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IoT-NGIN

D7.2 – Trial site set-up, initial results and DMP update

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DISCLAIMER

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ABSTRACT	SEE EXECUTIVE SUMMARY
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Document History

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v0.9	31/03/2022	I2CAT, SYN	Finalized alignment with IoT-NGIN technologies
v1.0	31/03/2022	I2CAT	Final version ready for submission

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List of Acronyms and Abbreviations

AGLV	Automated Guided Land Vehicles
AGV	Automated Guided Vehicles
API	Application Programming Interface
AR	Augmented Reality
BLE	Bluetooth Low Energy
CV	Computer Vision
DLT	Decentralised Ledger Technology
DMP	Data Management Plan
DoA	Description of Action
DSO	Distribution System Operators
FAIR	Findability, Accessibility, Interoperability, Reusability (of Data)
FL	Federated Learning
GAN	Generative Adversarial Networks
GDPR	General Data Protection Regulation
GPU	Graphics Processing Unit
HDV	Human Driven Vehicle
IDD	IoT Device Discovery
IDI	IoT Device Indexing
IPR	Intellectual Property Rights
KPI	Key Performance Indicator
LAN	Local Area Network
LL	Living Lab
MAD	Malicious Attack Detector
ML	Machine Learning
MLaaS	Machine Learning as a Service
MTD	Moving Target Defences
OBD	On-Board Diagnostics

ODC	Open Data Commons
ORDP	Open Research Data Pilot
PLC	Programmable Logic Controller
PMU	Phaser Measurement Units
PQA	Power Quality Analysers
QR	Quick Response
RFID	Radio Frequency Identification
SMX	Smart Meter eXtension
SSIs	Self-Sovereign Identities
ST	Semantic Twin
TBD	To Be Defined
TMC	Traffic Message Channel
TSN	Time-Sensitive Networking
UAV	Unmanned Aerial Vehicle
UC	Use Case
UWB	Ultra-Wideband
VLP	Visual Light Positioning
VM	Virtual Machine
VPN	Virtual Private Network
WP	Work Package

Executive Summary

This deliverable includes updates about the trial site set-up and other progress made in the IoT-NGIN Living Labs. In particular, it exposes, per use case, details about the required equipment and its procurement status, data collection, alignment with the required IoT-NGIN technologies, sequence diagrams of the use case (UC), testing and validation processes, execution timeline and initial results. These details were obtained through a questionnaire and constant collaboration between all WP7 partners and regular follow-up meetings with partners from technical work packages, WP2 through WP5.

On the other hand, the deliverable also includes updates about the project's Data Management Plan (DMP) presented in M6. In particular, it updates the data inventory table presented in the first version of the DMP with the new information available from the Living Labs. Furthermore, it discusses in detail the choice of the Open Data repository chosen by the consortium to publish these identified datasets.

1. Introduction

The definition and set-up of the IoT-NGIN Living Labs (LLs) started during the first year of the project. In that sense, *D1.1 – Definition and analysis of use cases and GDPR compliance* [1] provided the first vision into the IoT-NGIN LLs and their corresponding use cases. Afterwards, the partners responsible for the LLs started working with all the technical partners, specifically task leaders from WP2, WP3, WP4 and WP5, on how to align the IoT-NGIN technologies resulting from the technical work packages with their respective LLs and UCs. Simultaneously, progress has been made on the setting up of the different LLs, in particular in terms of acquiring the required equipment, the definition of testing and validation process as well as the abovementioned alignment with IoT-NGIN technologies.

On the other hand, the first draft of the Data Management Plan of the project was presented in *D7.1 – Data Management Plan (DMP)* [2] in M6. This deliverable outlined the guidelines of the project's DMP and included a preliminary data inventory table of the datasets identified to be collected in the different LLs. As progress on the LLs continues, this information needs to be updated according to the new updates occurring in the different LLs.

This deliverable encompasses all of the updates that have been made since M6 of the project in terms of the trial site setup as well as the DMP. It was led by the leading partner of T7.1 and involved extensive collaboration with all of the trial partners of WP7.

The rest of the document is structured as follows. Section 2 describes the methodology followed to collect the necessary information from the different trial partners. Afterwards, Section 3 details the advances in the different LLs and their use cases, based on the different aspects of the followed methodology. Then, Section 4 moves to the second aspect covered by the deliverable and includes updates about the Data Management Plan of the project. Finally, Section 5 concludes the document and outlines next steps to follow.

2. Methodology and trial coordination

In order to capture the necessary information about the trial site setup and validation processes of the different IoT-NGIN Living Labs, a questionnaire was sent out to all trial partners covering aspects such as trial site description, required equipment, involved IoT-NGIN technologies, data collection and initial results of each of the use cases of the different Living Labs. The questionnaire was coordinated by the leading partner of T7.1 (I2CAT) and the input received from the different trial partners was compiled into Section 3 of this deliverable document. The questionnaire also takes into account the information already provided about the trial use cases in *D1.1 – Definition analysis of use cases and GDPR Compliance*, such as the use case scenario, requirements and KPIs.

The rest of this section provides a description of the main sections in the mentioned questionnaire, which also correspond to the sub-sections of the description of each trial UC as provided in Section 3.

2.1. Trial site description

This section is meant to be an introduction to the UC and provides a short description of the trial site of each UC, which might include a summary of the *Narrative* section provided in *D1.1 – Definition analysis of use cases and GDPR Compliance*, along with new details such as where the UC will be conducted, the actors involved in the UC as well as any diagrams of the main components/equipment of the UC.

2.2. Required equipment

In order to better understand the equipment required for each UC, this section includes a detailed description of all required equipment for the UC, along with the procurement status of each: whether it is already available or will be procured. This includes any type of equipment such as servers, sensors, vehicles, robots, drones, software, etc. For some UCs, this information was already provided in *D1.1 – Definition analysis of use cases and GDPR Compliance* and was revised and completed in this deliverable for all UCs.

2.3. Data collection

This section covers the datasets that have been identified and possibly already collected in the UC. A preliminary list of datasets has already been included for each trial in *D7.1 – Data Management Plan* and this deliverable includes an update of that DMP along with any changes, modifications or new datasets identified in each UC. The details of the datasets identified in each UC are provided in *Annex I. Data Inventory Table*, whereas the FAIR Data considerations of the datasets are detailed in *Annex II. FAIR Data Considerations*.

2.4. Alignment with IoT-NGIN technologies

The most crucial aspect of the definition of the different trial UCs in this deliverable is the alignment of each use case with the different IoT-NGIN technologies. This section is the result of extensive work and continued collaboration between WP7 and the technical partners of all technical work packages (WP2 to WP5) to identify the IoT-NGIN technologies that will be involved in each of the trial use cases. This collaboration was done through continuous meetings and alignment between the different WPs, and included the identification of the following information for each of the IoT-NGIN technologies identified as part of a UC:

- Description of the use of the IoT-NGIN technology in the UC.
- Details of the adaptation, configuration and fine-tuning required for the IoT-NGIN technology to be used in the UC.
- Deployment details of the IoT-NGIN technology within the UC.
- The functional and non-functional requirements and KPIs of the UC (as defined in *D1.1 – Definition analysis of use cases and GDPR Compliance)* that the IoT-NGIN technology helps in satisfying.

Table 1 below shows a summary of this alignment. It lists the different IoT-NGIN technologies grouped by their corresponding WP and which Living Labs and use cases they are involved in. The in-depth analysis of the alignment of the technologies with the different Living Labs and use cases, as discussed above, can be found in the corresponding sub-sections of Section 3.

The plans of the Living Labs to use live 5G networks at their field trials are shown in Table 1. Some will use public 5G networks while those focussed on private local area 5G networks are planning to use prototype 5G networks provided by partners in WP2. Prototype functionality can be deployed in private 5G networks but not in public wide area networks due to regulatory constraints which apply to public networks as they support critical infrastructures and the testing of prototype functionality in public networks could disrupt the correct operation of these networks. Extensive 5G lab tests of functionality are on-going and planned for the 2nd reporting period. The alignment of the 5G enhancements developed in WP2 with the use cases is under development and will be reported in *D2.2 – Enhancing IoT Underlying Technology*, to be submitted in M20.

Table 1. Summary of the alignment of IoT-NGIN technologies with the different Living Labs.

IoT-NGIN Technology	Smart Cities			Smart Agriculture		Industry 4.0			Smart Energy	
	UC1	UC2	UC3	UC4	UC5	UC6	UC7	UC8	UC9	UC10
WP2 – Enhancing IoT Underlying Technology										
Use of 5G networks in trial sites	✓	✓	✓	*Public 5G not available yet at trial sites*			✓	✓	✓	✓
Secure edge-cloud execution framework				✓	✓					
WP3 – Enhancing IoT Intelligence										
MLaaS framework	✓	✓	✓	✓	✓	✓		✓	✓	✓
Deep Learning, Reinforcement Learning & Transfer Learning				✓	✓				✓	✓
Privacy-preserving Federated Machine Learning	✓	✓	✓	✓						
Polyglot Model Sharing component	✓	✓	✓	✓				✓		
WP4 – Enhancing IoT Tactile & Contextual Sensing/Actuating										

IoT-NGIN Technology	Smart Cities			Smart Agriculture		Industry 4.0			Smart Energy	
	UC1	UC2	UC3	UC4	UC5	UC6	UC7	UC8	UC9	UC10
IoT device discovery (Computer Vision)	✓	✓		✓		✓		✓		✓
IoT device discovery - Non-visual (RFID, QR, UWB)				✓		✓	✓	✓		
IoT device indexing	✓	✓		✓	✓	✓	✓	✓		✓
IoT device access control	✓	✓		✓	✓					✓
IoT AR toolkit				✓		✓	✓			✓
WP5 – Enhancing IoT Cybersecurity & Data Privacy										
Generative Adversarial Networks (GAN) based dataset generation				✓					✓	✓
Malicious Attack Detector (MAD)				✓					✓	✓
IoT vulnerability crawler	✓	✓		✓					✓	✓
Moving Target Defences (MTD) Network of Honeypots				✓						
Decentralized Interledger Bridge	✓	✓						✓		✓
Privacy preserving Self-Sovereign Identities (SSIs)	✓	✓	✓						✓	✓
Semantic Twins	✓	✓	✓					✓	✓	

2.5. Use case sequence diagram(s)

The objective of this section is to provide one or more sequence diagrams explaining the main steps in the UC execution, especially in relation with the IoT-NGIN technologies identified in the previous section. The diagrams show how the user interacts with the different equipment of the UC and which IoT-NGIN technologies and components are relevant. If the use case has various usage scenarios, multiple sequence diagrams are provided.

2.6. Testing and validation procedures

This section provides details about how the UC testing / validation will be carried out. This can include one or more of the following aspects:

- **Technical validation of the UC:** includes details about how the UC will be validated, which particular components will be involved in the validation, which KPIs will be validated, etc.
- **Validation stages:** describes whether the UC will be directly validated in the field or it will include a previous validation in a controlled environment. It can also include the different stages of the UC validation, for instance, preliminary lab validation, closed trial validation, final validations, etc.
- **User experience testing/validation:** if relevant, describes how feedback from the user will be collected, and other related aspects such as the participant groups, user profiles, satisfaction questionnaire, etc.

