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 D6.1

"Detailed requirements from scenarios and application specification"

Deliverable Type:	R
Dissemination Level:	Public
Contractual Date of Delivery to the EU:	30/06/2021
Actual Date of Delivery to the EU:	27/06/2021
WP contributing to the Deliverable:	WP6 – Proof of Concepts
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Short Abstract:	The goal of this deliverable is to specify the applications that will be powered by the LOCUS geolocation data and analytics
Keyword List:	PoC, Use Case, application, geolocation, analytics,

Executive Summary

This deliverable provides specification of applications that will be powered by the LOCUS geolocation data and analytics, describing Proof of Concept environment, explaining relevant Use Cases execution framework, and sketching implementation of PoC applications and their main components.

Version Control Table			
Version N.	**Purpose/Changes**	**Author (s)**	**Date**
1.0	Ready for submission	See list above	26/06/2021
1.1	Final revision by the coordinator	Nicola Blefari Melazzi	27/6/2021

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1 Introduction

A significant LOCUS project objective is the definition of use case scenarios and their targeted, measurable KPIs for performance monitoring, leading to the integration of the various LOCUS components, i.e. localization technologies, analytics platform and algorithms, and the overall system integration.

Three Proofs of Concept (PoC) have been planned to provide a test environment for the use cases:

1) Network Management based on Location Information
2) Network-assisted Self-driving Objects
3) People Mobility & Flow Monitoring, subdivided in two sub cases:
    3a) Flow tracking in densely populated indoor environments for smart retail and venue management
    3b) Crowd mobility analytics using wireless and auxiliary sensors

The PoC execution phase is the culmination of the project's work as it involves the demonstration of the previously selected scenarios, involving various technologies of LOCUS and displaying the interoperation of the various components. For a successful deployment, technologies will be verified through real operator data and -where available- in testbeds accessible to the partners.

This document provides a description of the three Proofs of Concept, including details of their implementation, and the realization of relevant Use Cases chosen from those selected in WP2.

1.1 List of Abbreviations

ABBREVIATION	FULL NAME
AGV	Automated Guided Vehicle
AR	Augmented Reality
FTM	Fine Time Measurement
PoC	Proof of Concept
POI	Point of Interest
SNM	Smart Network Management
UMA	University of Malaga
UWB	Ultra-Wideband
VR	Virtual Reality

Table 1: Abbreviation List

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1.4 Terminology

Use Case, Scenario, Proof of Concept, Architecture, Infrastructure

2 Proof of Concept description

2.1 PoC #1: Network Management based on Location Information

PoC #1 concerns the demonstration of LOCUS end-to-end capabilities in the context of network management based on location information. The goal is to concretize the LOCUS architecture: **a)** by deploying the virtualization of LOCUS functions and services, as described in D4.3 [1], on the cloud infrastructure provided by OTE, **b)** Integrating the OTE cloud infrastructure with the physical deployment site of an LTE network and WiFi/UWB technologies provided by the University of Málaga.

As shown in Figure 1, the PoC involves scenarios elaborated from WP4 knowledge building activities in addition to the coverage optimization and failure management use-cases described in D4.1 [2]. It also involves the implementation of localization enablers developed in WP3, to estimate devices positions relying on signal measurements from the deployed wireless technologies.

In the following sections, details on the cloud infrastructure, the virtualization of LOCUS functions, the planned localization enablers and WP4 scenarios will be provided.

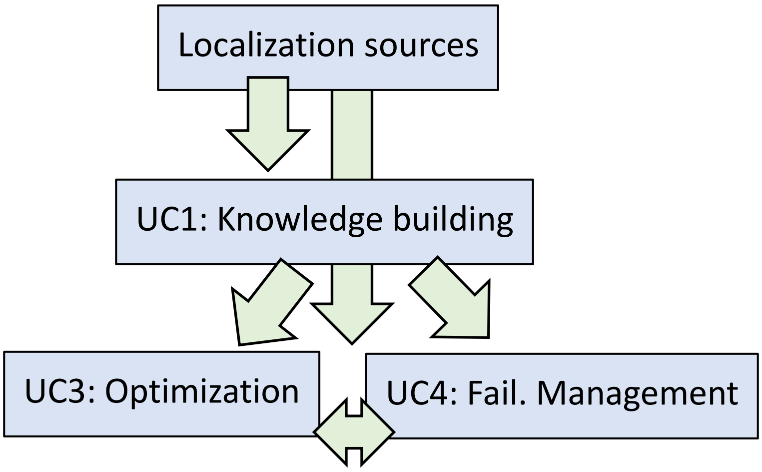


Figure 1: Proposed storyline: Location-aware SNM

2.1.1 PoC Storyline

Novel educational methods rely on location-based technologies, such as Virtual Reality (VR) and Augmented Reality (AR), which have stringent location accuracy and latency requirements. These novel technologies also have very demanding network requirements, mainly in bandwidth and latency. The selected storyline describes the use of location technologies for such applications. The reliance on location technologies will also lead to an optimal use of the available resources (access points, femto cells, etc.) which will be highly dependent on the location of the devices. Since most of the activity occurs indoors, the main challenge in this PoC is to provide indoors location with a moderate to high degree of mobility density.

2.1.2 LEN_UC4 Localization and network management for education

This use case will be implemented at the premises of the University of Málaga (UMA). The setup will include the following elements:

- Physical location: the activity of the PoC will take place in a scenario made up of two classrooms connected by a stretch of hallway, with infrastructure installed in both classrooms and some neighbouring classrooms out of the scenario.
- The indoors LTE network of UMA, made up of 12 picocells, out of which a subset of three (with possibility of increasing the number) will be used for the PoC activity.
- A set of UWB devices (DWM1001[1]) that will be used both as reference points (7) and location targets.
- Google WiFi Access Points, that support WiFi-FTM. A set of three is deployed in the scenario.
- Mobile device with an in-house developed application that collects location data from the reference points and sends it to a server in a LAN. This mobile device is only used for testing purposes, and the developed application is never installed in personal devices.
- Linux server collecting data and doing the required processing for the scenario. The software running in this server will migrate to the LOCUS platform in a second stage once the basic development is done.

With this setup, the ranging information collected by the target device will be processed in the server, performing the opportunistic location fusion algorithms developed by UMA in WP3, as part of T3.2, and providing a real time, high precision location. Figure 2 shows a map of the physical location for the PoC. The 1.1.1 and 1.1.2 classrooms are the main scenario location.

With this setup, we expect to obtain a dashboard with a real-time location of the target and a precision in the order of 10cm, which would be required for applications in education.

[1] https://www.decawave.com/dwm1001/datasheet/

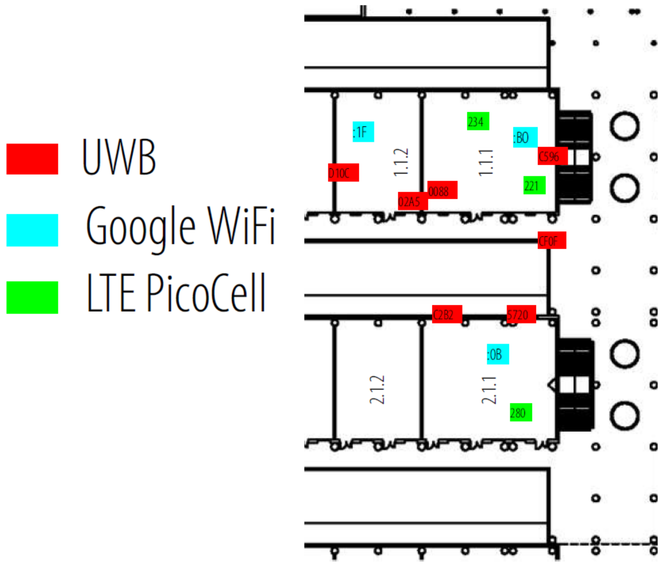


Figure 2: Map of the physical location in UMA

2.1.3 WP3 SI-based localization as localization enabler for PoC #1

Soft information (SI) [3] has been developed in WP3 as a localization enabler for 5G. In deliverables D3.1 [4] and D3.2 [5], SI framework has been presented and the performance gain of SI-based localization compared to classical single-value estimate has been shown by employing 5G specific measurements in 3GPP standardized scenarios. Integration of heterogeneous measurements obtained via 5G technology and WiFi technology (i.e., time-of-flight measurements) has also been reported in deliverable D3.3 [6].

