5GLOGINNOV

D5.6

Standardization and Spectrum Policy Report

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Meaning
5GPPP	The 5G Public Private Partnership
API	Application Programming Interface
CAD/CAM	Connected Automated Driving / Connected and Automated Mobility
CAN	Controller Area Network
CCAM	Cooperative, Connected and Automated Mobility
DL	Downlink
DOI	Digital Object Identifier
EAMS	Enterprise Asset Management System
EC	European Commission
FAIR	Findable, Accessible, Interoperable and Reusable
FOT	Field Operational Test
GDPR	General Data Protection Regulation
GNSS	Global Navigation Satellite System
GPS	Global Position System
HTTPS	Hyper Text Transfer Protocol (HTTP) over Secure Socket Layer (SSL)
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
LL	Living Lab
MNO	Mobile Network Operator
NSA	Non-Standalone
NFV-MANO	Network Function Virtualisation (NFV) - Management And Network Orchestration (MANO)
OBU	On-Board-Units
ORDP	Open Research Data Pilot
OSM	Open-source MANO
PCT	Piraeus Container Terminal
POPD	Protection Of Personal Data
PU	Public
QoE	Quality of Experience

REST	Representational state transfer
SME	Small and Medium Enterprise
TMT	Technical Management Team
TMS	Traffic Monitoring System
TRxP	Transmission Reception Point
UE	User Equipment
UL	Uplink
VIN	Vehicle Identification Number
VSaaS	Video Surveillance as a Service
WP	Work Package

EXECUTIVE SUMMARY

The report D5.6 Spectrum Policy is aimed to analyse different logistic use cases according to their requirements for spectrum policy. Basis for the examination is the specific situation in the 3 living labs with real executed scenarios. The proofed scenarios will lead to practical 5G network performance parameters in the different areas (e.g. bandwidth, latency, scaling, service level, coverage) and will compare these values with existing parameters. The report also presents the activities of the 5G Loginnov project to influence related standard bodies and organizations.

1 INTRODUCTION

1.1 Project Introduction

5G-LOGINNOV will focus on seven 5G-PPP themes and support to the emergence of a European offer for new 5G core technologies in 11 clusters 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 ports domains by creating new opportunities for LOGistics value chain INNOVation.

5G-LOGINNOV is supported by 5G technological blocks, including a 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 trail 11 families of Use cases targeting beyond TRL7, including a GREEN TRUCK INITIATIVE using CAD/CAM and 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 significantly optimize their operations and minimize their environmental footprint to the city and the disturbance to the local population.

5G-LOGINNOV will be a catalyst for market opportunities built on 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' doors 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 essential for the significant deep-sea European ports given the mega-vessel era (Hamburg, Athens), and are also relevant for medium-sized ports with limited investment funds (Koper) for 5G.

1.2 Purpose of the deliverable

The document is aimed to evaluate the requirements from different 5G-LOGINNOV use cases for spectrum utilization. The performance needs (e.g., bandwidth, latency, scalability, availability, coverage) are mirrored on the potential technical realizations for 5G networks. Detailed technical realizations are different in the living labs (e.g. Hamburg is based on the commercial network solution, and Athens is performed on 5G project solution). The spectrum needs will also differ according to the spectrum distribution in different countries (e.g. 100 MHz private spectrum in dedicated areas).

1.3 Intended audience

This deliverable is PUBLIC intended for the following audiences:

5G-LOGINNOV partners must use the deliverable as a recorded agreement, reference, and guideline throughout the development and deployment of the innovations.
The EU and related reviewers can use the deliverable to gain insight into how the development and deployment work result in delivering the 5G-LOGINNOV innovations.
Any reader can use the deliverable to gain insight into how these kinds of innovations are tracked and realized in 5G-LOGINNOV.

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

This deliverable is structured as follows:

- Introduction to the topic, motivation and background
- Description and summary of general technical requirements for different use cases in the living labs
- Gab analysis and recommendation for spectrum usage
- Possible inputs to standardization bodies

2 SPECTRUM POLICY RECOMMENDATIONS

Evaluating 5G network performance for logistic applications is essential to ensure reliable and efficient connectivity that meets the requirements of logistics operations. Here are some key considerations for evaluating 5G network performance in the context of logistic applications:

- **Network Coverage**: Assess the 5G network coverage in the areas where logistic operations are conducted. Evaluate the availability and strength of the 5G signal to ensure reliable connectivity across the logistics infrastructure, including warehouses, distribution centres, and transportation routes.

- **Bandwidth and Throughput**: Measure the available bandwidth and throughput of the 5G network to support the data-intensive requirements of logistic applications. Evaluate the network's capacity to handle large data transfers, real-time tracking, and communication between devices and systems involved in the logistics processes.

- **Latency:** Evaluate the latency of the 5G network, which is crucial for time-sensitive logistic operations. Low latency enables real-time monitoring, control, and synchronization of various components in the logistics ecosystem, such as inventory management systems, fleet tracking, and robotic automation.

- **Reliability and Resilience**: Assess the reliability and resilience of the 5G network to ensure uninterrupted connectivity for logistics applications. Evaluate the network's ability to handle high loads, maintain consistent performance, and recover quickly from failures or network congestion. Consider redundant connectivity options to mitigate potential disruptions.

- **Quality of Service (QoS):** Evaluate the network's ability to prioritize traffic and deliver the required QoS for logistic applications. Different logistic processes may have distinct QoS requirements, such as guaranteed bandwidth, low latency, or high availability. Ensure the 5G network can provide the necessary QoS to support critical logistics operations.

- **Mobility Support**: Logistic operations often involve mobile assets such as vehicles, drones, or handheld devices. Evaluate the network's ability to provide seamless connectivity during movement and transitions between different network cells or handover areas. Assess the network's handover performance, roaming capabilities, and the impact of mobility on latency and throughput.

- **Interference and Network Congestion**: Evaluate the 5G network's susceptibility to interference and network congestion, especially in high-traffic or dense urban areas. Assess the impact of neighbouring networks, interference sources, or simultaneous usage by other applications on the performance of logistic applications. Identify potential bottlenecks and optimize network resources accordingly.

- **Application Performance Testing**: Perform end-to-end testing of logistic applications on the 5G network to evaluate their performance under realistic conditions. Test scenarios may include real-time tracking, asset management, supply chain visibility, predictive analytics, and remote monitoring. Measure response times, data accuracy, and system reliability to ensure the 5G network meets the application's performance expectations.

- **Security and Data Privacy**: Evaluate the security measures and protocols implemented in the 5G network to protect logistic applications and data. Assess encryption mechanisms, authentication protocols, access controls, and privacy safeguards to ensure the confidentiality, integrity, and availability of sensitive logistic information.

- **Scalability and Future Readiness**: Consider the scalability of the 5G network to accommodate the growing demands of logistic applications. Evaluate its ability to handle increased data volumes, support integrating emerging technologies like IoT and AI, and adapt to future logistics requirements. Assess the network's compatibility with evolving 5G standards and potential upgrades to higher frequency bands or network architectures.

It is essential to conduct comprehensive testing and evaluation of 5G network performance in collaboration with network operators, logistics providers, and application vendors. Real-world deployment scenarios, testbeds, or simulation environments can assess the network's performance and optimize logistics operations for efficiency, reliability, and cost-effectiveness.

2.1 Principles

The radio frequency spectrum is a scarce resource, which is allocated to different services having different usage parameters, e.g. mobile service, fixed service, etc. Usually, the use of a certain spectrum is permitted with the specific authorization or license, normally license costs are associated to it. Some spectrum bands, known as unlicensed or license-exempt frequency bands, can be used without a license under pre-defined technical requirements. The spectrum dedicated to public mobile networks is typically licensed, where dedicated bands are designated for mobile network operators.

It is possible to obtain private 5G licenses up to 100 MHz in dedicated areas (e.g. private port regions, factory facilities, campus areas) in some parts of Europe (e.g. Germany).
Currently identified spectrum bands may not be sufficient to fulfill future needs of mobile services including those services for improving the safety and traffic efficiency situation of logistics, road transportation systems or standard traffic support in dense urban areas.
Therefore, new spectrum needs may be necessary for long term evolution also in logistics use cases including licensed and unlicensed bands. To identify appropriate frequency bands for Loginnov use cases and V2X technologies, this deliverable investigates both licensed and unlicensed spectrum in different regions of the world, including those frequency bands being considered for 5G technologies.

