PROJECT “LOCUS”: LOCalization and analytics on-demand embedded in the 5G ecosystem, for Ubiquitous vertical applicationS

Grant Agreement Number: 871249
(https://www.locus-project.eu/)

DELIVERABLE D2.1

“Scenarios, use cases and requirements”

Deliverable Type:	R
Dissemination Level:	Public
Contractual Date of Delivery to the EU:	30/04/2020
Actual Date of Delivery to the EU:	27/5/2020
WP contributing to the Deliverable:	WP2 – Use cases, requirements, security, system architecture
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Short Abstract:	The goal of this deliverable is to describe the LOCUS project use cases and to derive related technical requirements.
Keyword List:	Localization, analytics, 5G, use cases, requirements, smart networks, new services.

Executive Summary

The goal of the LOCUS project is to design and develop a location management layered infrastructure not only capable of improving localization accuracy and security, but also to extend it with physical analytics, and extract value out of it, meanwhile guaranteeing the end users' right to privacy. Deliverable D2.1 defines use cases that will be studied and developed during the project to fulfil the aforementioned goal. The LOCUS project use cases are split into four groups corresponding to the following four technical challenges addressed by the project:

- Defining a system architecture with built-in security and privacy.
- Defining Terminal localization techniques, including 5G cellular based localization, the integration with non-3GPP localization technologies and device-free localization.
- Designing highly efficient network management enriched with location information and analytics.
- Designing new services using location information and analytics.

Use cases are described and technical, functional and non-functional, requirements are derived to serve for further study and developments during the project. Besides, a preliminary functional architecture is derived and will serve as a basis for D2.4 "System Architecture, preliminary version".

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List of Abbreviations

Abbreviation	Full Name
2G	Second generation technology standard for cellular networks
3D	Three dimensions
3GPP	3rd Generation Partnership Project
5G	Fifth generation technology standard for cellular networks
5GAA	5G automotive association
AAS	Active antenna systems
AGV	Automated guided vehicle
AI	Artificial intelligence
AoA	Angle of arrival
API	Application programming interface
BS	Base station
BT	Bluetooth
CAPEX	Capital expenditure
CM	Configuration management
COTS	Commercial off-the-shelf components
Covid-19	Coronavirus disease 2019
CSI	Channel state information
C-V2X	Cellular vehicle-to-everything
DL	Deep learning
DoA	Difference of arrival
E2E	End to end
EMF	Electromagnetic field
ETSI	European telecommunications standards institute
FR	Functional requirement
gNB	g-Node B
GDPR	General Data Protection Regulation
GNSS	Global navigation satellite system
GSM	Global system for mobile communication
HV	Host vehicle
IIoT	Industrial internet of things

IMSI	International mobile subscriber identity
IOO	Indoor open office
IoT	Internet of things
KPI	Key performance indicator
LMNE	Location aware network management for education
LSC	Location services
ML	Machine learning
mmWaves	Millimetre waves
NLOS	Non-line-of-sight
NR	New radio
OEM	Original equipment manufacturer
OPEX	Operational expenditure
OTDoA	Observed time difference of arrival
PM	Performance management
POI	Point of interest
QoE	Quality of experience
QoS	Quality of service
RCA	Root cause analysis
Rel	Release
REM	Radio environment map
RNN	Recurrent neural network
ROI	Return on investment
RSS	Received signal strength
RSU	Roadside unit
RTT	Round trip time
SDR	Software defined radio
SINR	Signal to interference and noise ratio
SLR	Service level requirement
SUPI	Subscription permanent identifier
TBS	Terrestrial beacon systems
TDoA	Time difference of arrival
ToA	Time of arrival
TTFF	Time to first fix
UC	Use case

UE	User equipment
URLLC	Ultra-reliable and low latency communications
UWB	Ultra-wide band
V2X	Vehicular to everything
VNF	Virtual network function
VR	Virtual reality
VRU	Vulnerable road user
WiFi	Wireless fidelity
WLAN	Wireless local area network
WP	Workpackage

Table 1: Abbreviation List

Table Index

1 Introduction

Context-awareness is essential for many existing and emerging applications, and it mainly relies on location information of people and things. Localization, together with analytics, and their combined provision "as a service", will greatly increase the overall value of the 5G ecosystem, allowing network operators to better manage their networks and to dramatically expand the range of offered applications and services. The goal of the LOCUS project is to design and develop a location management layered infrastructure not only capable of improving localization accuracy and security, but also to extend it with physical analytics, and extract value out of it, meanwhile guaranteeing the end users' right to privacy.

The LOCUS project addresses the following scientific and technical goals. First, the project aims at defining a system architecture with built-in security and privacy, to take in due account the challenges coming from handling, analysing and providing sensitive data, such as location and behavioural analytics of people and things. The second big research axis of the project is terminal localization, including 5G cellular based localization, its integration with non-3GPP localization technologies to enhance the accuracy with low-complexity solutions and device-free localization that exploits different transmitters present in the environment to localize passive targets. The analysis of the behaviour of devices and targets will be developed using analytics, learning and inference technologies and exploited for efficient network management and exemplary localization-based services. Location and analytics will enable highly efficient network management as they allow rapid identification of network issues facilitating both network resilience and higher levels of service performance. The use of this rich data will also empower exemplary services. Accurate, seamless indoor-outdoor localization and tracking of 5G terminals and nodes would enable new services to be offered.

The LOCUS project studies and develops solutions corresponding to the four aforementioned research axes, namely, 1) Location security and privacy; 2) Localization enabling technologies including 3GPP, non-3GPP and device-free localization; 3) Location and analytics for smart network management; and 4) Location and analytics for new services. The use cases that will be studied in the project will feed the three main scenarios that aim at showcasing the LOCUS project solutions: 1) Smart network management based on 5G equipment localization; 2) Network-assisted self-driving objects 3) People mobility & flow monitoring. For each Use Case (UC) described in this document, the project scenario to which the UC contributes is captured in the "Use Case description" table (see Table 2).

This document presents the use cases that have been investigated and defined in the LOCUS project. These use cases will be further studied and developed in the different project workpackages and they will be exploited to derive the implementation of the LOCUS platform based on the corresponding functional and non-functional requirements. The LOCUS use cases are grouped into four sections corresponding to the aforementioned main research axes of the project.

As for the organization of the document, use cases related to security and privacy will be detailed in Section 2. The localization techniques and related analytics will be dealt with in Section 3. Section 4 will provide use cases for efficient network management and Section 5 will present new localization based services.

The description of the use cases is performed according to a common template described hereafter and including two tables: the use case general description presented in Table 2 and the technical requirements presented in Table 3. Considering technical requirements, Table 3 gives a typical list of requirements that can serve as a basis for use cases description. However, as the use cases studied in the project can be very different, the list of requirements and related KPIs are adapted to each of them. Besides, the current values of KPIs specified in the different technical requirement tables are subject to amendment based on the fundamental limits analysis that will be carried out in the project. Finally, based on the functional requirements issued from the different project use cases, a preliminary functional architecture will be derived in Section 6. The LOCUS functional architecture will be further studied and detailed in D2.4 “System Architecture, preliminary version” due in M9. Section 7 concludes the deliverable.

Use Case Name	<Use case name with an abbreviation>
Description / User Story	<Description of the use case in terms of context, objectives and user story>
Category	<The category field indicates the project scenario(s) that the use case feeds, namely 1) Smart network management based on 5G equipment localization 2) Network-assisted self-driving objects 3) People mobility & flow monitoring>
Actors	<Users (e.g. service provider), UEs, Network Elements, Application/Analytics Servers including defining who the sending and receiving actor is considered for the specific use case that may affect performance. In some use cases, the actor may refer to a “LOCUS” component or function. Please note that the naming of these entities may change in the final functional architecture (FA) description as the FA is under construction and will be detailed in a future deliverable (D2.4) >
Actors’ Roles	<The roles of each actor (e.g. UE reporting measurements)>
Localisation and Analytics Roles	<Role of localization and analytics in the use case>
Goal	<Primary objective of the use case (e.g. QoS improvement), including business impact>

Constraints / Assumptions	<Specific conditions need to be fulfilled by the actors (e.g. operational/regulatory constraints), and/or any assumptions made and the reasons for them>
External sources/references if any	<Reference to SoTA and/or standardization if relevant>
Geographic Scope	<Indoor or Outdoor or Hybrid or Other (e.g. underground - cave/ tunnel)>
Picture Exemplifying the Use Case	<Illustration showing actors' role>
Event Flow	<Who and what from the moment the use case is triggered to the moment the use case closes>

Table 2. Use case description template.

Service level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Localisation Accuracy	Meter or centimetre		
Security, privacy			
Service Latency and Set-up Time	Seconds or ms.		
Service Reliability	As a percentage		<The probability of success that the key KPI's can be met over the period the service is required.>
Service Availability	As a percentage		<The probability of success that localization functions can be performed over a specified period (accounting for service interruptions).>
rate/ periodicity			
Interoperability/ Regulatory/ Standardization	[yes/no]		

Required			
Other use case specific requirements			<As studied use cases may have different requirements, additional requirements can be added when appropriate >
Functional requirements	<Functional requirements specify the behaviour or function of the solution that will be studied. The different functional requirements will be put together to build the preliminary functional architecture of LOCUS system in section 6 that will be a basis for further study and enhancement in WP2, and delivered as part of D2.4.>		

Table 3. Technical requirements template.

2 Location security and privacy

To foster the exploitation of location data and relevant analytics, LOCUS pays topmost attention to both location security and privacy concerns, to make sure that the technical solutions proposed and implemented as part of the LOCUS platform will process data in compliance with the customer's privacy rights. To this aim, two specific UCs have been conceived: the location security UC and the location privacy UC.

2.1 Location Security Use Case (LSP-UC1)

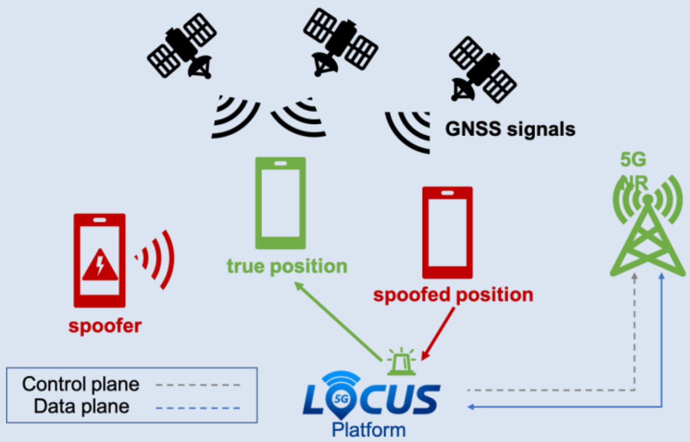
Location data in LOCUS will rely on metrics extracted from the uplink and down-link signals of new radio (NR) (3GPP-technologies) as well as non-3GPP technologies (e.g., Global Navigation Satellite System (GNSS), Terrestrial Beacon Systems (TBS), Bluetooth, WLAN, RFID, and sensors). In any case, the security requirements for localization techniques shall include the capability of identifying any kind of deviation from true locations. As a matter of fact, location data are highly vulnerable to data-level spoofing, signal-level spoofing, and meaconing attacks caused by malicious intruders. For example, in the recent years, radio frequency commercial off-the-shelf components (COTS) have been used for deception purposes in the context of GPS/GNSS signals [1]. Therefore, a location system needs to ensure that the provided location estimates are reliable: this process is called location verification.

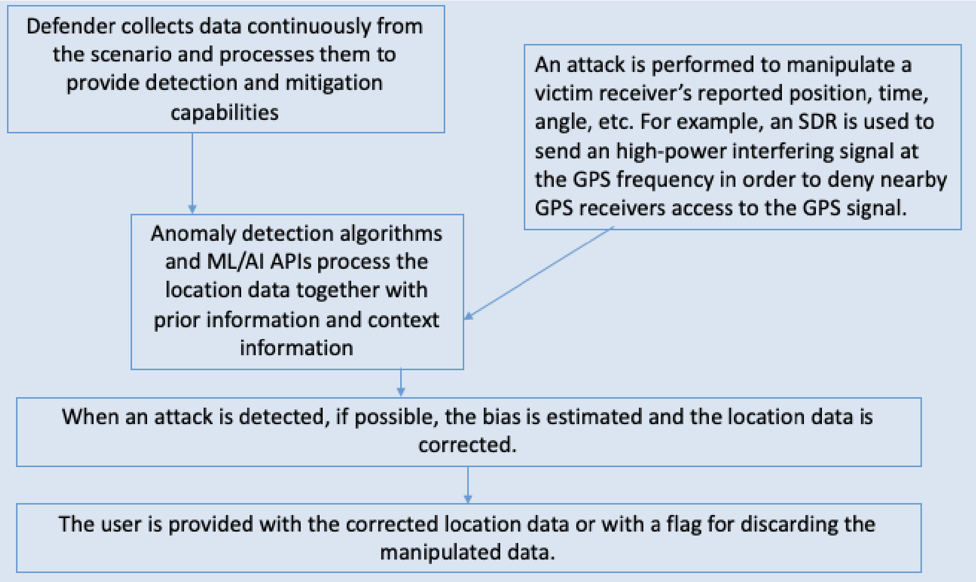
The goals of the location security use case are:

- Detection of attacks to location security
- Mitigation of the detected attacks

2.1.1 Use case description

Use Case Name	Location Security (LSP-UC1)
Description/ User story	Location security use case deals with the detection and mitigation of attacks to the security of location data. Location data is vulnerable to data-level spoofing, signal-level spoofing, and meaconing attacks caused by malicious intruders. When an attack is performed to manipulate location data of a user, a defender detects the attack and mitigates the potential impact. Location data labelled as corrupted is either discarded or corrected. Anomaly detection and mitigation rely on the processing of signal characteristics (e.g., OTDOA and DOA for NR, Doppler for GPS signals) through inference algorithms and/or ML-AI techniques (e.g., recurrent neural network (RNN)). The algorithm will be provided within the LOCUS platform.
Category	1) Smart network management based on 5G equipment localization 2) Network-assisted self-driving objects 3) People mobility & flow monitoring

Actors	• Attacker • Victims (legacy end devised/users) • Defender (connected to the LOCUS platform)
Actors' roles	• The attacker performs i) signal-level spoofing; ii) data-level spoofing, iii) signal-level spoofing, and iv) meaconing attacks; • The victim receives manipulated location data; • The defender deploys anomaly detection and mitigation techniques, providing the victim with a corrected location data or flagging the data as manipulated.
Localization and Analytics Role	Location security analysis relies on the processing of location estimates or raw data to detect any spoofing attack.
Goal	(i) Demonstrate that threats/attacks to location security are feasible and can rely on COTS; (ii) assess their impact and extent; and (iii) suggest/investigate/develop mitigation techniques and solutions.
Constraints / Assumptions	• The UC is feasible without constraints
Geographic Scope	Indoor and outdoor
Picture Exemplifying the Use Case	
Event flow	



2.1.2 Technical requirements

Service level Requirement	SLR Unit	SLR Value	Explanations/Reasoning/Background
Localisation accuracy	[m]		This requirement does not apply in general to this specific UC. However, in case of corrected location data after an attack is detected, the final location accuracy should be in line with the localization accuracy expected in the application scenario.
Security/ privacy	Level of security, anonymity and privacy of data.	Security needs to be very high Security-by-design	This is a security focused UC. Location data must be secure enough to prevent jamming, spoofing and meaconing.
Service Level Latency and set-up time	[s]	Maximum update interval = 1 s – 40s Initial service setup time = 120	The update interval can vary depending on the application – in the general case, the service level latency should be lower than the location update rate to avoid that decision are made based on biased locations. The latency depends on where in the network the anomaly detection and mitigation are performed.

		s	For small values of update interval, edge computing solutions are required.
Service Level Reliability	%	Detection rate: > 90%; False alarm rate: 1%	The reliability requirements can vary depending on the application scenario. The reliability depends on the detection and false alarm rate for anomaly detection. Also, the accuracy of corrected location data should be in line with the localization accuracy (see Location Accuracy description).
Service Level availability	%	90- 98%	The availability depends on the application scenario.
Rate/Periodicity			Depends on the localization periodicity (i.e. the one required by LEN UCs)
Interoperability/ Regulatory/ Standardization Required	[yes/no]	Yes / Yes / Yes	In order for the solution to work with any type of 5G devices, it should be standards compliant. Interoperability with different devices and access points needed.
Functional requirements	• **LSP-UC1_FR1:** The system shall have a localization service to provide location data from a victim (user) to the defender (platform component). • **LSP-UC1_FR2:** The system shall have machine learning functionality for analytics extraction, i.e. anomaly detection. • **LSP-UC1_FR3:** The system shall provide a notification of security violation through a trigger alarm functionality. • **LSP-UC1_FR4:** The system shall have a localization service to correct location data (mitigation).		

2.2 Location Privacy Use Case (LSP-UC2)

Attacks on cellular networks may lead to privacy concerns. The problem of privacy disclosure can be related to different aspects. For the users, certain data transmitted over the network are highly sensitive, such as location, trajectory, and identity information. If these sensitive data are revealed, the location privacy, trajectory privacy, and identity privacy can be leaked. Moreover, in mobility scenarios, the position of the user changes. While moving, several connections to different cells are established. Multiple connections are prone to data leakage risks, which may lead to the leakage of private information.

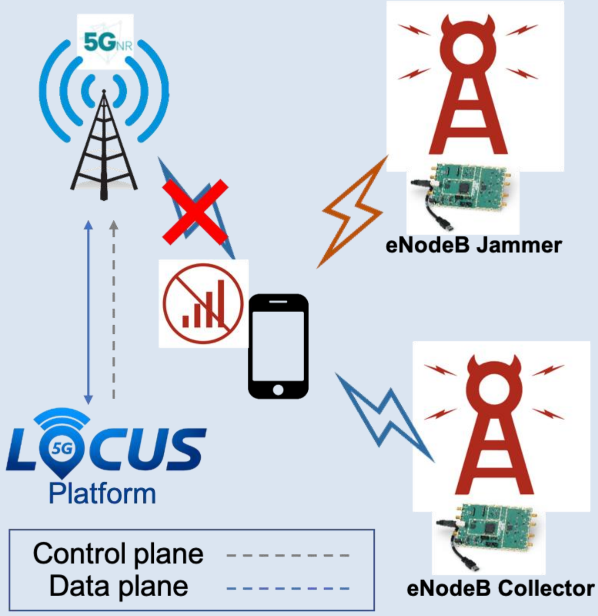
Location privacy has been a primary requirement in cellular networks since the GSM (2G) architecture was defined. 5G has further investigated into this, by standardizing a novel public key-based approach to conceal the subscriber identity. Location privacy encompasses (at least) two main requirements:

- Inability for an attacker to determine, from the registration/signalling messages, which user is connected to a cell. e.g. it should not be possible to retrieve the SUPI (Subscription Permanent Identifier) of a user connected/connecting at a given location.
- Inability for an attacker to track the user movements across cells. e.g. temporary identifiers used in different/adjacent cells should be unrelated.