The SI-based approach will be employed in PoC #1 to provide accurate and real-time estimates of the device positions. Despite the research carried out in WP3 being focusing on 5G, the SI-based approach is radio access technology agnostic and can easily be adapted for LTE. Moreover, given the three different technologies considered in PoC #1 (i.e., LTE, WiFi, and UWB), the SI-based localization represents a good candidate to perform data fusion via a unified framework. SI-based localization in PoC #1 will rely on pre-trained machine learning models obtained from measurement campaigns carried out in the PoC physical location or from simulation data.

2.1.4 WP4 components in PoC #1

WP4 uses knowledge building functionalities to enrich the network status information, using the localization information obtained from WP3. WP4 also develops specific location-aware management actions, such as optimization and failure management.

Here, two main functionalities are envisioned to be integrated in the PoC #1: “Automatic generation of contextualized indicators” and “Building radio maps with high accuracy”.

These two functionalities use different approaches to analyse the scenario performance and to detect typical radio problems (e.g., coverage holes), and they are expected to be enhanced by the localization techniques coming from WP3. Here the "Automatic generation of contextualized indicators" functionality is based on the generation of location-enriched metrics combining position and network information data as described in D4.1. The resulted metrics will then be used for failure troubleshooting by the "Contextualized indicators for failure detection and diagnosis" WP4 functionality. This will use the context information together with ML techniques to provide a more complex diagnosis of the system status. The latter will rely on previously collected data from the PoC #1 operation, including the localization, enabling the ML models training.

Another WP 4 functionality, "Building radio maps", is expected to generate radio coverage maps for the PoC scenario based on disperse and positioned UE traces. These would then be applied to trigger transmission power changes directly on PoC #1 cells in order to compensate problems. Two typical problems can be shown in the framework of this demonstration: coverage optimization, where a coverage hole is detected and corrected thanks to the radio coverage map, by an iterative algorithm; and cell outage detection and compensation; where a cell is sleeping for instance, the problem is detected thanks to the coverage map and transmission powers of the neighbouring cells is tuned in such a way that the lack of coverage is compensated.

2.2 PoC #2: Network-assisted Self-driving Objects

Logistics is a key area in industrial and seaport operations. Flexibility required by production in Industry 4.0 and deep automation of seaport activities require the massive introduction of automated transport systems like AGVs (Automated Guided Vehicles) that depend on accurate and real-time localization to achieve high performance navigation of the autonomous vehicles. The PoC#2 application refers to logistics in a seaport terminal where AGVs are used to shuttle general cargo freights between the reception and the warehouse area at goods arrival in the seaport and between the warehouse area and the crane during the loading operations. The general cargo freights are goods characterized by variable size and shape (e.g. crates, pipes, vehicles). The PoC addresses the aspects related to the verification of the performances of the 5G positioning system in this operative scenario. The activities of a real seaport terminal are simulated using a realistic digital twin of a seaport terminal. The inputs from the 5G positioning system feeds the AGV navigation system to drive it during its shuttling operations. A high precision is required for a successful pick, transport, and placement of freights in the planned positions.

The PoC can be run in two modes: the first replicating all the operations, the second in which only the loading operations are simulated. The first mode can be useful to evaluate the performance of the 5G positioning system in detail during a specific operation. The loading simulation is useful to evaluate in a reasonable time the effect of cumulative errors executing a sequence of shuttling operations.

2.2.1 NSE_UC4: Logistics in a seaport terminal using Automated Guided Vehicles

The use case focuses on general cargo control with AGVs analysing both unloading (from the truck) and loading (to the ship) operations. More specifically, the general cargo logistics use case can be divided into two main phases (Figure 3):

- **Tracking and Storage** - this phase concerns all operations related to the handling of the goods from when they arrive in the port until they are placed in the yard
- **Loading Operations** - this phase comprises the selection of goods to be loaded on the ship and the transfer to the crane.

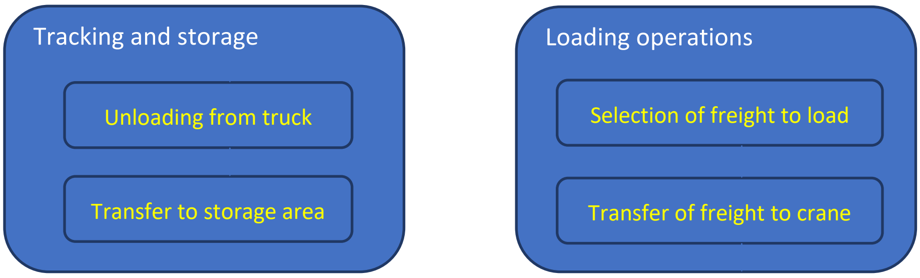


Figure 3: Use case phases

A control system coordinates the missions and plan the trajectory for the AGV that moves under the control of the AGV motion controller, as shown in Figure 4. The control system determines the next move the AGV has to do to accomplish its mission, based on stored map and real time location information received by the positioning system. The control system architecture and implementation are described in Deliverables D5.1 [9] and D5.3 [10] .

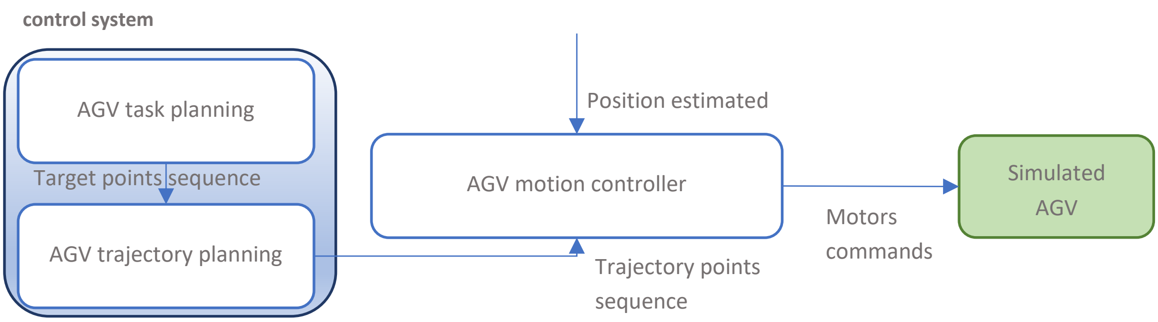


Figure 4: Control system of the AGV

2.2.1.1 Tracking and Storage

The Tracking and Storage phase includes two operations:

a) Unloading from truck
b) Transfer to the storage area

a) Unloading from the truck

The unloading of the freights from the truck is a manual operation. The AGV is driven by an operator with a joystick and picks the freight out of the truck. Then the AGV waits for the indication about the storage place by the control system (Figure 5).

Figure 5: AGV after unloading of the truck waiting for the trajectory to follow

b) Transfer to Storage Area

The control system, according to the allocation plan, determines the trajectory that the AGV should follow during the shuttling mission. Then, it sends to the AGV the navigation commands. The transfer operation can be monitored with the digital twin where the current position and the expected one are shown on the visor screen. In the virtual reality environment, an avatar of the vehicle is present showing the expected position of the AGV.