2.7. Execution timeline

This section provides details of an estimated execution timeline of the UC, along the lines of the different trial execution stages defined in the project proposal and DoA. In particular, the UCs are divided into the following stages and estimated start and end dates are provided for each stage:

- Trial setup and equipment procurement
- Initial implementation and validation
- Intermediate implementation and validation
- Final implementation and validation

2.8. Initial results

In this final section, any initial results that have been already obtained in the UC are listed and explained. Given that the Living Labs are still in their preliminary stages, results can be related to one or more of the following aspects:

- Trial site set-up, for instance equipment procurement, set-up completed, etc.
- Data collection, for instance if any dataset is already available, generated, procured, etc.
- Preliminary validation / benchmarking of a particular KPI, IoT-NGIN technology, or any particular equipment of the ones mentioned in previous sections.

3. Trial-site setup and validation process

3.1. Human-Centred Twin Smart Cities Living Lab

3.1.1. UC1 – Traffic Flow Prediction & Parking prediction

The Jätkäsaari area is one of the most congested in the city of Helsinki and it is a former island, which has been linked to the mainland via a single land connection (a landfill) and one bridge for cars. Jätkäsaari is also the home to the major port facility in Helsinki, where all the passenger car ferries travelling between the cities of Helsinki and Tallinn converge. The port facility serves both passenger and cargo traffic and is considered to be one of the busiest international traffic connections in Europe serving around 4.1 million passengers annually (2020).

The objective of UC1 is to address the traffic-related challenges facing the city of Helsinki and the Jätkäsaari port's managing company, Port of Helsinki (owned by the city) as described in Section 3.1.1.1. To reduce the congestion, efficient prediction of traffic flows and parking availability is planned in these bottleneck locations. The solutions tested in Helsinki are developed to be applicable for other cities addressing their specific traffic situations as they are designed to be scalable and can be replicated in other cities with relative ease. To best address the above development areas, the city of Helsinki has established an ecosystem actor, the Jätkäsaari Mobility Lab (https://mobilitylab.hel.fi) to foster innovations and public-private sector collaboration. It offers the Living Lab-environment for UC1 and UC2.

UC1 has also identified business cases for the sustainability of the use case development and third-party involvement for value-added service development.

3.1.1.1. Trial site description

UC1 provides solutions to a common problem in large cities which is traffic inefficiencies. Not only is time wasted driving at suboptimal speeds, but it also increases the polluting factor of cars. Collecting road data (car count, speed etc.) and combining that to weather data as well as public transportation information, could potentially, through machine learning (ML) mechanisms, provide insights on the traffic jams and on possible solutions.

The current high volume of travel and the geographical location of Jätkäsaari pose significant challenges for the city of Helsinki's traffic management. Thus, UC1 is seeking active models that aid drivers in:

- Choosing a less-trafficked road and/or time
- Provisioning of information on available parking options
- Demonstrating the application of deep learning technologies for advanced traffic flow prediction including unpredictable conditions like weather, delays and accidents.

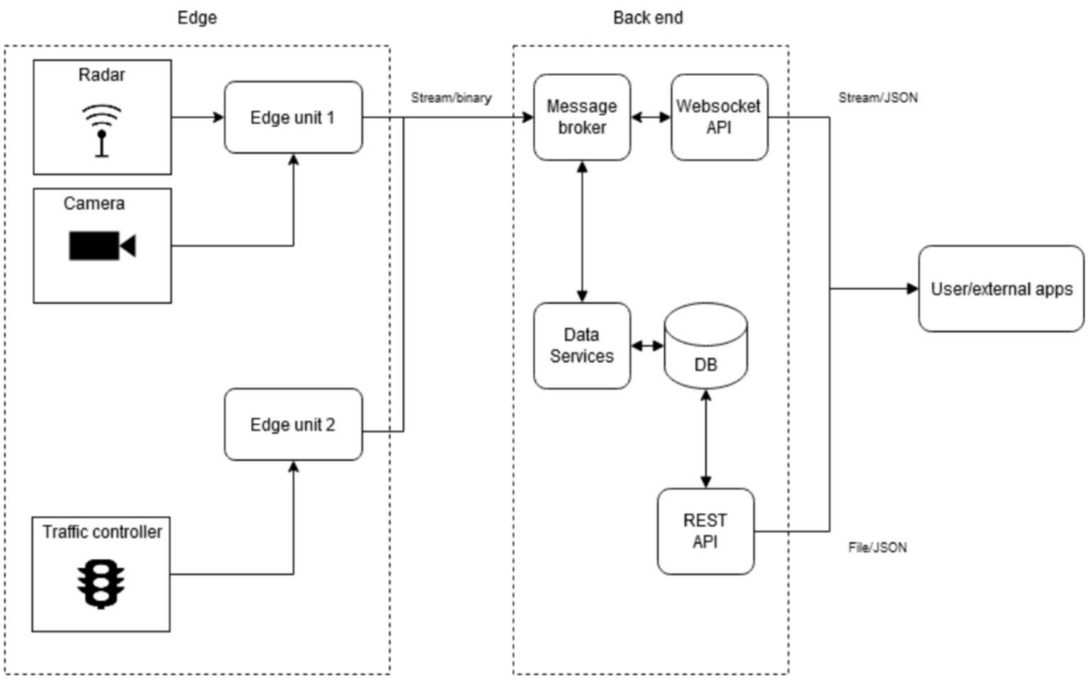


Figure 1. The Smart Junction Project's Open Data Platform is used to collect and analyse the traffic data in UC1. The main components are Radars, Cameras, Edge units and Backend components.

The Jätkäsaari Smart Junction project[1] produces data on traffic fluency through cameras, radars, and other sensors installed at the bottleneck intersections of Mechelininkatu, Hietalahdenkatu and Jätkäsaarenlaituri. The data from the junctions includes lane-specific vehicle counts, travel times, and stops. With the data collected, the ML process is then used to identify traffic patterns. This information will be provided in the least intrusive way to users, e.g., using Traffic Message Channel (TMC) systems to broadcast the information to the drivers in the area.

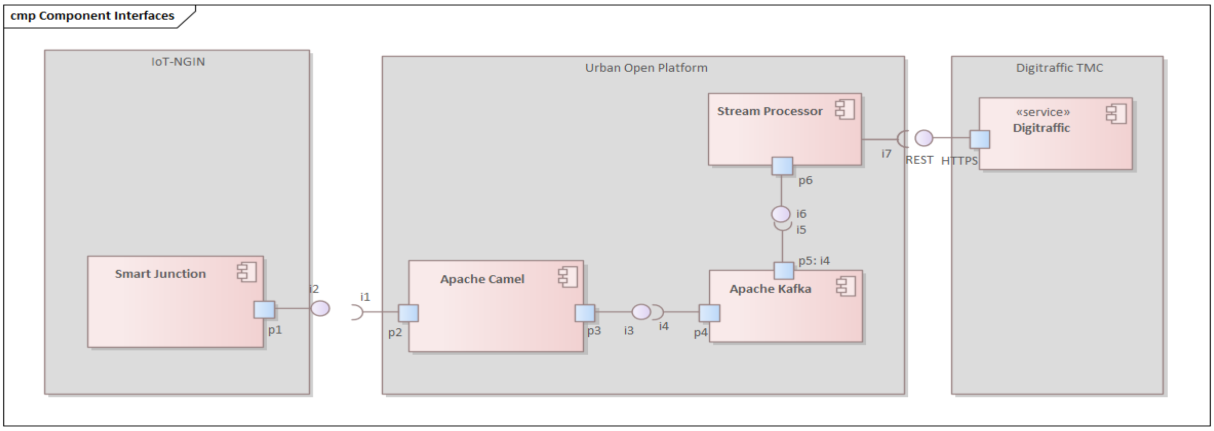


Figure 2. The Urban Open Platform links the IoT-NGIN-based solution to the Digitraffic TMC system used to distribute the traffic information.

[1] Jätkäsaari Smart Junction project: https://mobilitylab.hel.fi/projects/jatkasaari-smart-junction/

Impact of the use case

For the City of Helsinki, UC1 provides ways to reduce the overall CO_2 footprint of traffic via intelligent traffic management solutions. This enables the City of Helsinki to reach its overall climate neutrality goals (Carbon Neutral Helsinki by 2030). The traffic in the Jätkäsaari area represents a significant share in the city's total greenhouse gas emissions and it mostly occurs beyond the direct control of the city. Providing solutions for intelligent traffic management and influencing the behaviour of individual drivers is an important part of the city's strategy.

Besides the overall emission control impact, UC1 also addresses the direct business needs of the Port of Helsinki-company, which operates the Jätkäsaari West Harbour cargo and passenger traffic. The continuous traffic problems associated with the Jätkäsaari-area harm the current business image of the port company and it already is the major recipient of traffic-related complaints. Thus, UC1 can act as a solution provider to the Port of Helsinki to reduce the above business harm and to offer new opportunities for service creation in traffic management.

These new services could be potentially operated by the Port of Helsinki as a platform for third-party service developers in:

- Efficient solutions to manage cargo traffic to-and-from the port. Potential customers are logistics companies and other service providers using the traffic data.
- Efficient management of cargo and passenger traffic flows to reduce congestion and to provide alerts. These solutions could potentially scale to the Port of Tallinn as well for cross-border collaboration.
- Potential for CO_2-footprint data collection for the Port of Helsinki and the companies using the port facilities.

The expected impact of UC1 includes the scalability and efficient deployment effect of the solutions for wider deployment purposes and linking to other systems. These can extend the potential use of the solutions for wider end-user groups such as other cities and companies.

3.1.1.2. Required equipment

Table 2 below shows a detailed description of the required equipment for UC1, along with its type and status (whether it is available or still be procured).

Table 2. Detailed description of the required equipment for UC1.

Equipment	Description / Specifications	Type	Status
Radar	Radar sending data about real-time vehicle positions for traffic management purposes.	sensor	Available through Jätkäsaari Smart Junction project
Camera	On-location cameras will be installed to monitor the movement of vehicles and pedestrians in the site of the living lab. The produced data will be aggregated to count the number of the	sensor	Available in limited quantities through Jätkäsaari Smart Junction project

	different types of objects passing through the living lab location at a given time.		
Signal controller	Traffic signal status	controller	Available through Jätkäsaari Smart Junction project
Signal controller	Detector status	sensor	Available in limited quantities through Jätkäsaari Smart Junction project
Lidar	Near real-time positions of vehicles, pedestrians and bicycles within the intersection area.	sensor	Available in one junction through Jätkäsaari Smart Junction project

3.1.1.3. Data collection

The following dataset(s) have been identified as part of the use case:

- **On-location camera feed:** On-location cameras will be installed to monitor the movement of vehicles and pedestrians in the site of the living lab. The produced data will be aggregated to count the number of the different types of objects passing through the living lab location at a given time.
- **Radar imagery:** Radar imagery will be used to detect cars in a given area and count the totals of different types of vehicles passing through an area at a given time.

3.1.1.4. Alignment with IoT-NGIN technologies

Table 3 below shows the IoT-NGIN technologies relevant for UC1. For each technology, a description of its role is provided along with any adaptation it might need to be used in the UC, deployment details and related UC requirements and KPIs.

Table 3. Alignment of UC1 with the relevant IoT-NGIN technologies.