This use case addresses the problem of privacy leakage in 5G location system. LOCUS will perform analytics on raw location position data. Attacks to system can be leveraged to identify device location data. The goals of this use case are: i) understand if is present threats/attacks to location privacy; ii) show mechanics to mitigate threats/attacks to location privacy.

2.2.1 Use case description

Use Case Name	Location Privacy (LSP-UC2)
Description/ User story	The attackers attempt to de-anonymize and track connected customers. LSP-UC2 will be demonstrated in LOCUS by means of either i) IMSI-catching-type attacks devised to show that despite the currently deployed solutions, a clever attacker may still exploit downgrade/bid-down attacks de-anonymize and track users, as well as ii) counter measures including also the ability to detect and thwart rogue BSs.
Category	1) Smart network management based on 5G equipment localization 2) Network-assisted self-driving objects 3) People mobility & flow monitoring
Actors	• SDRs for 4G/5G rogue BS (and when necessary emulation of legitimate operator's BS) • Targets equipped with commercial devices
Actors' roles	• Attacker performing i) jamming of legitimate signals, and ii) deploying rogue BS • Victims: legacy end devised/users • Defenders: operators and legitimate infrastructure providers, which deploy mitigation techniques (e.g. measurements, anomaly detection, etc.)
Localization and Analytics Role	The UC deals with attacks to the privacy of localization data
Goal	Experimentally demonstrate that threats/attacks to location privacy are still feasible and **at very low cost**, assess their impact and extent, and suggest/investigate/develop mitigation techniques and solutions.

Constraints / Assumptions	• To anticipate experimental work, we will initially start with already deployed 4G devices and BSs • Migration to 5G technologies will be done in the second part of the project
Geographic Scope	Indoor and outdoor
Picture Exemplifying the Use Case	
Event flow	**Tracking part:** Attacker will inspect (via tools such as Mnmap, which we plan to extend in the project) device features to be used as "fingerprints" for tracking purposes **Deanomymization part:** Attacker will deploy an SDR implementing a rogue BSs, and will "convince" the user device to connect to this (this phase will involve jamming of legitimate signals) ↓ Bid-down/downgrade techniques will be developed in the SDR, so as to force the end device to reveal the IMSI/SUPI Note that this SDR will be configurable and programmable, and will therefore be also used as a vulnerability assessment tool for operators' networks ↓ Attack detection techniques (e.g. anomaly detection) will be then tested over such attacks

2.2.2 *Technical requirements*

Service level Requirement	SLR Unit	SLR Value	Explanations/Reasoning/Background
privacy of user identity	Level of anonymity and privacy of data.	Identification of configurations which are	Analysis of the different types of attacks, and of the resilience of configurations and network settings to such attacks

		robust to attacks	
Success conditions for an attack	[%]	% versus user density and environmental setting	Analysis of the success of attacks versus the environmental conditions (e.g. user density, attacker's proximity, etc.)
Interoperability/ Regulatory/ Standardization Required	[yes/no]	Yes / Yes / Yes	Since many of the so far standardized 5G protection techniques are optional, we will test their application and deployment
Functional requirements	• **LSP-UC2_FR1:** The system shall provide the identification, specification, configuration and support of data management policies (filtering, aggregation, anonymization, obfuscation). • **LSP_UC2_FR2:** The system shall provide advanced cryptographic techniques for location data analytics (homomorphic encryption, secure multiparty computation, and secure conditional sharing techniques). • **LSP-UC2_FR3:** The system shall provide a notification of privacy violation through a trigger of alarm functionality.		

3 Localization enablers

The work package 3 (WP3) of the LOCUS project is focused on the localization enabling technologies, both in the 3GPP and non-3GPP domains and also on investigating the novel concept of device free localisation through the backscattering from an illuminated passive object. Amongst the main technical objectives for WP3 are derivation of the theoretical performance limits with 5G as with procedures defined in 3GPP release 16, extraction of localisation related parameters from non-3GPP technologies and their fusion, development of algorithms and techniques for device free localization and design of final integrated solutions with these multiple technologies.

In order to meet these objectives, WP3 has developed 5 UCs which address a wide variety of application areas with stringent KPI requirements. These UCs will be studied in-depth and the KPI's achieved through the 3GPP, non-3GPP and device-free localisation techniques are developed in this WP. The 3GPP techniques will utilize the outcomes from the recently concluded NR-positioning work in release 16 [2][3] and will work to improve the baseline performances as simulated in [3]. As the NR-positioning work moves to a normative phase with tighter requirements in release 17 [4], it is expected that some of the study results on these use cases from WP3 will have some standardisation impact. In terms of non-3GPP techniques, WP3 will investigate GNSS, WiFi, Bluetooth and UWB based techniques in these UCs, to bring together some of the recent advances in optimisations and analytics to derive better results. The fusion of both 3GPP and non-3GPP based techniques to deliver improved performances will be a key target for WP3. The device free localisation is a novel exploration area, with one use case dedicated to its study. The final objective for WP3 is to bring all these techniques together as integrated solutions to achieve the most challenging KPIs. The list of use cases related to the localization enablers to be developed in WP3 is as follows, with their generic and technical details noted in the subsequent sections.

- 3D Indoor Localisation for Emergency Services (LEN-UC1)
- Positioning and Flow Monitoring in Large Venues and Dense Urban Environments (LEN-UC2)
- High accuracy indoor positioning for industrial IoT (LEN-UC3)
- Localisation and Network Management for Education (LEN-UC4)
- Device-free Localization (LEN-UC5)

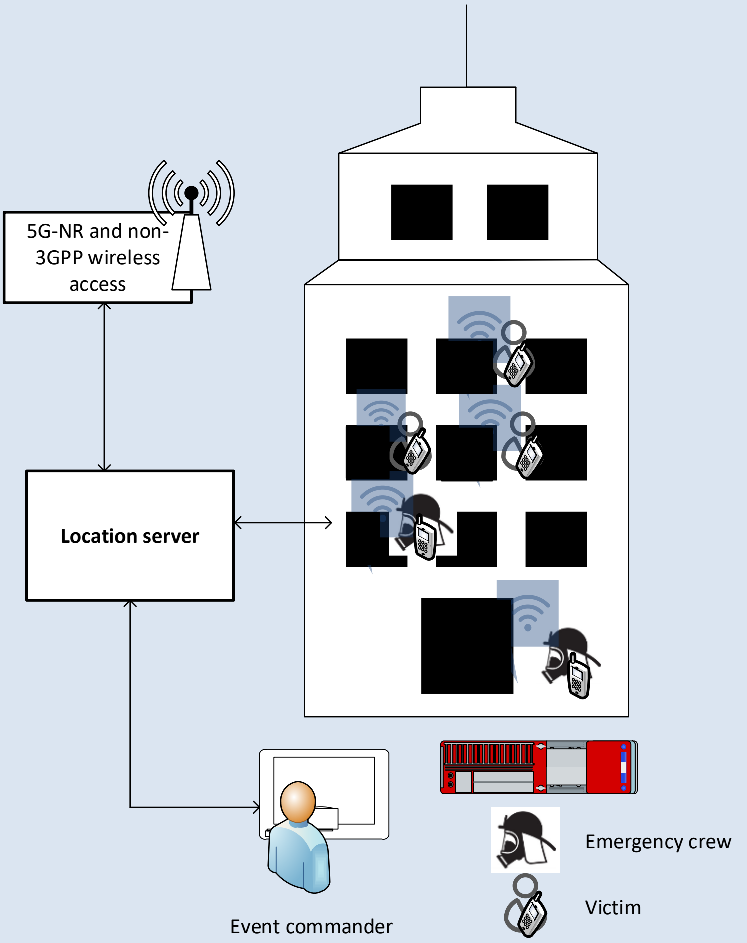
3.1 3D Indoor Localisation for Emergency Scenarios (LEN-UC1)

There are many scenarios requiring indoor emergency localisation, like building fire, kidnap/terrorism incident, medical emergency, building evacuation in emergencies. Novel localisation mechanisms are required, as indoor locations are not supported by GNSS and we cannot rely on the existing wireless infrastructure (like WiFi nodes, femto cells) within the premises. These devices can get damaged in the emergency and can also suffer from power loss.

Indoor locations present many challenges as a radio environment, including multipath, blocking and, for an emergency support service, high levels of accuracy, service reliability and availability need to be achieved. Also, if the solution is contracted with an emergency service, the solution should be available throughout their emergency service area. It should be deployable even under challenging conditions. The location accuracy and reliability can be enhanced using fusion techniques in an opportunistic manner, integrating any usable wireless technology - on top of the baseline localization technology.

3.1.1 Use case description

Use Case Name	3D Indoor Localisation for Emergency Scenarios (LEN-UC1)
Description / User Story	Victims and emergency service personnel are localized within an indoor 'incident' environment. This localisation capability will be provided to the emergency crew as a service, with guaranteed levels of accuracy, reliability, service availability and other agreed KPIs. The emergency crew will use this localisation service to manoeuvre their operations and ensure safety of victims as well as emergency crew attending the indoor 'incident'.
Category	3) People mobility & flow monitoring
Actors	• The localisation service provider • Emergency event commander, who has overall localisation view of the victims and the crew • Emergency crew who enter the building as first responders • Victims of the emergency, inside the building – who may be in a responsive or unresponsive state
Actors' Roles	• The service provider would enter into a contract with the emergency services to meet the necessary accuracy, reliability, and availability criteria in localisation service. • The event commander will use the localisation inputs to guide the emergency crew attending the incident. • The emergency crew will use the victims' localities to reach them quickly and even to pass them instructions.
Goal	• Provide accurate, real time localisation of victims and of emergency crew in an indoor emergency.
Constraints / Assumptions	Assumptions will be required for the following information: • The devices used by victims and emergency crew will be 5G-NR compliant. • The gNBs in the vicinity and any ad-hoc gNBs can be quickly configured to collaborate. • Any privacy settings with respect to localisation in the victims' devices can

	be overridden, considering the threat to life in the emergency scenario.
Picture Exemplifying the Use Case	
Event Flow	Emergency service requests the 3DILES service from the provider ↓ Service provider configures the service logistics and makes service available ↓ 3DILES service is ready to use, within the agreed service set-up time and update rates: a) Event commander can see locality of victims and the emergency crew inside the site b) Emergency crew see the location of the victims inside the site ↓ Event Commander notifies the end of the event to the 3DILES service provider ↓ Service provider dismantles the service logistics and ends the service

3.1.2 *Technical requirements*

Service Level Requirement (SLR)	SLR Unit	SLR Value	Explanations/Reasoning/Background
Localisation Accuracy	[m]	Horizontal ± 2m Vertical ± 1m	For buildings with a lot of smaller rooms, this level of horizontal accuracy is needed to identify victims and emergency crew within the right room, saving precious time. For vertical accuracy, assume the multi-storey buildings have a minimum 4 m floor height. Vertical accuracy is critical to ensure identification is done at the correct floor level, as movement between floors can be difficult and restrictive.
Security / privacy	[yes/no]	Yes / Yes	Security – the localisation data should be highly secure and should be transmitted, recorded, and stored securely – for operational, legal, and ethical reasons. The privacy of the victims and emergency crew should be maintained in any post-processing or storage of data.
Service Latency and Set-up Time	[s]	Maximum update interval = 40 s Initial service setup time = 135 s	This is the location update rate for the emergency crew and the victims (if they are moving), as specified by the US first responders [5]. This is the maximum allowable setup time for this localisation service to go live. Time estimated from the moment the emergency crew are ready to enter the affected building, as specified by the US first responders [5].
Service Reliability	%	99.9%	Reliability of the above accuracy levels and update rates should be maintained at this rate.
Service Availability	%	98%	The service should be available at the reliability levels at least 98% of the time during the event duration. If the service reliability levels are decreasing, the service provider should inform the event commander.
Interoperability/	[yes/no]	Yes / Yes /	In order for the solution to work with any type of 5G

Regulatory/ Standardization Required		Yes	device, it should be standards compliant. Interoperability with different devices and access points is also required. Regulatory approval will be needed as the solution deals with sensitive data.
Functional requirements	• **LEN-UC1_FR1:** The system shall have as input the following data: Time Difference of Arrival (TDoA), Angle of Arrival (AoA) and received signal strength (RSS) from multiple access points in the physical layer. • **LEN-UC1_FR2:** The system shall provide and update the localities of multiple targets to the Location Services (LCS) client. The output shall be the coordinates (updated regularly) of the target referenced onto an indoor map of the building and provided to the LCS client. • **LEN-UC1_FR3:** The system shall be able to distinguish between the emergency crew and victims. • **LEN-UC1_FR4:** The localisation server shall provide only relevant information to the emergency service. It shall use the building boundaries as a delimiter to remove any crew or victims moving/taken out of the building form localisation updates. • **LEN-UC1_FR5:** The localisation server shall be informed about any changes in the infrastructure used to estimate the location information (e.g. drone replacement) and all relevant external information such as building boundaries, indoor maps etc. • **LEN-UC1_FR6:** The system shall offer the necessary protocols and interfaces for physical layer and external input data. • **LEN-UC1_FR7:** The system shall notify the client of a possible degradation of service availability in these instances. • **LEN-UC1_FR8:** The system shall offer data security and privacy functionalities, and any services built on top shall adhere to these strict requirements. For example, anonymized location and movement data of the victims and emergency/response crew can be used to develop training tools for the emergency crew.		

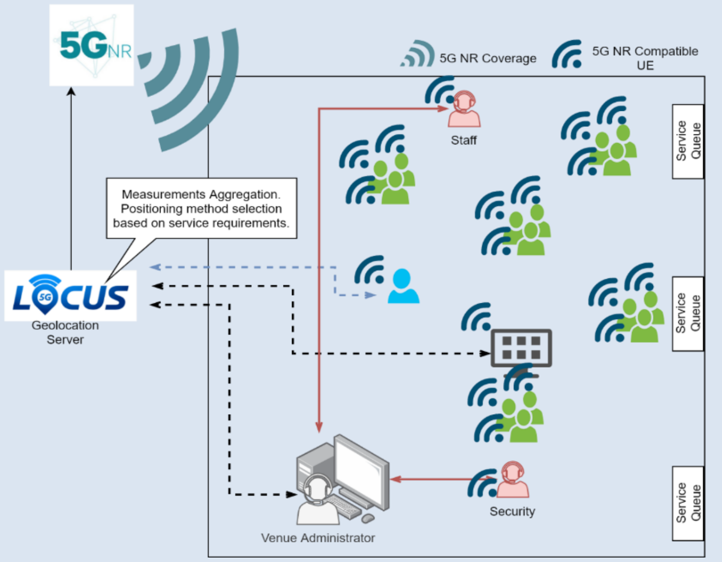
3.2 Positioning and Flow Monitoring in Large Venues and Dense Urban Environments (LEN-UC2)

Large venues and shopping areas (airports, train stations, malls, stadiums, etc.) are characterized by gatherings of large crowds, with complex mobility behaviour. This calls for efficient flow and resources management, and creates opportunities to maximise QoE (Recommendations, Queues, logistics, staff, security, etc.).

This use case's goal is the exploration of positioning methods that exploit possible positioning measurements within a 5G NR deployment. The generated positioning information can enable vertical services and advanced Analytics. It can also be exploited for smart network management.

3.2.1 Use case description

Use Case Name	Positioning and Flow Monitoring in Large Venues and Dense Urban Environments (LEN-UC2)
Description / User Story	1. **User Story 1:** Large venues and transportation hubs (airports, train stations …) exhibit gathering of crowds, with complex mobility behaviour. This affects individual quality of experience (e.g., long queues), and puts a stress on management resources (staff, security, etc.). Security and safety issues could arise at emergency events (e.g., Fren-zy fans). LOCUS will exploit 5G based reference signals to collect measurements and deploy hybrid positioning methods to extract locations and track mobility. 2. **User Story 2:** Shopping experience in large venues and transportation hubs, where various commercial stores, restaurants, cafes and so on exist, can be enhanced if contextualized with geolocation information. The 5G system can provide geolocation information to improve shop-ping experience and commercial advertisement.
Category	3) People mobility & flow monitoring
Actors	• 5G Compliant User: UE (Passenger/Customer/Fan), Things. • LOCUS Geolocation Server • Geolocation User (Venue administrator, Advertisers, Shop owner, Individual user…etc.)
Actors' Roles	• Service users will be subscribing to the 5G-based localisation service, and 5G-based localisation enabled services (Shop owner, venue administrator...). • LOCUS Geolocation Server will use 5G-based signals and/or other measurements to satisfy service requirements and decide on positioning methods to use and/or to fuse.
Goal	• Enhanced indoor positioning, and enablement of vertical services. • Provide real time commercial and convenience information, User

	Experience Enhancement
Constraints / Assumptions	• Data Privacy/Security. • 5G NR (3GPP Release >= 15) deployment. (**User Story 1**) • 3GPP Release >=15 compliant UE. (**User Story 1**)
Geographic Scope	Dense Urban Environment (Indoor/Outdoor/Hybrid)
Picture Exemplifying the Use Case	
Event Flow	**Event Flow 1** 1. The LOCUS geolocation server will receive an authenticated and permitted request to track the location of one or more UEs on the 5G network 2. The LOCUS geolocation server will optionally reconfigure the 5G network to generate or facilitate measurements to support the geolocation 3. The 5G infrastructure/UEs will generate one or more type of data to support geolocation 4. The LOCUS geolocation server will collect and process the data to calculate locations and routes of target UEs 5. The LOCUS geolocation server will provide the resulting locations to an authenticated and permitted entity. **Event Flow 2** **1.** Possible customer (user) strolls in a market or a street shopping area. The user will be able to receive 5G-based localisation commercial information about the area. 2. Information is updated every 5- 12 min depending on its new geolocation and on previous preferences

3.2.2 Technical requirements

Service level Requirement	SLR Unit	SLR Value	Explanations/Reasoning/Background
Localisation Accuracy	m	Horizon-tal: <=3 Vertical: <=3	High accuracy NR reference signals-based Position-ing. As per Rel-16 NR positioning requirements, and sub-ject to further analysis in terms of performance/ complexity trade-offs of NR positioning radio-layer solutions
		Horizon-tal: <=5 Vertical: <=50	Marketing based on outdoor Geolocation
Latency/Time To First Fix	sec	TTFF <=10 per TR 22.872 Latency <=1	As per Rel-16 NR positioning requirements, and sub-ject to further analysis in terms of performance/ complexity trade-offs of NR positioning radio-layer solutions
Update rate	sec	10	
		720	Marketing based on outdoor Geolocation
Service Reliability	%	80	per 3GPP Rel. 16
Service Availability	%	80-90	The probability of success that localization functions can be performed over a specified period (account-ing for service interruptions). The service should be available at the reliability lev-els at least 90% of the time during the event dura-tion.
Interoperability/ Regulatory/ Stand-ardization Required	[yes/no]	Yes	• Solution depends on 5G compliant UE, and NR-Compliant Signals, and regulatory ap-proval for collection and processing of geo-location data. • GDPR compliant since we are dealing with personal data.