2.2.1.2 Loading Operations

This phase includes the following operations (Figure 6):

a) Selection of the freight to load
b) Transfer of the freight to the crane

a) Selection of the freight to load

The loading plan, already prepared and provided to the control system, is followed to select the freight to be loaded on the ship. When an object is selected, the control system computes the optimal trajectory and sends the AGV the navigation information.

b) Transfer of the freight to the crane

The transfer operation of the AGV is monitored with the digital twin. Its current position and the expected one are shown, representing respectively the AGV and its avatar in the VR environment.

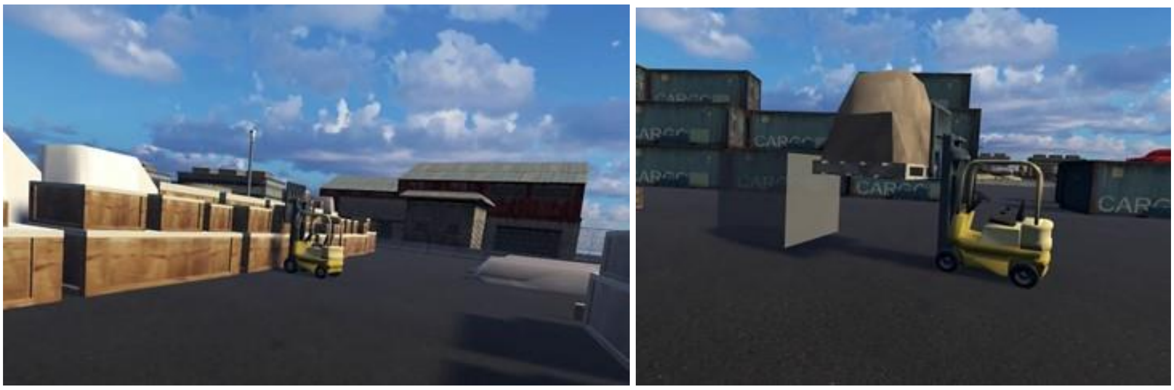


Figure 6: AGV picking a freight (left) and delivering it in front of the crane (right)

2.2.1.3 Loading operation sequence simulation

The Digital Twin can be used also as a simulation environment for making statistical analysis of the performance of the operations of interest.

Figure 7: AGV moving a freight towards the crane in the automated simulation

When this VR environment mode is used, the simulation is fully automated, and a complete loading sequence is executed focusing on the pick, place and shuttling operations of the AGV. In this way the cumulative effects deriving from the 5G positioning system errors in estimating the position can be measured. The AGV navigation system is able anyway to compensate at least part of this error, so it is likely that most of the errors are compensated by the motion control system of the vehicle.

2.2.1.4 The Digital Twin as Human-Machine Interface

It is possible to interact with the Digital Twin using a headset and a couple of joysticks. The Helmet that is used is the Oculus Rift S [2]. The digital twin consists of four main components (Figure 8):

Figure 8: Digital twin components

[2] https://www.oculus.com/rift-s/

1. model of the physical space
2. models of the freight
3. model of the AGV
4. models of the cameras that can be used for monitoring the operations.

Inside the Digital Twin, the left-hand controller contains a clipboard, and the right-hand controller contains a laser pointer (Figure 9).

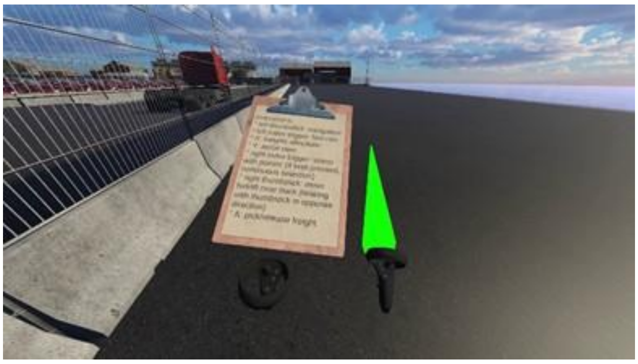


Figure 9: Virtual clipboard and laser pointer

The Player can interact with the virtual environment in several ways:

1. The player can move around the Cargo Storage area using the thumb joysticks on the left-hand controller (Figure 10). To rotate, the player must turn himself/herself.

Figure 10: Joystick with selection button

2. When the player points the laser pointer at a piece of freight, the freight is highlighted in green. The player can select the freight using the button under the right index finger. When the player selects a piece, if it is a freight, information about that object is displayed on the clipboard in the player's left hand. If the button is kept pressed, the continuous selection mode is enabled, and just pointing to different freights the content of the clipboard changes following the pointed object.
3. When the player points and selects one of the 3 port area cameras, the camera's feed is displayed on the clipboard in the player's left hand. To select a camera, the player points the laser pointer to its base and clicks the button under the right index finger (Figure 11).

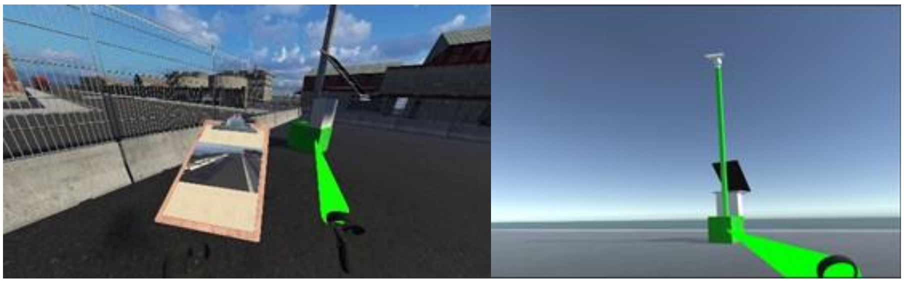


Figure 11: Camera selection

4. Clicking the "X" button on the left-hand controller, the optimal allocation of freights in the warehouse area is activated. This can be done at runtime. Initially the warehouse area is empty. By clicking "X" the sorting algorithm elaborates a real loading plan and arranges the freights in the area. The algorithm arranges freights in such a way that each one can be reached at any time without the need to move other freights and takes into account also the spacing required by the AGV for moving freights.
5. The environment includes a moving AGV that can start the loading operations as soon as the freights are allocated in the warehouse area. Before starting the loading operation, this vehicle is placed close to the crane. The AGV shuttles freights between the storage area and the crane following the loading plan. An avatar of the AGV is also shown. The latter uses an AI navigation algorithm for moving in the yard, showing the optimal computed trajectory at runtime.
6. When unloading a freight from a truck, the AGV can be manually driven using the right-hand joystick. Then the automated shuttling mission can start with the AGV moving towards the position where the freight must be placed.

When moving forward, the player moves the joystick in backward direction to brake. When the AGV stops, if one continues keeping the joystick in backward position, the auto-reverse is activated, and the AGV starts moving back. To brake in this case, it is enough to move the joystick forward. Continuing keeping the joystick in forward direction the AGV stops and then starts moving forward again. To turn left and right, it is just enough to move the joystick gradually to the left or to the right. The joystick controls the acceleration of the AGV. It is possible to control the speed modulating the acceleration when moving.

The big freight close to the truck can be moved to the crane by the AGV. To pick up the freight it is enough to move the AGV so that its fork goes under the freight. The front part of the AGV should touch the freight. When in this position, the freight is picked up by clicking the "A" button on the right-hand. The freight is lifted and is ready for being moved by the AGV following the trajectory provided by the control system (Figure 12).

A semi-transparent box appears in the place where the freight should be dropped (Figure 13). The AGV should move the freight in that position. Once the freight is dropped, the semi-transparent box disappears.