WP3 – MLaaS framework	
Description	Required to enable the use of the Privacy-preserving Federated Learning component for training the ML models and the Polyglot Model Sharing component for sharing these models for the inference of ML services.
Adaptation and fine-tuning	N/A
Deployment	Cloud

Related requirements	**REQ_SC1_F02** – Gain access to the city's traffic data
Related KPIs	**KPI_SC_1** – Different types of sensors' data (multispectral/visual camera, RFID) to be analysed > 6 **KPI_SC_4** – Improve efficiency and traffic congestion in twin smart cities by at least 20% **KPI_SC_5** – Increase Twin Smart Cities IoT infrastructure utilization by at least 30%
WP3 – Privacy-preserving Federated Learning	
Description	Federated Learning is used to jointly train the visual recognition of cars by combining training at multiple nodes without revealing the training data to other nodes.
Adaptation and fine-tuning	At least two different nodes will be used for training as participants of the federated learning system. Could be either physical or simulated depending on the availability of data or infrastructure.
Deployment	Cloud/edge
Related requirements	**REQ_SC1_F02** – Gain access to the city's traffic data **REQ_SC1_NF03** – Privacy of information and security have to be guaranteed
Related KPIs	**KPI_SC_1** – Different types of sensors' data (multispectral/visual camera, RFID) to be analysed > 6 **KPI_SC_4** – Improve efficiency and traffic congestion in twin smart cities by at least 20% **KPI_SC_5** – Increase Twin Smart Cities IoT infrastructure utilization by at least 30%
WP3 – Polyglot model sharing component	
Description	Used as part of the MLaaS framework to access the ML model.
Adaptation and fine-tuning	N/A
Deployment	Cloud
Related requirements	**REQ_SC1_F02** – Gain access to the city's traffic data
Related KPIs	**KPI_SC_1** – Different types of sensors' data (multispectral/visual camera, RFID) to be analysed > 6 **KPI_SC_4** – Improve efficiency and traffic congestion in twin smart cities by at least 20%

	KPI_SC_5 – Increase Twin Smart Cities IoT infrastructure utilization by at least 30%
WP4 – IoT device discovery (Computer Vision)	
Description	The IoT Device Discovery component will be used to detect cars from camera feeds. This data will then be used to avoid bottlenecks and traffic jams as well as provide a parking prediction solution to the commuters.
Adaptation and fine-tuning	The models will need to be trained with appropriate data.
Deployment	Cloud deployment.
Related requirements	**REQ_SC1_F02** – Gain access to the city's traffic data **REQ_SC1_F04** – Consideration over streets and parking topology
Related KPIs	**KPI_SC_4** – Improve efficiency and traffic congestion in twin smart cities by at least 20%
WP4 – IoT device indexing	
Description	Used to maintain a list of devices the IoT vulnerability crawler scans.
Adaptation and fine-tuning	The devices to be scanned need to be registered with this component.
Deployment	Cloud/edge.
Related requirements	**REQ_SC1_NF02** – Privacy of information and security have to be guaranteed
Related KPIs	N/A
WP4 – IoT device access control	
Description	SSIs and VCs will enable access control to IoT devices and Semantic Twins (STs) based on dynamic personalised access rights. Further, the IoT Device Access Control component provides access control for the other IoT-NGIN components.
Adaptation and fine-tuning	We need to add users and credentials for the IoT-NGIN services.
Deployment	For the IoT devices the enforcement functionality will be deployed to the device itself or to a related edge node and for the STs the deployment will be to the cloud. The management activities will be deployed to the cloud.

Related requirements	**REQ_SC2_NF02** – Privacy of information and security have to be guaranteed
Related KPIs	**KPI_SC_1** – Different types of sensors' data (multispectral/visual camera, RFID) to be analysed > 6
WP5 – IoT vulnerability crawler	
Description	Used periodically or on-demand to scan the IoT devices for any known vulnerabilities.
Adaptation and fine-tuning	Devices to be scanned need to be registered with the IoT Device Indexing component. The crawler needs to be configured with the scanning schedule.
Deployment	Cloud
Related requirements	**REQ_SC1_NF02** – Privacy of information and security have to be guaranteed
Related KPIs	N/A
WP5 – Decentralised interledger bridge	
Description	Private Decentralized Interledger Technologies (DLTs) are used for enabling immutable history for the STs, and Interledger transactions are then used to anchor the data to a more trustworthy (public) ledger.
Adaptation and fine-tuning	N/A
Deployment	Cloud
Related requirements	**REQ_SC1_NF02** – Privacy of information and security have to be guaranteed
Related KPIs	N/A
WP5 – Privacy-preserving Self-Sovereign Identities (SSIs)	
Description	SSIs also enable dynamic lookup of STs via Quick Response (QR) codes and GS1 Digital Links.
Adaptation and fine-tuning	N/A
Deployment	Cloud

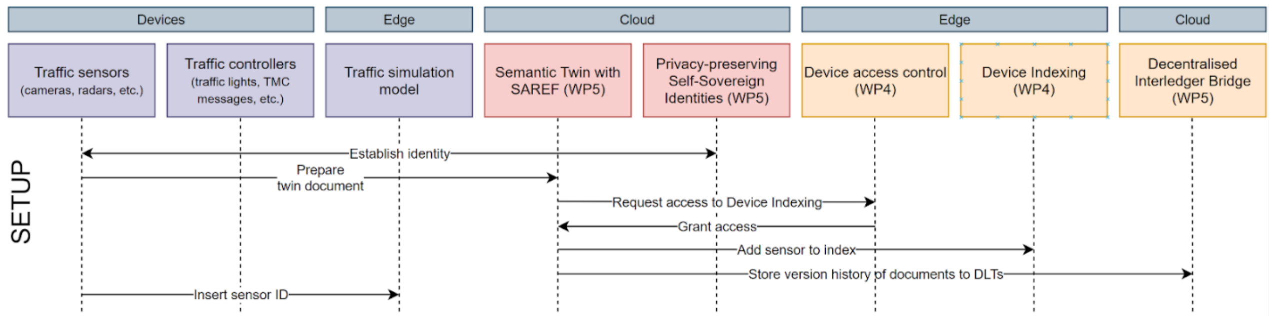
Related requirements	**REQ_SC1_NF01** – Data integrity **REQ_SC1_NF03** – Privacy of information and security have to be guaranteed
Related KPIs	**KPI_SC_1** – Different types of sensors' data (multispectral/visual camera, RFID) to be analysed > 6
WP5 – Semantic Twins	
Description	The Semantic Twin solution is used to describe traffic related objects, such as sensor devices, and their interfaces to distribute these descriptions to data users. The descriptions and their distribution will be implemented in a uniform manner to enable universal machine readability using SAREF ontologies. Semantic Twins will enable building the traffic management and parking prediction solutions more efficiently and help integrate them further into related systems.
Adaptation and fine-tuning	UC-specific Semantic Twins will be created. For example, a Semantic Twin of a traffic radar describes the location and orientation of the sensor and the data interface to access the sensor data.
Deployment	Semantic Twins will be deployed in the cloud for this UC.
Related requirements	**REQ_SC1_F02** – Gain access to the city's traffic data **REQ_SC1_F03** – Availability of function on aspects such as weather, events, environmental information **REQ_SC1_F04** – Consideration over streets and parking topology **REQ_SC1_NF01** – Data integrity **REQ_SC1_NF03** – Privacy of information and security have to be guaranteed
Related KPIs	**KPI_SC_1** – Different types of sensors' data (multispectral/visual camera, RFID) to be analysed > 6 **KPI_SC_4** – Improve efficiency and traffic congestion in twin smart cities by at least 20% **KPI_SC_5** – Increase Twin Smart Cities IoT infrastructure utilization by at least 30%

3.1.1.5. Use case sequence diagrams

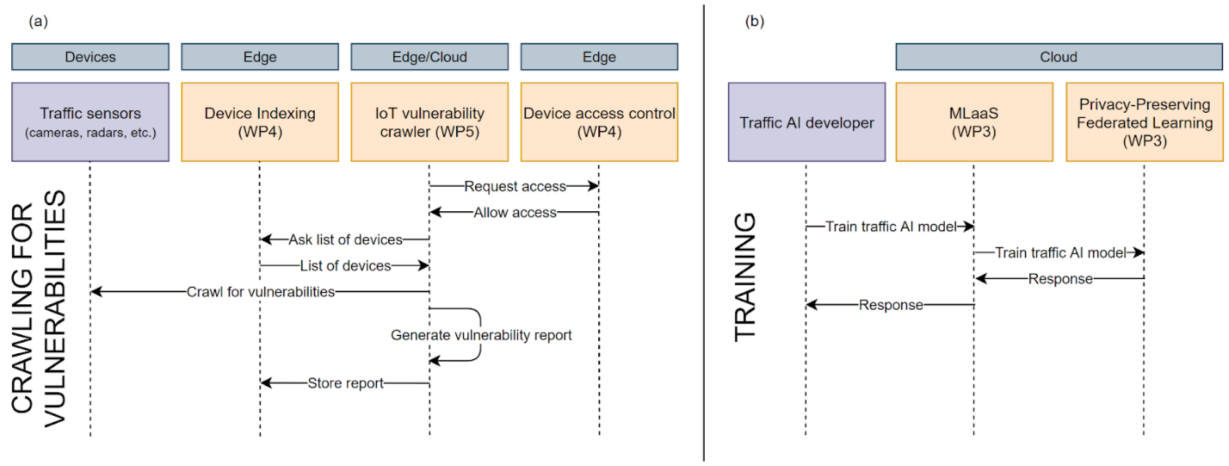
The main steps in the sequence diagram of this use case can be summarized as follows:

- Cameras and possibly other sensors are gathering data about vehicle movements.
- ML detects vehicles to help predict where and when traffic bottlenecks are likely to occur.
- In case of the potential bottlenecks being identified, traffic controllers are used to notify and guide the drivers towards alternative routes.

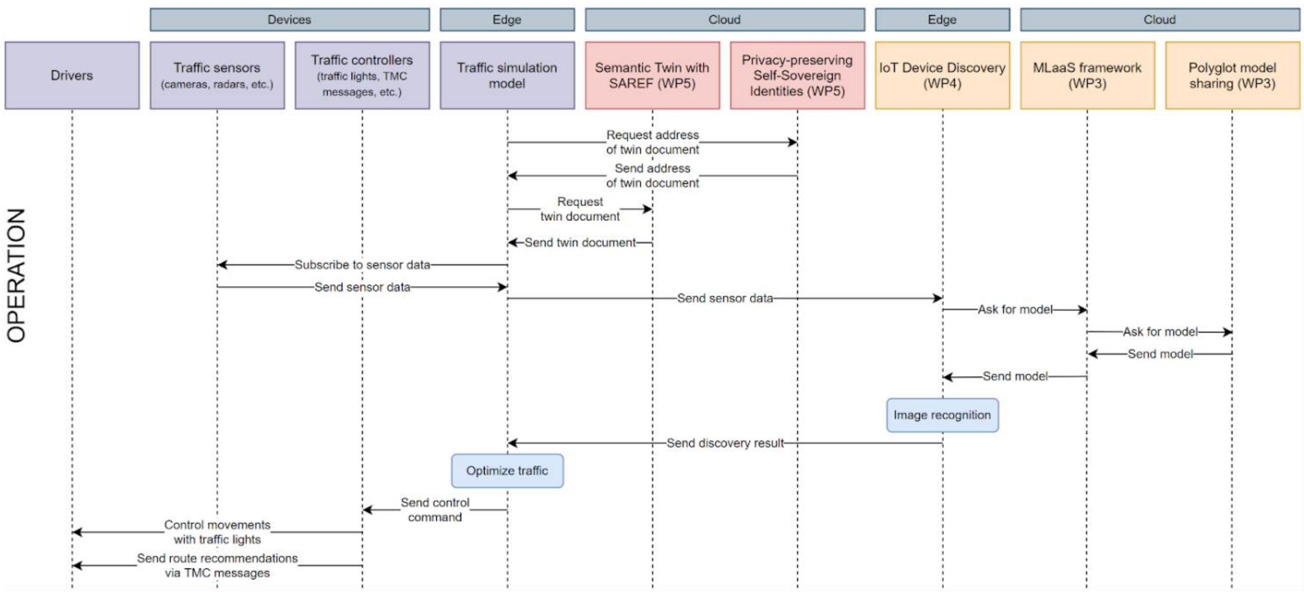
- Vulnerability crawler performs regular checks of the security of the sensors.