Functional Requirements	• **LEN-UC2_FR1**: The system shall employ 5G-NR defined reference signals and measurements, acquired through 5G-NR measurement acquisition procedures.
	• **LEN-UC2_FR2**: The system shall be able to acquire positioning-relevant measurements, both actively and passively:
	    • Actively: using positioning relation measurement campaigns.
	    • Passively using measurements performed for other purposes in the 5G system.
	• **LEN-UC2_FR3**: The system shall provide the appropriate authentication and data safety procedures, throughout the whole cycle of data acquisition and storage.
	• **LEN-UC2_FR4**: The system shall have the ability to collect and store measurements, necessary to continuous localization and tracking.
	• **LEN-UC2_FR5**: The system shall rely on the presence of proper API and interfaces to expose the resulting location information to relevant parties.

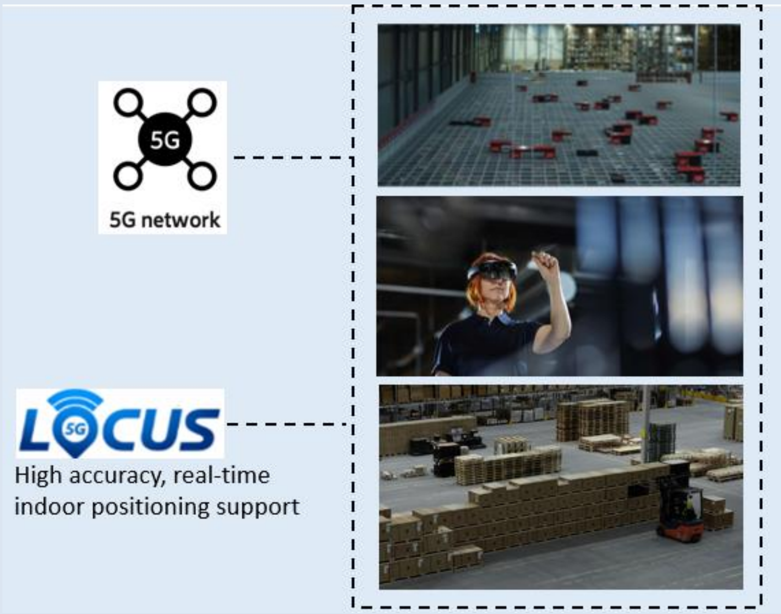
3.3 High accuracy indoor positioning for industrial IoT (LEN-UC3)

Industrial IoT (IIoT) use-cases are characterized by challenging system requirements for positioning accuracy. For example, on the factory floor, it is important to locate assets and moving objects such as forklifts, or parts to be assembled. Similar needs exist in transportation and logistics. The deployment scenario for different indoor industrial environments has a significant impact on the positioning performance in terms of both accuracy and availability of the service. The Indoor Factory (InF) model is public and can act as baseline for comparing between companies and partners in different projects. The impact of the various objects that are present in a factory hall are implicitly considered through their effect on the path-loss and multipath parameters in this model. The indoor open office (IOO) scenario is also another model which can be used for simulating and evaluating the indoor positioning performance of IIoT use-cases.

3.3.1 Use case details

Use Case Name	High accuracy indoor positioning for Industrial Internet of Things (LEN-UC3)
Description/ User story	In the factories and many indoor industrial environments, there is a great need for automation and asset tracking. User Story 1: There are autonomous fork lifts which move around the indoor environment of the factory building and for proper performance they require high precision positioning. User Story 2: Different “things” may require to share their accurate positioning information to each other and evaluate their distance to other

	objects with very low latency.
Category	1) Smart network management based on 5G equipment localization 2) Network-assisted self-driving objects 3) People mobility & flow monitoring
Actors	• Indoor IIoT user • Autonomous IIoT UE, e.g. autonomous forklifts • Service provider • Event commander
Actors' roles	• The indoor IIoT user would like to track and control different equipment in the indoor environment • The autonomous IIoT UE requires high precision positioning for proper functioning • The service provider would enter into an agreement with the industrial sectors or factories to meet the necessary accuracy, reliability, latency and service availability criteria. • The event commander provides a global view of the factory with the real-time information of each indoor IIoT or autonomous IIoT UE on the map.
Goal	• To provide high accurate, real time positioning for industrial autonomous user equipment. • To evaluate the impact of the deployment planning scenario on the positioning accuracy • To analyse the densification impact on 5G accuracy and availability
Constraints / Assumptions	• IIoT users would be supported by 5G NR (3GPP Release >= 15). • The deployment scenario is not constrained to network coverage planning objectives, meaning that for high positioning performance we are allowed to densify and move around radio nodes.
Geographic Scope	Indoor

Picture Exemplifying the Use Case	
Event Flow	An industrial sector or a factory requests for high accuracy indoor positioning for IIoT as a service from the provider ↓ Service provider deploys and configures the service in the factory. ↓ All supported IIoT devices in the factory are able to use the indoor positioning system for their own positioning and for tracking other IIoT devices. ↓ The industrial sector or factory can report issues of nonreliable or no availability of the positioning service to the service provider in case requirements were not fulfilled. ↓ Service provider is responsible to maintain the accuracy and availability of the positioning requirements in the industrial sector or a factory.

3.3.2 Technical requirements

Service level Requirement	SLR Unit	SLR Value	Explanations/Reasoning/Background
Localisation accuracy	Meter or centimetre	< 0.2 m	Autonomous forklifts and many other facilities in the factory require high horizontal position accuracy. Vertical positioning accuracy needs to be

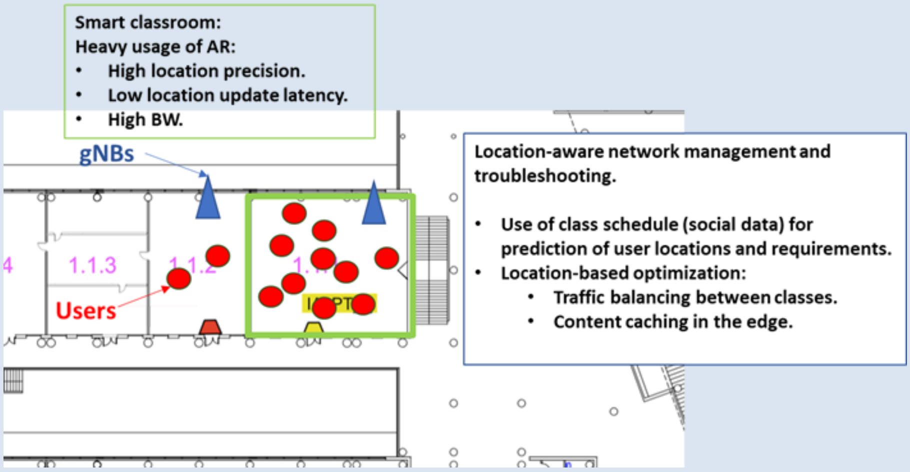
			evaluated.
Security/ privacy of data requested/generated	Level of security or anonymity of data	Highly secure	As the service is provided privately to the industrial sector it is required to be highly secured.
Service Latency and Set-up Time	Seconds or ms	< 100 ms	The target latency requirement is < 100 ms; for some IIoT use cases, latency in the order of 10 ms is desired.
Service Reliability	As a percentage	99 %	High reliability is required for any autonomous driving use-case.
Service Availability	As a percentage	99 %	In order for the IIoT user to be able to work properly within the factory, the positioning service shall be highly available everywhere.
Interoperability/ Regulatory/ Standardization Required	[yes/no]	Yes / Yes / Yes	Interoperability is needed to support all sort of IIoT users, Regulatory approval in terms of frequency band is needed. In order for the solution to work the devices should be standard compliant.
Functional requirements	The use-case functional requirements are as follows: • **LEN-UC3_FR1:** All industrial devices/equipment or factory user which require high accuracy positioning functionality shall support the indoor positioning network service. • **LEN-UC3_FR2:** Each device and user shall have their own unique device category recognition with known characteristics at the service provider. • **LEN-UC3_FR3:** The event commander shall provide filtered real-time information of the registered devices on the indoor map applicable to each certain device. • **LEN-UC3_FR4:** The indoor network devices need to be synchronized. • **LEN-UC3_FR5:** The service shall be capable to apply any sort of analytics and machine learning algorithms on the measurements to enhance the positioning estimations.		

3.4 Localization and Network Management for Education (LEN-UC4)

This use-case describes the use of localization technologies in an education scenario where technologies such as Augmented Reality (AR) and Virtual Reality (VR) are deployed. Novel educational methods rely on location-based technologies, such as VR and AR, which have very stringent location accuracy and speed requirements. These novel technologies also have very stringent network requirements, mainly in terms of bandwidth and latency. This calls for an optimal use of the available resources (access points, femto cells, etc.) which will be highly dependent on the location of the devices. In LEN-UC3, two main challenges are present: firstly, all those inherent to indoors (multipath, blocking, etc.), and secondly, the students will usually access contents simultaneously, creating traffic and interference hotspots.

3.4.1 Use case description

Use Case Name	Localization and Network Management for Education (LEN-UC4)
Description/ User story	Localization for AR/VR and other location-based technologies, and network management for optimal resource management.
Category	1) Smart network management based on 5G equipment localization 3) People mobility & flow monitoring
Short Description	The challenges of future “smart classes” are twofold. On the one hand, devices have very stringent requirements on the network, which must provide a very high bandwidth with a low latency, as well as a high location accuracy also with a low latency. On the other hand, the scenario is on itself a challenge for wireless technologies, since all these requirements must be fulfilled in traffic hotspot and indoors conditions.
Actors	• Users: teacher and students that will access multimedia contents in AR/VR. • Content creators: creators of multimedia contents. • Network operators: must ensure the correct and optimal behaviour of the network elements.
Actors’ roles	The network operator will need to have a minimal deployment that suits the requirements of the users. The network capabilities must fulfil the requirements of the contents uploaded by the creators, who must know the limitations in advance.
Localisation and Analytics Roles	Analytics are required to improve the network location with fusion algorithms (for instance, with UWB, WiFi, etc.). Also, analytics help to optimize the network based on predictions of the usage of gNBs base on external data sources such as class schedule.
Goal	Provide accurate, real time localisation for AR/VR; and provide location-

	based network optimization.
Constraints / Assumptions	• The AR/VR devices will be 5G-NR compliant and have the required additional technologies (e.g. UWB) • The operator will have a deployment of gNBs and other location technologies that can provide the required levels of service. • The contents accessed by the users will be designed with a known margin for latency (both for data and location), location accuracy and data bandwidth.
Geographic Scope	Indoor
Picture exemplifying the use case	
Event flow	1: User requests location aware network management for education (LMNE) service. 2: Network operator creates a service and optimizes it taking into account predictions of traffic, user location, contents, etc. 3: LNME service is ready to use, AR/VR receives location updates with the negotiated frequency 4: Last users finishes LNME session 5: Network operator releases the resources

3.4.2 Technical requirements

Service level Requirement	SLR Unit	SLR Value	Explanations/Reasoning/Background

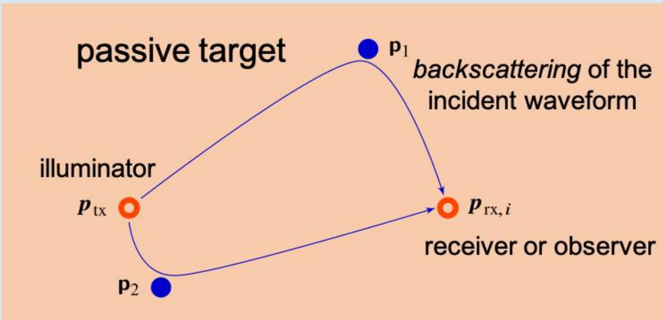
Localisation accuracy	[m]	Horizontal ±0.1m Vertical ±0.1m	VR and especially AR are very dependent on a highly accurate location in order to offer a satisfying experience for the end-users.
Security/ privacy of data requested/generated	Level of security, anonymity and privacy of data.	Security and privacy needs to be very high	Location data must be secure enough to prevent unwanted tracking of users (students and teachers), and for protecting their privacy.
Time to First Fix	[s]	<= 20	Setup time can be much less restrictive, since elements such as loading bars may provide a smoother experience.
Set-up time	[s]	<=20	
Update Frequency	Hz	>=100	To prevent dizziness, the location update must be very low.
Service Reliability	%	99.999%	URLLC-level reliability is required to prevent desynchronization between the real world and AR.
Service availability	%	98%	
Rate/periodicity	ms	<=10	
Interoperability/ Regulatory/ Standardization Required	[yes/no]	Yes / Yes / Yes	In order for the solution to work with any type of 5G devices, it should be standards compliant. Inter-operability with different devices (including non-3GPP sources) and access points needed. Regulatory approval will be needed as the solution deals with sensitive data.
Data Virtualization	[yes/no]	no	
Functional	• **LEN-UC4_FR1:** The system shall use the results of localization for network		

requirements	management, therefore the appropriate interfaces with a network management module is assumed. • **LEN-UC4_FR2**: The system shall enable network operators to create optimized service, taking into account predictions of traffic, user location, contents, etc. • **LEN-UC4_FR3**: The localization analytics shall involve fusion algorithms (for instance, with UWB, WiFi, etc.). • **LEN-UC4_FR4**: The localization shall be provided to the AR/VR devices as coordinates with the predetermined frequency and accuracy. The AR/VR devices will be 5G-NR compliant and have the required additional technologies (e.g. UWB). • **LEN-UC4_FR5**: Network topology and parameters, as by extension the capabilities and limitations shall be available in order to ensure the optimal use of all the resources (access points, femto cells, etc.). • **LEN-UC4_FR6**: Several information shall be available in advance, such as: external data sources like class schedule for usage prediction, content requirements by the creators (as each service will be designed with a known margin for latency -both for data and location-, location accuracy and data bandwidth).

3.5 Device-free Localization (LEN-UC5)

There are many scenarios where we need to detect, localize, or extract analytics related to people and things (targets) not equipped with communicating devices – cars, bikes, and pedestrian for road safety; anti-intruder systems; people flow monitoring. In many of such scenarios there are communication systems emitting signals for other purposes (e.g., 5G base stations for communication, 5G V2X communication). Device-free Localization consists in processing such signals after target backscattering at one or multiple nodes to extract information about presence, range, location that may serve as input for analytics extraction. Device-free Localization presents many challenges as clutter, multipath and NLOS conditions. For example, in a road safety scenario, LEN-UC5 can be complementary also to NSE-UC3, where the device-based localization of a vulnerable road user (VRU) equipped with a 5G-compliant device is considered. Device-free localization can be used for the detection of device-free VRU.

3.5.1 Use case description

Use Case Name	Device-free Localization (LEN-UC5)
Description / User Story	In this UC, the detection and localization of the targets is performed by processing signals at a network of receivers (which can be "usual" UEs used for this purpose and equipped with suitable software, namely radar-UEs).
Category	3) People mobility & flow monitoring
Actors	• 5G signal emitter • Targets not equipped with devices, to be detected and localized • Network of receivers that processes signal after target backscattering • Service provider
Actors' Roles	The 5G emitter emits the signal in the environment (broadcast, positioning signal); targets backscatter the incident signal, which is received at the network of receivers, where it is processed to infer information about the presence and location of the targets. The service provider ensures that the device-free localization meets the necessary accuracy, reliability and service availability criteria.
Goal	Provide real time information about people or object presence, location, or flow directions
Constraints / Assumptions	Assumptions will be required for the following information: • The signals used for device-free localization will be 5G-NR compliant. • The eNBs is in the vicinity and can illuminate the scene • One or multiple UEs can receive the signal, acting as radar-UEs
Picture Exemplifying the Use Case	

Event Flow	Service provider initiates the DFL service ↓ Service provider configures the network of UEs receivers, the service logistics and makes service available ↓ DFL service is ready to use, within the agreed service set-up time and update rates: a) Signal at different UEs are processed b) The information about DF targets is estimated ↓ The monitored event or period of time allocated for the radar application ends ↓ Service provider dismantles the service logistics and ends the service

3.5.2 Technical requirements

Service Level Requirement (SLR)	SLR Unit	SLR Value	Explanations/Reasoning/Background
Localisation Accuracy	[m]	Horizontal ±1m-5m Vertical ±1m - 5m	The location accuracy can vary depending on the application – e.g., for road safety (see, e.g., NSE-UC3 for comparison) we might need a very strict requirements (less than 1 meter) whereas flow monitoring applications can accept larger errors
Security / privacy	[yes/no]	Yes / Yes	Location data must be secure enough to prevent spoofing and meaconing. The privacy of the target is intrinsically guaranteed since device-free localization systems do not rely on target identity and personal data
Service Latency and Set-up Time	[s]	Maximum update interval = 1 s – 40s Initial service setup time = 120 s	The update interval can vary depending on the application – e.g., for road safety we might need a very short update time (~1s) that can be larger for flow monitoring (~40s) The setup time is needed to allow clutter mitigation algorithm to collect enough data and learn the environment

Service Reliability	%	90-99.9%	The reliability depends on the application scenario. We expect higher values for safety applications and lower values for flow monitoring.
Service Availability	As a percentage	90-98%	The availability depends on the application scenario. We expect higher values for safety applications and lower values for flow monitoring.
Interoperability/ Regulatory/ Standardization Required	[yes/no]	Yes / Yes / Yes	In order for the solution to work with any type of 5G devices, it should be standards compliant. Inter-operability with different devices and access points needed.
Other use case specific KPIs (TBD)	Detection and false-alarm probability	Detection rate >90% False-alarm rate<0.1%	Detection of device-free targets is needed for localization. The required values are scenario-dependent.
Functional requirements	• **LEN-UC5_FR1**: The system shall have the appropriate interfaces with other LOCUS functional components for the continuous acquisition of waveform samples and/or CSI. • **LEN-UC5_FR2**: The network of receivers should be synchronized.		

4 Localization and analytics for smart network management

New 5G features, such as massive MIMO and beamforming, multi-connectivity, use of mmWave and unlicensed bands, amplify the network operators' need to efficiently manage networks that are getting more complex and efficiently use the limited radio resources. To achieve the optimum end-to-end service performance for the growing, highly diverse, and extremely demanding 5G traffic, user-centric network management should replace the traditional network-oriented operation. The LOCUS project will use the location information of the network users and advanced data analytics techniques to achieve an enhanced smart network management. Accurate network localization and advanced network analytics will enhance smart network management by rapidly identifying network issues, profoundly increasing network resilience, and empowering the optimization of service performance.

Smart network management is studied in the framework of LOCUS WP4. In this context, four main use cases related to smart network management have been identified:

- Knowledge building for smart network management.
- Location aware network planning in 5G
- Location aware network optimization in 5G
- Location aware network Location aware network resilience in 5G.