The different use cases in the project require different network parameters and functions. Few examples are displayed in the following table:

	UC8/9: FTED	UC10a: GLOSA	UC11: DCET	UC10b: VRU protection
Communication range	> 1000 m	50 to 100 m	> 70 m	**10 -50 m**
data volume	30 kByte per trip km	10 KByte/s per traffic light	30 KByte per trip km	**10 KByte per intersection**
Reliability	99%	99%	99%	**99.99%**

Bit Error Rate	10-5	10-5	10-5	**10-7**
Modulation scheme	QPSK 3/4	64QAM 3/4	QPSK 1/2	**QPSK 1/2**
Sensitivity + S.N.R	**-82dBm**	**-67dBm**	**-85dBm**	**-85dBm**

Table 1: KPI requirements for dedicated use cases

Real-case approaches give the values for the different use cases.

5G Spectrum usage

5G networks operate across a range of frequencies, each with its own characteristics in terms of bandwidth and coverage. The specific frequencies and bandwidth estimation for traffic use cases can vary depending on the region, regulatory environment, and network deployment strategies. Here are some general considerations for 5G frequency bands and their potential bandwidth for different traffic use cases. These frequency bands mainly fall into three ranges: 600 MHz / 700 MHz in the low band range, 3.1-4.2 GHz and 4.4-5.0 GHz in the mid-band range, as well as 26/28 GHz and 38/42 GHz in the high band range. Identifying 5G frequency bands in low, mid, and high band ranges will enable the 5G system to fulfill a wide range of requirements of applications, ranging from wide area coverage to high system capacity.
In Europe, the following frequency bands were being considered for 5G deployment:

- **700 MHz (Band 28):** This band offers good coverage and is suitable for wide-area deployment. It can be repurposed from its previous use in digital TV broadcasting.
- **3.4-3.8 GHz (C-band):** This band offers a balance between coverage and capacity and is considered one of the primary bands for 5G deployment. It provides good capacity for urban and suburban areas.
- **26 GHz (Millimeter Wave Band):** Higher frequency bands like 26 GHz are being explored for high-capacity, short-range applications in densely populated areas. These millimeter wave bands enable incredibly high data rates but require more cell sites due to their limited coverage area.

Frequency Range 1 (FR1) covers frequency bands up to 7 GHz. These bands are in use by 1G to 4G networks, and two of the three 5G pioneer bands in Europe (694-790 MHz – called the 700 MHz-Band; 3.4-3.8 GHz – called the 3.6 GHz-Band; and above FR1, 24.25-27.5 GHz – called the 26 GHz-Band). The maximum channel bandwidth defined for FR1 is 100 MHz, due to the scarcity of continuous spectrum in this crowded frequency range. The band in this range most widely used for 5G in Europe is the 3.6 GHz-band.
Frequency Range 2 (FR2) reaches up to 33.4 GHz in Europe. In other parts of the world, higher bandwidths are in use, up to 90 GHz. Bands in this range are called millimeter wave ranges, with a shorter range, but higher available bandwidth than FR1. The minimum channel bandwidth defined for FR2 is 50 MHz, and the maximum is 400 MHz. The higher the frequency, the greater the ability to support high data-transfer speeds.

Dynamic Spectrum Sharing (DSS) is another approach to access spectrum for 5G. Existing bands (e.g. 2.1 GHz in Germany) is used on demand for 5G connectivity. DSS is standardised in 3GPP.

mmWave Bands:

Frequency Range: mmWave (millimeter-wave) bands refer to frequencies above 24 GHz, including bands like 28 GHz, 39 GHz, and 60 GHz.
Bandwidth Estimation: mmWave bands offer a significant amount of available spectrum, typically in the range of several hundred MHz up to a few GHz. Sometimes, even higher bandwidths can be allocated, enabling extremely high data rates.
Ultra-High-Speed Data: mmWave bands are well-suited for delivering ultra-high-speed data, making them ideal for applications like HD/4K video streaming, virtual reality (VR), and augmented reality (AR). MmWave bands are suitable for deployments in dense urban areas due to their ability to handle high-capacity traffic demands.
It's important to note that the exact frequency bands and bandwidth allocations for 5G can vary between countries and regulatory bodies. Additionally, network operators may utilize a combination of sub-6 GHz

and mmWave bands to optimize coverage and capacity based on the specific requirements of different traffic use cases.

The following table shows the mmWave approaches in Europe.

Source: https://www.everythingrf.com/community/5g-frequency-bands-in-europe

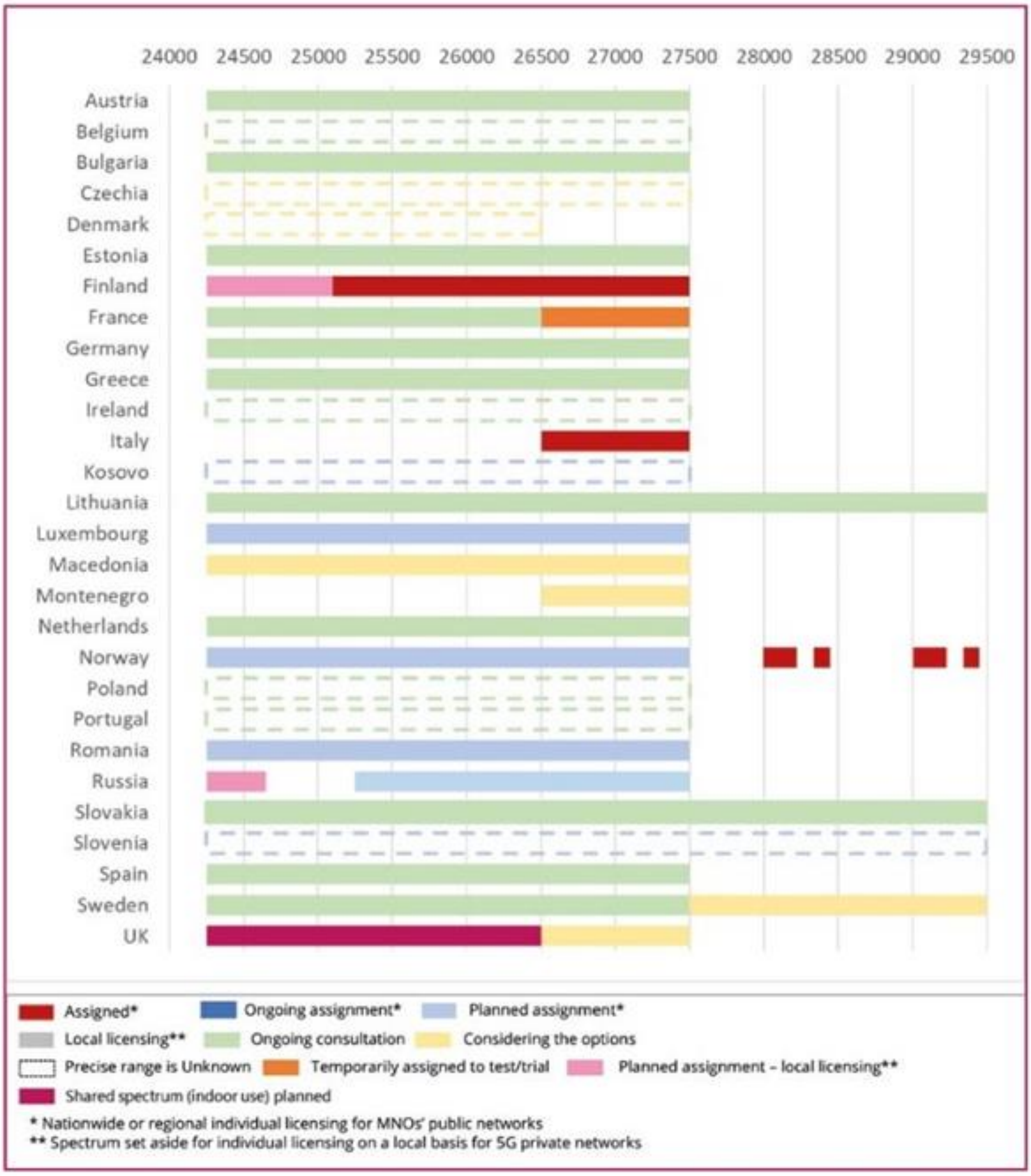

Table 2: mmWave Usage in Europe

2.2 5G Approach for Logistic Applications

The 5G Loginnov use cases have verry of different requirements for spectrum, bandwidth (uplink/downlink usage), latency, scaling and availability. Different areas should be displayed for the evaluation:

- **Network Densification:** the ambitious requirements of some use cases may need a small cell deployment. This could be costly for operators and may threaten the business model possibilities.
- **Network Slicing:** is the possibility to have "various simultaneous and different instances of a communication network" running on top of a common infrastructure. This feature shall help to boost new business models by reducing the infrastructure costs and improving the flexibility to cope with dynamic demands from services**.**
- **Mobile Edge Computing:** consists of installing and operating computing capabilities closer to the final user of a radio communication technology. Having computing capabilities closer to the user reduces latency, improves reliability, and off-loads the core and transport networks.
- **Cellular radio-based positioning and tracking:** 5G radio technologies can provide better performance than LTE and complement existing solutions based on GNSS. This feature may become crucial for autonomous driving**.**
- **Sidelink:** appears as a complementary link to operator cellular network, without using the infrastructure at least for the user traffic. These direct communications can enable new use cases and business models.
- **Integrated Moving Networks:** enabling moving vehicles to act as temporary and nomadic infrastructure for the communication network, can bring a practical extension of the cellular coverage and improve a dynamic network deployment. Sidelink Communications and its business model have to be defined.