(a) Setup phase



(b) Crawling and training phases



(c) Operation phase

Figure 3. Sequence diagram of UC1.

3.1.1.6. Testing and validation procedures

Technical validation of the UC

- The key objective of UC1 is to address the traffic issues in Jätkäsaari, which is also reflected in KPI_SC_4, which calls for a traffic congestion reduction of 20%. Reaching that KPI, thus, also validates the use case[2].
- This use case also helps validate the visual recognition functionality of the IoT Device Discovery component.
- The Smart City living lab is used to aid the development of the ST and SSI solutions to ensure they include the necessary properties to aid efficient development, deployment, and interfacing with other systems. This goal is then validated with the other living labs utilising these technologies.

Validation stages

- The components will first be validated individually in a lab environment during the development process.
- Afterwards, the whole solution will be validated in field conditions.

User experience testing/validation

- UC1 user experience will be validated with selected questionnaires for the drivers and the port authority. Targeted interviews are conducted to confirm the perceived effect on the business case.

3.1.1.7. Execution timeline

The execution timeline of UC1, divided into multiple phases, is detailed in Table 4 below.

Table 4. Execution timeline of UC1.

Phase	Estimated start date	Estimated end date	Notes
Trial set-up and equipment procurement	Ongoing	June 2022 (M21)	First batch of sensors (cameras and radars) installed and initial calibrations completed.
Initial implementation and validation	M22	M26	Second batch of sensors (e.g., lidars) installed and calibrated. Additional calibrations for the first batch if necessary.

[2] A challenge for validating this KPI is that the COVID-19 pandemic has caused significant changes in the traffic so that may have an impact in the traffic measurements.

Intermediate implementation and validation	M27	M31	Sensors connected to the simulation model.
Final implementation and validation	M32	M36	Potential business cases to be developed for sustainability.

3.1.1.8. Initial results

The Smart Junction project has already installed several types of equipment in Jätkäsaari area:

- 17 radars, which already provide data
- 17 cameras, which are being calibrated
- 7 signal controllers, which are being calibrated
- 1 LIDAR, which is being calibrated

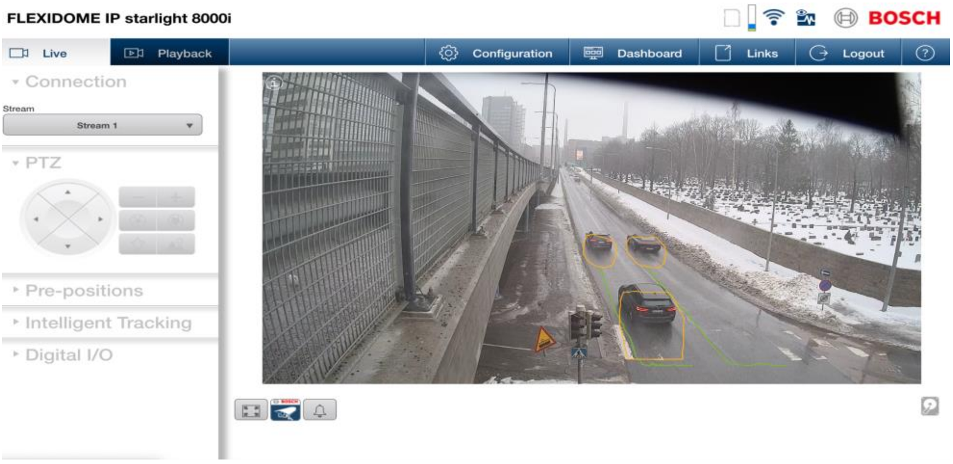


Figure 4. A view from the camera used in the use case (Conveqs, City of Helsinki, and Aalto University ©).

The sensors are then used to create a situational view of the traffic in the monitored corridor as demonstrated in Figure 5.

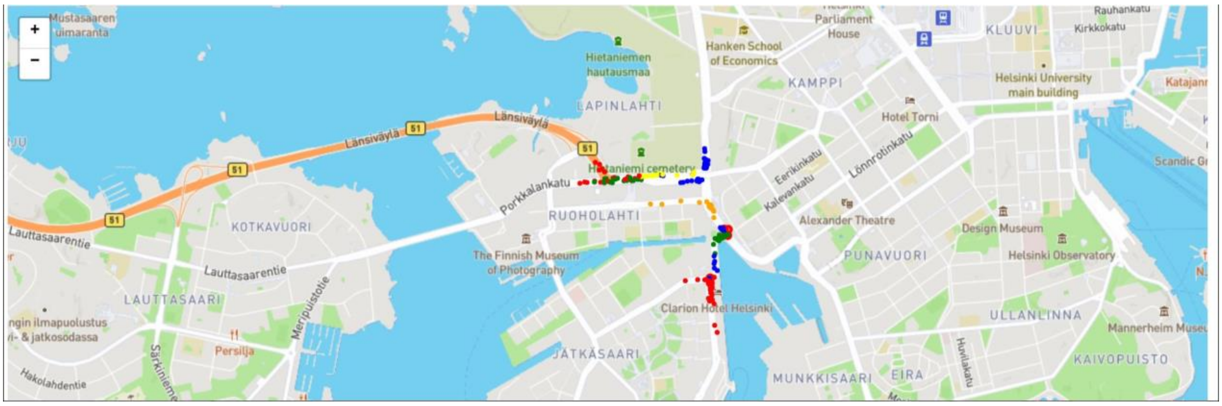


Figure 5. Data provided by radars (Conveqs, City of Helsinki, and Aalto University ©).

3.1.2. UC2 – Crowd Management

As described in UC1, the Jätkäsaari area in the city of Helsinki poses several key challenges for the city of Helsinki due to its geographical location and the high density of traffic flows in the area. UC2 demonstrates the use of open data, user data, and IoT data on crowd management. Of these, the role of IoT data for crowd management purposes is the most advanced and is now fully operational in the Jätkäsaari area. There, the Port of Helsinki company and HSL (Helsinki Regional Transport) are potential Helsinki-based business case partners.

In the IoT-driven UC2, traffic fluency will be monitored and processed via cameras and radars installed at bottleneck intersections to achieve crowd steering based on the application of AI. UC2 is also considering crowd management monitoring of the busy Helsinki-Tallinn cross-border commuter harbour during daily peak hours and any unexpected events based on predictive algorithms.

The role of open data and user data in UC2 closely follows the development progress of the *Urban Open Platform* conducted by the cross-border FinEst Twins-project[3] between the cities of Helsinki and Tallinn, operated by the FinEst Centre based in Estonia. The FinEst Centre focuses on mobility, energy, and the built environment working together by governance and urban data analytics. The centre develops cross-border knowledge transfer infrastructure and acts as a springboard for the exportation of Finnish-Estonian knowledge and combined service solutions on a global scale.

3.1.2.1. Trial site description

The UC2 trial will be conducted at the Jätkäsaari harbour in Helsinki, Finland, where traffic congestion and the ongoing construction of new residential and office buildings only worsens the situation for the pedestrians, and the increased volumes of public transport options have not yet successfully resolved the major challenges faced by passenger traffic to-and-from the port. Anonymous monitoring of the crowd movement fluency is expected to provide new insights on how and why the bottlenecks form. After pinpointing the key issues, with adequate communication methods, the crowd flows are to be steered and managed to prevent or diminish the effect of bottlenecks.

The UC2 will develop these solutions in the Jätkäsaari harbour environment for the Port of Helsinki and HSL, the city of Helsinki's local public transport company. Port of Helsinki has expressed clear objectives for UC2 activities, which include efficient crowd and traffic management outside of the harbour terminal, parking space management, and efficient access and availability of public transport beyond traditional scheduling.

For this purpose, the UC2 team will also tap into the work and insights of the GAIA-X community on mobility. An example of shared insights is the EONA-X, a French-company driven pilot creating a shared data-space environment for travel information between various transport companies and developing a single user interface for the combined information.

[3] FinEst Project: https://cordis.europa.eu/project/id/856602

3.1.2.2. Required equipment

Table 5 below shows a detailed description of the required equipment for UC2, along with its type and status (whether it is available or still be procured).

Table 5. Detailed description of the required equipment for UC2.

Equipment	Description / Specifications	Type	Status
Radar	Radar sending data about real-time vehicle positions for traffic management purposes.	sensor	Available through Jätkäsaari Smart Junction project
Camera	On-location cameras will be installed to monitor the movement of vehicles and pedestrians in the site of the living lab. The produced data will be aggregated to count the number of the different types of objects passing through the living lab location at a given time.	sensor	Available in limited quantities through Jätkäsaari Smart Junction project
Signal controller	Traffic signal status	controller	Available through Jätkäsaari Smart Junction project
Signal controller	Detector status	sensor	Available in limited quantities through Jätkäsaari Smart Junction project
Lidar	Near real-time positions of vehicles, pedestrians and bicycles within the intersection area.	sensor	Available in one junction through Jätkäsaari Smart Junction project

3.1.2.3. Data collection

The following dataset(s) have been identified as part of the use case:

- **On-location camera feed:** On-location cameras will be installed to monitor the movement of vehicles and pedestrians in the site of the living lab. The produced data will be aggregated to count the number of the different types of objects passing through the living lab location at a given time.
- **Radar imagery:** Radar imagery will be used to detect cars in a given area and count the totals of different types of vehicles passing through an area at a given time.

3.1.2.4. Alignment with IoT-NGIN technologies

Table 6 below shows the IoT-NGIN technologies relevant for UC2. For each technology, a description of its role is provided along with any adaptation it might need to be used in the UC, deployment details and related UC requirements and KPIs.

Table 6. Alignment of UC2 with the relevant IoT-NGIN technologies.

WP3 – MLaaS framework	
Description	Required to enable the use of the Privacy-preserving Federated Learning component for training the ML models and the Polyglot Model Sharing component for sharing these models for the inference of ML services.
Adaptation and fine-tuning	N/A
Deployment	Cloud
Related requirements	**REQ_SC1_F02** – Gain access to the city's traffic data
Related KPIs	**KPI_SC_1** – Different types of sensors' data (multispectral/visual camera, RFID) to be analysed > 6 **KPI_SC_4** – Improve efficiency and traffic congestion in twin smart cities by at least 20% **KPI_SC_5** – Increase Twin Smart Cities IoT infrastructure utilization by at least 30%
WP3 – Privacy-preserving Federated Learning	
Description	Federated Learning is used to jointly train the visual recognition of cars by combining training at multiple nodes without revealing the training data to other nodes.
Adaptation and fine-tuning	At least two different nodes will be used for training as participants of the federated learning system. Could be either physical or simulated depending on the availability of data or infrastructure.
Deployment	Cloud/edge
Related requirements	**REQ_SC1_F02** – Gain access to the city's traffic data **REQ_SC1_NF03** – Privacy of information and security have to be guaranteed
Related KPIs	**KPI_SC_1** – Different types of sensors' data (multispectral/visual camera, RFID) to be analysed > 6

	KPI_SC_4 – Improve efficiency and traffic congestion in twin smart cities by at least 20% **KPI_SC_5** – Increase Twin Smart Cities IoT infrastructure utilization by at least 30%
WP3 – Polyglot model sharing component	
Description	Used as part of the MLaaS framework to access the ML model.
Adaptation and fine-tuning	N/A
Deployment	Cloud
Related requirements	**REQ_SC1_F02** – Gain access to the city's traffic data
Related KPIs	**KPI_SC_1** – Different types of sensors' data (multispectral/visual camera, RFID) to be analysed > 6 **KPI_SC_4** – Improve efficiency and traffic congestion in twin smart cities by at least 20% **KPI_SC_5** – Increase Twin Smart Cities IoT infrastructure utilization by at least 30%
WP4 – IoT device discovery (Computer Vision)	
Description	The IoT Device Discovery component will be used to detect objects such as cars, traffic flow, and crowds. This data will then be used for crowd management to avoid bottlenecks and intersections with heavy car traffic.
Adaptation and fine-tuning	Generic ML models are available, but they will need to be further trained with appropriate data.
Deployment	Cloud deployment.
Related requirements	**REQ_SC2_F02** – The application has to provide maps with the crowd real-time situation **REQ_SC2_NF03** – The application has to guarantee reliability, availability and low latency
Related KPIs	**KPI_SC_4** – Improve efficiency and traffic congestion in twin smart cities by at least 20%
WP4 – IoT Device Indexing	
Description	Used to maintain a list of devices the IoT vulnerability crawler scans.