4.1 Knowledge Building for network management (SNM-UC1)

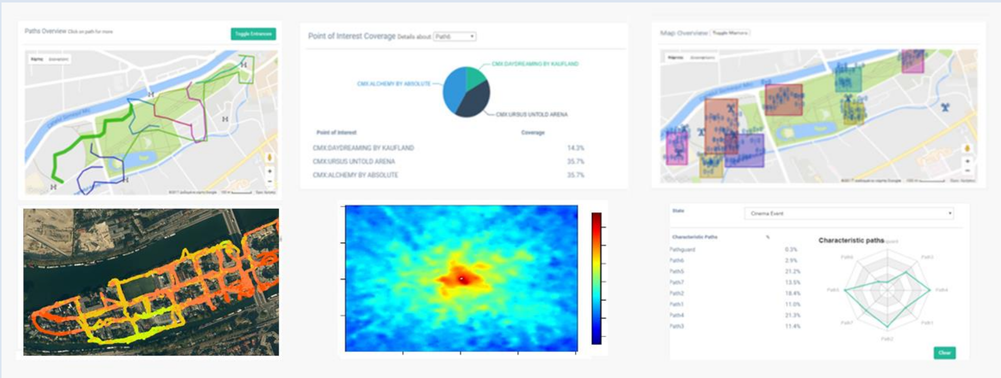
While location data on their own are extremely valuable information, combined with other network and geospatial data they can provide even more useful and meaningful insights. Furthermore, raw location information can be difficult to handle due to their volume and complexity and therefore difficult to track and interpret.

This use case refers to the building of knowledge based on the aforementioned data through the use of spatiotemporal analytics ranging from simple computations/aggregations to advanced analytics and machine learning approaches. While these approaches may vary depending on the insights provided, the common ground is that they achieve an abstraction of the location information in conjunction with network and other KPIs, extracting meaningful information, such as maps given specific network measurements or other KPIs, creation of new aggregated metrics that describe the underlying network status, detecting common trajectories and points/areas of Interest (POIs).

The resulting analytics can be further exploited for monitoring/analysis purposes and strategic decisions, e.g. network diagnostics, optimization at runtime or improvement of network design/redesign and planning.

4.1.1 *Use case description*

Use Case Name	Knowledge Building for network management (SNM-UC1)
Description / User Story	This use case involves the capability of the LOCUS platform to monitor network KPI/ measurement data in conjunction with location information for the extraction of meaningful and highly informative insights. The latter can then be used for other purposes such as network diagnostics, optimization at runtime or improvement of network design/redesign and planning. In detail, these insights are derived from advanced calculations/ analytics, as well as spatiotemporal ML approaches. A set of functionalities are enumerated below: • Geospatially correlated network KPIs and inferring the network status within a certain underlying area. Creation of new location-aware indicators (contextualized indicators) such as determination of Points of Interest (POIs) and frequent/periodic paths/trajectories. • Creation of images (e.g. heatmaps), SINR and Bitrate maps, Radio Environment Maps (REM) and other that provide information about the network status. • Other Analytics per path/ POI at a spatio-temporal level
Category	1) Smart network management based on 5G equipment localization
Actors	LOCUS analytics engine Network Manager/3rd-party App developer
Actors' Roles	• The LOCUS analytics engine will be performing constant ML-based KPI transformations in order to obtain contextualized indicators and images. • The Network manager or any App developer will be able to monitor and utilize the extracted KPIs and insights for network management purposes.
Localisation and Analytics Roles	The role of localization and analytics is a key factor to the creation of these new information sources; in order to extract meaningful insights such as paths/POIs and to create for example heatmap images where a certain KPI value is assigned to each pixel, advanced analytics and ML models will have to be deployed.
Goal	• Visualize network KPIs with the geospatial information provided by LOCUS platform. • Apply ML for spatiotemporal information, building knowledge for network management, optimization & planning. • Automatic generation of contextualized indicators and fusion of cellular, location and application data for metrics generation

Constraints / Assumptions	• This use case assumes a detail meta-data store with the geography and topology of the network • This use case assumes that the processed information is time-correlated with low delay • Access to network measurements of the standardized 3GPP network KPIs that will be used. • Location -where necessary- will be given through WP3 algorithms.
Geographic Scope	Outdoor/indoor
Picture Exemplifying the Use Case	
Event Flow	As users move through a specific area, network measurements and KPIs are collected along with location information and are stored. The LOCUS Analytics Engine performs regular calculations and advanced analytics based on the historical data in order to extract meaningful information, updating POI and Path information, creating heatmaps etc.

4.1.2 Technical requirements

Service level Requirement	SLR Unit	SLR Value	Explanations/Reasoning/Background
Localisation accuracy	[m]	1-5	Different meter-level localization accuracy is re-quired depending on Analytics and application to be utilized (see [6])
Security/ privacy of data requested/generated	Level of security, anonymity and priva-	High Security-by-design	The consumer of these LOCUS platform services stemming from this use case will interface directly with the aggregated/ abstracted insights based on raw location data. No user location data will be uti-

	cy of data.		lized by 3rd parties. Analysis/ML employed will hide the personal information of the underlying area.
Service Level Latency and set-up time	[s]	variable	Variable depending on the KPI and the critically of service to be offered. The latency of the service can be on the order of the API specifications and is independent of the location and network data latencies, as the generation of analytics does not necessarily correspond to the actual raw data input rate.
Analytics Update Frequency	[Hz]	variable	The update interval for the Analytics can vary depending on the application. The analytics update rate should not be lower than the network KPIs/ measurements' and location data update rates.
Service Level Reliability	%	90-99%	Depending on application and 3rd party requirements.
Service Level availability	%	90- 99%	The availability depends on the application scenario.
Interoperability/ Regulatory/ Standardization Required	[yes/no]	Yes	Southbound interfacing with the Network Elements and/or database where these data are stored. Northbound interfacing for the provision of the extracted/aggregated data to 3rd parties.
Functional requirements	• **SNM-UC1_FR1:** The system shall use network and geolocation information for heatmap visualization of multiple network KPIs. • **SNM-UC1_FR2:** The system shall exploit geolocation data to provide identified areas. • **SNM-UC1_FR3:** The system shall use geolocation data to identify paths. • **SNM-UC1_FR4:** Aggregation analytics for network KPIs per area and path shall be implemented for the purposes of the use case. • **SNM-UC1_FR5:** Interfacing with the Locus geolocation services for acquisition of raw anonymized data shall be available. • **SNM-UC1_FR6:** The system shall provide southbound interfacing with the Network Elements and/or a database where cell-level metrics and related KPI data are stored.		

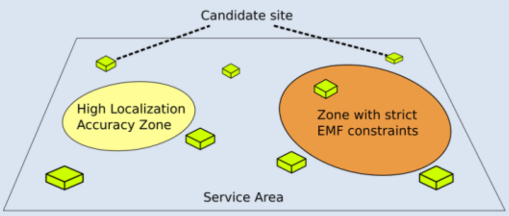
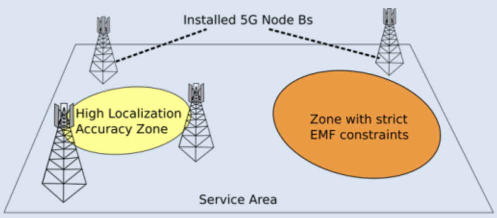
	• **SNM-UC1_FR7:** Interfacing capabilities for 3rd party Apps for network monitoring, planning, network optimization and network diagnostics purposes shall be available.

4.2 Location-Aware network Planning in 5G (SNM-UC2)

The goals of this UC are, on the one hand, to explore the impact of 5G Node B positioning on the accuracy of localization and, on the other hand, to exploit localization information to detect optimal 5G Node B emplacements.

4.2.1 Use case description

Use Case Name	Location-Aware network Planning in 5G (SNM-UC2)
Description / User Story	In general, the planning of 5G networks is a complex and variegate task, which includes CAPital EXpenditures (CAPEX) constraints, ElectroMagnetic Fields (EMFs) constraints, performance constraints and Return on Investment (RoI) targets. Intuitively, a sparse positioning of 5G Node Bs over the territory may result into a minimization of CAPEX. However, the localization precision and the network performance may be negatively impacted. On the other hand, a very dense deployment may guarantee an extremely high localization precision and network performance, but with a strong impact on the EMF exposure and the total costs. This UC will therefore explore the impact of introducing localization constraints in the planning process.
Category	1) Smart network management based on 5G equipment localization
Actors	- Server running the 5G planning tool designed in this UC - 5G Analytics Engine
Actors' Roles	The 5G planning tool will be the core element of this UC. The tool will be run on a server. The planning tool will receive as input a set of candidate sites for installing 5G Node Bs, as well as the description of the scenarios in terms of buildings, legacy 2G/3G/4G networks, targeted goals (e.g., localization performance maximization, 5G service maximization, EMF minimization, CAPEX minimization, or a composite set of goals). Part of the inputs may be derived from the 5G Analytics Engine implemented in LOCUS. The planning tool will then exploit an optimization-based approach to model the constraints of the problem, which will include e.g., coverage constraints, 5G service constraints, maximum EMF limits, and localization constraints over the territory. The planning tool will then produce as output the set of chosen sites to host 5G-Node Bs, the configuration of each site in terms of antenna elements/settings, and the costs/performance/EMF/localization values.

Localisation and Analytics Roles	The role of localization is to drive the planning process in order to derive an optimal planning of 5G Node-Bs. The role of analytics may be double: i) on one side, it can be exploited to introduce localization constraints over the territory (e.g., to select the subset of areas where a high localization precision is required), ii) on the other side, it can be used to derive the 5G performance service constraints by users, which can be varying in time and in space.
Goal	• formulate the problem of location-aware network planning in 5G and the associated constraints • solve the problem in a representative scenario, while meeting the EMF/CAPEX/performance constraints; • design new algorithms to solve the problem in large-scale scenarios
Constraints / Assumptions	• This use case assumes to model the localization precision as a constraint that can be computed from a given positioning of 5G Node-Bs; • The other constraints (CAPEX, EMF, service) are assumed to be tailored to the 5G network equipment.
Geographic Scope	Indoor/Outdoor
Picture Exemplifying the Use Case	 Fig.1: input scenario to the planning tool: candidate sites and constraints over the territory.  Fig.2: output o the planning tool: i) installed 5G Node-Bs over the territory, ii) radio configuration of each installed 5G Node-B.
Event Flow	- The planning module receives all the input parameters; - The module then computes a solution to the problem; - The set of selected 5G Node-Bs, their configuration, as well as the CAPEX/EMF/localization/performance metrics are produced as output.

4.2.2 Technical requirements

Service level Requirement	SLR Unit	SLR Value	Explanations/Reasoning/Background
Localisation Accuracy	m	Constraint that can be set as input to the problem.	The goal is to test the planning for different values of minimum localization accuracy in order to evaluate the impact on the other variables (e.g., CAPEX, EMF, service)
Security/ Privacy of data Requested/Generated	none	none	The problem can be run on a custom scenario, which can be publicly released.
Service Latency and Set-up Time	n.a.	n.a.	Since the problem is not intended to be run in the operational network, the latency and the set-up constraints do not apply.
Service Reliability	[%]	Constraint that be set as input.	The level of reliability can be also chosen as input to the problem. Ideally, the level of reliability should be 100% for a given localization accuracy. However, we will also study the impact of relaxing this constraint.
Service Availability	[%]	100	Since this problem is run during the design step, it is assumed that an availability of 100% of the localization service will be provided.
Rate / Periodicity	n.a.	n.a.	The planning problem has to be run one time for each considered scenario.
Interoperability/ Regulatory/ Standardization Required	[yes/no]	YES	UC will select a set of candidate 5G Node Bs to be installed over the territory. The installation of the 5G Node Bs will have to adhere to the EMF constraints, whose regulations strongly varying across the countries in the world. Therefore, the

			problem will be solved under different EMF regulation constraints.
Other use case specific KPIs	-minimum/ average/maximum 5G service throughput -minimum / average/ maximum EMF exposure -total installation costs	Output values to be defined.	Specific KPIs evaluated in the problem include the amount of throughput provided to users, the level of EMF exposure over the territory, and the monetary costs of the installed 5G NodeBs. These values will be produced as output to the problem.
Functional requirements	• **SNM-UC2_FR1:** Localization data from the LOCUS system shall be available for location-aware network planning in 5G. • **SNM-UC2_FR2:** Auxiliary data from the 5G system and other required sources shall also be utilized. • **SNM-UC2_FR3:** Post-processed data and knowledge built in SNM_UC1 shall be accessed for the purposes of this UC. • **SNM-UC2_FR4:** Feedback to SNM_UC1 shall be provided. • **SNM-UC2_FR5:** The system shall have access to up-to-date network topology and parameters. • **SNM-UC2_FR6:** The system shall provide planning recommendations. • **SNM-UC2_FR7:** The system shall send a request to the network that enforces recommended changes if appropriate interface is available and if the UC is allowed to do so.		

4.3 Location aware network optimization in 5G (SNM-UC3)

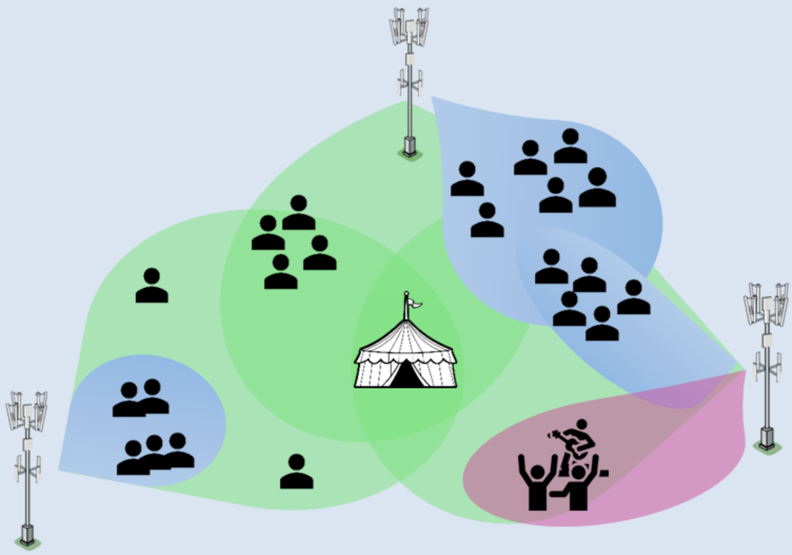
The objective of SNM-UC3 is the design of a system that allows the network operator to decide their network optimization policies in order to enhance the network capacity, network coverage or the

Quality of Experience perceived by UEs in 5G including both sub 6GHZ and mmWaves systems and multi-connectivity scenarios.

This system is location-aware in the sense that it is capable of collecting localized data from users and terminals. The system has access to Performance Management (PM) and Configuration Management (CM) network data, and it may also access to social information. The system has also access to the output of SNM-UC1 (and can also trigger it). The geolocation knowledge includes geolocation-based information directly collected as well as post-processed geolocation information provided by the SNM-UC1 system.

4.3.1 Use case description

Use Case Name	Location aware network optimization (SNM-UC3)
Description / User Story	The system designs network optimisation policies/algorithms using geolocation knowledge including: • Multi user scheduling enhancement • Radio resource optimization in multi-connectivity scenario • Mobility parameters optimization • Load management • General performance and QoE degradation prevention, using both network and social information • Active Antenna Systems (AAS) reconfiguration for coverage and capacity optimization • Packed Duplication activation/deactivation based on location for Ultra-Reliable communications. The network optimization actions will rely on improved prediction of cellular performance metrics in addition to performance indicators of the network, and social data when available. Thus, it will propose proactive actions, in order to compensate performance drops.
Category	1) Smart network management based on 5G equipment localization
Actors	• LOCUS optimization engine • LOCUS analytics engine • Network elements
Actors' Roles	• Locus optimization engine will decide network optimization policies based on geolocation knowledge. • Locus optimization engine will use and/or request output from the locus analytics engine • Network elements will activate multi-connectivity capabilities as well as AAS will be reconfigured when needed based on the network scenario in real time, to actuate the optimization policies defined by the Locus Optimization Engine.

Localisation and Analytics Roles	The role of the localisation is being one of the main inputs which are used to reconfigure the AAS parameters in order to optimize the coverage and capacity. The role of analytics is their use to proactive compensation in the network.
Goal	• Improving both Quality of Service and Quality of Experience of end-users. • Designing ML forecasting techniques including social information and performance indicators of the network • Improved optimization based on relative position of cell and venues (concerts, parks…) as well as user mobility and traffic patterns • Saving OPEX costs when compensation techniques are carried out
Constraints / Assumptions	• Multi-connectivity capability is enabled. • Access to UE measurement reports, cell-level metrics, UE position, E2E data and social data. • This use case assumes that modifying AAS configuration parameters is available • Access to radio resources scheduler
Geographic Scope	Outdoor and indoor
Picture Exemplifying the Use Case	
Event Flow	The system knows the current state of the network based on performance indicators, UE reports, UE positions, social data and the configuration parameters. Then, the system uses all this information to seek further optimized states of the network in terms of coverage, capacity or users' QoE that may be reached by reconfiguration of AAS parameters as well as changing the radio resource allocation in 5G multi-connectivity scenarios. Likewise, the system forecasts if the users' QoE

	will drop in order to carry out compensation actions.

4.3.2 Technical requirements

Service level Requirement	SLR Unit	SLR Value	Explanations/Reasoning/Background
Localisation Accuracy	m	1-5	Meters location accuracy is required because beams should be as directive as possible.
Security/ Privacy of data Requested/Generated			Location information must be protected from possible third parties. Manipulation may also produce inaccuracies that provoke malfunctions.
Service Latency and Set-up Time	ms	Latency: 0-1s	The latency of the system is widely variable. That is, some functions of the system as the radio resource allocation must carry out with quite less latency than others, e.g., AAS parameter reconfigurations.
Service Reliability	[%]	>99	It depends on the criticality of the service that is provided.
Service Availability	[%]	>99	It depends on the criticality of the service that is provided.
Interoperability/ Regulatory/ Standardization Required	[yes/no]	Yes	Compliance with 3GPP.

Functional requirements	• **SNM-UC3_FR1:** Localization data from the LOCUS system shall be available for location-aware network planning in 5G. • **SNM-UC3_FR2:** The system shall have access to up-to-date network topology and parameters. • **SNM-UC3_FR3:** Auxiliary data from the 5G system and other required sources shall also be utilized. • **SNM-UC3_FR4:** Post-processed data and knowledge built in SNM_UC1 shall be accessed for the purposes of this UC. • **SNM-UC3_FR5:** The system shall enable SNM_UC1 to trigger for additional measurements or to request pre-processed data. • **SNM-UC3_FR6:** The system shall provide network optimization decisions and -given availability of the appropriate APIs- may enforce actions in the network with the required time granularity. • **SNM-UC3_FR7:** The system shall provide optimization recommendations as decision support for operational teams.