2.3 General Use Case Requirements

The logistic use cases in the living labs help to understand the 5G network requirements for logistics. There are three main areas to evaluate:

- specific network parameters (e.g. uplink/downlink speed; latency)
- scaling effect in real operational environments (number of devices in a cell, cell structure, frequency usage, DSS etc)
- operational solutions, system design (MEC approach, network slicing, network design, coverage, service level, availability)

These aspects are connected in different ways. High traffic loads will lead to higher latency, mobile edge computing (MEC) supports lower latencies, Dynamic Spectrum Sharing (DSS) will offer more data capacity in given areas, network slicing can offer higher availabilities etc.

The evaluation for the different logistic use cases is determined by questions in different areas:

Properties: What are the business and functional needs for various properties of the service.
Challenges: What are the challenges that must be overcome to successfully take the service to market.
Needs: Specific non-functional needs that have to be fulfilled parties involved in value chain: Who are the parties necessary to create the service.
Customer: Who is the customer for the service. May be different than the person using the vehicle.
Customer benefit (Value): What is the value created by the service will drive the business for the service?
Potential 5G business model element impact: What are the new features in 5G that could affect the business model of the service?

2.4 Athens Living Lab

At the port multiple trucks arrive and depart continuously. Each truck driver can be aware of another trucks position by using a mobile app that displays location of all trucks on the port. Traditionally trucks are fitted with GPS devices that transmit data over GPRS networks. A remote server is used to receive device's GPS position. Each data transmit is based on the following simplified flow:

- Device CPU reads the GPS location.
- The device modem opens a connection.
- Location data are transmitted to the platform.
- Data are processed and pushed to mobile devices or another server for further processing.

The above flow contains a time delay between the time of the actual location and the time is visualized to the user. This process includes the following time costs:

- Device signal acquisition.
- Data post from device to server.
- Data processing on the server.
- Data transferred from the server to the device.

This use case aims to leverage the 5G low latency in order to reduce the data transit time. On top of this, the device will be configured to run as a streaming device with no network negotiation times (open/close transmit sockets etc.).

Service Name	**UC2 - Device Management Platform Ecosystem**	
Goal	**Reduce emissions by utilizing mobility data and make suggestions, offer better parking tools for truck drivers.**	
Short Description	**Based on the mobility data of trucks outside (near port, to and from the port entrances), inside the port run analytics to identify possible improvements / suggestions to reduce fuel and emissions. An updated version of the use case incorporates mobile application that leverage 5G video capabilities to generate a bird-eye view of the truck while parking.**	
Properties	Coverage	**large**
	Availability	**Medium**
	Bandwidth	**Medium**
	Latency	**Medium**
	Data volume	**Very high**
	Target endpoint(s)	**OEM backend**
	Special properties	**Dynamic definition of the environment**
Challenges	• **Data volume** • **Small area to cover and offer alternatives (not many alternative routes or waiting spots)**	

Needs	• **5G network deployment.** • **5G connected trucks.**
Parties involved in value chain	• **Vodafone** • **PCT** • **ICCS**
Customer	• **Port managers** • **Fleet managers / operators** • **Truck drivers**
Customer benefit (Value)	• **Reduce costs (fuel)** • **Reduce emissions and CO** • **Reduce time waiting**
Potential 5G business model element impact	**eMBB for end users.**

UC3 - 5G & AI enabled collision warning system

Piraeus Container Terminal relies heavily on internal yard trucks for the horizontal movement of containers between stacking areas and loading/unloading areas for vessels and road/rail. Along the routes taken by the trucks within the Port area (about 2.5 square kilometres) for facilitating the daily port operations, personnel engaged in different Port activities or other people (authorized or not), might be in close proximity. Given the size of the truck (and carried cargo), potential blind spots from the perspective of the truck driver could cause an accident with severe consequences. Towards this direction UC3 is focused in providing a cloud native 5G&AI enabled collision warning service between truck's and people in proximity. The developed service utilizes 4K (uplink) video streams (from a high-resolution camera installed on the truck) transmitted over 5G to PCT cloud, where the AI containerized service resides, and infers the presence of people in truck's close proximity. In case of positive inference, rapid alerts are delivered to the truck driver to avoid the accident. The figures below depict typical truck routes within the Port premises, within the range of the gNB.

Service Name	**UC3 - 5G & AI enabled collision warning system**	
Goal	**Optimal (near-)real time assignment of container jobs to yard trucks.**	
Short Description	**Collision warning system for blind spots utilizing video streams and human detection system**	
Properties	Coverage	**large**
	Availability	**Medium**
	Bandwidth	**Medium**
	Latency	**Medium**
	Data volume	**Very high**
	Target endpoint(s)	**OEM backend**

	Special properties	**Dynamic definition of the environment**
Challenges	• **4K Real time video stream** • **ML on video feed.**	
Needs	• **5G network deployment.** • **5G connected trucks.**	
Parties involved in value chain	• **Vodafone** • **PCT** • **ICCS**	
Customer	• **Port managers** • **Fleet managers / operators**	
Customer benefit (Value)		
Potential 5G business model element impact		

UC4-Optimal surveillance cameras and video analytics

Frequent incidents involving boom collisions, gantry collisions or stack collisions along with the presence of stevedoring personnel within the Port area make the risk for serious bodily injuries considerable. Hence, detecting the presence of people in high-risk areas, e.g., areas with intensive crane and/or truck operations, is of paramount importance for the Port operator for ensuring a safer environment in daily operations for employees and visitors. Additionally, AI-enabled surveillance can further aid Port security by detecting the presence of people in restricted areas, e.g., close to a warehouse area. Towards this direction, UC4 focused on the development of a cloud native 5G&AI-enabled human presence detection service. The developed solution exploits the eMBB service of 5G to transmit the 4K (uplink) video streams of the relevant areas, which are exploited by the developed ML service for the inference task of human presence detection, and based on the inference result generate in real-time respective alerts (i.e., live inference/annotated streams to security patrols, or PCT's central monitoring system).

Service Name	**UC4-Optimal surveillance cameras and video analytics**	
Goal	**Minimizing risk for bodily injuries in specified areas. Real-time video surveillance with portable and mobile capabilities.**	
Short Description	**Use of AI in video security stream to alert of human detection and proximity to dangerous or unauthorized areas.**	
Properties	Coverage	**large**
	Availability	**Medium**
	Bandwidth	**Medium**

	Latency	**Medium**
	Data volume	**Very high**
	Target endpoint(s)	**OEM backend**
	Special properties	**Dynamic definition of the environment**
Challenges	• **Real time video feed** • **ML on human detection and real time alerting mechanisms**	
Needs	• **5G network deployment.** • **5G connected cameras.**	
Parties involved in value chain	• **Vodafone** • **PCT** • **ICCS**	

UC5-Automation for ports: port control, logistics and remote automation

Use case 5 is focused on port control, logistics and remote automation, and aims at detecting the presence/absence of container seals without intervention from human personnel. To this purpose, operating port machinery (such as lifts, forklifts, terminal tractors, etc.) will be equipped with industrial 4K cameras for capturing Ultra-High Definition (UHD) images and/or video streams that will be transmitted to the MANO platform utilizing the broadband 5G network at PCT. Each camera will be directly connected to a novel 5G-IoT device that will additionally be equipped with an on-board GPU (e.g. Jetson AGX Xavier Developer Kit), to perform locally, based on computer vision techniques, image/video processing tasks that detect the presence or absence of container seals. The inference of the model (i.e. seal present/absent) will be transmitted to the MANO platform in real time over the 5G network.