Adaptation and fine-tuning	The devices to be scanned need to be registered with this component.
Deployment	Cloud/edge.
Related requirements	**REQ_SC1_NF02** – Privacy of information and security have to be guaranteed
Related KPIs	N/A
WP4 – IoT device access control	
Description	SSIs and VCs will enable access control to IoT devices and STs based on dynamic personalised access rights. Further, the IoT Device Access Control component provides access control for the other IoT-NGIN components.
Adaptation and fine-tuning	We need to add users and credentials for the IoT-NGIN services.
Deployment	For the IoT devices the enforcement functionality will be deployed to the device itself or to a related edge node and for the STs the deployment will be to the cloud. The management activities will be deployed to the cloud.
Related requirements	**REQ_SC2_NF02** – Privacy of information and security have to be guaranteed
Related KPIs	**KPI_SC_1** – Different types of sensors' data (multispectral/visual camera, RFID) to be analysed > 6
WP5 – IoT vulnerability crawler	
Description	Used periodically or on-demand to scan the IoT devices for any known vulnerabilities.
Adaptation and fine-tuning	Devices to be scanned need to be registered with the IoT Device Indexing component. The crawler needs to be configured with the scanning schedule.
Deployment	Cloud
Related requirements	**REQ_SC1_NF02** – Privacy of information and security have to be guaranteed
Related KPIs	N/A
WP5 – Decentralised Interledger Bridge	

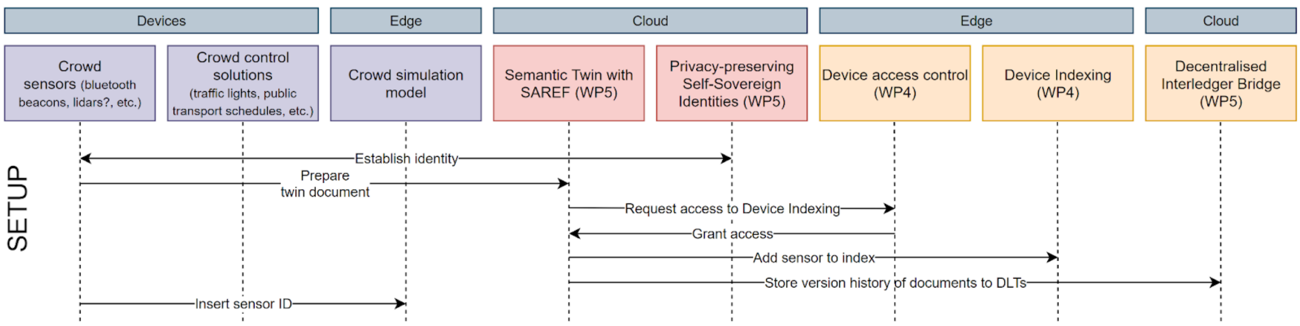
Description	Private DLTs are used for enabling immutable history for the STs, and interledger transactions are then used to anchor the data to a more trustworthy (public) ledger.
Adaptation and fine-tuning	N/A
Deployment	Cloud
Related requirements	**REQ_SC1_NF02** – Privacy of information and security have to be guaranteed
Related KPIs	N/A
WP5 – Privacy-preserving Self-Sovereign Identities	
Description	SSIs also enable dynamic lookup of STs via QR codes and GS1 Digital Links.
Adaptation and fine-tuning	N/A
Deployment	Cloud
Related requirements	**REQ_SC1_NF01** – Data integrity **REQ_SC1_NF02** – Privacy of information and security have to be guaranteed
Related KPIs	**KPI_SC_1** – Different types of sensors' data (multispectral/visual camera, RFID) to be analysed >6
WP5 – Semantic Twins	
Description	The Semantic Twin solution is used to describe traffic related objects, such as sensor devices, and their interfaces to distribute these descriptions to data users. The descriptions and their distribution will be implemented in a uniform manner to enable universal machine readability using SAREF ontologies. Semantic Twins will enable building the traffic management and parking prediction solutions more efficiently and help integrate them further into related systems.
Adaptation and fine-tuning	UC-specific Semantic Twins will be created. For example, a Semantic Twin of a traffic radar describes the location and orientation of the sensor and the data interface to access the sensor data.
Deployment	Semantic Twins will be deployed in the cloud for this UC.
Related requirements	**REQ_SC1_F02** – Gain access to the city's traffic data

	REQ_SC1_F03 – Availability of function on aspects such as weather, events, environmental information **REQ_SC1_F04** – Consideration over streets and parking topology **REQ_SC1_NF01** – Data integrity **REQ_SC1_NF03** – Privacy of information and security have to be guaranteed
Related KPIs	**KPI_SC_1** – Different types of sensors' data (multispectral/visual camera, RFID) to be analysed > 6 **KPI_SC_4** – Improve efficiency and traffic congestion in twin smart cities by at least 20% **KPI_SC_5** – Increase Twin Smart Cities IoT infrastructure utilization by at least 30%

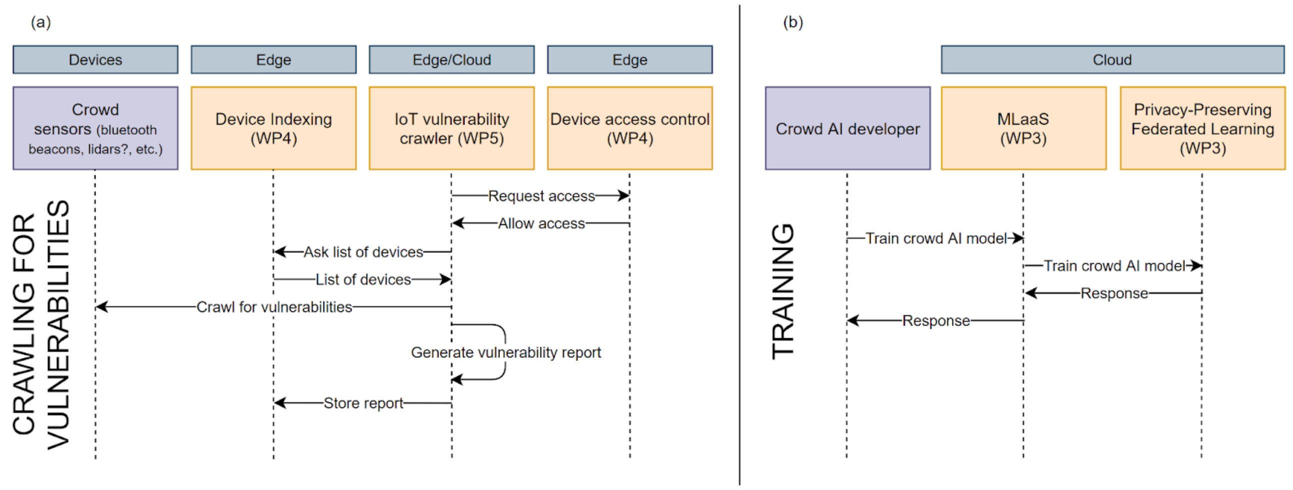
3.1.2.5. Use case sequence diagrams

The main steps in the sequence diagram of this use case can be summarized as follows:

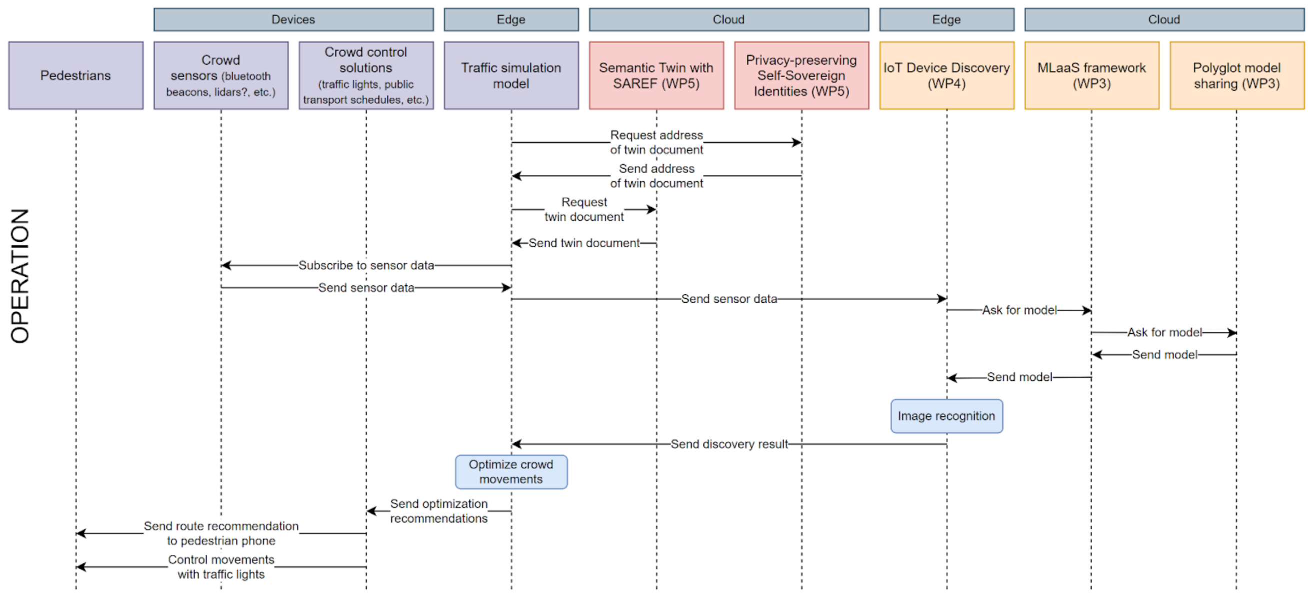
- Cameras and possibly other sensors are gathering data about crowd movements.
- ML detects crowds to help predict where and when traffic bottlenecks are likely to occur.
- In case of the potential bottlenecks being identified, crowd control solutions are used to notify and guide the crowds towards alternative routes.
- Vulnerability crawler performs regular checks of the security of the sensors.



(a) Setup phase



(b) Crawling and Training phases



(c) Operational phase

Figure 6. Sequence diagram of UC2.