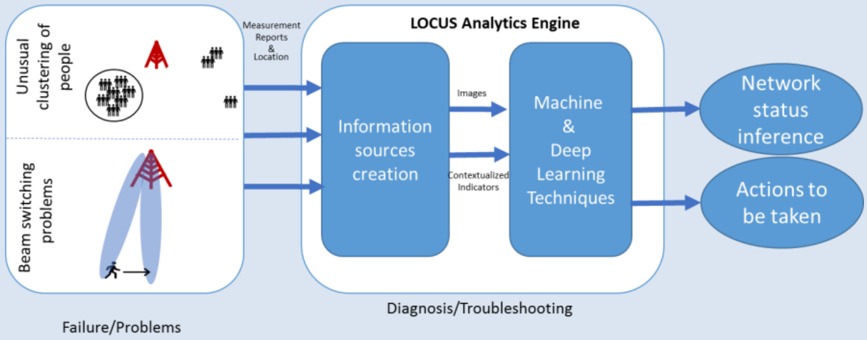
4.4 Location aware network resilience in 5G (SNM-UC4)

Network resilience has been classically addressed in Radio Access Networks by means of the self-healing function [7] of Self-Organising Networks (SON), which include failure detection, diagnosis and compensation. With 5G deployments, it will be necessary to consider new types of problems or network states (e.g. related to network virtualization), as well as to study the way in which these will be manifested through the network and service performance indicators and the context [8] In addition, more efficient compensation algorithms will be developed taking advantage of multi-link communications or the use of unlicensed bands in 5G. The aim of SNM-UC4 is to model, diagnose and troubleshoot these emerging failures.

4.4.1 Use case description

Use Case Name	Location aware network diagnosis/troubleshooting in 5G (SNM-UC4)
Description / User Story	The first step will consist on modelling the 5G emerging failures (e.g. too late/early beam switching), that may be due to changes on users' positions, or an unusual clustering of people. After their definitions, it will be a requirement to consider

	location information about the users to achieve a better diagnosis and solution of the problem. Hence, contextualized indicators will allow the network operator to perform the RCA of the problems by using machine learning over time-series style metrics. Alternatively, deep learning techniques will be applied over the positioned terminal data and performance to improve the troubleshooting process.
Category	1) Smart network management based on 5G equipment localization
Actors	LOCUS analytics engine Network elements
Actors' Roles	The LOCUS analytics engine will use contextualized indicators and/or positioned data coming from the connected devices of the scenario in order to apply both machine and deep learning techniques. This will result in an accurate problem detection and their root causes identification. Bearing this information in mind, the LOCUS analytics engine will take different actions might be taken in order to solve the problem.
Localisation and Analytics Roles	The role of localization is to drive the root cause analysis more accurate and to improve the compensation results adapting the actions to be taken to the specific situation. The role of analytics is to correctly identify maximum number of problems associated with the novel 5G networks as well as influence on network reconfiguration process.
Goal	• Identify network performance problems accurately. • Provide reliable information about the problems and their causes to the network management system. • Deep learning approach for location-aware diagnosis.
Constraints / Assumptions	• This use case assumes that location information about users is always available.
Geographic Scope	Indoor/Outdoor

Picture Exemplifying the Use Case	
Event Flow	• LOCUS analytics engine notices a problem on the network performance by monitoring contextualized indicators and created images (information sources). • Root cause analysis is performed to model the failure. • Compensation actions are taken to limit degradations produced by the failure. • Failure and possible compensation information is provided to the network management system.

4.4.2 Technical requirements

Service level Requirement	SLR Unit	SLR Value	Explanations/Reasoning/Background
Localisation Accuracy	m	1-5	Location accuracy will be provided by other uses cases
Security/ Privacy of data Requested/Generated	none	none	Location data from users may be private
Service Latency and Set-up Time	seconds	Up to 10	It will be dependent on the ML/DL technique used and, also, on the other use cases latency. Also, dependent on the information source creation latency, which comes from another use case.

Service Reliability	[%]	Up to 95	It will be dependent on the ML/DL used technique.
Service Availability	[%]	90	Always available depending on the user report and the KPI measurement performed by the network elements deployment.
Rate / Periodicity	seconds	Up to 5	It will be dependent on the user report rate
Interoperability/ Regulatory/ Standardization Required	[yes/no]	yes	Location reporting procedures by the UEs to the network
Other use case specific KPIs	None	Contextua lized indic ators and images	This KPIs will be used to apply the Machine and Deep Learning techniques in order to infer the network status and, eventually, determining the actions to be taken upon the network's parameters configuration.
Functional requirements	• **SNM-UC4_FR1:** The system shall have the appropriate interfaces with other LOCUS functional components for the continuous acquisition of low-level positioning information (stemming from WP3 work). • **SNM-UC4_FR2:** Measurement data, cell-level metrics and related KPI data shall be stored and accessed at all times, as well as auxiliary data from the 5G system and other required sources. • **SNM-UC4_FR3:** Post-processed data and knowledge built in SNM_UC1 shall be accessed for the purposes of this UC. • **SNM-UC4_FR4:** Feedback shall be provided to SNM_UC1 when relevant. • **SNM-UC4_FR5:** The system shall have access to up-to-date network topology and parameters. • **SNM-UC4_FR6:** The system shall provide network failure management decisions. • **SNM-UC4_FR7:** Information shall be generated at the applicable rate per case, as some analytics may be dependent on the rate of location data acquisition, with respect to quality and accuracy of results.		

5 Localization and analytics for new services

The UCs presented in this Section address all the aspects related to analytics in support of new services on top of 5G. The UCs are structured to develop and achieve the following specific objectives:

- **Design and implement a flexible virtualization platform** that can natively extend the 5G network orchestration layer and capable to **configure seamless chaining of network and application virtual functions** to more efficiently implement and serve applications requests beyond connectivity.
- **Realize appropriate information abstraction** so as to optimize the following trade-off: no exposure of sensitive network information and personal data, while being meaningful and rich to realize advanced applications.
- **Realize advanced analytic mechanisms**, which will leverage on the abstracted location information, and power the advanced applications.
- Integrate and manage virtualized localization data collectors and processors into the virtualization platform to **implement the LOCUS localization and analytics "as a service" model**.
- **Enable the realization of advanced applications based on geolocation information** that will derive from the 5G era, and corresponding advanced analytics that will deliver higher level insights.

Such objectives will be developed and achieved within the following use cases:

- Flow Monitoring and Management in Large Venues and Dense Urban Environments (NSE-UC1)
- Crowd mobility analytics using mobile sensing and auxiliary sensors (NSE-UC2)
- Vulnerable Road User (NSE-UC3)
- Logistics in a seaport terminal using AGVs (NSE-UC4)
- Transportation optimization based on identification of traffic profiles (NSE-UC5)
- Positioning and Flow Monitoring for Controlling COVID-19 (NSE-UC6)

5.1 Flow Monitoring and Management in Large Venues and Dense Urban Environments (NSE-UC1)

Large venues and transportation hubs (airports, train stations, malls, stadiums, etc.) exhibit the gathering of large crowds, with complex mobility behaviour. While for example LEN-UC2 deals with the providing signal processing solutions in such scenarios, NSE-UC1 provides solution for an efficient flow and resources management to maximise QoE (Queues, logistics, staff, security, etc.).

By using the virtualized location information at the LOCUS Geolocation Server, the LOCUS Analytics service will provide the best routes, smart notifications/ recommendations adapted to individual preferences (walking, shopping, food, etc.) - when offered - and current flow and contextual information, through a mobile application and/or smart panels.

Venue administrators and the transportation companies can be informed, by the LOCUS server, of their clients' situation in near real-time: they can use the information to optimise their embarking operations and reduce risk for last minute call to gate, flight delays because of one passenger, etc.

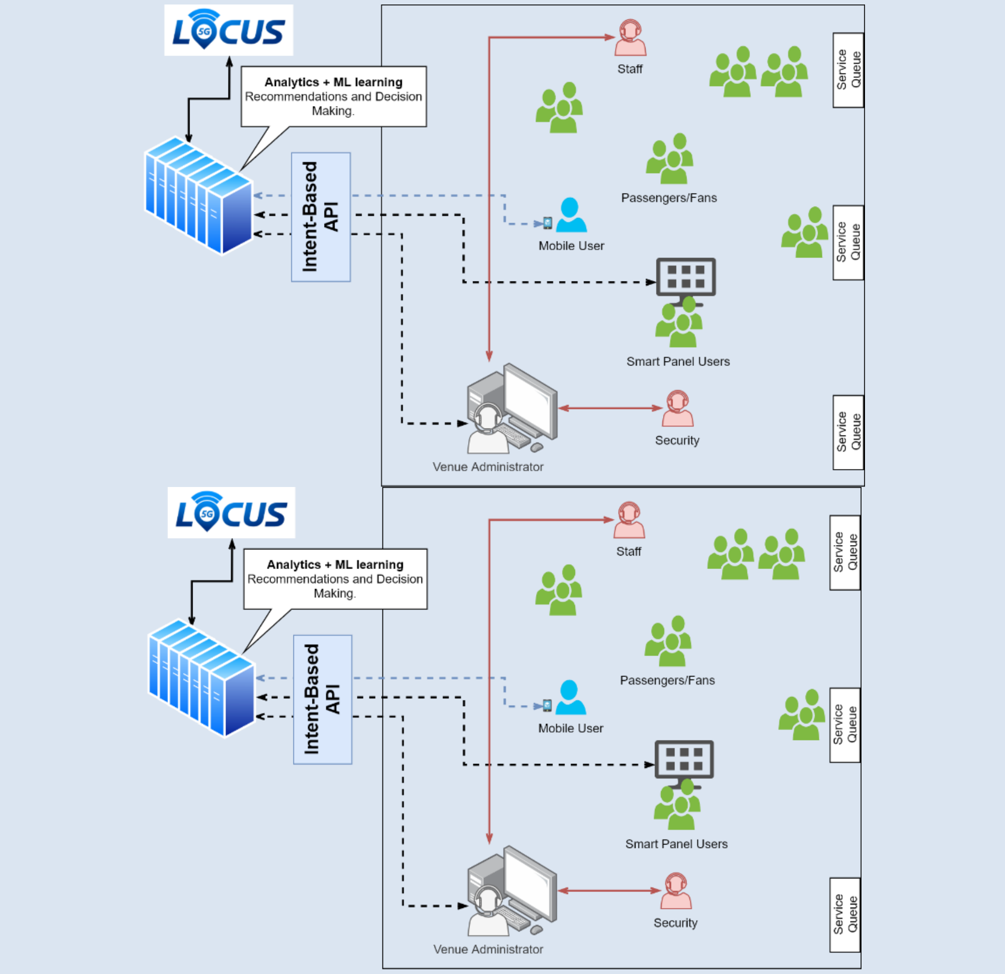
Using location information, the venue will be able to elaborate statistics on people's flow to optimise their organisation and signalling to customers and passengers.

By Extension, 5G Network Operators can assess network performance and exploit the LOCUS Analytics service to improve QoS in relation to people's mobility and traffic patterns.

5.1.1 Use case description

Use Case Name	Flow Monitoring and Management in Transportation hubs and Large Venues (NSE-UC1)
Description / User Story	Leveraging LOCUS's ML and Analytics capabilities, to provide reliable monitoring and high-level insights on people's locations and mobility, and assist in decision making and fusion with contextual information. More in details we can define the following applications: 1. Given an indoor and/or outdoor environment, such as a mall, airport, an open area venue, a highly touristic area etc., with multiple buildings/ shops (e.g. boutique stores, diners/ cafés, recreational spaces) which create varying mobility and network access patterns. Mobility patterns (movements through time and space, network usage) are deduced through machine learning in order to identify useful location analytics, such as possible visitor paths and points of interest, abstracting user-specific location. A recommendation model could for instance utilize the aforementioned information, by following any user with an installed retail App as he or she moves within a specified area, and provide retail recommendations. 2. Use case takes place in a security monitored indoor area, i.e. a mall, an airport or other venue, where various mobility profiles are found, that also includes authorized and unauthorized areas. People mobility is tracked at all times. Specific alerts may be customized in order for the venue security to receive alerts, including the existence of unauthorized persons in specific area and the presence of a large number of people in other points of interest. This way, any violation/ infringement can be quickly detected, and management of people traffic is achieved.

Category	3) People mobility & flow monitoring
Actors	• 5G LOCUS User: UE (Passenger/Customer/Fan), Venue Administrator, Smart Panels • LOCUS Geolocation Server • LOCUS Analytics/ML Server exposed as a service with an Intent-Based API • 3rd Party Service Provider: This could be an App for example.
Actors' Roles	• 5G LOCUS User: Will be requesting routes, flow patterns, trends, anomaly detection, recommendations, and real time notifications during their presence in the venue, through a 3rd party App or Smart Panels. • LOCUS Geolocation Server: The entity that aggregates the low-level geolocation data and provides it as virtualized data structures, offering an abstracted version of this information to be used for vertical applications. • LOCUS Analytics/ML Server: Runs Analytics and ML models, and interacts with User requests through a RESTful Intent-Based API. The interaction is Bi-directional.
Localisation and Analytics Roles	Analytics to be performed for spatio-temporal KPI aggregation, as well as abstraction of localization information to identify trends, bottlenecks, and mobility patterns. ML will be employed to optimize the decision making and to provide recommendations. Lastly, Analytics and ML will be used to achieve localization.
Goal	QoS/QoE improvement, improve resources management.
Constraints / Assumptions	• Data Privacy is ensured through anonymization and abstraction of location information. • Availability of contextual information (venue maps, user preferences, etc.) • Location data derived from analytics/ ML will be expected as input for the models developed for location abstraction and decision making/ recommendations/ notifications. • Possible constraints due to limited computation/communication capabilities on the devices (sensors)
Geographic Scope	Dense Urban Environment (Indoor/Outdoor/Hybrid)

Picture Exemplifying the Use Case	
Event Flow	• Flow 1: The passenger/customer/fan enters the venue. Turns on an App or looks at directions on “Smart Panels”, after having expressed her consent. Receives suggestions for best itineraries, conditioned on personal preferences (little walking, food nearby, etc.). And real-time alerts when set goals (departure and other) are at risk, based on analytics and ML provided by the LOCUS system. • Flow 2: Passengers/customers/fans enter the venue. Administrators get real-time view of people’s mobility, can manage resources accordingly (staff, security), track QoE (seats filled before games, late arrival at gates and so on), based on analytics and ML provided by the LOCUS system.

5.1.2 Technical requirements

Service level Requirement	SLR Unit	SLR Value	Explanations/Reasoning/Background

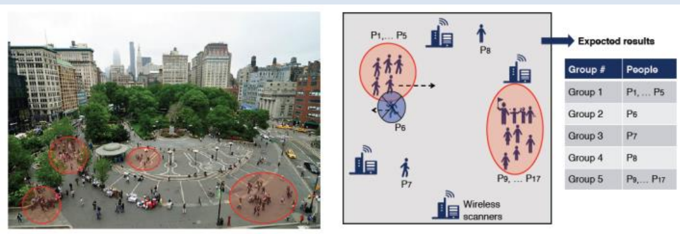
Localisation Accuracy	[m]	<=10: Horizontal <=3: Vertical	
Security/ Privacy of data Requested/ Generated	Level of security or anonymity of data	High	• For installed Apps and user information, solution must allow for acceptance and withdrawal of user consent. • Flow/movement monitoring should be appropriately abstracted through ML models/Analytics in order to be further used by third parties.
Time To First Fix	s	<=10	
Set-up Time	h	1-2	Time for ML recommendation/optimization models to train based on sufficient abstracted location data in an area after first setup.
Update Frequency	Hz	Variable	At this level, position information is aggregation from multiple sources, with varying update rates, and provided to the end user at update rates that can be selected as service parameters.
Service Reliability	%	95	The reliability is important due the nature of supported verticals, and the need for constant monitoring.
Service Availability	%	99	High availability is important due the nature of supported verticals, and the need for constant monitoring.
Rate/ periodicity	[ms]	Variable	Depends on availability of low-level positioning, and characteristics of specific deployed verticals.
Interoperability/ Regulatory/ Standardization	[yes/no]	TBD	Depends on LOCUS Architecture, and on alignments with potential 3GPP WG/Specs (e.g. 3GPP TR 28.812 0)

Required			
Data Virtualization	[yes/no]	Yes	Task 5.2 relies on virtualization technologies for the specification of high-level data structures and mechanisms to interact with it.
Functional requirements	• **NSE-UC1_FR1**: Localization data from the LOCUS system shall be available for this UC. • **NSE-UC1_FR2**: Auxiliary data from the 5G system and other required sources shall also be utilized. • **NSE-UC1_FR3**: The appropriate protocols to acquire low level positioning information and auxiliary data, periodically, event-based and on-demand, shall be available. • **NSE-UC1_FR4**: A virtualization platform shall allow for geolocation data from multiple sources and in multiple formats to be aggregated and virtualized for Analytics consumption. • **NSE-UC1_FR5**: The system shall offer the appropriate anonymization capabilities for data in-use. • **NSE-UC1_FR6**: Interfacing capabilities for 3rd party Apps shall be provided.		

5.2 Crowd mobility analytics using mobile sensing and auxiliary sensors (NSE-UC2)

LOCUS will perform crowd analytics in urban areas, using limited auxiliary sensors, such as cameras, for benchmarking and improving the accuracy of the estimation, as well as machine learning with training from the historical data. Individual device location data can be leveraged to identify individualistic movement patterns using recurrent neural networks. Data manipulation, data fusion, and ML methods offered by LOCUS will be verified. Crowd sizes, group movement behaviours, people flow behaviours, and waiting time analyses will be conveyed via advanced visualizations. The crowd analytics results aim to optimize smart mobility by improving decision making such as path planning of vehicles by humans or autonomous vehicles. Relevant references for this use case can be found in [9] and [10].