Service Name	UC5-Automation for ports: port control, logistics and remote automation	
Goal	**Automated support for detecting the presence/absence of container seals.**	
Short Description	**Automate port operations; detecting the presence/absence of container seals without intervention from human personnel.**	
Properties	Coverage	**large**
	Availability	**Medium**
	Bandwidth	**Medium**
	Latency	**Medium**
	Data volume	**Very high**

	Target endpoint(s)	**OEM backend**
	Special properties	**Dynamic definition of the environment**
Challenges	• **Real time video feed** • **ML on image recognition – seals -, human presence and real time alerting mechanisms**	
Needs	• **5G network deployment.** • **5G connected trucks.**	
Parties involved in value chain	• **Vodafone** • **PCT** • **ICCS**	

UC7-Predictive Maintenance

Predictive maintenance is a significant contributor to increasing operational efficiency and reducing unplanned downtime of expensive equipment by identifying and solving problems before they occur. In PCT, the maintenance of yard vehicles is currently performed with regularly scheduled manual checks; thus, a lot of issues are identified at breakdown. Within UC7, 5G access points will be installed aboard yard vehicles and will be connected to existing data sources (e.g. CAN-Bus, sensors for container presence, TOS terminals, etc.); the 5G access points will collect in real-time telemetry data and will forward them to the MANO orchestrated platform over the 5G network (low latency) via the relative API, where the AI logic for the predictive maintenance service will reside (Figure 18). The proposed tool will capture historical and recent status data for the assets in question, by taking advantage of 5G technology that provides a flexible, reliable and predictable environment to remotely keep track of the connected assets on a real time basis.

Service Name	UC7-Predictive Maintenance	
Goal	**Reducing port operational costs through predictive maintenance.**	
Short Description	**Using a variety of sensors and historical data this UC aims to predict maintenance tasks in advance.**	
Properties	Coverage	**large**
	Availability	**Medium**
	Bandwidth	**Medium**
	Latency	**Medium**
	Data volume	**Very high**
	Target endpoint(s)	**OEM backend**

	Special properties	**Dynamic definition of the environment**
Challenges	• **5G network deployment.** • **5G connected trucks.**	
Needs	• **Vodafone** • **PCT** • **ICCS**	

2.5 Hamburg Living Lab

The Hamburg Living Lab is using the standard 5G (NSA) network from Deutsche Telekom. This network is using DSS and can support a 3rd party solution for MEC.

This combination can support all the actual Hamburg Living Lab use cases in a sufficient way (capacity/latency). Future developments of the services (based on the selected use cases) may lead to scaling issues. This aspect is covered in the chapter performance evaluation.

UC Floating Truck & Emission Data (FTED)
The automatic detection and evaluation of driving manoeuvres (based on real data from individual vehicles), their resulting effect on emissions and the related influence of infrastructure are key when it comes to the demonstration and proof of the effectiveness of a dynamic traffic management. The large number of vehicles in an urban environment requires a bidirectional communication infrastructure with a high bandwidth and a low latency. Therefore, 5G is a "must" requirement to ensure a secure and reliable communication strategy.

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Service Name	**UC8/9 - Floating Truck & Emission Data (FTED)**	
Goal	**automatic detection and evaluation of driving manoeuvres**	
Short Description	**Analyzing the behaviour of the vehicle in order to detect the vehicle problems and to optimize OPEX**	
Properties	Coverage	**Medium**
	Availability	**Medium**
	Bandwidth	**Medium**
	Latency	**High**

	Data volume	**Very high**
	Target endpoint(s)	**OEM backend**
	Special properties	**Dynamic definition of the environment**
Challenges	• **Artificial intelligence to be integrated** • **High data volume expected**	
Needs	• **Exchange between the on-board and backend**	
Parties involved in value chain	• **Car OEM** • **Tier1 vehicle control unit supplier** • **Mobile network operators**	
Customer	• **Fleet operator** • **Car OEM**	
Customer benefit (Value)	• **End customer – Higher satisfaction with the product usage and optimizes the TCO**	
Potential 5G business model element impact	• **Network slicing** • **Mobile Edge Computing (MEC): to increase and improve the exchanges** **between the on-board and backend. It could be used for a specific road or situation (urban environment, motorway)**	

5G GLOSA & Automated Truck Platooning (ATP)-under 5G-LOGINNOV Green initiative

The basis for proving and demonstrating the effectiveness of GLOSA in interaction with ATP is, in addition to a safe and target-oriented communication strategy and environment, the automatic recognition and evaluation of the emission impact of driving manoeuvres, and the related influence of the infrastructure, TMS systems and TMS GLOSA measures. The driving manoeuvres are classified into characteristic cases (braking, accelerating, constant speed) and linked to the static infrastructure characteristics (curve, uphill, downhill); in parallel, the dynamic traffic control systems (traffic lights, lane and speed displays) are recorded/localised (and located as specific GLOSA POIs) and the specific information need/available content is queried and structured.

Service Name	UC8/9 - Floating Truck & Emission Data (FTED)	
Goal	**automatic recognition and evaluation of the emission impact of driving manoeuvres**	
Short Description	**Analyzing the behavior of the vehicle in order to detect the vehicle problems, reduce fuel consumption.**	
Properties	Coverage	**large**
	Availability	**Medium**
	Bandwidth	**Medium**
	Latency	**Medium**
	Data volume	**Very high**
	Target endpoint(s)	**OEM backend**
	Special properties	**Dynamic definition of the environment**
Challenges	• **Real-time information to be treated** • **Artificial intelligence to be integrated**	
Needs	• **Exchange between the on-board and GLOSA backend**	
Parties involved in value chain	• **Car OEM** • **Tier1 vehicle control unit supplier** • **GLOSA operators**	
Customer	• **End customer** • **City administration**	
Customer benefit (Value)	• **End customer – Higher satisfaction with the product usage and optimizes the TCO**	
Potential 5G business model element impact	• **Mobile Edge Computing (MEC): to increase and improve the exchanges**	

Dynamic Control Loop for Environment Sensitive Traffic Management Actions (DCET)

Virtual Traffic Management System is located in the Cloud and can be used for different application areas, e.g. to inform different road user groups about the city air quality, as well as to collect, analyse, take decisions and act managing the traffic related to the port and Hamburg City, in order to decrease the air pollution resulting from motorized traffic.

Service Name	UC8/9 - Floating Truck & Emission Data (FTED)	
Goal	**Virtual Traffic Management System for detection pollution data in order to decrease the non-quality costs and improve customer satisfaction.**	
Short Description	**inform different road user groups about the city air quality, as well as to collect, analyze, take decisions and act managing the traffic related to the port and Hamburg City**	
Properties	Coverage	**Large**
	Availability	**Low**
	Bandwidth	**Medium**
	Latency	**High**
	Data volume	**Very high**
	Target endpoint(s)	**OEM backend**
	Special properties	**Dynamic definition of the target values**
Challenges	• **Adaptation to actual information needs** • **Artificial intelligence to be integrated.**	
Needs	• **Exchange between the on-board and backend**	
Parties involved in value chain	• **Car OEM** • **Tier1 vehicle control unit supplier** • **City authorities**	
Customer	• **End customer** • **Car OEM**	
Customer benefit (Value)	• **End customer – Higher satisfaction with the product usage** • **Reduction of air pollution**	
Potential 5G business model element impact	• **Network slicing** • **Mobile Edge Computing (MEC): to increase and improve the exchanges**	

Key performance evaluation for UC's HH

VRU protection UC (collision avoidance)

The Vulnerable Road User protection (VRU protection) use case will be relevant for nearly all people in the service area. The service area can be described by the following parameters (working assumptions):

- bandwidth need per VRU / per and car up / down 10 kbit/s up / 10 kbit/s down
- service area 10 qkm (2 x 5 km) pre-port area TAFV
- number of base stations per qkm 50, number of sectors / beams 10
- capacity 3,6 GHz per beam (90 MHz x 6 Bit/Hz → 540 Mbit/s)
- number of parallel streams per intersection (number of VRU's and cars) 100
- intersection per cell 1
- max service latency 100 ms

The use case will be covered by standard 5G networks (low bandwidth requirements). The requested service latency should by supported with MEC approach.

In 6G networks the VRU protection can be improved by advanced object detection in mmWave bands (25 GHz and higher).

GLOSA (Green Light Optimal Speed Advisory)

The GLOSA service has limited requirements for capacity (1 Kbit/s) and latency (500ms). Service upscaling is not critical for 5G networks:
number of traffic lights per intersection 10
user per intersection / per direction 100
intersections per cell 1

The use case requirements will be covered by standard 5G networks.