Figure 12: Lifted freight

Figure 13: Semi-transparent box showing the dropping area

7. An aerial camera is flying over the area following a circular trajectory.

It is possible to get the aerial view of the seaport terminal clicking the “Y” button on the left-hand controller. The video-stream is displayed on the clipboard (Figure 14). It stops being displayed as soon as a freight or a camera is selected using the laser pointer.

Figure 14: Video stream displayed on the clipboard

2.3 PoC #3: People Mobility & Flow Monitoring

2.3.1 Demonstration of LOCUS platform horizontal components

The LOCUS platform introduces a large variety of interoperating components that interface with each other via database connector integration. These components are designed to be passive in a sense that an orchestration entity (Data Operations Controller) will be responsible for the initialization and control of their operations. The purpose of this PoC is to showcase the successful end-to-end integration of the following LOCUS core platform components:

a) South-Bound interface (SB) (based on simulation)
b) Persistence module
c) Localization enabler (fingerprinting)
d) Data Operations Controller (AirFlow Implementation).

2.3.1.1 PoC System Architecture Blueprint

The system will be developed in the internal environment of Incelligent, based on two core component types: full VM and docker containers. This simplistic approach can allow for the migration of the solution in the infrastructure of other partners, such as the UMA testbed or the OTE testbed. Each Operational block of the PoC will be developed as a standalone LOCUS platform SDK module including a docker-compose file, the required schema details and the operational code wrapped in the REST API (Flask) that is used for controlling the execution. Initialization of all containers will include the preparation of their requirements, including schema initialization. Then, the execution will be done manually (the execution of the platform tasks will be a scheduled task or a trigger-based task, in real conditions)

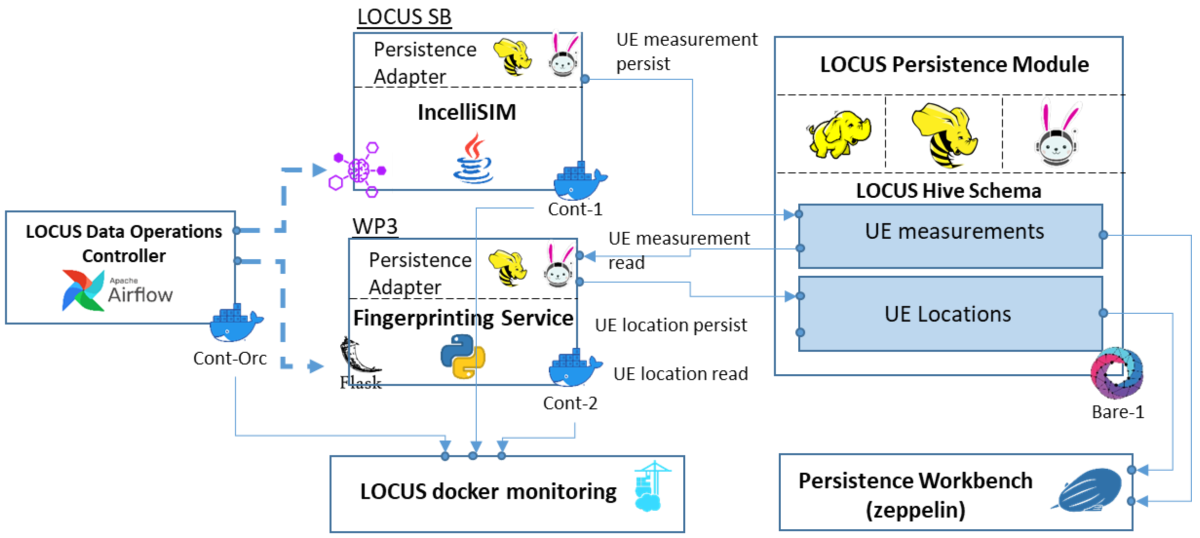


Figure 15: LOCUS PoC #3 system architecture

2.3.1.2 Pipeline execution control and monitoring

This PoC will include the UI presentation of the LOCUS Data Operations Controller based on an AirFlow pipeline. The visualization will include AirFlow web-based graphical user interface, which will show the various LOCUS pipelines (DAG) and all its internal components.

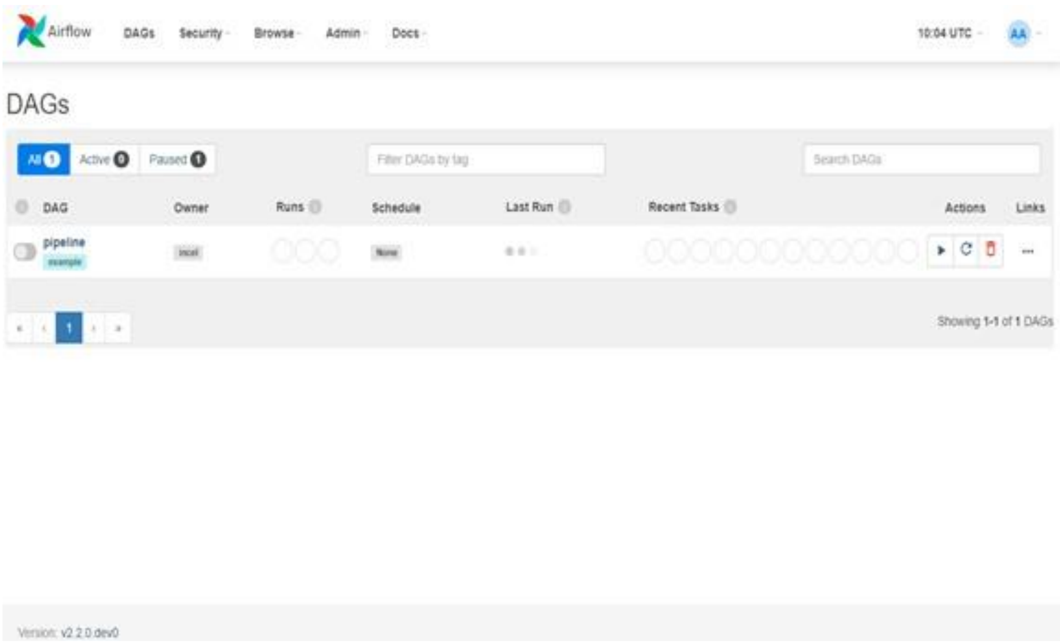


Figure 16: LOCUS platform pipeline Data Operations Controller

For the monitoring of the operational health of the system, specialized systems have been installed and selected to provide the best visibility of the execution environment of the LOCUS functions. These systems are a) Portainer.IO and Apache Zeppelin.

Portainer.IO [12] is a system for managing the docker containers of the infrastructure. This will be acting as our core resource monitoring tool for the PoC infrastructure.

Figure 17: LOCUS platform virtualization monitoring

Zeppelin [13] is a web IDE that is used combined with Big-Data lakes to run multiple programming language scripts that interface and query with big data systems, such as the core components of the LOCUS Persistence Module (Hive, Presto.IO). During the operation of the PoC activities, we will use this in order to check the schema structure and the data integrity in the input and output of the various LOCUS analytics functions and execution blocks.