5.2.1 *Use case details*

Use Case Name	Crowd mobility analytics through mobile sensing and auxiliary sensors (NSE-UC2)
Description / User Story	Prediction of crowd mobility characteristics/behaviours using sensory data in urban environments (outdoor or indoor). This prediction can be used for both monitoring and planning allocation of resources at urban macro level.
Category	3) People mobility & flow monitoring
Actors	• Humans/crowd (i.e., mobile device users), IoT sensors, physical entities (e.g., roads, buildings, rooms), (possible) vehicles. • LOCUS Geolocation Server • LOCUS Analytics/ML Server exposed as a service with an Intent-Based API
Actors' Roles	• Humans carry and use mobile devices • Physical entities can be extracted as context information • IoT sensors collect data from their environment • LOCUS Geolocation Server: The entity that aggregates the low-level geolocation data. • LOCUS Analytics/ML Server: Runs Analytics and ML models.
Localisation and Analytics Roles	Localization is not considered for individuals, IoT sensors may be localized Analytics can be shared partially on the edge and cloud
Goal	Accurate, scalable, and privacy-aware prediction of crowd mobility behaviours
Constraints / Assumptions	• Presumption: Availability or possibility of collection of ground-truth for benchmarking (permission in a city or university, collaboration with LOCUS partners) • Possible constraints due to limited computation/communication capabilities on the devices (sensors) • Possible constraints for privacy and security of data from IoT devices
Geographic Scope	Outdoor / indoor
Picture Exemplifying the Use Case	

<table>
<tr><td></td><td>Crowd mobility analytics using wireless scanners


Fig. 2: Context generation with mobile sensing</td></tr>
<tr><td>Event Flow</td><td>Pre-conditions:

Deployment of sensors and/or mobile sensing application for smartphones for multivariate data collection
Expected crowded scenarios (e.g., public events, open-air activities, gatherings in conference room) or people flows
Information regarding the schedule of events in the controlled or uncontrolled application scenario
The application zone should be available for benchmarking/ground-truth data collection
Anonymization & privacy measures should be taken, consent from the people involved

Main Event Flow:

Periodical events happen where the predictions are compared against the reality (e.g., crowd size, existence of groups)
Time interval to be decided based on the application scenario
(possible) Traffic congestions or other events that may affect the context from the environment
Visualization of events in a dashboard

Post Event Flow

Generation of insights from historical data over prolonged periods (e.g., 1 month)
Documenting insights for event management and possible data-driven recommendations
</td></tr>
</table>

5.2.2 Technical requirements

Service level Requirement	SLR Unit	SLR Value	Explanations/Reasoning/Background
Localisation Accuracy	[m]	1m (3σ)	Localization accuracy should be in the level of the defined ranges for each sensor for crowd estimation (e.g., up to 20m). For mobility analytics of group characteristics, the accuracy (e.g., for cameras, for wireless data) should be in the level of 1 to 2m. For characteristics such as transport modes, GNSS data (e.g., GPS) accuracy should be in 1 to 2m.
Security / privacy	[yes/no]	Yes / Yes	IoT devices to cloud communication should be private. Security measures such as multiple-layered firewalls are going to be taken. Privacy measures should be taken for anonymization of any personal data.
Service Latency and Set-up Time	[ms]	Latency: 100-500msec	The latency can be tolerated up to 500msec for crowd estimation or characteristics such as waiting time detection. Possible requirement: The latency up to 100msec can be tolerated for characteristics such as real-time mobility mode detection or prediction of individual pedestrian mobility behaviour.
Service Reliability	%	95	The reliability is important due to enabling pattern recognition from spatiotemporal data. The accuracy may greatly suffer due to service failures. For instance, for daily or weekly mobility pattern analytics the system should be up and running for prolonged periods.
Service Availability	As a percentage	99	The whole system (cloud, IoT devices, communication components) must be up and running almost all time of the defined time periods.

Rate/ periodicity	[ms]	Up to 1000	For mobile sensing data collection up to a second rate is necessary. Similar for possible image frames from cameras.
Interoperability/ Regulatory/ Standardization Required	[yes/no]	Yes / Yes / Yes	To share information with all the components and partners, standard data models may be used (e.g., FIWARE NGSI data model). The use case depends on the wireless communication protocols/standards.
Other use case specific KPIs (TBD)	None	None	None
Functional requirements	• **NSE-UC2_FR1:** System shall offer analytics for extracting crowd mobility behaviours in real-time or offline, employing ML methods for processing various data (e.g. image data, wireless data, mobile sensing data). • **NSE-UC2_FR2:** Communication capabilities with IoT devices (4G, WLAN or others), e.g. Bluetooth scanners, cameras, gateways, shall be offered. • **NSE-UC2_FR3**: Analytics and ML for pre-processing videos and other sensor data at the edge shall be employed. • **NSE-UC2_FR4:** The system shall provide the appropriate anonymization functions on the IoT devices' data (video/ image anonymization, anonymization of mobile sensing data), also at the edge. • **NSE-UC2_FR5:** The appropriate data safety and authentication procedures (authentication and firewalls, access through private keys to IoT devices) shall be available. • **NSE-UC2_FR6**: Localization data from the LOCUS system shall be available for location-aware network planning in 5G. • **NSE-UC2_FR7**: Auxiliary data from the 5G system and other required sources shall also be utilized. • **NSE-UC2_FR8**: The appropriate protocols to acquire low level positioning information and auxiliary data, periodically, event-based and on-demand, shall be available. • **NSE-UC2_FR9:** A virtualization platform shall allow for geolocation data from multiple sources and in multiple formats to be aggregated and virtualized for Analytics consumption. • **NSE-UC2_FR10:** The system shall allow for cloud storage for collected data in JSON/HTML format using NoSQL and/ or SQL databases.		

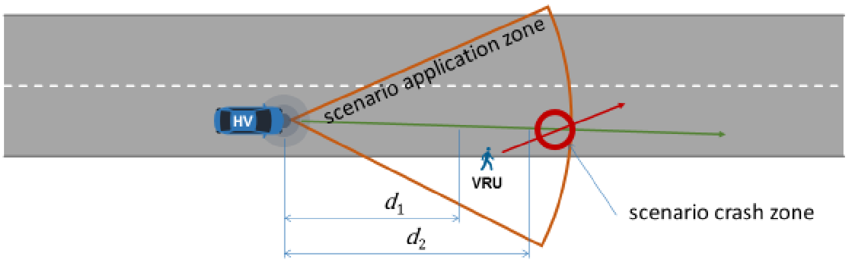
	• **NSE-UC2_FR11:** The system shall be able to use sensor devices or IoT services (e.g., open data Cloud services) for multi-variate data collection.

5.3 Vulnerable Road User use case (NSE-UC3)

In case a VRU is not equipped with a 5G compliant device, solutions based on device-free localization can be considered (see LEN-UC5).

5.3.1 Use case description

Use Case Name	Vulnerable Road User (NSE-UC3)
Description / User Story	Alert Host Vehicle (HV) of approaching Vulnerable Road User (VRU) in the road
Category	2) Network-assisted self-driving objects 3) People mobility & flow monitoring
Actors	• HV represents the vehicle moving forward • VRU represents a pedestrians, bike, eBike, motorbike, skateboard etc. that is travelling along the road
Actors' Roles	HV approaches the VRU along roads that are defined by their lane designations and geometry. The HV should be able to avoid collision with the VRU.
Localisation and Analytics Roles	In order to correct positioning based on GNSS (e.g., GPS, Galileo), positioning accuracy should be enhanced via the 3GPP System. Analytics could provide more detailed insight into the characteristics of the system e.g. tracking Time to Collision parameter for different type of VRU users in different weather conditions.
Goal	Avoid collision between HV and VRU.
Constraints / Assumptions	• Assumptions will be required for the following information: ○ HV's safe stopping distance ○ VRU's trajectory is constant ○ extent of scenario application zones
External sources/references if any	Use case adopted from 5GAA 'White Paper on C-V2X Use Cases: Methodology, Examples and Service Level Requirements' [11]
Geographic Scope	Outdoor

Picture Exemplifying the Use Case	Vulnerable Road User In Road  • d1=stopping distance of HV • d2=distance from HV to scenario crash zone

Event Flow	**Pre-conditions:**
	• HV is moving forward.
	• Before establishment of LoS, if any
	• Known VRU is characterized (pedestrian, bike, motorcycle, etc.)
	• The scenario application zone is determined from:
	  ○ HV's location and dynamics
	  ○ HV's safe stopping distance
	  ○ lane designations and geometry
	  ○ road conditions (if available)
	Main Event Flow:
	• If VRU is in the scenario application zone;
	  ○ If HV's trajectory and VRU's trajectory are on a collision course then warn HV of the risk of collision with the approaching VRU
	  ○ Otherwise caution HV of the approaching VRU
	Post-conditions:
	• HV/Driver is aware of its approach towards the VRU and any risk of collision (Day 1-1.5)
	• HV is aware of its approach towards the VRU and takes the necessary safety measures to avoid or mitigate collision (Day 3)

5.3.2 Technical requirements

Service level Requirement	SLR Unit	SLR Value	Explanations/Reasoning/Background
Localisation Accuracy	[m]	1m (3σ)	The 3GPP System shall provide a positioning accuracy of 1 – 2 m, e.g., considering support of GNSS, highly accurately positioned RSU and C-V2X UEs.

Security / privacy	[yes/no]	Yes / Yes	VRU communications security and privacy should be guaranteed.
Service Latency and Set-up Time	[ms]	Laten-cy: 100 Recom-mended communica-tion latency: 20 Set-up time: < 100ms	This is the maximum latency tolerable for allowing for a reaction due moving VRUs very near the road. 20 ms for VRU communication latency are compara-ble to that of cooperative maneuvers and sensor sharing because we see that the VRU situations will occur much unexpected and in close proximity to the vehicle. Thus, longer communication latencies would be adversarial to the intended purpose. Example for justification: For a 50 km/hr drive in dense urban environments (80m communication ra-dius), the total time budget until a potential com-plete stop has to be initiated is approximately 3.96 sec.
Service Reliability	%	99.9	High, the reliability here should be sufficient to guar-antee QoS. 99.9% should be sufficient, since addi-tional vehicle sensors are in place that can help to avoid collisions.
Service Availability	As a per-centage		The probability of success that localization functions can be performed over a specified period (accounting for service interruptions).
Rate/ periodicity	[ms]	100-1000	Corresponds to periodicity of V2X messages (e.g. ETSI Cooperative Awareness Message)
Interoperability/ Regulatory/ Stand-ardization Required	[yes/no]	Yes / Yes / Yes	In order to make it possible to share information and data on VRUs between vehicles, inter-OEM-operability should be guaranteed. Interoperability of UEs with RSUs, vehicles, and other local entities should be also guaranteed.
Functional requirements	• **NSE-UC3_FR1**: If the VRU is outside of the scenario application zone, the system shall have not warn the HV of the approaching VRU as the collision risk is limited. • **NSE-UC3_FR2**: In case of the failure of the communication based VRU pro-tection solution, the system shall be supported by other means e.g. VRU detection by internal vehicle sensors (camera, radar) used as a fall-back mechanism. • **NSE-UC3_FR3**: The system shall utilize various data, including VRU and ve-hicle location data from GNSS. • **NSE-UC3_FR4**: The system shall utilize VRU and vehicle location dynamics (current velocity and moving direction) data from Cooperative Awareness Messages (for definition see ETSI TS 102 637-2 V1.2.1 [12]). • **NSE-UC3_FR5**: The system shall utilize VRU and vehicle dimensions data from Cooperative Awareness Messages (for definition see[12]). • **NSE-UC3_FR6**: The system shall determine vehicle stopping distance from Cooperative Awareness Messages (for definition see [12]). • **NSE-UC3_FR7**: The system shall determine vehicle distance to scenario crash zone from VRU and vehicle location, dynamics, dimensions and vehi-		

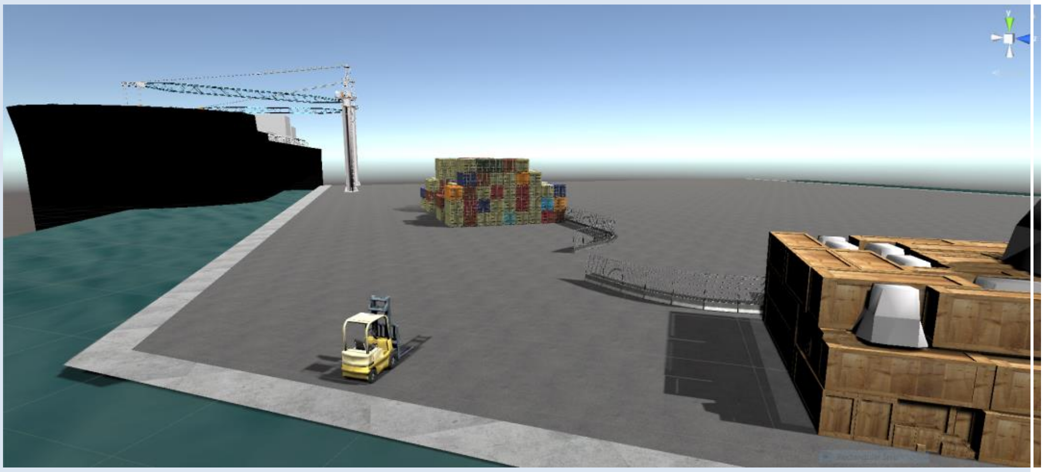
	cle stopping distance. • **NSE-UC3_FR8**: The system shall support enhanced localization data accuracy (vs GNSS in VRU/ vehicle device) from the 5G system/ LOCUS platform to fulfil required localisation requirements. Interfacing with a localization component shall be provided. • **NSE-UC3_FR9**: To realize 'Time To Collision as a Service', the LOCUS platform shall perform 'Time to Collision' parameter tracking/ analytics (see ETSI TS 101 539-3 V1.1.1 [13] document for the 'Time To Collision' parameter definition). Interfacing with an analytics component shall be offered. • **NSE-UC3_FR10**: 'Time to Collision' data shall be aggregated for individual VRU/ vehicle or a group of them located in a specific region, weather conditions etc.

5.4 Logistics in a seaport terminal using Automated Guided Vehicles (AGV) (NSE-UC4)

The use case refers to the handling of general cargo freights by means of AGVs in a seaport terminal.

5.4.1 Use case description

Use Case Name	Logistics in a seaport terminal using AGVs (NSE-UC4)
Description / User Story	The use case refers to the handling of general cargo freights by means of AGVs in a seaport terminal. A VR simulated environment reproducing a real terminal of the Livorno's seaport will be implemented for shuttling cargo freights between the terminal reception area, the storage and the loading place in front of the ship. A virtual model of AGV will be managed and guided using a dedicated mission/navigation system. The latter will use the position information provided by the 5G network to determine the next moves on the planned path.
Category	2) Network-assisted self-driving objects
Actors	Simulated 5G network positioning system Automated mission/navigation system Simulated AGV
Actors' Roles	• Simulated 5G network positioning system: it provides periodically the estimated position of the AGV • Automated mission/navigation system: it manages tasks, navigation plans

	and provides the AGV with navigation data computed on the basis of the position provided by the 5G positioning system • Simulated AGV: It models the behaviour of the AGV, providing inputs to the positioning system and getting movement instructions by the navigation system
Localisation and Analytics Roles	Localization is used to determine the current position of the AGV Analytics is made by the mission/navigation system to determine the next move the AGV has to do
Goal	Evaluate the performance of the 5G positioning system in a realistic context
Constraints / Assumptions	None
Geographic Scope	Hybrid or outdoor (Hybrid in case part of the storage area is in a warehouse)
Picture Exemplifying the Use Case	
Event Flow	Mission orders for AGVs (e.g. move object X from place A to place B within the port area) are sent to the mission/navigation system. The mission/navigation system drives the selected AGV in the shuttling operation, utilizing positioning data received by the LOCUS platform.

5.4.2 Technical requirements

Service level Requirement	SLR Unit	SLR Value	Explanations/Reasoning/Background
Localisation Accuracy	Meter or centimetre	Decimetre outdoor Centimetre indoor	Outdoor the accuracy required to navigate in the seaport terminal area and for picking and placing freights can be in the order of a 10-20 cm. In indoor conditions the accuracy should be around few centimetres to avoid collision with doors and

			walls
Quality of Information Requested/Generated	Quality of generated information incl. security	--	
Service Latency and Set-up Time	Seconds or ms	Service latency: 15 ms RTT	AGV requires an update every 50-80 ms for safe navigation. Most of the time is required by the navigation processing unit. 15 ms of RTT for the radio part can allow sufficient processing time
Service Reliability	As a percentage	98%	The probability of success that the key KPI's can be met over the period the service is required.
Service Availability	As a percentage	99.999%	The probability of success that localization functions can be performed over a specified period (accounting for service interruptions).
Interoperability/ Regulatory/ Standardization Required	[yes/no]	--	
Functional requirements	• **NSE-UC4_FR1**: The Use Case shall exploit 5G network data for the positioning of an AGV in the context of a freights shuttling task. • **NSE-UC4_FR2**: 5G based positional data shall be used as inputs to the automated mission/ navigation system. • **NSE-UC4_FR3**: The automated mission/ navigation system shall handle the planning of the shuttling tasks. • **NSE-UC4_FR4**: The automated mission/ navigation system shall determine the trajectory of the AGV. • **NSE-UC4_FR5**: The automated mission/ navigation system shall exploit the current position of the AGV and its velocity received from the LOCUS platform. • **NSE-UC4_FR6**: The automated mission/ navigation system shall compute and transfer the next motor command to the AGV. • **NSE-UC4_FR7**: The AGV shall implement the motor commands received		

	by the automated mission/ navigation system.

5.5 Transportation optimization based on identification of traffic profiles (NSE-UC5)

This use case involves the abstraction of location information at a large scale in an outdoor area. Given this outdoor setting, where various high or low traffic streets, avenues and motorways as well as train routes and pedestrians exist, a variety of different mobility profiles emerge.

This use case will enable flexible aggregation of low-level anonymized positioning and velocity information, and will offer an abstracted view of location-based data with the purpose of ambient monitoring. The LOCUS platform will take the necessary steps to exploit its capabilities to satisfy UC requirements, offering services such as (a) identifying different mobility profiles through an augmentation and fusion process and (b) extraction monitoring options to users through an App/Dashboard. The App itself could potentially be used by state entities like traffic police in order to enhance decision processes and could be further expanded to include various functionalities, e.g. near-future predictions of traffic in the selected area, detection of any anomalies/incidents and so on.

5.5.1 Use case description

Use Case Name	Transportation optimization based on identification of traffic profiles (NSE-UC5)
Description / User Story	Use case takes place in a general outdoor area where various mobility profiles exist, i.e. pedestrians, high/low traffic roads and main avenues, railway routes, with ever-changing velocity patterns. Based on the historical data available, these profiles will help the identification of near-future predictions of traffic in the selected area, as well as detect any anomalies/incidents. These changes can then further be used to alert the authorities (e.g. traffic police to manage their human resources and/ or connect with traffic lights management system) and monitored through a dashboard.
Category	• 3) People mobility & flow monitoring
Actors	• Area visitors • 5G LOCUS User, i.e. Authorities-Traffic police • LOCUS Geolocation Server • LOCUS Analytics/ML Server exposed • 3rd Party Service Provider: This could be an App/Dashboard.

