release 15 with the supported 5G UE types MBB and NB-IoT.
  - If required USIM with required data and QoS profile will be provided.
  - Connectivity between UE and VM’s in the Living Lab Cloud will be assured.
- Cloud capabilities
  - Standard VM (e.g. VMware) can be deployed in Koper Living Lab cloud environment. Required compute and storage capabilities needs to be agreed.

- Secure remote access will be available (e.g. VPN).

- Services and applications

  - Live video streams in standard formats (e.g. h264) from the deployed stationary UHD cameras and drones can be provided to the applicants, but they will be available only inside the Koper Living Lab in the controlled cloud environment.
  - Telemetry information data collected from the vehicles can be provided to the applicants, but they will be available only inside the Koper Living Lab in controlled cloud environment.
  - A general insight to know-how and the existing security-related drone capabilities in the port can be provided to applicants.

- Physical access to the facility

  - Physical access to the Koper Living Lab will be also available for the deployment of applicant HW and SW equipment (e.g. drone charging stations) and testing purposes, under the announced Security and Trade Secrets Act conditions described in the 5G-LOGINNOV open call under the section Living Lab Koper.

4 CONCLUSION

The D1.3 deliverable reflects the different aspects of the project use cases according to each individual Living Lab. All three Living Labs have elaborated its solution architecture linked to the business oriented use case description given in chapter 2. It was also described how the 5G features and hardware are used to enhance existing services in the areas of maintenance, safety, security and traffic management. The planned components were described up to hardware and software specification level. Thus, the fundament of implementation according to the work package 2, “Living Labs development and deployment”, was described.

More details are presented in chapter 3, where infrastructure requirements of the specific Living Labs are introduced.

In subsection 3.1 the requirements of Living Lab Athens are described and give an overview of the planned components and system architecture. After this general introduction, the Athens LL description goes into the details of the component specification and shows how they are linked to the specific use cases planned in Athens. Besides aspects of automation and yard logistics, Athens is using the existing 5G test-bed including mobile communications, yard truck logistics, precise positioning and real-time truck location. The orchestration of all different components for all use cases can then be found in the corresponding chapter.

In subchapter 3.2, the requirements of the Hamburg Living Lab infrastructure are described. The chapter includes an overview of components and architecture and gives details about the logistics corridor context for the planned use cases such as Floating Truck Emission Data, Automate Truck Platooning and Dynamic Traffic Management. The component specification includes a high-level system architecture for the greenlight optimum speed advice (GLOSA) App, and the 5G enabled truck platooning. The chapter also shows how vehicle platoons can approach the traffic light controlled intersection by making use of the mobile edge computing server and sophisticated vehicle to vehicle communication based on the low latency functionalities of the 5G network. Based on the different hardware components planned, an outline for participants of the open call is added to the document.

Finally, subchapter 3.3 describes the requirements in the Living Lab Koper, starting again with an overview of components in architecture referring to use cases 1, 5 and 6. Following with aspects of the mobile network and the given cloud infrastructure reference to the applications and services planned in Luka Koper are introduced in the context of 5G drones, video analytics and telematics as well as to wearable high-tech cameras for improved port operations. At the end of the chapter in outlook is given for the Competitive open call which is planned to the support the Living Lab deployment.

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