3.1.2.6. Testing and validation procedures

Technical validation of the UC

- The key objective of UC2 is to address the crowd management issues in Jätkäsaari and the harbour terminal. This objective is related to the KPI_SC_4, which considers traffic congestion reduction, and the aim is to evaluate the reduction of crowds as part of evaluating this KPI.
- This use case also helps validate the visual recognition functionality of the IoT Device Discovery component.

- The Smart City living lab is used to aid the development of the ST and SSI solutions to ensure they include the necessary properties to aid efficient development, deployment, and interfacing with other systems. This goal is then validated with the other living labs utilizing these technologies.

Validation stages

- The components will be first validated individually in a lab environment during the development process
- Then the whole solution will be validated in field conditions.

User experience testing/validation

- UC2 user experience will be validated with selected questionnaires for the pedestrians and the port authority. Targeted interviews will be conducted to confirm the perceived effect on the business case.

3.1.2.7. Execution timeline

The execution timeline of UC2, divided into multiple phases, is detailed in Table 7 below.

Table 7. Execution timeline of UC2.

Phase	Estimated start date	Estimated end date	Notes
Trial set-up and equipment procurement	Ongoing	June 2022 (M21)	First batch of sensors (cameras and radars) installed and initial calibrations completed.
Initial implementation and validation	M22	M26	Second batch of sensors (e.g., lidars) installed and calibrated. Additional calibrations for first batch if necessary.
Intermediate implementation and validation	M27	M31	Sensors connected to simulation model.
Final implementation and validation	M32	M36	Potential business cases to be developed for sustainability.

3.1.2.8. Initial results

The traffic cameras provided by Conveqs for UC1 can also be used for measuring crowd movements when coupled with appropriate machine vision service. A potential Computer Vision solution has been developed at Aalto University as shown in Figure below.

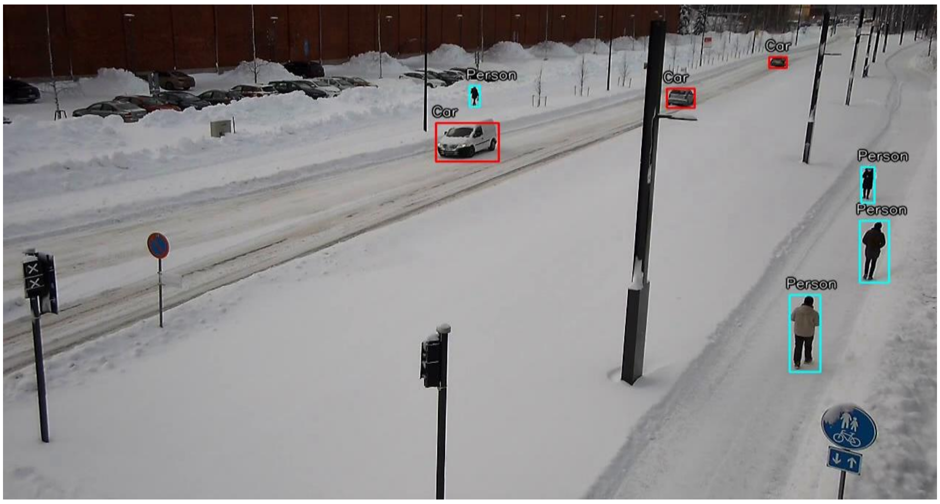


Figure 7. Result of machine vision solution detecting cars and people from camera image. Image by Risto Ojala, Aalto University.

Another source for crowd management data are the Bluetooth beacons in pedestrians' mobile devices. Hypercell and City of Helsinki provide crowd activity data based on Bluetooth beacon measurements as shown in Figure below. Some of the data streams are publicly available and access to more specific data streams can be acquired from the providers.

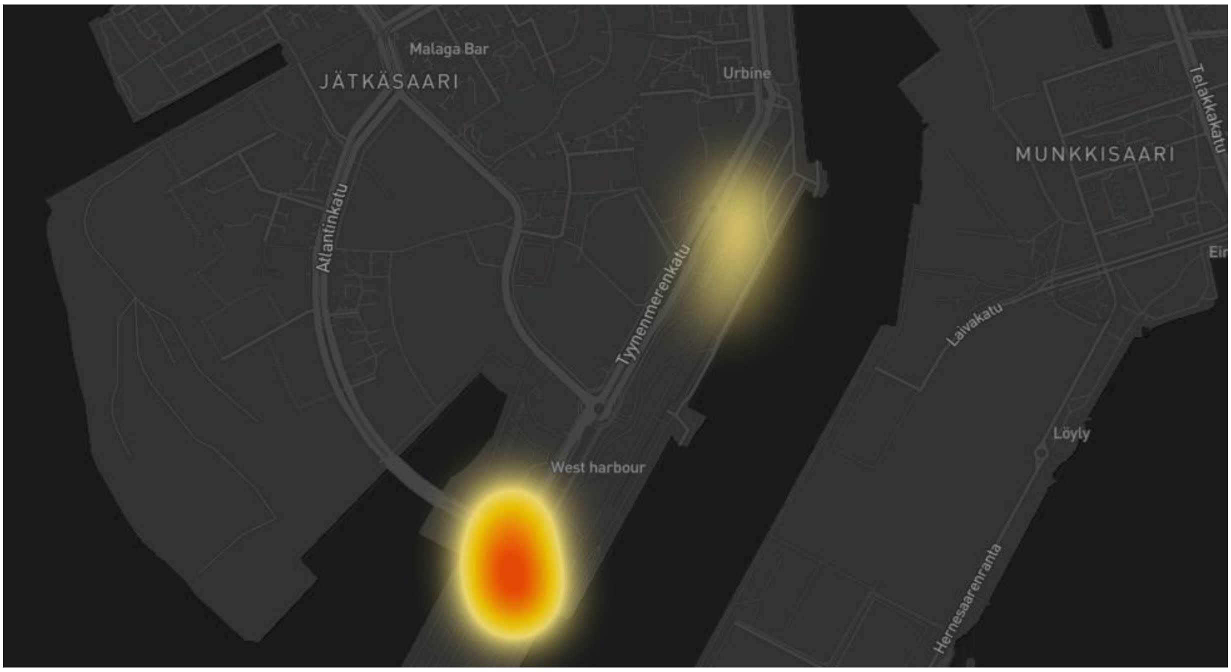


Figure 8. Heatmap based on Bluetooth data from Jätkäsaari harbour area, which highlights the need for efficient crowd management in the harbour terminal (the red hotspot). Screenshot from website made by Hypercell (https://www.heatmap.fi/helsinki/).

3.1.3. UC3 – Co-commuting solutions based on social networks

The UC3 activity on co-commuting solutions is linked to the local crowd management activity of UC2, where local business partners are also seeking solutions for a combined, co-commuting offer to enhance efficient passenger traffic flows, and to UC1 to further help reduce traffic congestion in the Jätkäsaari area.

UC3 can in close co-operation with the developing Urban Open Platform (UOP) of FinEst Twins Project (H2020 856602[4]) seek ways for trusted and intelligent traffic information management and sharing, which can facilitate safe co-commuting solutions. The traffic information is shared via the information systems on-board the passenger ferries and at the passenger terminals in Helsinki and Tallinn, and the co-commuters can then use their mobile apps to request or offer rides.

3.1.3.1. Trial site description

The UC3 will build on top of UC1 and UC2 and will mainly focus on the Jätkäsaari district as the COVID-19 pandemic has made cross-border commuting quite challenging. UC3 will further enrich the awareness of transportation needs by utilizing social media, especially Twitter. Stream processing functionalities will be provided that can contain advanced analytics such as Natural Language Processing (NLP). The advanced analytics together with the information from UC2 will be enabling the future development of co-commuting services that benefit from predictive demand recognition.

The scope of the UC3 is to demonstrate the data flow and provide the proof of concept of such service as feasible. The scope of the project does not include a ride-sharing service so the UC3 will focus on the information flows used to demonstrate the potential benefit of the IoT-NGIN concept on advanced stream processing in the mobility domain.

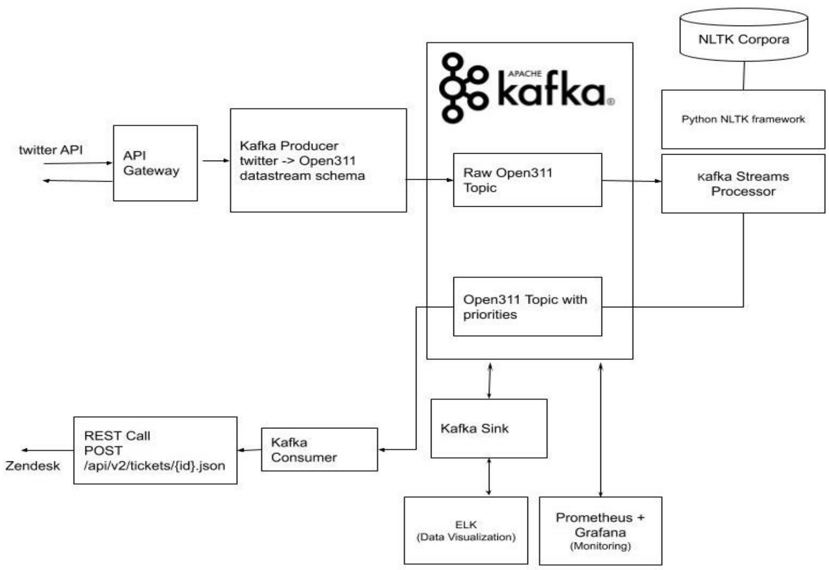


Figure 9. Main technical components involved in UC3.

[4] FinEst Project: https://cordis.europa.eu/project/id/856602

Considering the scope of this use case and the changing realities of cross-border travel due to the COVID-19 pandemic, work on this use case has been significantly impacted and has not progressed at the same pace as the other 2 Smart City use cases. Therefore, the information provided in this deliverable, such as required equipment and alignment with IoT-NGIN technologies, will be likely updated with more details in future deliverables as cross-country travel returns to normal and the definition of the UC continues.

3.1.3.2. Required equipment

Table 8 below shows a detailed description of the required equipment for UC3, along with its type and status (whether it is available or still be procured).

Table 8. Detailed description of the required equipment for UC3.

Equipment	Description / Specifications	Type	Status
Commuters' mobile device	The mobile devices of commuters in the use case trial site area, from which data will be collected.	Mobile device	To be procured
Information displays	The information displays at the Harbour Terminals and on ferries from which data will be collected.	Displays	To be procured

3.1.3.3. Data collection

The following dataset(s) have been identified as part of the use case:

- **Social network feeds:** The social network feeds of the volunteers in the living lab will be collected to retrieve routes, commute times and features of the provided commuting solution.

3.1.3.4. Alignment with IoT-NGIN technologies

Table 9 below shows the IoT-NGIN technologies relevant for UC3. For each technology, a description of its role is provided along with any adaptation it might need to be used in the UC, deployment details and related UC requirements and KPIs.

Table 9. Alignment of UC3 with the relevant IoT-NGIN technologies.

WP3 – MLaaS Framework	
Description	Required to enable the use of the Privacy-preserving Federated Learning component for training the ML models and the Polyglot Model Sharing component for sharing these models for the inference of ML services.