Actors' Roles	• Area visitors: Moves around the area on foot, on board trains or vehicles. • User/ Authorities-Traffic police: uses App/Dashboard information in order to track incidents and impending traffic. • LOCUS Geolocation Server: The entity that aggregates the low-level geolocation data and provide it in virtualized data structures, offering an abstracted version of this information to be used for vertical application. • LOCUS Analytics/ML Server: The LOCUS analytics engine will receive a combination of south-bound measurements from the Network elements in order to process it into the intermediate and finalized abstracted location information • 3rd Party Service Provider: Provides the app that offers that detects inci-dents and near-future events in order to notify authorities for the issue and possible actions necessary based on locations Analytics/Flow monitoring in-formation.
Localisation and Analytics Roles	Analytics to be performed for spatio-temporal KPI aggregation, as well as abstraction of localization information. The location information is utilized to extract useful time-dependent location metadata and identify trends, such as probable routes, points of interest, velocity, bottlenecks and mobility patterns etc. Location information abstraction is done through advanced analytics and is then exploited further in the application algorithms.
Goal	To prove the feasibility and exploitability of location information through time for smart city traffic management.
Constraints / Assumptions	• Data Privacy is ensured through anonymization and abstraction of location information. • We assume some knowledge of position of avenues, train routes, smaller roads etc. • A localization algorithm - depending on geographic scope- feeds the models for the abstraction of location information.
Geographic Scope	Dense Urban Environment - Outdoor
Picture Exemplifying the Use Case	

<table>
<tr><td></td><td>
</td></tr>
<tr><td>Event Flow</td><td>Localization information is gathered for the various mobile terminals that are moving in a large transportation hub consisting of various mobility profile users. This information is transformed into data mined paths from the LOCUS platform and their mobility profiles are analysed. The 3rd party application consumes the mobility profiles of the various identified routes and monitor any changes. Authorities-Traffic police will use App/Dashboard information in order to track incidents and impending traffic.
As an extension of this event, flow smart city infrastructure (e.g. smart traffic lights) can then be adjusted to improve the traffic flow of curtain avenues/areas.</td></tr>
</table>

5.5.2 Technical requirements

Service level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Localisation Accuracy	[m]	<=10: Horizontal <=3: Vertical	..
Security/ Privacy of data Requested/ Generated	Level of security or anonymity	High	Flow/ movement monitoring is appropriately abstracted through ML models/Analytics in order to be further used by third parties.

	of data		
Set-up Time	h	Setup time <2h	Recalculation of profiles to be delivered at regular intervals. For Set-up time, time is needed for ML recommendation/optimization models to train based on sufficient abstracted location data in an area after first setup.
Update Frequency	Hz	Variable	At this level, position information is aggregation from multiple sources, with varying update rates, and provided to the end user at update rates that can be selected as service parameters.
Service Reliability	%	95	The reliability is important due the need for constant monitoring.
Service Availability	%	99	High availability is important due the need for constant monitoring.
Rate/ periodicity	[ms]	Variable	Depends on availability of low-level positioning, and user requirements.
Interoperability/ Regulatory/ Standardization Required	[yes/no]	Yes	API layer with Analytics as a Service and interfacing with Localization Service.
Functional requirements	• **NSE-UC5_FR1**: The system shall exploit geolocation-velocity data to provide identified areas. • **NSE-UC5_FR2**: The system shall use geolocation-velocity data to identify paths. • **NSE-UC5_FR3**: Aggregation analytics on areas and paths shall be implemented for the purposes of the use case. • **NSE-UC5_FR4**: The system shall enable mobility profile extraction from aggregated analytics. • **NSE-UC5_FR5**: Interfacing with the Locus geolocation services shall be provided for acquisition of raw anonymized geolocation data as velocity		

	vectors, where the merging of geolocation data and velocity vectors per entity shall be offered. • **NSE-UC5_FR6**: An anonymization/ privacy component shall be employed by the geolocation services. • **NSE-UC5_FR7**: The system shall offer interfacing capabilities for 3rd party Apps.

5.6 Positioning and Flow Monitoring for Controlling COVID-19 (NSE-UC6)

We are living in a critical time due to the COVID-19 pandemic. In such a condition, the researchers of the Project LOCUS have asked themselves "How can we help? Which tools can we offer to enhance the level of health safety in the restarting phase or to make our Countries ready to prevent any future waves?" On March 19, 2020, the European Data Protection Board issued a statement emphasizing that member states should attempt to do what they can with anonymized data but notes that they have the power to "introduce legislation to enable the processing of non-anonymized location data where necessary to safeguard public security", including the location tracking of individuals, under strict privacy safeguards. As a matter of fact, each Country is trying to react as fast as possible with ad-hoc solutions to track people movements in accordance to privacy rules.

There are two main approaches envisaged: one based on 3GPP operators' data and one relying only on an app that derives proximity/contact data from non-cellular technologies (e.g., Bluetooth). While the first suffers of limited location accuracy, the second suffers of possible limited number of people that will really install such app (for various reasons such as privacy and security concerns, digital divide issues, fragmentation of the market with several apps offering incompatible solutions). In addition, contact tracing systems can follow two different models: i) centralized, in which the generation of identifiers and generation of contact graphs are done on a central server; and ii) decentralized, which avoid accumulating any contact data on a centralized server.

According to the General Data Protection Regulation (GDPR), proposed systems must ensure personal data minimization. The central server should only observe anonymous identifiers of infected people without any proximity information; health authorities learn no information before the notification of an person as infected people; and epidemiologists obtain minimal information regarding close contacts. Finally, the solutions need to prevent abuse of data and tracking of non-infected users.

Given the fact that the COVID-19 crisis will last months and most Countries are just entering the so-called Phase 2, we aim to propose solutions in this area with an effort to put together knowledge and expertise at different levels. With this spirit, LOCUS proposes the use case on location-awareness and analytics to control COVID-19, as described below. In addition, LOCUS believes that a better architectural design of cellular networks is needed for the general case of pandemic events. 5G has the opportunity to develop privacy-preserving secure contact tracing solutions and people flow monitoring solutions, using both LTE/NR 3GPP-based and non-3GPP based infrastructures (also referred to as RAT-dependent and RAT-independent). The proposed solution will prevent abuse of data through i) minimization of contacts storage, ii) anonymization procedure, iii) encryption algorithm, and iv) dismantling after a period of time. A brief state-of-the-art on privacy regulations in different countries and a brief state-of-the-art description of currently-under-discussion solutions are reported below.

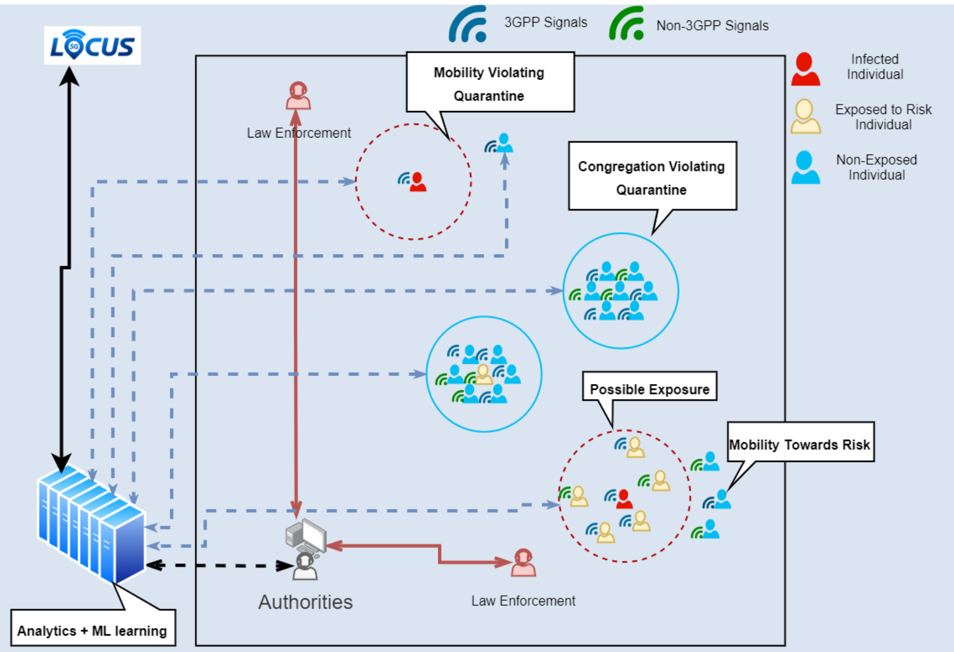
Country	**Privacy**	**ICT solutions**
Italy	GDPR	One BT-based application "Immuni" was selected out of 347 submitted to a national call for contact tracing solutions. It is expected the application will be installed on a voluntary basis.
Spain	The AEPD (Spanish Agency for Data Protection) has released some recommendations about collecting or processing data for COVID research. GDPR still applies, and the public interest argument *only* applies for data being collected and processed by competent public authorities: Ministry of Health, the Health Councils of the Autonomous Communities, and to health professionals who treat patients or intervene in the control of the epidemic. Private entities that collaborate with said authorities may only use the data in accordance with their instructions and, in no case, for purposes other than those authorized.	There is also an official app, used only to enter symptoms. It records the GPS position too. https://play.google.com/store/apps/details?id=es.gob.asistenciacovid19 The most promising initiative so far is Open-Coronavirus (https://github.com/open-coronavirus/open-coronavirus), but there is no public information about its adoption and when.
Sweden	The Swedish Public Health Agency has been granted access to mobile data by network operator Telia. The data will be aggregated and anonymised. The data could subsequently also be used as a basis for future policy proposals or to assess the effects of measures that have already been taken to limit the spread of the virus, such as the recommendations regarding social	A number of public–private partnershipss are beginning to emerge with the goal of providing support for the COVID-19 outbreak.

	distancing and avoiding unnecessary journeys.	
UK	There are concerns that the introduction of an app to help tackle the coronavirus in UK may compromise user privacy: https://www.bbc.co.uk/news/technology-52003984	UK National Health Service considers introduction of an app, used on a voluntary basis, to warn users if they have been in proximity to someone suspected to be infected with the coronavirus (https://www.bbc.co.uk/news/technology-52263244).

5.6.1 Use case description

Use Case Name	Positioning and Flow Monitoring for Controlling COVID-19 (NSE-UC6)
Description / User Story	1. **User Story 1:** A person is tested positive to the virus and it is needed to trace back the persons he/she has potentially been in proximity within a certain number (to be set) of previous hours/days. 2. **User Story 2:** Risk factors based on epidemiological data are associated to flow of people moving from one area to another area. **3. User Story 3:** A person is tested positive to the virus or is one of the categories at risk (e.g. elderly people). It is required to identify if he/she is moving outside of a quarantine area. **4. User Story 4:** Automatic control of non-allowed grouping person, or above a certain group size, and in certain locations. **5. User Story 5:** User is informed about infection probability per given public area (e.g. metro). *All these user stories require certain degrees of privacy control measures that might vary with the Country*
Category	3) People mobility & flow monitoring
Actors	• LTE/NR RAT-dependent interface: UE (Passenger/Customer/Fan), Things • RAT-independent interface: GPS, WLAN, Bluetooth

	• Operators of cellular networks • Providers of WLANs • LOCUS Geolocation Server • Geolocation User (Authorities)
Actors' Roles	• People equipped with LTE/NR 3GPP and non-3GPP equipment. • Authorities that monitor people movements • Operators of cellular networks providing data on mobility of people's flow • Providers of WLAN services providing data on hot-spots accesses • LOCUS Geolocation Server will fuse and filter positional data collected from LTE/NR RAT-dependent and RAT-independent infrastructures to extract analytics
Goal	• Extraction of location-aware analytics for the purposes of user stories 1, 2, and 3 • Provision of real time information on people grouping for the purpose of user story 4 • Advertise people if there is a positive tested person in the same area where they are for user story 5 • Prevent abuse of data usage through i) minimization contacts storage, ii) anonymization procedure, iii) encryption algorithm, and iv) dismantling after a period of time.
Constraints / Assumptions	• Data from operators and providers with privacy/security. • Deployment of 3GPP (Release >= 15) network • Availability of RAT independent (e.g., GPS, BT, WLAN) networks • LTE/NR RAT-dependent and RAT-independent user equipment • Regulation on the use of location-aware analytics
Geographic Scope	Urban and sub-urban environments (indoor/outdoor/hybrid)
Picture Exemplifying the Use Case	

	
Event Flow	• The LOCUS geolocation server will receive an authenticated and permitted request to trace back or track the proximity of one or more UEs. • The LOCUS geolocation server will optionally reconfigure the network to generate or facilitate measurements to support the geolocation • The 3GPP infrastructure/ or the UEs will generate one or more type of data to support geolocation leveraging both LTE/NR RAT-dependent and RAT-independent deployments. • The LOCUS geolocation server will collect and process the analytics of target UEs, discarding them after the contagiousness window. • The LOCUS geolocation server will provide information to each user about the presence of a positive tested person in the area. • The LOCUS geolocation server will provide the analytics to an authenticated and permitted entity/authority.

5.6.2 Technical requirements

Service level Requirement	SLR Unit	SLR Value	Explanations/Reasoning/Background

Localisation Accuracy	m	Horizontal: <=3 Vertical: <=3	LTE/NR RAT-dependent and RAT-independent data fusion for user stories 1 and 3.
		Horizontal: <=30 Vertical: <=30	LTE/NR RAT-dependent and RAT-independent for user story 2, 4, and 5.
Latency/Time To First Fix	sec	TTFF <=10 Latency <=1	As per Rel-16 positioning requirements and considering data fusion with RAT-independent technologies. Subject to further analysis in terms of performance/ complexity trade-offs of NR positioning radio-layer solutions
Update rate	sec	20	
Service Reliability	%	90	Per 3GPP Rel. 16 and considering data fusion with RAT-independent technologies
Service Availability	%	80	The probability of success that location aware analytics can be performed over a specified period (accounting for service interruptions). The service should be available at the reliability levels at least 90% of the time during the event duration.
Interoperability/ Regulatory/ Standardization Required	[y/n]	yes	Regulatory: GDPR compliant since we are dealing with personal data.

Functional Require-ments	• **NSE-UC6_FR1:** The LTE/NR RAT-dependent infrastructure UEs shall generate data to support geolocation. • **NSE-UC6_FR2:** The RAT-independent infrastructure shall be accessed by the UE to generate data to support geolocation. • **NSE-UC6_FR3:** The LOCUS geolocation server shall collect and process the data to calculate locations/routs and to extract analytics of target UEs. **NSE-UC6_FR4:** The LOCUS geolocation server shall provide the resulting analytics to an authenticated and permitted entity/ authority through the Lawful Interception Architecture defined in 3GPP. NSE-UC6_FR5: An anonymization/privacy component shall be employed by the LOCUS geolocation server.

6 Preliminary description of the LOCUS functional architecture

6.1 Consolidation of functional requirements

Based on the aforementioned Functional Requirement Analysis performed per use case in the previous sections, a set of global functional requirements for the LOCUS System emerge. The following Table (Table 4) attempts to consolidate the per-use case requirements that correspond to multiple LOCUS System aspects. Requirements are labelled based on categories, involving Functional Requirements for Localization Enablers, Security & Privacy, Smart Network Management, New Services, data ingestion and interfacing aspects. It should be noted that UC requirements not directly related with the LOCUS Platform are omitted from this table, as they do not have any effect on its architecture.

FR No	Description	Category	Related FRs
FR_01	The system will have the appropriate protocols in order to access network positioning-related measurements. The System will have the ability to acquire positioning-relevant measurements, passively using measurements performed for other purposes in the 5G system, or actively using positioning-initiated measurement campaigns.	***Data acquisition & ingestion***	LEN-UC1_FR1, LEN-UC1_FR6, LEN-UC2_FR1, LEN-UC2_FR2, LEN-UC5_FR1, SNM-UC1_FR1, NSE-UC2_FR8, NSE-UC1_FR3, NSE-UC4_FR1, NSE-UC6_FR1
FR_02	The system will be able to store network measurements and data collected, necessary to continuous localization and tracking with varying levels of historicity.	***Data acquisition & ingestion***	LEN-UC2_FR4, SNM-UC1_FR1, NSE-UC1_FR4, NSE-UC2_FR9, NSE-UC2_FR10
FR_03	The System shall have access to up-to-date network topology and parameters.	***Data acquisition & ingestion***	LEN-UC4_FR5, SNM-UC1_FR6, SNM-UC2_FR2, SNM-UC2_FR5, SNM-UC3_FR2, SNM_UC4_FR5
FR_04	The system will be able to acquire store network KPIs and/or cell-level KPIs, as well as auxiliary/ external data (e.g. indoor maps), with variable granularity and historicity for the purposes of network management and new services.	***Data acquisition & ingestion***	LEN-UC1_FR5, LEN-UC1_FR6, LEN-UC4_FR6, SNM-UC1_FR6, SNM-UC2_FR2, SNM-UC3_FR3, SNM_UC4_FR2, NSE-UC1_FR2, NSE-UC2_FR7
FR_05	The system shall communicate directly (online) with various user devices, IoT devices (4G, BT, WLAN or others), e.g. cameras, sensors, etc.	***Data acquisition & ingestion***	LEN-UC3_FR2, LEN-UC3_FR3, LEN-UC4_FR4, NSE-UC2_FR2, NSE-UC3_FR2, NSE-UC6_FR2
FR_06	The system shall be able to utilize GNSS positioning data.	***Data acquisition & ingestion, Localization Enablers***	NSE-UC3_FR3, NSE-UC6_FR2
FR_07	The system shall enable protocols for standard CAM (Cooperative Awareness Messages) for transmitting geographically aware information for VRU and vehicle presence, positions, location dynamics and so on.	***Data acquisition & ingestion***	NSE-UC3_FR4, NSE-UC3_FR5, NSE-UC3_FR6
FR_08	The System shall be able to interface with services or IoT-related datasets (e.g., open data Cloud services), collect and ingest various data.	***Data acquisition & ingestion,***	NSE-UC2_FR11

		Interfacing aspects	
FR_09	The System shall have a localization service that provides user's location data.	***Localization Enablers***	LSP-UC1_FR1, LEN-UC3_FR1 All LEN-UCs
FR_10	The system shall be able to distinguish between different targets/ users and areas, e.g. to distinguish among the emergency crew and victims, VRUs and vehicles, and focus on a specific area/ building etc.	***Localization Enablers - Analytics***	LEN-UC1_FR3, LEN-UC1_FR4, NSE-UC3_FR1
FR_11	The system shall have a localization service to correct location data (mitigation).	***Localization Enablers, Security & Privacy***	LSP-UC1_FR4
FR_12	The system shall employ data fusion algorithms and other Analytics/ ML approaches for localization purposes.	***Localization Enablers - Analytics***	LEN-UC4_FR3, LEN-UC3_FR5
FR_13	The System needs to ensure that the provided location estimates are reliable, i.e. offer location verification functionality. Furthermore, it shall provide estimates for accuracy of localization and positioning-related information and possible service degradation.	***Localization Enablers - Analytics, Security & Privacy***	LSP-UC1_FR1, LEN-UC1_FR7
FR_14	The system shall provide authentication, advanced cryptographic techniques for all network interfaces (homomorphic encryption, secure multiparty computation, and secure conditional sharing techniques) and support lawful interception functions (in line with Lawful Interception Architecture defined in 3GPPP).	***Security & Privacy***	LSP-UC2_FR2, LEN-UC2_FR3, NSE-UC2_FR5, NSE-UC6_FR4
FR_15	The system shall provide data management policies (anonymization, obfuscation) for ensuring privacy regulations, including video/ image anonymization and anonymization of mobile sensing data at the edge.	***Security & Privacy***	LEN-UC1_FR8, LSP-UC2_FR1, LEN-UC2_FR3, NSE-UC1_FR5, NSE-UC2_FR4, NSE-UC5_FR6
FR_16	The System shall deploy ML models for Security purposes (e.g. Anomaly detection).	***Security & Privacy - Analytics***	LSP-UC1_FR2
FR_17	The system shall offer notifications through a trigger alarm functionality for security and privacy violations.	***Security & Privacy***	LSP-UC1_FR3, LSP-UC2_FR3
FR_18	The system shall have proper API and interfaces to expose the resulting location information from LEN components to relevant parties/ other LOCUS Platform components for smart network management (SNM) & new services (NSE).	***Interfacing aspects (internal to LOCUS)***	LEN-UC1_FR2, LEN-UC2_FR5, LEN-UC4_FR1, SNM-UC1_FR5, SNM-UC2_FR1, SNM-UC3_FR1, SNM-UC4_FR1, NSE-UC1_FR1, NSE-UC2_FR6, NSE-UC3_FR8, NSE-UC4_FR5, NSE-UC5_FR5
FR_19	The system shall allow for the outputs of Analytics and ML processes related to SNM and NSE to be utilized by other SNM and NSE components of the platform.	***Interfacing aspects (internal to LOCUS)***	SNM-UC1_FR7, SNM-UC2_FR3, SNM-UC2_FR4, SNM-UC3_FR4, SNM-UC3_FR5, SNM_UC4_FR3, SNM_UC4_FR4
FR_20	The system shall provide interfacing options for 3rd party Apps for network monitoring, planning, network optimization and network diagnostics purposes.	***Interfacing aspects - 3rd party Apps***	SNM-UC1_FR7