5G throughput evaluation

The following chapter will present a theoretical example of the 5G user capacity and will compare this calculation with the measurement results in the living lab HH.

The capacity for a given 5G terminal will be influenced by following aspects:

- RF modulation order can be related to MCS values, for uplink and downlink, relate it to a CQI ref TS 38.214, chap. 5.2.2.1]
- Number of MIMO Layers or number of antenna.
- SCS and carrier bandwidth
- Frequency group, FR1, or FR2
- TDD pattern format, these one carry some importance because different patterns do favor UL throughput demanding service.
- Number of active UEs

$$\text{data rate (in Mbps)} = 10^{-6} \cdot \sum_{j=1}^{J\Sigma} \left(v_{Layers}^{(j)} \cdot Q_m^{(j)} \cdot f_{\square}^{(j)} \cdot R \frac{N_{PRB}^{BW(j),\mu} \cdot 12}{T_s^{\mu}} \left(1 - OH^{(j)}\right)_{max} () \right)$$

(Remark: The estimation is done for FDD)

The table below shows a example scenario, were assumed a cell into the FR1 band, only one carrier[no aggregation], with a SCS of 30 Khz and carrier bandwidth for 100 MHz, Duplexing mode: TDD with a pattern 45 were the "F" Symbol are 80 percent DL, giving then a relationship of DL 7,6:14 and UL 6,4:14, the excel table used for the calculations in attach:

Parameter	Description	Value
j	, # of carriers	1
$V^{(j)}$	, MIMO Layer	2
$Q_m^{(j)}$	Modulation Order	4
$f^{(j)}$	Scaling factor	1
R_{max}		0,92578125
NPRBBW(j).µ	RB allocation	162
T_s^{μ}	Average OFDM symbol duration in a subframe for µ value	3,57143E-05
OH	Overhead, Freq Band Dependent	0,14
µ		1
TDD DL factor	7,6:14	0,542857143
TDD DL factor	6,4:14	0,457142857
		Calculated Value
DL Trougthput	DL trougthput per cell	**188,207388**
DL Trougthput	UL trougthput per cell	**158,490432**

Table 3: Theoretical Bandwidth Calculation for 5G Connection

These theoretical values are reached in the living lab. The DSS approach (using multiple bands) leads to figures higher than the calculated amount.
The values for the MEC scenario are higher than in the Azure configuration. This can be explained by the direct connection from the user to the MEC server (no large network configuration in between).

Field Measurements with MEC HH

Measurement	Max. Bandwidth [MBit/s]	Average [MBit/s]	Standard Deviation [MBit/s]
2022-09-13-11-05-12.json	370.3	210.6	90.5
2022-09-13-12-00-46.json	366.9	189.8	94.0
2022-09-13-14-24-28.json	354.3	225.1	72.9
2022-09-15-10-50-38.json	380.1	209.1	84.5
2022-10-04-12-35-12.json	**420.1**	160.9	88.6
2022-10-05-11-32-31.json	416.9	153.5	95.6
2022-10-05-14-54-25.json	388.8	239.4	73.5
2022-10-06-10-54-59.json	383.5	207.7	75.7
2022-10-06-12-01-44.json	357.7	217.8	74.7
2022-11-22-11-05-08.json	280.8	186.2	58.0
2022-11-22-11-26-01.json	316.4	187.5	66.2
2022-11-22-11-52-24.json	242.0	103.9	55.3
2022-11-23-11-03-09.json	323.5	190.3	75.5
2022-11-23-11-26-52.json	296.3	143.2	75.4
2022-11-24-11-08-22.json	283.0	176.9	51.4
2022-11-24-11-51-47.json	293.5	142.7	69.6
2022-11-24-12-17-39.json	324.1	203.5	67.7
		184.4	**83.8**

Field Measurements Azure HH

Measurement	Max. Bandwidth [MBit/s]	Average [MBit/s]	Standard Deviation [MBit/s]
2022-09-14-10-17-26.json	182.6	59.6	41.1
2022-09-14-13-45-15.json	109.8	47.3	27.8
2022-10-04-15-20-02.json	182.4	57.8	45.0
2022-10-05-10-20-51.json	**187.6**	59.8	41.1
2022-10-05-14-14-03.json	184.0	60.3	43.1
2022-10-06-12-24-29.json	174.1	50.0	40.3
2022-11-22-14-32-16.json	**187.6**	58.7	37.9
2022-11-23-13-08-40.json	182.8	59.0	41.0
2022-11-24-10-18-49.json	183.8	72.1	43.4
2022-11-24-13-16-15.json	182.8	58.1	41.1
2022-09-15-11-33-25.json	149.2	44.5	29.9
2022-09-15-13-37-12.json	179.2	72.8	38.5
2022-11-22-14-55-42.json	105.3	50.4	24.5
2022-11-22-15-08-20.json	82.7	45.0	17.2
		58.5	**39.6**

Signal Latency HH

	Trial	Measurement	Average RTT [ms]	Average Total [ms]
No MEC	#1	Azure2022-09-14-11-11-14.csv	24.8 ± 10.7	25.3 ± 10.5
	#1	Azure2022-09-14-14-27-47.csv	27.7 ± 8.7	
	#1	Azure2022-09-14-11-39-19.csv	23.9 ± 11.5	
MEC	#1	MEC2022-09-14-10-41-57.csv	21.7 ± 10.8	21.6 ± 11.3
	#1	MEC2022-09-15-11-58-33.csv	21.5 ± 9.6	
	#2	MEC2022-10-04-13-02-51.csv	21.6 ± 14.4	

Compare 5G throughput model results with measurement results in Living Lab HH
Real performance (with DSS, channel bundling, LTE combination, low 5G usage)
The measured figures are inline with the theoretical calculation. Extreme high data rates can be explained by a low 5G usage rate for the observed time frame and the possibility to use multiple base stations in parallel.

2.6 Koper Living Lab

UC 5G-LOGINNOV MANO for Port Automation

The automated deployment and life cycle management of a network and applications in a 5G-enabled port environment are paramount for the modernization and optimization of port operations. As ports are bustling hubs of activity with diverse operational needs, a seamless integration of 5G technology, coupled with tools like VNF, CNF, Kubernetes, and OpenStack, is essential. Such a setup not only provides agility but also ensures the reliability of operations. This adaptive infrastructure brings forth a high level of efficiency, scalability, and resilience, meeting the specific demands of the Port of Koper. The use of 5G, with its high bandwidth and low latency capabilities, is crucial for fostering an environment where data-intensive operations and IoT-driven applications coexist and operate in harmony, driving the port towards Industry 4.0 standards.

Service Name	UC 5G-LOGINNOV MANO for Port Automation	
Goal	**Demonstration of automated deployment and life cycle management of a network and applications in a 5G-enabled port environment.**	
Short Description	**Automating the network infrastructure of the Port of Koper using 5G technology, integrated with VNF, CNF, Kubernetes, and OpenStack to enhance operational functions and services.**	
Properties	Coverage	**Comprehensive**
	Availability	**High**
	Bandwidth	**High**
	Latency	**Low**
	Data volume	**Very high**
	Target endpoint(s)	**Port of Koper IoT and 5G applications**
	Special properties	**Integration with 5G, Kubernetes, and OpenStack to optimize port operations**
Challenges	• **Developing and implementing a private 5G system tailored for the port.** • **Ensuring compliance with security and legislative standards.** • **Introducing a 5G IoT platform and corresponding devices.**	
Needs	• **Creation of a robust and adaptive 5G network optimized for the port's needs.** • **Automated integration and management with VNF and CNF components.**	

Parties involved in value chain	• **5G-LOGINNOV project partners.** • **Infrastructure solution providers (e.g., Kubernetes, OpenStack).** • **Mobile operator: Telekom Slovenije**
Customer	• **Port of Koper** • **Partners and stakeholders in the port benefiting from the 5G services.**
Customer benefit (Value)	• **Improved automation and efficiency of port operations.** • **Enhanced reliability and speed of the communication infrastructure.**
Potential 5G business model element impact	• **Network slicing: Provisioning separate network segments for different services and users within the port.** • **Mobile Edge Computing (MEC): Enhancing capacity and reducing latency for critical port applications.**

5G Automation for Ports: Control, Logistics & Remote Automation

UC5 exemplifies the next frontier in port operations by harnessing 5G's rapid communication capabilities for improved logistics, port control, and remote automation. By integrating real-time 4K UHD video streams from STS cranes equipped with industrial cameras, the system can swiftly identify container markers and detect structural damages with advanced AI/ML techniques. Moreover, telemetry data from crucial port equipment is seamlessly transmitted over the 5G network, providing invaluable real-time insights. As part of the 5G-LOGINNOV initiative, UC5 positions Luka Koper at the forefront of modern port operations, merging advanced technology with operational efficiency.