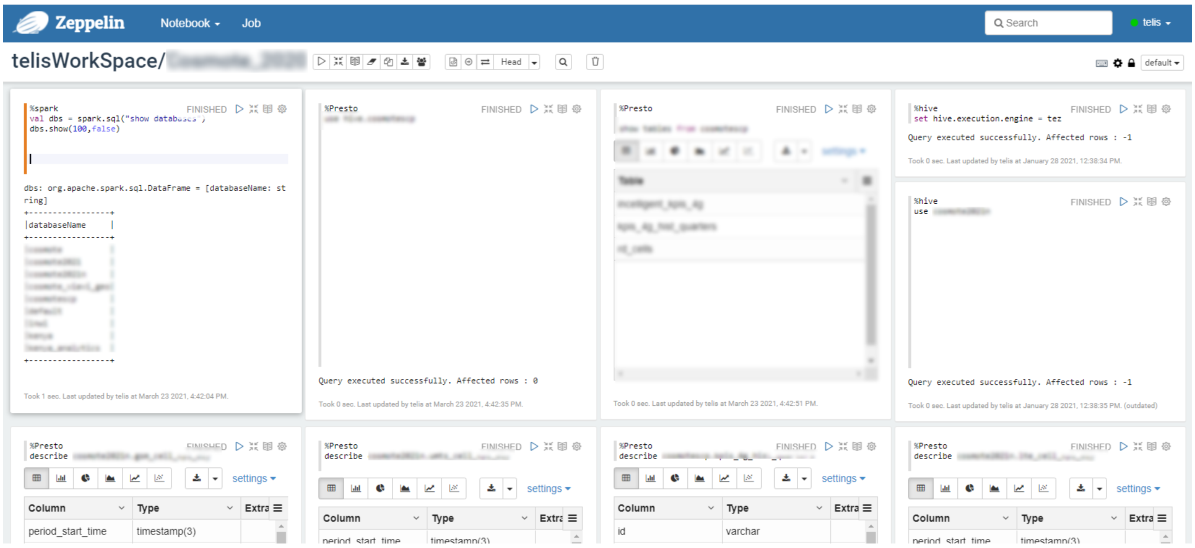
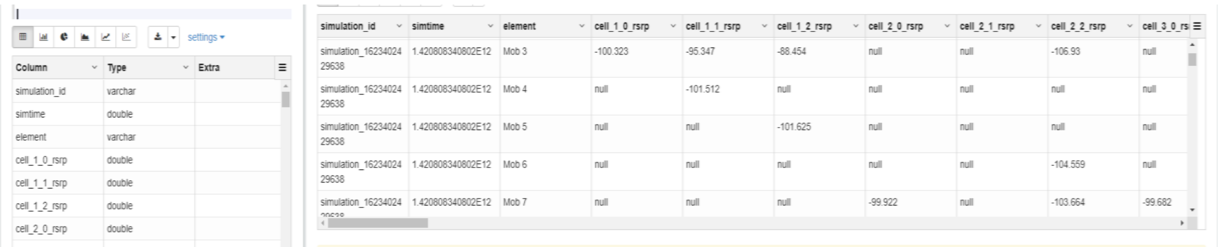


Figure 18: Monitoring of the persistence schema using Zeppelin web UI

2.3.1.3 Simulation-based generation of South-bound Interface for mixed indoor / outdoor scenarios

The Incelligent 3GPP/non-3GPP wireless network and mobility simulator IncelliSIM [11] will act as the LOCUS platform southbound interface providing realistic Network measurements (see Figure 19). These measurements will be the computed signal strength of each available

Wireless device (WiFi or 3GPP) received by each moving user equipment terminal of the venue.



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simulation_16234024	1.420808340802E12	Mob 7	null	null	null	-99.922	null	-103.664	-99.682

Figure 19: IncelliSIM generated RSRP per Wireless Device Measurements

The measurements will be ingested into the LOCUS persistence schema in real time and later on used for processing by the WP3 localization enabler function. The network simulator will also utilize the LOCUS SDK/ Hive connector to save the measurements of 3GPP and non/3GPP access points into the predefined schema.

Figure 20: IncelliSIM as a LOCUS SB emulator

During the WP3 Model training activities, the IncelliSIM simulator [11][11] was used as a validation and training software for several models, such as the WP3 AI-based fingerprinting implementation (WP 3 - Task 3.1-3.2 INCE). A specialized simulation for a large mall area has been selected to be the core source of network information for the PoC #3a, b. This simulation includes Dense Urban placement of 5G cells and a large amount of WiFi access points placed in key locations of a mall area, near Athens, Greece. Mobility pattern design based on realistic user relocation habits for this zone has been used in order to provide the maximum amount of realism to the emulated environment. In addition, different dwell times have been incorporated on different types of areas (e.g. long for cinemas, restaurants short for commercial shops) to further increase the accuracy of the environment. Finally, at the exit of the UE devices from the mall area, we gradually convert their mobility into vehicular, by increasing their speed and guiding them from the parking lot towards the revolving avenues.

2.3.1.4 WP3 Fingerprinting service for location detection and persistence for usage in the LOCUS analytics functions

The next step for the PoC #3 is the conversion of the network measurements into actual locations. For the detection of user location, this POC will have a pretrained neural network-based fingerprinting regression model (developed in WP3 and based on the specifications of WP2) that will be executed to provide an estimation of the actual UE locations within the system's venue.

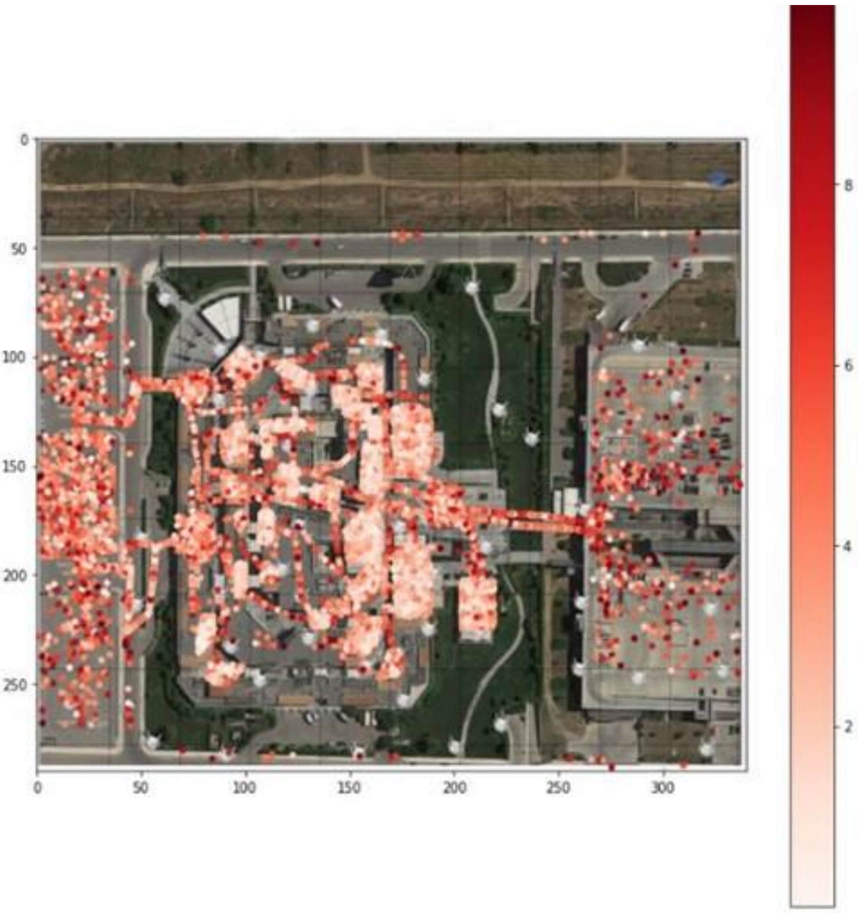

Figure 21: Deployed fingerprinting model performance

2.3.2 PoC #3A: Flow tracking in densely populated indoor environments for smart retail and venue management

The commercial activities of a complex, modern smart venue are strongly correlated with the dynamic marketing value of various key locations or "POI"s. Analytics on the population density and the footfall on the various identified sections can then be used to determine the value of a renting property or the cost of an advertisement due to increased or decreased successful marketing penetration. The LOCUS WP4+5 high level services allow API consumers to detect such areas and include this information into their marketing decisions.