FR_21	The system shall provide interfacing options for 3rd party Apps with NSE components.	***Interfacing aspects - 3rd party Apps***	NSE-UC1_FR6, NSE-UC3_FR9, NSE-UC4_FR2, NSE-UC5_FR7
FR_22	The system interfacing options with 3rd party Apps shall allow different rates of Analytics results' acquisition, based on (i) App requirements and (ii) actual dependencies on data acquisition rates for specific data within the system that may affect quality and accuracy of the results.	***Interfacing aspects - 3rd party Apps***	SNM_UC4_FR7
FR_23	The system shall provide the appropriate analytics functions that allow the use of network and geolocation information for heatmap visualization of various network KPIs and of the various ML modelling results.	***SNM - Analytics***	SNM-UC1_FR1
FR_24	The system shall employ analytics and machine learning for the purpose of modelling spatiotemporal data for the derivation of positioning/ user-abstracted information, such as areas/ points of interest (POIs) and trajectories/ paths.	***SNM - Analytics,*** ***NSE - Analytics***	SNM-UC1_FR2, SNM-UC1_FR3, NSE-UC5_FR1, NSE-UC5_FR1, NSE-UC6_FR3
FR_25	The system shall provide location-based KPI information, enabling KPI aggregations in requested areas as well as in extracted -using ML- POIs and paths.	***SNM - Analytics,*** ***NSE - Analytics***	SNM-UC1_FR4, NSE-UC3_FR10, NSE-UC5_FR3
FR_26	The system shall provide planning recommendations.	***SNM - Analytics***	SNM-UC2_FR6
FR_27	The system shall provide recommended changes in the network parameters that -given availability of the appropriate APIs- can be applied in the network. Applying network actions per se in not part of the System.	***SNM - Analytics***	SNM-UC2_FR7
FR_28	The system shall provide Network Optimization Decisions that -given availability of the appropriate APIs- can be enforced in the network. Enforcing network actions per se in not part of the System.	***SNM - Analytics***	SNM-UC3_FR6, SNM-UC3_FR7
FR_29	The system shall provide network failure management decisions.	***SNM - Analytics***	NSE-UC4_FR6
FR_30	The system shall employ machine learning and AI models for predictions, including usage/ traffic prediction.	***SNM - Analytics***	LEN-UC4_FR2
FR_31	The system shall provide mobility profiles (e.g. for pedestrians, moving vehicles) based on Analytics and ML off-line.	***NSE - Analytics***	NSE-UC5_FR4
FR_32	The system shall employ analytics and machine learning for extracting crowd mobility behaviours in real-time or offline.	***NSE - Analytics***	NSE-UC2_FR1
FR_33	The system shall be able to employ analytics for the purpose of pre-processing IoT device data.	***NSE - Analytics***	NSE-UC2_FR3
FR_34	The system shall provide VRU/ vehicle analytics and AGV mission/ navigation system KPI calculations for New Services (3rd party Apps).	***NSE - Analytics***	NSE-UC3_FR7, NSE-UC4_FR5

Table 4. Consolidated Functional Requirements.

6.2 Functional Architecture Design

The consolidated requirements reflect the major functionalities that the LOCUS System will need to cater to, so as all the UCs described previously can be enabled and facilitated. Therefore, the resulting requirements consolidation is in fact the basis for the Functional Architecture of LOCUS.

In Figure 1, a preliminary version of the High-level Functional Architecture of LOCUS is presented, showing its main functional components along with the relevant data flows, i.e. input/ outputs of the LOCUS System and its various internal components.

It should be mentioned that a more detailed description of the functional blocks, their subcomponents and interfacing aspects along with the LOCUS's Data Architecture will be presented in more detail in the relevant preliminary version deliverable, i.e. D2.4 "System Architecture: preliminary version".

As shown in Figure 1, the system shall support the appropriate protocols and data formats in order to access data stemming from multiple sources with variable rates (FR_1, FR_17, FR_04, FR_05, FR_06, FR_08, FR_07). Indicatively, these data may refer to:

- *5G network data*, which may include positioning-related measurements (e.g. RSS, ToA, AoA, DoA, TDoA) acquired passively or actively through measurement campaigns
  - 3GPP location data, providing user device location information in the 5G network through 5G Core Location Management Functions (LMFs), as defined in the 3GPP TS 29.572 [14].
  - 5G network KPI data, including cell-level or area-wide network KPIs (e.g. traffic, flows, etc.) coming from network monitoring and management analytics, if required by interacting with 5G Core network functions.
  - Network configuration data, including network topology and configuration parameters information related to network devices.
- *User device data,* referring to additional positioning data and information from user devices, such as GPS, barometer and others.
- *External data, such as environment and other external auxiliary to positioning data***,** as the system shall communicate directly (online) with various IoT devices (4G, WLAN or others), e.g. cameras, sensors and have access to open data cloud services. Furthermore, the various components for ***Localization enablers***, ***Localization & Analytics for Smart Network Management*** and ***Localization & Analytics for New Services*** may will have access to other auxiliary information, such as indoor maps, building boundaries and so on.
- *Social data,* that can be either directly collected from 3rd Party Apps (as specific case of external data) or produced by LOCUS analytics components.

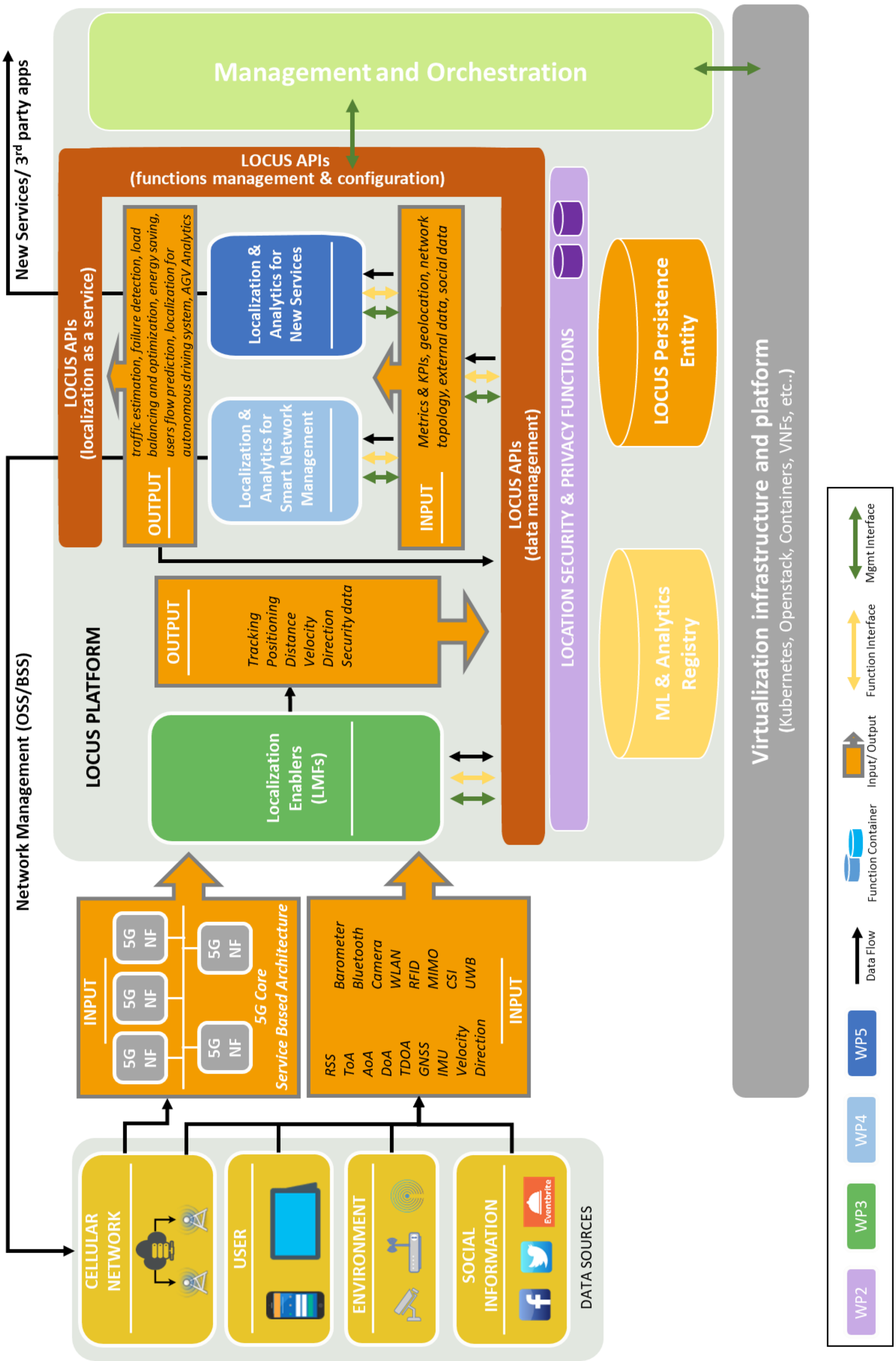


Figure 1. High-level Functional Architecture of the LOCUS System.

All of the above data are expected to be produced by different data sources, that can be both external and internal to the LOCUS system, as depicted in Figure 1. The ***Localization Enablers*** functional block will be responsible to provide the user device location data (e.g. coordinates, velocity, direction) needed by the other LOCUS components (FR_09, FR_18). This functional block should:

- Be able to distinguish (a) between different targets/users and areas, e.g. to distinguish among the emergency crew and victims, VRUs and vehicles, and (b) focus on a specific area/ building and so on (FR_10).
- Ensure location data reliability and estimate the accuracy of the localization and the possible degradation of service (FR_13).
- Include a "Defender Component", which is responsible for detecting and mitigating attacks to manipulate location data based on ML mechanisms and specifically Anomaly detection schemes (FR_16).
- Offer a Localization service for the correction of location data (FR_11) with respect to the ***Security*** ML modelling aspects mentioned previously.
- Employ data fusion and other algorithms (FR_12).

In addition to this, the ***LOCUS Persistence Entity*** will allow, through the ***LOCUS APIs***, the storage of all the network measurements, other data collected, analytics results, predictions and ML models as well as various external data and meta-data, necessary to (a) the continuous localization and tracking with varying levels of granularity and (b) further exploited from other components (FR_01, FR_02, FR_04). The ***LOCUS Persistence Entity*** will enable both batch ingestion in structured databases as well as data streaming functionalities for data coming from outside the LOCUS System or the LOCUS functional components. All of these data are exposed within the LOCUS system through the ***LOCUS APIs*** *Functions.*

Indeed, the LOCUS APIs provide a common and unified layer to access various LOCUS system functionalities and capabilities. The scope of the LOCUS APIs is threefold: i) regulate access to data for the LOCUS system internal components, enabling reading and writing in the LOCUS Persistence Entity, ii) enable lifecycle management for the LOCUS system functions and services, for their deployment and configuration in the virtualization infrastructure as virtualized functions (e.g. container-based microservices), iii) expose LOCUS data analytics functions for new services (for localization as a service towards third parties), and for smart network management towards OSS/BSS. In particular, the ***LOCUS APIs*** shall include all proper APIs and interfaces to expose the resulting location information coming from the ***Localization enablers*** as input to the relevant system components (*FR_18*) (***Analytics for Smart Network Management*** and ***Localization & Analytics for New Services)***, and will facilitate the storage of the related outputs for reuse by various subcomponents (FR_19). The LOCUS APIs will also provide traditional access control functionalities for enabling authorization and authentication for the exchanged data within and outside the LOCUS system.

The expected output of the ***Analytics for Smart Network Management*** and ***Localization & Analytics for New Services*** shall be sufficiently diverse, depending on the proposed LOCUS use case as shown in Figure 1. As long as the data privacy regulations, through the anonymization functions of the ***Security & Privacy Layer***, are followed, the appropriate APIs to expose their results to 3rd party Apps for network management and other vertical applications shall be available by the LOCUS System for localization as a service (FR_20, FR_21).

The ML and Analytics capabilities of the LOCUS System are highly diverse and the various related functions refer to all major Functional Blocks: ***Localization enablers***, employing ML & Analytics for positioning/ tracking-related and location correction aspects; ***Analytics for Smart Network Management*** and ***Localization & Analytics for New Services,*** employing methodologies with respect to network management and various new services/ 3rd party Apps respectively. The ***ML & Analytics Registry*** refers to all the related functions of the system that shall be employed by more than one component through the ***LOCUS APIs***. This registry will include analytics functions, supervised and unsupervised ML models, e.g. clustering, anomaly detection, classification, regression, time-series modelling. In detail, the various ML/ Analytics purposes can be summarized in Table 5 (FR_12, FR_16, FR_23-34):

ML/ Analytics Function	Related Functional Block
Heatmap generation, KPI monitoring	*Analytics for Smart Network Management*
KPI/ ML results' aggregation & Filtering (per area, path, POI etc.)	*Analytics for Smart Network Management, Localization & Analytics for New Services*
Security Purposes (e.g. Anomaly detection)	Location Security and Privacy
Mobility Profiling (pedestrians/ vehicles etc.)	*Localization & Analytics for New Services*
Flow monitoring/ prediction and crowd mobility	*Localization & Analytics for New Services*
Path/ trajectory and POI identification	*Analytics for Smart Network Management, Localization & Analytics for New Services*
Calculation of positioning accuracy and degradation of service	*Localization enablers*
Fusion algorithms, and Analytics/ ML approaches for localization purposes	*Localization enablers*
VRU/ Vehicle KPI calculations	*Localization & Analytics for New Services*
AGV mission/ navigation system KPI calculations	*Localization & Analytics for New Services*
ML/ Analytics for Traffic & User location predictions	*Analytics for Smart Network Management*
Pre-processing sensor data at the edge	*Localization & Analytics for New Services*
Network Planning Recommendations	*Analytics for Smart Network Management*
Network Management Recommendations	*Analytics for Smart Network Management*
Network Optimization Decisions	*Analytics for Smart Network Management*
Network Failure Management Decisions	*Analytics for Smart Network Management*

Table 5. TML & Analytics Functions and related Functional Blocks.

The various functions described above and part of the LOCUS system, thus including the localization enablers, the analytics functions for smart network management and those for localization & analytics for new services, are subject to automated lifecycle management through dedicated LOCUS Management and Orchestration (MANO) features, as shown in Figure 1. By following the microservices approach defined by 3GPP for the 5G Core service-based architecture, LOCUS enables the packaging of the whole set of localization and analytics functions as cloud-native applications, which are deployed by the LOCUS MANO in the form of virtualized network functions (VNFs), following the ETSI NFV principles for functions virtualization and their management. For this, a combined 5G edge and core virtualized infrastructure capable to offer isolated running environments for such functions is required. LOCUS makes use of de-facto standard virtualization infrastructure managers like Openstack [15] and containers orchestration tools like Kubernetes [16] to realize such 5G edge and core virtualized infrastructure.

In practice, the LOCUS MANO layer manages the automated instantiation, configuration, and operation of the heterogeneous localization and analytics microservices, including when required their integration with the 5G core components. The chaining of these microservices, together with the selection of edge and core virtualized infrastructures for running them, is still coordinated by the LOCUS MANO with the aim of fulfilling the requirements of each specific 5G network optimization or third-party vertical service.

Moreover, at all stages of the described data flows (incoming and outgoing to LOCUS data, flows among the various components), the ***Location Security & Privacy Functions*** shall ensure all data privacy and security aspects through the ***LOCUS APIs*** which handles data acquisition and sharing within the components. These functions will comprise the following:

- Trigger alarm functionality, offering notifications in case of Privacy and Security violations (FR_17).
- Authentication and advanced cryptographic techniques for all network interfaces (homomorphic encryption, secure multiparty computation, and secure conditional sharing techniques) (FR_14).
- Data management policies (e.g. anonymization, obfuscation) for ensuring privacy regulations, including video/ image anonymization and anonymization of mobile sensing data at the edge (FR_15).

Also, for location data security aspects, a “Defender Component”, part of the **Localization Enablers** Functional Block, is responsible for detecting and mitigating attacks to manipulate location data based on ML mechanisms and specifically Anomaly detection schemes (FR_16).

7 Conclusions

This Deliverable D2.1 presented use cases that have been investigated and defined in LOCUS. These use cases are split into four groups corresponding to the main technical challenges of the project, namely

- Defining a system with built-in security and privacy.
- Defining Terminal localization techniques, including 5G cellular based localization, the integration with non-3GPP localization technologies and device-free localization.
- Designing highly efficient network management enriched with location information and analytics.
- Designing new services using location information and analytics.

The use case description and related technical requirements will serve as a basis for further study and development in the different project Workpackages. Privacy and security use cases will be studied in the framework of WP2, Task 2.2 and documented in Deliverable D2.2 "Security and Privacy" due in M8. The LOCUS architecture will be further detailed in D2.4 "System Architecture, preliminary version" due in M9.

Location enablers related use cases will be developed in the framework of Workpackage 3 in three streams. Preliminary results on Concepts and solutions for cellular-based localization for 5G will be documented in Deliverable D3.1 "5G-based localization solutions" due in M11. The integration of cellular localization with candidate non-3GPP technologies will be the scope of the first version of Deliverable D3.3 "Integrated localization technologies" due in M12 and the integration of device free localization will be documented in Deliverable D3.5 "Integration with Device-Free Localization" due in M10 as well.

Smart network management use cases will be studied in Workpackage 4. Deliverable D4.1. "Localization & Analytics for Smart Network Management" , due in M 11,will describe the architecture, functionalities, algorithms and interfaces of the Smart Network Management plane together with some preliminary results for the developed use cases.

Use cases related to localization and analytics in support of new services will be studied in the framework of Workpackage 5 and documented in Deliverable D5.1 "Design and implementation of virtualization technologies and pattern recognition mechanisms for physical analytics" due in M13.

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