Service Name	**UC - 5G Automation for Ports: Control, Logistics & Remote Automation**	
Goal	**Streamline port operations through the integration of 5G for enhanced logistics, port control, and remote automation.**	
Short Description	**Analysing the behaviour of the vehicle in order to detect the vehicle problems, reduce fuel consumption.**	
Properties	Coverage	**Large**
	Availability	**High**
	Bandwidth	**High**
	Latency	**Low**
	Data volume	**Very high**

	Target endpoint(s)	**Luka Koper operations center and infrastructure backend**
	Special properties	**Dynamic response to port traffic patterns and conditions.**
Challenges	**Real-time data processing from multiple sources (cameras, telemetry)** **Integration and synchronization of AI/ML techniques with video analytics** **Achieving low-latency responses in high-traffic scenarios**	
Needs	**Seamless data exchange between port machinery, vehicles, and the advanced port operational backend.** **Consistent 5G connectivity across the port for uninterrupted data transfer.**	
Parties involved in value chain	**Industrial camera suppliers** **AI/ML video analytics providers: Vicomtech** **5G system providers: Telekom Slovenije, Internet Institute** **Port machinery telemetry providers: Continental**	
Customer	**Luka Koper port administration and operations** **Equipment operators within Luka Koper**	
Customer benefit (Value)	**Enhanced efficiency in port operations through real-time insights.** **Accurate and swift identification of container markers and damages, reducing operational delays.** **Proactive equipment maintenance based on telemetry data, reducing downtimes.**	
Potential 5G business model element impact	**Network slicing: To ensure dedicated and optimized 5G connectivity for various port operations.** **Mobile Edge Computing (MEC): Facilitating on-site data processing and analytics, enhancing operational responsiveness.**	

5G-Enhanced Mission Critical Surveillance for Port Security

Leveraging 5G capabilities, this advanced surveillance system is deployed within Luka Koper. Combining body-worn cameras, drone-based surveillance, and AI-driven video analytics, it aims to revolutionize port security operations. The primary objective is real-time, comprehensive monitoring of critical areas, including railway entrances and vehicular gates. This system also empowers security personnel with real-time insights and critical alerts, ensuring swift responses to security events, all backed by the reliability and speed of 5G.

Service Name	UC Mission Critical Surveillance in Port security	
Goal	**Implement real-time, 5G-enabled video surveillance and analytics to enhance port security operations.**	
Short Description	**Deployment of 5G-enhanced body-worn cameras, portable video surveillance cameras, drone surveillance, and advanced AI/ML video analytics for comprehensive port security, including motion detection and vehicle classification.**	
Properties	Coverage	**Large**
	Availability	**High**
	Bandwidth	**HIgh**
	Latency	**Low**
	Data volume	**Very high**
	Target endpoint(s)	**Port Security Operation Centre**
	Special properties	**Dynamic surveillance based on security needs.**
Challenges	• **Integration of various video sources (body-worn, drone, portable cameras).** • **Legislative and privacy concerns related to real-time video streaming.** • **Reliability demands of the 5G infrastructure for mission-critical operations.**	
Needs	• **Reliable 5G infrastructure for real-time video transfer.** • **Advanced video analytics platform for automated motion detection and vehicle classification.** • **Dedicated application for security management operation.**	
Parties involved in value chain	• **Luka Koper: Port Operator, Trial Leader** • **Telekom Slovenije: Provider of commercial 5G system**	

	• **Internet Institute: Provider of private 5G system, MANO orchestration platform, and 5G IoT platform** • **Vicomtech: Provider of advanced video analytics**
Customer	• **Luka Koper Port Security and Administration**
Customer benefit (Value)	• **Enhanced real-time surveillance capabilities, ensuring port security.** • **Efficient monitoring of various port areas using diverse surveillance methods.** • **Automated motion detection and vehicle classification, optimizing security responses.** • **Improved security personnel management and operational insights.**
Potential 5G business model element impact	• **Network slicing: Dedicated connectivity for mission-critical security operations.** • **Mobile Edge Computing (MEC): Real-time analytics and response based on video streams and data insights.**

2.7 Spectrum Requirements

The 5G LOGINNOV use cases show the importance of different new 5G network features, like addressing high numbers of end systems, high data rates in up-link direction, precise positioning (10 cm), and data computing in distributed environments (MEC).

These working areas are addressed with the following solutions:

Multicast & broadcast transmissions in dedicated cells (areas)

Multicast is efficient for transmitting data to multiple recipients simultaneously. It reduces network traffic by sending a single copy of the data to multiple recipients, rather than individual copies to each recipient.

Multicast scalability for scenarios where there are many recipients. The sender only needs to send one copy of the data, regardless of the number of receivers.

Since data is sent to a group of recipients, it conserves network bandwidth and resources. This is particularly useful for multimedia streaming or software updates in large networks.

Multicast is ideal for real-time applications like video conferencing, live streaming, and positioning, where all recipients must receive data simultaneously with low latency.

The choice between multicast and unicast transmission depends on the specific requirements of a given network and application. Multicast is more efficient for one-to-many scenarios, while unicast is better suited for one-to-one communication with guaranteed delivery. Consider the network's size, bandwidth constraints, security needs, and application requirements when selecting the appropriate transmission method.

Video transmission uplink direction

The logistic use cases have the requirement to get support for up-link data rates up to 50 Mbit/s. This will lead to adapting the configuration in the mobile network (capacity distribution between up-link and down-link). 5G offers the possibility for a flexible configuration of such parameters (TDD pattern).

Regional pre-computation with Mobile Edge Computing

Mobile Edge Computing (MEC) offers several advantages that can significantly enhance the performance and capabilities of mobile networks in the logistic area. Here are some of the key advantages of Mobile Edge Computing:

- **Low Latency**: MEC brings computing resources closer to the end-users and devices, reducing the round-trip time for data to travel to distant data centers. This results in ultra-low latency, making it ideal for real-time applications such as augmented reality (AR), virtual reality (VR), online gaming, and autonomous vehicles.
- **Improved Quality of Service**: Lower latency and reduced network congestion at the edge enable a higher quality of service, enhancing the user experience for applications that demand fast response times and reliability.
- **Bandwidth Efficiency**: By processing data at the edge, MEC can filter and compress data before transmitting it to the cloud, reducing the amount of data sent over the network. This helps optimize network bandwidth and lower operational costs.
- **Local Data Processing**: MEC enables local data processing, which is beneficial for applications that require real-time decision-making based on local data. This is crucial for applications like predictive maintenance, IoT sensors, and industrial automation.
- **Enhanced Security and Privacy**: Local data processing and reduced data transfer to the cloud can enhance security and privacy by minimizing the exposure of sensitive data to potential threats in transit. It allows for more control over data handling.
- **Scalability**: MEC architecture is scalable and can be deployed distributed, making it easy to add new edge servers or clusters as needed to accommodate increased workloads.
- **Content Caching**: MEC servers can cache frequently requested content and applications at the edge, reducing the need to fetch data from distant data centers. This not only improves content delivery but also conserves network resources.
- **Location-Based Services**: MEC can support location-based services, enabling businesses to deliver personalized content and advertisements to users based on their geographical location, enhancing user engagement.
- **Resource Offloading**: By processing data locally, MEC can offload the central cloud infrastructure, reducing the load on data centers and freeing up resources for other tasks and applications.
- **Reduced Backhaul Costs**: By handling data locally, MEC can reduce the reliance on expensive backhaul connections between cell towers and data centers, saving operational costs.

In summary, Mobile Edge Computing is a technology that can revolutionize how applications and services are delivered in mobile networks. Its low latency, improved quality of service, and other advantages makes it particularly well-suited for logistic use cases.

On the other hand, MEC needs heavy investments in a distributed computing infrastructure.