2.3.2.1 NSE_UC1 Flow monitoring and management in large venues and densely urban environments

This use case involves the use of the LOCUS platform for the analysis of real network data (3GPP/non-3GPP) to provide accurate location estimates of UE terminals that are moving on an area that can be considered as a mixed indoor – outdoor smart retail hub. Using these as input data, we will perform the analytics function of POI (Point of Interest) identification to understand which important zones or areas exist, based on the UE's behavioural pattern and how these can be *a)* identified and converted in useful data structures and *b)* included in campaigns and other commercial activities by the venue operators. In addition to the detection of the venue's POIs, the dwell time will be an important KPI that will also provide context for the zones/POIs in order to select these areas for key advertisement or promotion activities and separate them from simple pass-through zones (e.g. the parking zone).

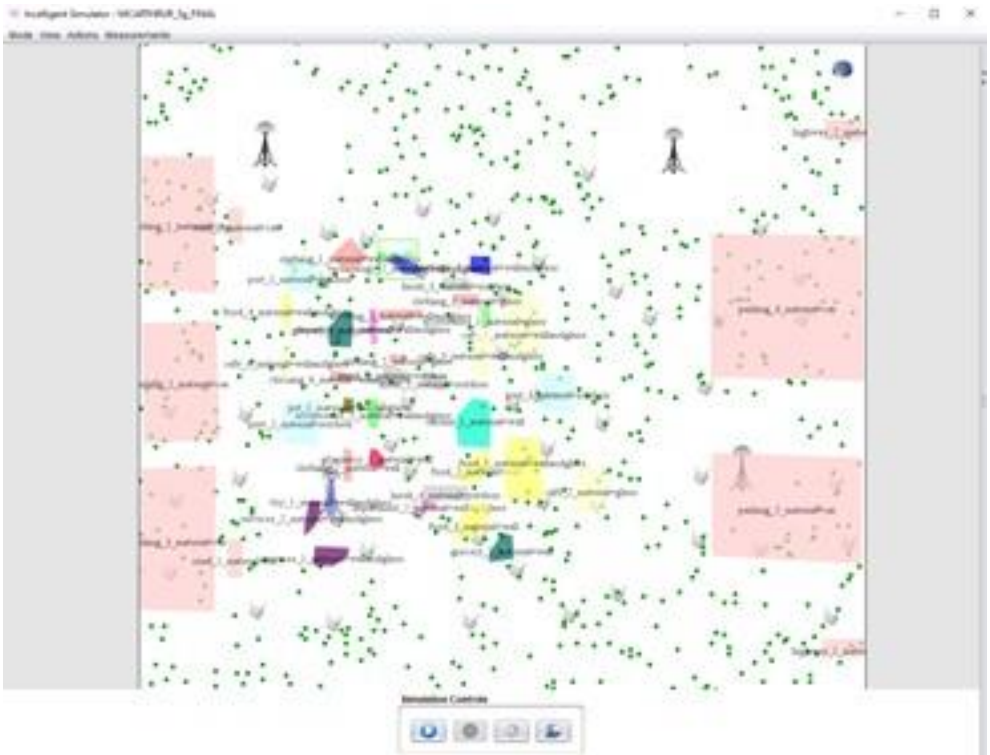

Figure 22: Commercial Points of interest in the simulation

The IncelliSIM network simulator's mobility module is using a combination of stochastic modelling, geometric areas and predefined polyline-based paths in order to produce realistic user relocation inside the preselected commercial simulation zone (placed near Athens, Greece).

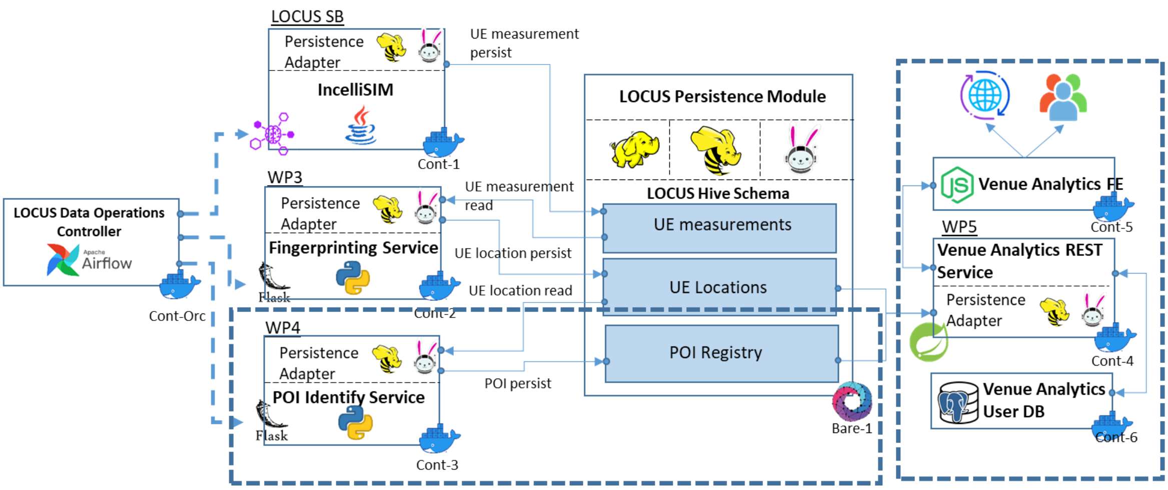

Figure 23: LOCUS PoC3a System architecture (extensions highlighted)

The PoC infrastructure that was setup in the previous chapter 2.3 will be extended in this use case with the addition of a new component: The AI-based POI identify service. Tis component will be responsible for analysing the location data (provided by the persistence module) into a pipeline of cleaning, post-processing, interpolation, and geometrical processing (i.e., convex hull algorithm) in order to identify the shapes with the highest density in the simulation zone. These will be registered in the appropriate schema to be consumed by a 3rd party application, which will act as the smart venue's retail administration panel.

The expected results of this use case will be presented by an interactive UI of the "3rd party application" that will be consuming the outputs of the LOCUS platform services. This UI will display the selected map area, including the various "POIs" that have been identified by the LOCUS WP5 analytics function. The user (smart venue admin) will be also able to define his own POIs and see the analytics of user data (i.e., footfall, average duration, density, etc.) for all the system areas. This information can be further exploited by promoting applications, discounts and other retail-related activities.