Adaptation and fine-tuning	N/A
Deployment	Cloud
Related requirements	**REQ_SC1_F02** – Gain access to the city's traffic data **REQ_SC1_NF03** – Privacy of information and security have to be guaranteed
Related KPIs	**KPI_SC_1** – Different types of sensors' data (multispectral/visual camera, RFID) to be analysed > 6 **KPI_SC_4** – Improve efficiency and traffic congestion in twin smart cities by at least 20% **KPI_SC_5** – Increase Twin Smart Cities IoT infrastructure utilization by at least 30%
WP3 – Privacy-preserving Federated Learning	
Description	Federated ML learning is used to mine social networks for data to help better match and organise the co-commuters with available shared rides.
Adaptation and fine-tuning	At least two different nodes will be used for training as participants of the federated learning system. Could be either physical or simulated depending on the availability of data or infrastructure.
Deployment	Cloud/edge
Related requirements	**REQ_SC1_F02** – Gain access to the city's traffic data **REQ_SC1_NF03** – Privacy of information and security have to be guaranteed
Related KPIs	**KPI_SC_1** – Different types of sensors' data (multispectral/visual camera, RFID) to be analysed > 6 **KPI_SC_4** – Improve efficiency and traffic congestion in twin smart cities by at least 20% **KPI_SC_5** – Increase Twin Smart Cities IoT infrastructure utilization by at least 30%
WP3 – Polyglot Model Sharing component	
Description	Used as part of the MLaaS framework to access the ML model.

Adaptation and fine-tuning	N/A
Deployment	Cloud
Related requirements	**REQ_SC1_F02** – Gain access to the city's traffic data
Related KPIs	**KPI_SC_1** – Different types of sensors' data (multispectral/visual camera, RFID) to be analysed > 6 **KPI_SC_4** – Improve efficiency and traffic congestion in twin smart cities by at least 20% **KPI_SC_5** – Increase Twin Smart Cities IoT infrastructure utilization by at least 30%
WP5 – Privacy-preserving Self-Sovereign Identities	
Description	SSIs will be used to improve the privacy of co-commuters. The commuting service will know the co-commuters' real identities, while co-commuters will only be aware of each other's pseudonymous SSI-based identities.
Adaptation and fine-tuning	N/A
Deployment	Issuance of SSI-based credentials will be deployed in the cloud. Commuters' mobile devices will be able to generate new SSI-based identities and verify SSI-based credentials issued by the service.
Related requirements	**REQ_SC3_F03** – Data will be gathered after consent of the volunteers is granted, which will then be anonymized
Related KPIs	**KPI_SC_2** – User generated data sources to be integrated and analysed > 6 **KPI_SC_3** – Cross-border data models proposed > 4
WP5 – Semantic Twins	
Description	Short-lived Semantic Twins are explored as a means of describing the co-commuting vehicles while maintaining the privacy of the drivers/vehicle owners.
Adaptation and fine-tuning	Short-lived STs will be distributed directly to the related parties instead of making them publicly available on the internet.

Deployment	TBD
Related requirements	**REQ_SC3_F03** – Data will be gathered after consent of the volunteers is granted, which will then be anonymized
Related KPIs	**KPI_SC_2** – User generated data sources to be integrated and analysed > 6 **KPI_SC_3** – Cross-border data models proposed > 4

3.1.3.5. Use case sequence diagrams

Figure 10 below shows a sequence diagram of UC3, depicting the involved actors and their interactions with the relevant IoT-NGIN technologies.

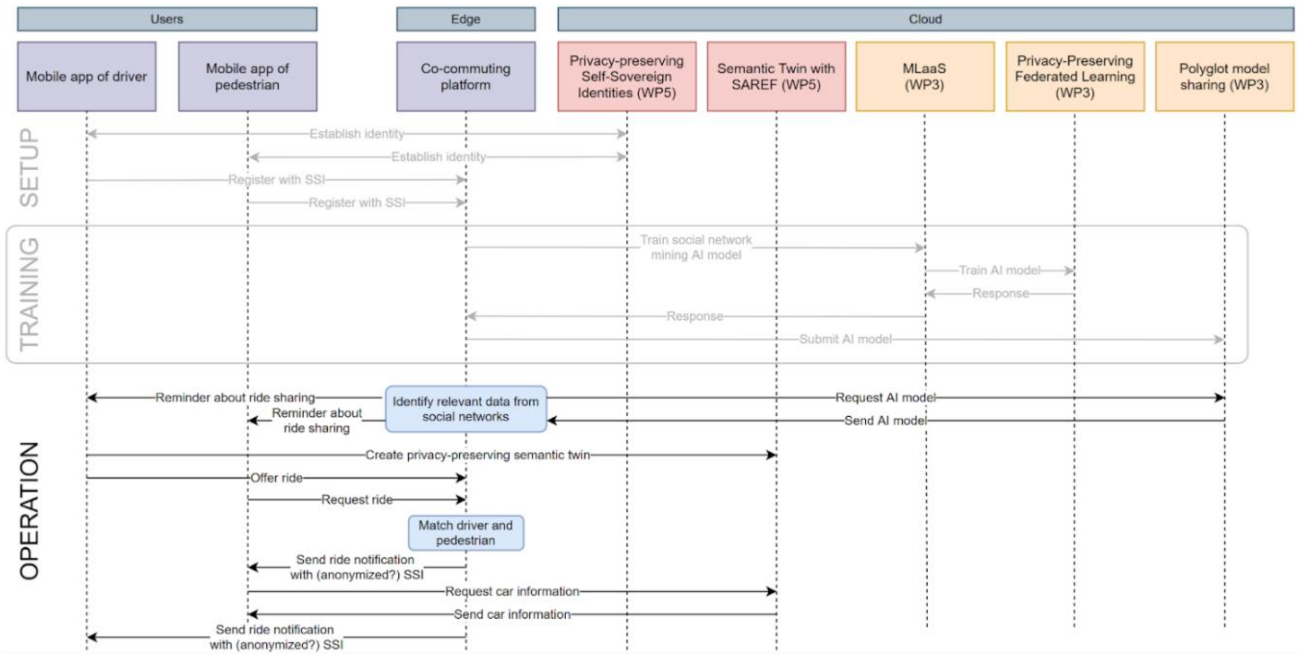


Figure 10. Sequence diagram of UC3.

3.1.3.6. Testing and validation procedures

Technical validation of the UC

- The Smart City living lab is used to aid the development of the SSI solutions to ensure they include the necessary properties to aid efficient development, deployment, and interfacing with other systems. This goal is then validated with the other living labs utilising these technologies.

Validation stages

- The components will first be validated individually in a lab environment during the development process
- Then the whole solution will be validated in field conditions

User experience testing / validation

- UC3 user experience will be validated with selected questionnaires for the commuters. Targeted interviews will be conducted to confirm the perceived effect on the business case

3.1.3.7. Execution timeline

The execution timeline of UC3, divided into multiple phases, is detailed in Table 10 below.

Table 10. Execution timeline of UC3.

Phase	Estimated start date	Estimated end date	Notes
Trial set-up and equipment procurement	M20	September 2022 (M24)	Dependence on preliminary results of UC1 and UC2
Initial implementation and validation	M25	M30	
Final implementation and validation	M31	M36	Potential business cases to be developed for sustainability.

3.1.3.8. Initial results

Given that UC3 will build on top of UC1 and UC2 and requires some results from these use cases, work has not yet started on this use case and there are currently no initial results available. Results on this use case will be included in future deliverable of WP7.

3.2. Smart Agriculture IoT Living Lab

3.2.1. UC4 – Crop diseases prediction, smart irrigation and precision aerial spraying

Efficient and effective crop management are key to sustaining economic and food security, challenged by climate change and plant pests. The scarce availability of physical resources, like water, along with the according production costs, urge for efficient use of water in the irrigation process, without compromising yield quantity and quality. In addition, the prediction of crop diseases is imperative in the fight against plant pests, which risk is increased by the climate change, according to the Food and Agriculture Organization of the United Nations (FAO) [3]. Last, but not least, excessive use of pesticides and herbicides affects both the soil quality and surrounding ecosystem and must, thus, be minimized.

This UC aims to address these challenges via crop disease prediction, smart irrigation and precision aerial spraying. Smart monitoring of the farm, based on telemetry data, collected via a number of sensors perceiving the air, soil and plant conditions will feed advanced analytics which account for identification of states in which irrigation is actually needed and will accordingly trigger actuation of smart irrigation processes. Moreover, crop disease prediction will rely on both IoT and Artificial Intelligence (AI) technologies. Crop images will be collected via Unmanned Aerial Vehicles (UAVs), which are drones with extended functionality, flying over the fields. Portions of these data will be temporarily kept on the UAV for inference based on pre-trained models and will be later sent to an adjacent edge node for persistence purposes, while ensuring data sovereignty for the Smart Farmer.

The collected data will feed a Machine Learning (ML) service for crop disease prediction. This service will rely on ML models trained at the edge node via unsupervised ML or Deep Learning (DL) as part of a Federated Learning (FL) system, in which the edge nodes act as FL participants, while the cloud node acting as an aggregator node. Moreover, the inference services will be provided at the UAV, which will run the ML service for disease prediction based on already trained models. Depending on the inference results, actuation controls may be decided at the UAV, for spraying at areas identified as infected rather than the whole orchard. Moreover, orchard micro-climate data can be made available to third parties under IoT-NGIN data sovereignty guarantees.

3.2.1.1. Trial site description

The trial will be conducted in a commercial vineyard at Peloponnese, Greece, in which a number of SynField[5] nodes has been already installed.

For the IoT-NGIN LL use cases, the topology of Figure 11 will be implemented, which has been introduced in *D1.1 - Definition analysis of use cases and GDPR Compliance* [1]. The figure depicts the communication among the main devices participating in UC4:

- Sensors, which are used to monitor the soil, leaf and weather conditions
- Solenoid valves, which are used for actuating irrigation control
- SynField devices, which may integrate a number of sensors or solenoid valves, as well as communicate with other nodes via external connectivity (e.g., WIFI or cellular)
- UAVs, which are equipped with multi-spectral cameras and will capture images of the crops, allowing detection of crop diseases.
- Edge server, which will collect the data acquired from both sources, namely SynField devices and UAVs, while it will support the Digital Twin services of UC4.
- Cloud server, which will conduct computationally intensive tasks of IoT-NGIN, which are not possible or efficient to be executed at the edge devices

[5] SynField nodes are the hardware (IoT) devices of Synelixis' SynField Smart Agriculture platform: https://www.synfield.gr