Precise positioning

Precise positioning in mobile networks refers to the ability to determine the exact geographical location of a mobile device or user with high accuracy. This capability is essential for a wide range of applications in the logistics area. Precise positioning is becoming increasingly important with deploying advanced technologies like 5G and the growth of the Internet of Things (IoT). There are several methods and technologies used for achieving precise positioning in mobile networks:

- **Global Navigation Satellite Systems** (GNSS): GNSS, such as the Global Positioning System (GPS), is a widely used technology for precise positioning. Mobile devices have built-in GPS receivers that can triangulate their position using satellite signals. GPS provides high accuracy in outdoor environments but may have limitations in urban canyons and indoor areas.
- **Assisted GPS** (A-GPS): A-GPS improves GPS performance by utilizing assistance data from the cellular network to acquire GPS satellite signals faster and with greater accuracy. It is beneficial for reducing the time required to obtain a GPS fix.
- **Wi-Fi Positioning**: Wi-Fi positioning relies on the signals from Wi-Fi access points to estimate a device's location. This method is effective in indoor environments and urban areas with dense Wi-Fi coverage. It can also be combined with other positioning technologies for better accuracy.
- **Cellular Triangulation**: Cellular networks can estimate a device's location by triangulating its position based on the signal strength and timing of transmissions from nearby cell towers. This method is less accurate than GNSS but works in urban areas and indoors where GPS signals may be weak.
- **Bluetooth and Bluetooth Low Energy** (BLE) Beacons: Bluetooth and BLE beacons can be used for precise positioning within small areas, such as indoor spaces, retail stores, and warehouses. Devices can determine their position relative to the beacons.
- **Inertial Sensors**: Mobile devices often include accelerometers and gyroscopes, which can estimate a user's movement and orientation. Combining this data with other positioning methods can improve accuracy, especially in cases where GNSS signals are weak or unavailable.
- **Sensor Fusion**: Sensor fusion combines data from multiple sensors, such as GNSS, Wi-Fi, cellular, and inertial sensors, to improve positioning accuracy and reliability. Advanced algorithms and machine learning can be applied to optimize sensor fusion.
- **5G NR** (New Radio): 5G networks offer features that enhance precise positioning, including support for centimeter-level accuracy through technologies like "5G NR Positioning" and "Time Sensitive Networking (TSN)." These technologies are valuable for applications like autonomous vehicles and industrial automation.
- **Network-Based Positioning**: Mobile networks can use network-based positioning methods to estimate a user's location. This may involve measuring signal delays, signal strengths, and other parameters from the device to multiple cell towers. While less accurate than GNSS, it can be useful for network management and non-GNSS-enabled devices.
- **Geospatial Augmentation**: Geospatial augmentation techniques involve the use of additional data sources, such as terrain models, building layouts, and environmental factors, to improve the accuracy of positioning, especially in challenging environments.
- **Hybrid Positioning**: Many modern positioning systems use hybrid approaches that combine multiple positioning technologies to achieve the highest accuracy. For example, combining GNSS, Wi-Fi, and cellular data can provide robust and precise positioning.
- **Crowdsourced Data**: Data from other users' devices can be aggregated to improve positioning accuracy. Crowdsourcing can be especially useful in real-time applications and refining map and location databases.

The choice of precise positioning method depends on the specific use case, accuracy requirements, and environmental conditions. In many scenarios, a combination of multiple positioning technologies is employed to achieve the best results. The continued advancement of technology and the rollout of 5G networks are expected further to enhance the capabilities of precise positioning in mobile networks.

3 STANDARDISATION ACTIVITIES

3.1 Introduction and Overview

The rather complex relationship between different standardization bodies dealing with mobile communication is depicted in *Figure 1*. The overall standardization body International Telecommunication Union (ITU) with its sector for International Mobile Telecommunication (IMT) defines technical and service requirements leading to reports and technical specifications defining technologies classified as 3rd Generation Partnership Project (3GPP).

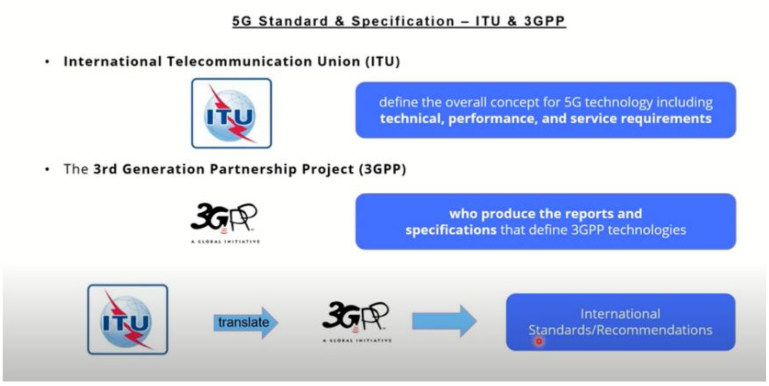

Figure 1: Standardization bodies (top level)

The first edition of the IMT-2020 specifications, the name used in ITU for the standards of 5G, has been published in February 2021 (ITU-R M. 2150). Since then, more than 200 commercial launches across the world and more than 1200 announced devices (at least 870 commercially available) can be noted, according to www.ITU.int media centre. The context of the different Releases is shown in Figure *2*.

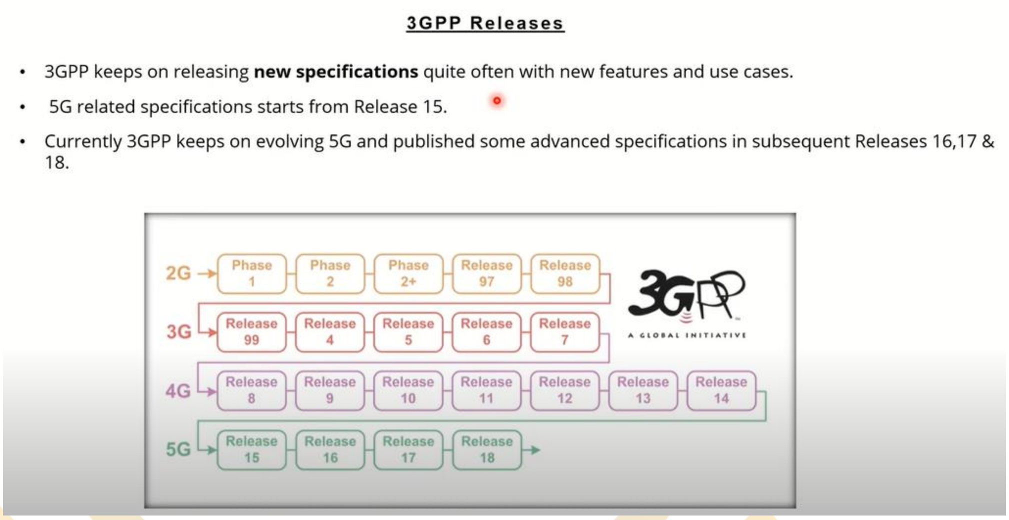

Figure 2: 3GPP Releases leading to 5G technologies.

Finally, it has to be mentioned that the 5G-PPP user eco-system includes numerous organisations and stakeholders related to solutions leading to future commercial applications. This is shown in Figure *3* . It has to be highlighted that ERTICO and 5G-AA are important Vertical Associations complemented by Transport & Logistics covering Vertical Industry and Research.

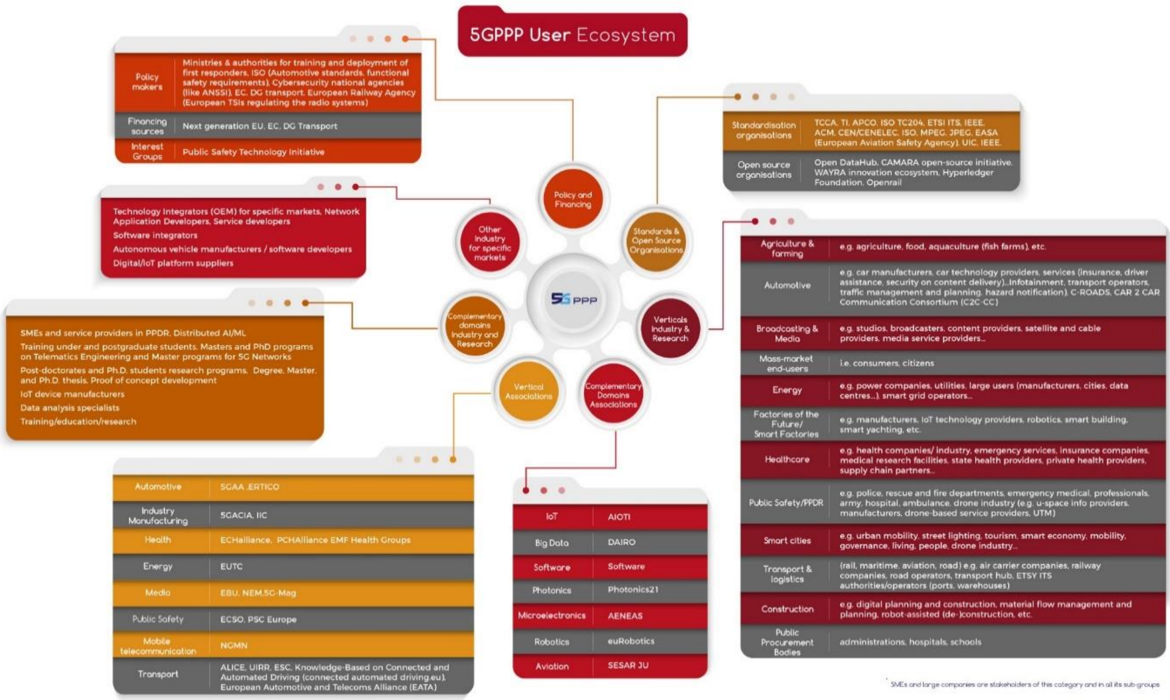

Figure 3 – Stakeholder mapping and sectors engaged in 5GPPP

Whereas the Technical Specification Groups of 3GPP define key feature and use cases for new Releases, there is additional need for specific Information Elements for enabling Nomadic Devices and Mobile Networks to exchange data. This leads to use cases on top of the 5G infrastructure linked to transport. Chapter 3.2 will describe further details in the following paragraphs.