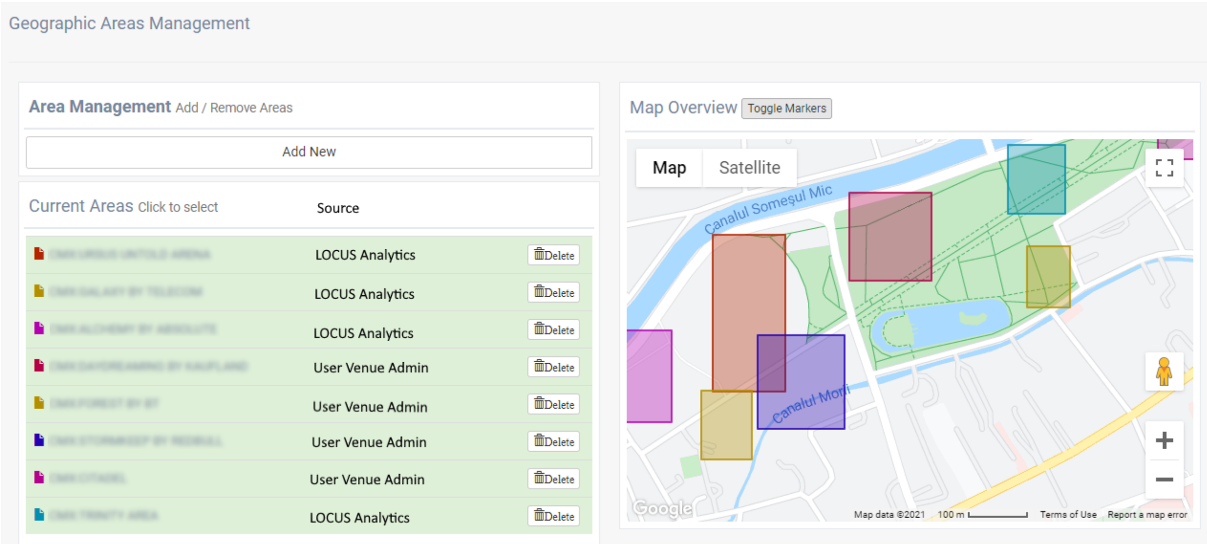

Figure 24: Example PoC #3a Use Case 3rd party application

2.3.3 PoC #3B: Crowd mobility analytics using wireless and auxiliary sensors

Crowd mobility analytics have very high value in mixed mobility situations such as pedestrian, car and high-speed fixed means. It can be utilized by a number of stakeholders varying from public authorities to smart venue managers in order to perform actions based on the identified mobility profiles and changes that occur in conjunction with other contextual changes such as social events (e.g. demonstrations, music concerts) and emergency situations (e.g. traffic jam, accidents). The LOCUS platform WP5-related high-level services can leverage the location information to provide such services via its designated service access layer.

2.3.3.1 NSE_UC2 Crowd mobility analytics using wireless and auxiliary sensors

This use case involves the use of the LOCUS platform for the analysis of real network data (3GPP/non-3GPP) to provide accurate location estimates of UE terminals that are moving on an area that can be considered as a multi-mobility transportation hub. Using these as input data, we will generate transportation meta-data and path detection in order to understand the mobility patterns within a specific area. The various paths will be also accompanied with important velocity profile-based meta-data that can be used by statistical post-processing, as means to identify the transportation state (e.g., a highway with low traffic or a pedestrian street).

Figure 25: User relocations paths in the simulation

As in the previous UC, we will be using the IncelliSIM mobility module to generate movement for the UE terminals, according to a predefined realistic pathway layout (correlated with the aforementioned POIs).

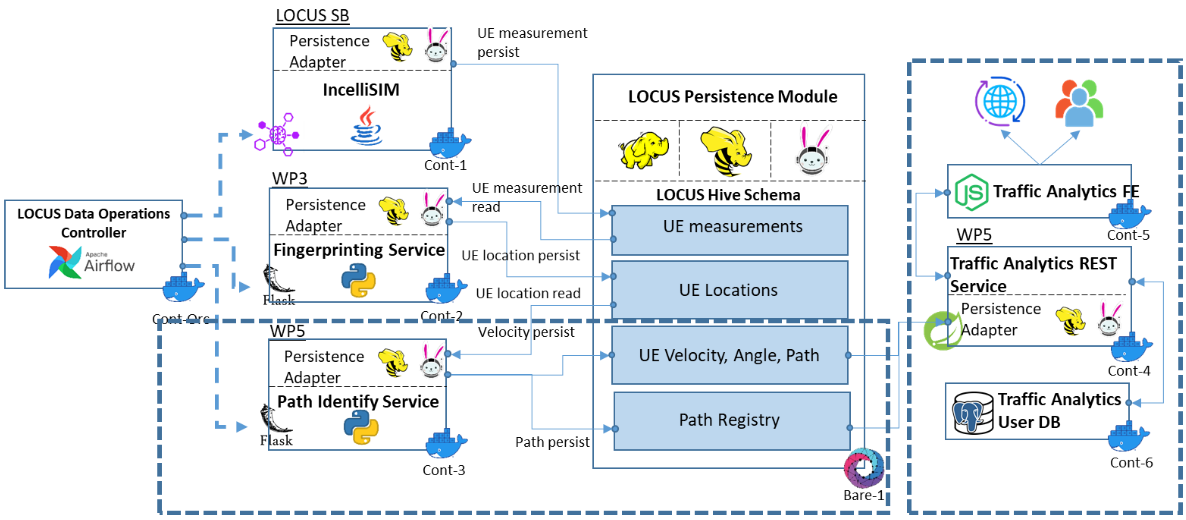

Figure 26: LOCUS PoC #3b system architecture (extensions highlighted)

The analytics function that will extend the reference architecture of the horizontal PoC will perform two tasks: a) the identification of the paths by the means of location information processing using ML algorithms on spatio-temporal data, b) the computation of important features (i.e., velocity, direction) that will be used by the higher layers as means to generate the mobility profiles.

The end result of this use case will be presented by an interactive UI of the "3rd party application" that will be consuming the outputs of the LOCUS platform services. This UI will display the selected map area, including the various "paths" that have been identified by the LOCUS analytics functions. In addition, continuous polling of the REST API will provide the transportation profiles of each path. This can be used to detect changes in the status of these paths that can possible be caused by an incident, such as an accident or traffic jam which in turn will require an action by the system operator.

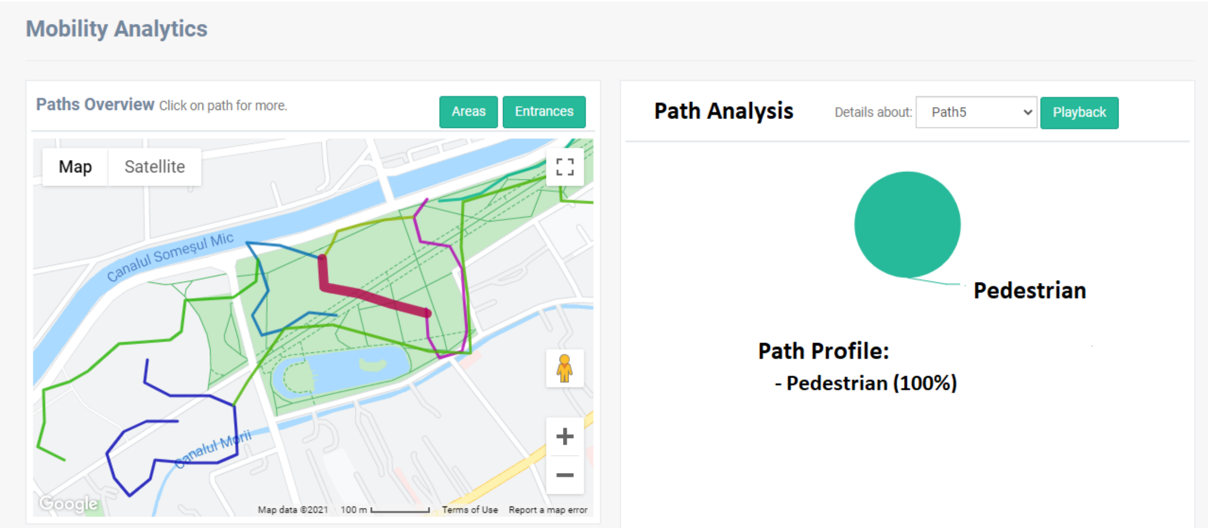

Figure 27: Example PoC3b Use Case 3rd party application

Group-In [7] [8] (Group Inference) is a prototype crowd mobility analytics that implements the NSE_UC2, Functionality 1, in the WP5 as one of the outcomes of the LOCUS project. The system enables understanding group mobility characteristics for indoor and outdoor environments. The system leverages unsupervised graph clustering models for predictions, whereas the parameters of the graph clustering algorithms can be trained via a small ground-truth dataset described in [7]. The ground-truth wireless dataset has been previously collected in a controlled setup. Technical details about the leveraged analytics algorithms can be found in the WP5 deliverables [10].