3.2 ISO TC204-WG17 Nomadic Devices in ITS Systems

3.2.1 Introduction

ISO TC204 is the International ITS committee. It was originally called Transport Information Control Systems (TICS) but changed its name to Intelligent Transport Systems several years ago. This was the second ITS standardisation body to start after CEN TC278.

TC204 was patterned on TC278, and the cooperation is regulated by the Vienna Agreement (VA) between ISO and CEN, which means that many working groups have joint meetings to ensure alignment.

ISO TC204 Working group17 (WG17) "Nomadic Devices in ITS Systems" started initially looking at the integration of smart phones in cars.

The work now includes the use of nomadic and mobile devices to support ITS service and multimedia provision in vehicles. The work relates to vehicle interfaces or gateways for vehicle-internal data access including security, data definitions and protocols.

Several standards are in the process of completion. Part of the work regarding vehicle gateways has met some opposition from car makers, but an agreement with ISO TC22 has clarified most of the challenges. Its convenor is Dr. Young-Jun MOON from the republic of Korea. Experts from Europe are following the work closely.

3.2.2 New standard for the estimation of CO_2 emissions

In the framework of 5G-LOGINNOV and earlier funded pan-European projects, T-Systems developed a methodology to obtain information about the energy behaviour per trip. This led to a low-cost solution called Low Carbon Mobility Management (LCMM) for which a cloud platform architecture has been developed and applied in a number of pan-European logistics projects. The solution considers the economic constraints felt by most logistics companies and their difficulties in investing in the introduction of new technologies. A plug-&-play solution is adopted, where GPS data provided by the vehicles (typically cargo trucks) is sent to a database, elaborated, analysed, mapped, and then given back in a simplified version to drivers and dispatchers.

The service uses in-vehicle nomadic and mobile devices and a client server architecture where the dynamic speed profile per second is evaluated with fixed vehicle configuration parameters inside the server. With the near real-time communication between the nomadic device (ND) and the server, the results of the calculation can also be made visible to the driver during the trip for eco-drive purposes.

The application allows NDs to become a measurement tool for quantifying the energy contributions and inertia forces of a moving vehicle in units of [%] relative to the virtual vehicle moving along the reference cycles.

ERTICO presented LCMM already in September 2018 at the G-ITS workshop held at the 52nd ISO TC204 plenary meeting in Budapest. The document was received enthusiastically by the meeting participants and the WG17 convenor invited ERTICO and T-Systems to formalise the LCMM methodology into an ISO standard. This kind offer was accepted and under the 5G-LOGINNOV budget ERTICO proceeded the document throughout the ISO standardisation process until the publication as ISO 23795:2022 “Intelligent transport systems — Extracting trip data using nomadic and mobile devices for estimating CO2 emissions — Part 1: Fuel consumption determination for fleet management”

The document can be used by fleet operators, logistic service providers, public transport operators and eco-drive trainers to develop applications which allow the measurement (in units of [%]) of the energy consumption in litres of gasoline or diesel equivalent (in joules or kWh), relative to the energy consumption of a given standard vehicle.

3.2.3 5G-LOGINNOV Use Cases in ISO TR 17748-1

In 2022, WG17 founded two sub-WG (SWG) to more efficiently cover specific aspects of the ITS related use of nomadic devices.

SWG17.1 aims to develop a series of international standards which define the roadside infrastructure supported location based services and specify general requirements and use-cases for providing the services on nomadic & mobile devices for vulnerable road users (VRU) and connected and/or automated mobility to be applicable in specific roadway sections, such as pedestrian crossings, school zones, unsignalized intersections, T-intersections, roundabouts, weaving area, ramp metering zone, etc. The ultimate objective is to reduce fatalities in traffic, consequently the SWG was nicknamed “Save the people”-SWG

SWG17.2 is developing a series of international standards which define energy-based green ITS services providing urban transport management and smart city mobility applications on nomadic & mobile devices by means of measuring energy consumption and CO_2 emissions and also providing information to users on energy capacity in transportation sectors in the smart city. This SWG aims at reducing the environmental impact of traffic and at reducing traffic related emissions and was consequently named “Save the planet”-SWG.

ERTICO, the 5G-LOGINNOV coordinator, was appointed in 2022 as convenor of ISO TW 204 SWG 17.2 due to ERTICO’s earlier achievements in the standards development for ISO TC204 WG17.

The first output of SWG17.2, ISO TR 17748-1 “Energy-based green ITS services on nomadic & mobile devices for smart city mobility applications – Part 1: General information and use cases definition” has been officially added to the ISO work programme by ISO TC204. A call for contributions to collect use cases on a global basis was launched and 5G-LOGINNOV has contributed with use case descriptions e.g., one covering carbon emission credits trading on floating vehicle emission data. Further parts of the ISO 17748 series will cover the functional requirements of data platforms (part2) and the data exchange requirements for electric vehicles (EV)-based demand response charging services (part 3).

The work of SWG17.2 started during the ISO TC204 plenary meeting held in Tampere 2 - 6 October 2022with appointment of ERTICO as convenor. The scope of the SWG was exactly defined and presented to the TC204 plenary in a workshop.

ERTICO hosted the following ISO TC204 WG17 meeting in its office in Brussels on 8 and 9 December 2022. 5G-LOGINNOV use cases were presented as candidates for inclusion in TR 17748-1.

During the following ISO TC204 plenary meeting in San Antonio on 15 – 19 May 2023 the 5G-LOGINNOV use cases were accepted as integral part of TR 17748. The work on this technical report continued during the next plenary meeting scheduled for 23-27 October 2023 in Singapore.

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OUTLOOK / R&D

The existing spectrum of available 5G frequencies is considered sufficient for the 11 use cases tested and deployed in Luka Koper, Athens, and Hamburg. Nevertheless, it must be said that operational teleoperation for drones (Koper) and automated shuttle buses (Hamburg) needs further technical tests and studies in the mobile communication domain. Functional safety for such use cases requires guaranteed stability and reliability. 5G networks support this need with dedicated QoS-based connections (e.g., via network slicing).
The expansion of spectrum from 3 GHz (4G) to 30 GHz (5G) sets a reasonable basis for drone and AV teleoperation using low latency, video imaging, and bandwidth for “Big Data”. Still, it might not be sufficient when it comes to scaling up these solutions.
Further network evaluations toward 6G will lead to frequency uses of 50 GHz and more. This approach offers significantly higher bandwidth in a scalable environment. mmWave solutions will also support new functions for object detection (e.g. VRU detection in intersections), and network coupling from terrestrial to non-terrestrial networks.

4 CONCLUSION

For all 5G-Loginnov pilot sites and use cases, the existing 5G spectrum capacity covers the technical requirements for the services in Athens, Hamburg, and Luka Koper to a high degree. Innovative technological solutions like Dynamic Spectrum Sharing (DSS), 5G network slicing, or Mobile Edge Computing (MEC) in 5G NSA (Non-Stand-Alone and 5G SA (Stand-Alone) support the logistic requirements sufficiently. This is no longer the case whenever, e.g., autonomous driving or drone operation takes place in large-size areas such as an entire city or region. Especially in busy urban or port areas, autonomous driving remains a safety-critical application, and trajectories anticipating potential collisions can only be calculated using radar-like frequencies in the range of 30 to 80 GHz. The same holds for latency and bandwidth, features that must be reliable not only for traffic surveillance services but also for all other services showcased within 5G-Loginnov.

5 REFERENCES

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