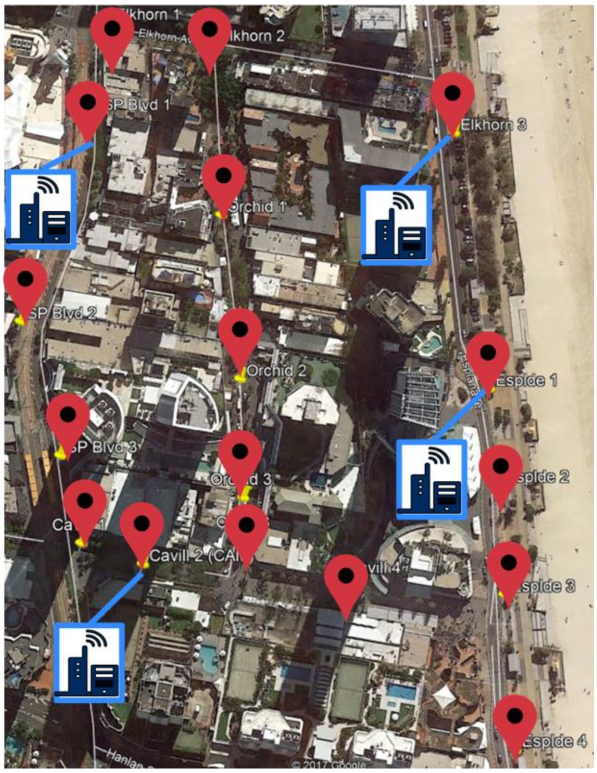

Figure 28: City-scale crowd mobility analytics data collection from wireless base stations.

The proposed algorithms are implemented and tested as a prototype system. The tests are conducted on the ground-truth Bluetooth dataset [7]. The Group-In system is able to predict the groups with a high-accuracy in terms of pairwise grouping as well as Jaccard similarity of real groups and observed groups. The prototype tests include controlled test of various indoor mobile or static scenarios. The initial tests provided more than 80% accuracy [7] in almost all of the scenarios, without extensive parameter calibration using three graph clustering algorithms in a centralized and decentralized fashion. Furthermore, the same analytics algorithms are applied on a larger WiFi dataset [8] and we observe that the system does not produce any significant overhead in terms of the computation time, which enables real-time city-scale measurements. Therefore, WiFi datasets are considered for city-scale crowd mobility analytics. On the other hand, location data sources and in particular high-accuracy 5G localization data can be leveraged for more fine-granular city-scale measurements through base stations deployed in a city environment, as illustrated in Figure 28.

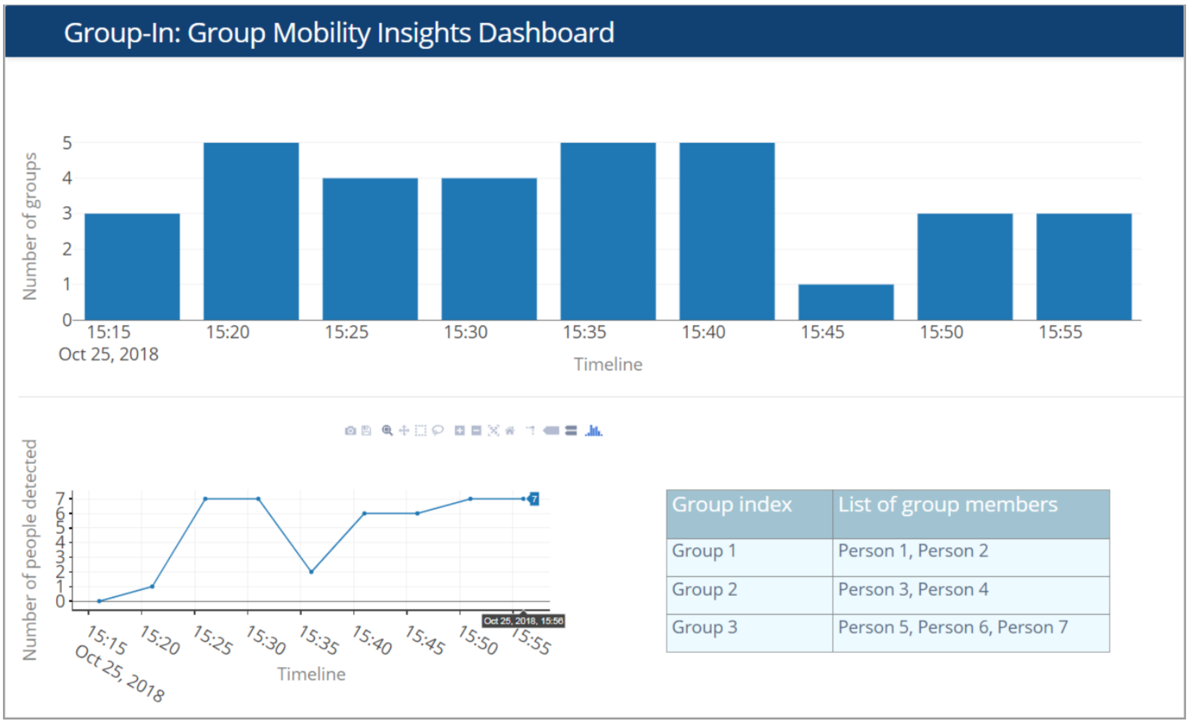

Figure 29: Group mobility analytics insights dashboard.

Figure 29 shows the expected outcome insight figures from the crowd mobility analytics, particularly for the group inference from the crowds. The live dashboard interface provides real-time or offline analytics results, such as number of people, number of groups, and the sizes of each detected group. The Group-In prototype is planned to be tested and further improved during the PoC. Possible improvements and extensions include application to other data sources, such as 5G localization data modalities, as well as implementing more advanced supervised and semi-supervised machine learning models.

3 References

[1]	Deliverable D4.3 EU LOCUS project “Implementation of the Virtualization platform for network control and management”
[2]	Deliverable D4.1 EU LOCUS project “Localization & Analytics for Smart Network Management”
[3]	A. Conti, S. Mazuelas, S. Bartoletti, W. C. Lindsey, and M. Z. Win, "Soft information for localization-of-things," Proc. IEEE, vol. 107, no. 11, pp.2240 - 2264, Nov. 2019.
[4]	Deliverable D3.1 EU LOCUS project “5G Based Preliminary Localization Solutions”
[5]	Deliverable D3.2 EU LOCUS project “5G Based Advanced Localization Solutions”
[6]	Deliverable D3.3 EU LOCUS project “Integrated localization technologies: preliminary version”
[7]	G. Solmaz, J. Fürst, S. Aytac, and F.-J. Wu. “Group-In: Group Inference from Wireless Traces of Mobile Devices.” In *Proceedings of ACM/IEEE IPSN'20*, April 2020.
[8]	S. Bartoletti, et al. “Location-based Analytics in 5G and Beyond”, To appear in *IEEE Communications Magazine (ComMag), Special Issue on Location Awareness for 5G and Beyond*, 2021.
[9]	Deliverable D5.1 EU LOCUS project “Design and implementation of virtualization technologies and pattern recognition mechanisms for physical analytics”
[10]	Deliverable D5.3 EU LOCUS project “Design of the localization & analytics as a service solution”
[11]	IncelliSIM 3GPP network simulator https://www.incelligent.net/products-services/211-simulator
[12]	Portainer.IO https://www.portainer.io/
[13]	Apache Zeppelin https://zeppelin.apache.org/