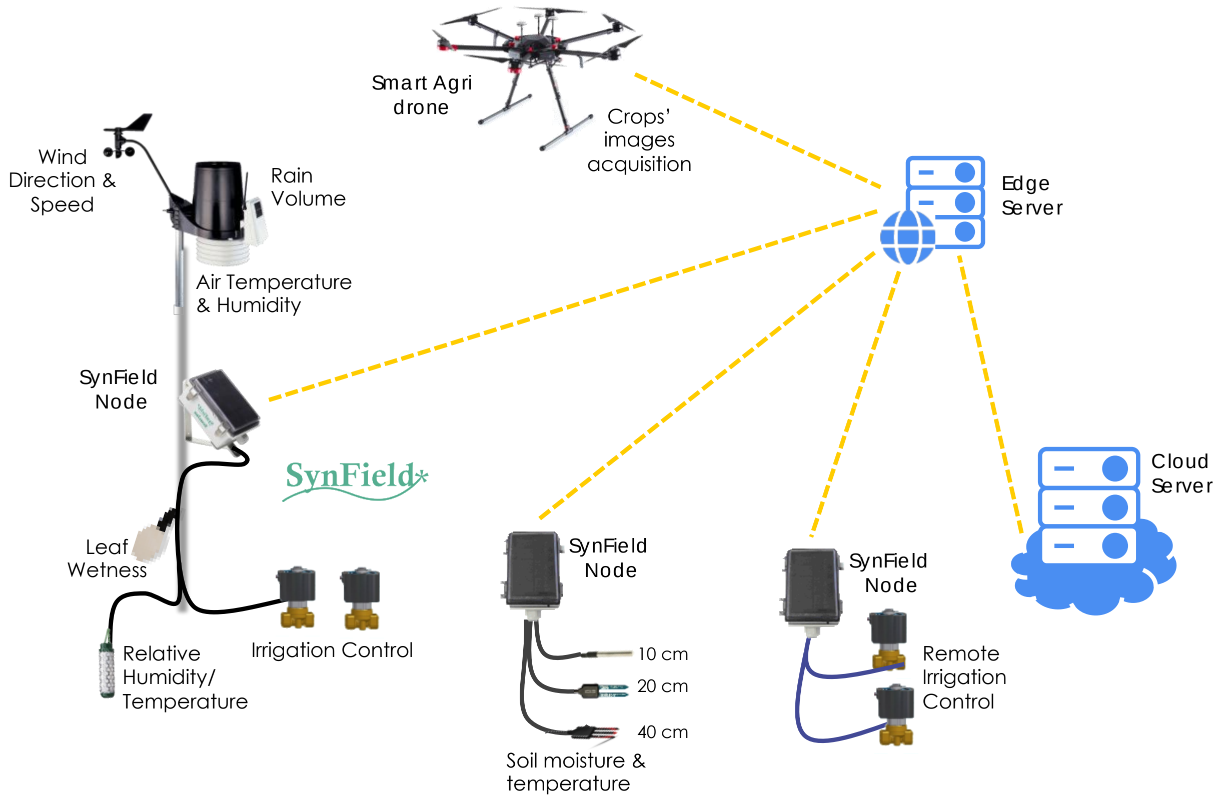


Figure 11. A graphic description of the trial site of UC4.

As shown in the figure, the sensors and the solenoid valves are directly attached to SynField nodes via cable connection. The SynField nodes support WIFI and cellular connectivity, through which they communicate with the edge server. This channel may be used for data communication, as well as control messages exchange, e.g., for triggering irrigation. Moreover, the UAV is equipped as well with similar wireless interface, through which it communicates its data to the edge server, and receives control messages, such as updating its ML models for crop disease detection. Last, but not least, the edge server communicates with the cloud server in order to receive the output of IoT-NGIN components running in the cloud, such as newly trained ML models.

3.2.1.2. Required equipment

Table 11 below shows a detailed description of the required equipment for UC4, along with its type and status (whether it is available or still be procured).

Table 11. Detailed description of the required equipment for UC4.

Equipment	Description / Specifications	Type	Status
SynField Node	SynField Head Node (SF-HN-06) which is able to collect sensor measurements and transmit	IoT node integrating	Available

	them to the edge or the cloud, as well as send commands to the actuators (e.g., for irrigation control)	sensors and actuators	
Smart Agri Drone	DJI Matrice 600 PRO, ideal for professional aerial photography with an extended flight time and a 5km long-range transmission, intelligent batteries, and maximum payload of 6kg.	drone	Procured
Multispectral camera	Parrot Sequoia, multi-band sensor designed for agriculture, featuring excellent precision, flexible integration, and small size and weight, compatible with the Smart Agri Drone.	Camera	Procured
Processing unit	NVIDIA Jetson Nano 4GB, a small, powerful computer which is able to run multiple neural networks in parallel for applications like image classification, which is desired for the crop disease prediction application.	Processing board	Procured
Edge node	Edge node for running Digital Twin functionality and local ML model training. The edge node will host the client-side services of the IoT-NGIN framework.	Edge server	Available
Cloud node	Cloud resources used for permanent storage and ML model aggregation/training activities. Also, here the server-side services of IoT-NGIN will be deployed.	Cloud	Available within the Consortium

3.2.1.3. Data collection

The following dataset(s) have been identified as part of the use case:

- **Field sensor measurements:** data collected from SynField IoT platform and integrated sensors, including micro-climate data (air temperature, air humidity, wind direction, wind speed, rain volume, rain intensity) and soil and crop data (leaf wetness, soil type, soil temperature, soil humidity, soil conductivity). This dataset will be used to calculate the crop growing degree days (ripening indicator).
- **Drone camera images:** images collected from multi-spectral cameras on drones. The images will be associated with time information and geospatial/location information provided by GPS.

3.2.1.4. Alignment with IoT-NGIN technologies

Within the scope of UC4, the majority of IoT-NGIN components will be validated in the Smart Agriculture LL. Table 12 below summarizes the context in which each component will be used in UC4, any adaptations needed and the planned deployment. Moreover, each component is associated with a set of requirements and KPIs, as defined in D1.1 [1].

Table 12. Alignment of UC4 with the relevant IoT-NGIN technologies.

WP2 – Secure edge-cloud execution framework	
Description	This framework will be used in order to enable secure deployment and operation of IoT-NGIN services. Indicatively, it will host the prediction models deployed on the agricultural drone or the malicious attack detection module.
Adaptation and fine-tuning	The Secure Execution framework will be integrated with the MLaaS platform, enabling secure deployment of ML models. As such, no adaptation is needed.
Deployment	Multi-layer, including edge and cloud resources.
Related requirements	**REQ_SA1_NF01** – The IoT-NGIN platform must respect security and privacy requirements
Related KPIs	**KPI_SA1_01** – Reduction in the water needed for irrigation compared to manual irrigation = 20% **KPI_SA1_02** – Reduction in pesticides used for spraying compared to manual irrigation = 20% **KPI_SA1_03** – Increase in quantity of fruits harvested compared to manual irrigation and spraying >/=15%
WP3 – MLaaS framework	
Description	The MLaaS framework will be used to provide ML/AI services to the use case, related to ML model training and model serving, in order to support the crop disease prediction application.
Adaptation and fine-tuning	No adaptation of the MLaaS framework is needed for the purposes of UC4. The crop disease prediction application will consume the MLaaS services interacting with its API.
Deployment	A project-wide deployment can be used. The use case does not require a dedicated instance of the MLaaS framework.
Related requirements	**REQ_SA1_F05** – The platform should provide predictions of crop diseases, based on ML/FL performed over sensor measurements and drone images/videos

	REQ_SA1_F06 – The platform should provide prediction accuracy probability **REQ_SA1_F09** – The platform should provide support for microclimate measurements sharing, respecting data sovereignty and privacy requirements **REQ_SA1_NF02** – IoT-NGIN should support High Availability features
Related KPIs	**KPI_SA1_01** – Reduction in the water needed for irrigation compared to manual irrigation = 20% **KPI_SA1_02** – Reduction in pesticides used for spraying compared to manual irrigation = 20% **KPI_SA1_03** – Increase in quantity of fruits harvested compared to manual irrigation and spraying >/=15%
WP3 – Deep Learning, Reinforcement Learning & Transfer Learning	
Description	Deep Learning techniques will be used to train locally the crop disease prediction ML models at the edge nodes.
Adaptation and fine-tuning	No adaptation need identified at this point.
Deployment	N/A
Related requirements	**REQ_SA1_F05** – The platform should provide predictions of crop diseases, based on ML/FL performed over sensor measurements and drone images/videos **REQ_SA1_F06** – The platform should provide prediction accuracy probability **REQ_SA1_F07** – The platform should provide automated irrigation and aerial spraying based on crop disease prediction
Related KPIs	**KPI_SA1_01** – Reduction in the water needed for irrigation compared to manual irrigation = 20% **KPI_SA1_02** – Reduction in pesticides used for spraying compared to manual irrigation = 20% **KPI_SA1_03** – Increase in quantity of fruits harvested compared to manual irrigation and spraying >/=15%
WP3 – Privacy-preserving Federated Machine Learning	
Description	This framework will be used in order to allow training the ML models at multiple edge nodes in a federated-distributed manner. The locally trained models will be aggregated at the cloud server. The training refers to crop disease prediction models.

Adaptation and fine-tuning	The FL framework will be configured to work with a number of "participants" (clients) equal to the number of edge nodes and UAVs used in UC4. The edge nodes will participate as Private Aggregation of Teacher Ensembles (PATE) teachers, while the UAV will participate as a Flower Client.
Deployment	Multi-layer, including edge and cloud resources, as described above.
Related requirements	**REQ_SA1_NF01** – The IoT-NGIN platform must respect security and privacy requirements
Related KPIs	**KPI_SA1_01** – Reduction in the water needed for irrigation compared to manual irrigation = 20% **KPI_SA1_02** – Reduction in pesticides used for spraying compared to manual irrigation = 20% **KPI_SA1_03** – Increase in quantity of fruits harvested compared to manual irrigation and spraying >/=15%
WP3 – Polyglot Model Sharing component	
Description	This component will allow serving the ML models to the UAV.
Adaptation and fine-tuning	No adaptation need identified at this point.
Deployment	As part of the MLaaS platform
Related requirements	**REQ_SA1_F05** – The platform should provide predictions of crop diseases, based on ML/FL performed over sensor measurements and drone images/videos **REQ_SA1_F06** – The platform should provide prediction accuracy probability **REQ_SA1_F07** – The platform should provide automated irrigation and aerial spraying based on crop disease prediction
Related KPIs	**KPI_SA1_01** – Reduction in the water needed for irrigation compared to manual irrigation = 20% **KPI_SA1_02** – Reduction in pesticides used for spraying compared to manual irrigation = 20% **KPI_SA1_03** – Increase in quantity of fruits harvested compared to manual irrigation and spraying >/=15%
WP4 – IoT device discovery (Computer Vision, Code Scanner)	
Description	The Code Scanner and Computer Vision (CV)-based recognition parts of the component will allow identification of SynField nodes as images, as well as QR-

	based identification, respectively, through a user's mobile device. This two-step identification will support the access management to the SynField monitoring data and actuation.
Adaptation and fine-tuning	CV models will be trained over SynField node images.
Deployment	Cloud
Related requirements	**REQ_SA1_F01** – The platform should provide access to measurements **REQ_SA1_F02** – The platform should provide options to manage/view sensors/devices **REQ_SA1_F16** – The platform should allow the user to execute manually the recommended irrigation or spraying plans
Related KPIs	**KPI_SA1_01** – Reduction in the water needed for irrigation compared to manual irrigation = 20%
WP4 – IoT device indexing	
Description	This module will allow accessing data collected by SynField devices and UAVs, as well as any information accompanying these devices.
Adaptation and fine-tuning	No adaptation need identified at this point.
Deployment	Edge
Related requirements	**REQ_SA1_F01** – The platform should provide access to measurements **REQ_SA1_F02** – The platform should provide options to manage/view sensors/devices **REQ_SA1_F08** – The platform should provide access to irrigation and aerial spraying data **REQ_SA1_F10** – The platform must monitor the weather and plant conditions **REQ_SA1_F11** – The platform must be able to retrieve plant photos via drones **REQ_SA1_NF04** – The UC4 Application of IoT-NGIN should be vendor-independent **REQ_SA1_NF05** – The UC4 Application of IoT-NGIN should be scalable in terms of adding/removing devices or device types and integrating hundreds of devices
Related KPIs	**KPI_SA1_04** – Number of sensors tested for connectivity with IoT-NGIN Smart Agriculture app > 9

WP4 – IoT device access control	
Description	This module will provide access management to the SynField nodes, before allowing access to monitoring data or actuation control actions.
Adaptation and fine-tuning	No adaptation need identified at this point.
Deployment	Cloud
Related requirements	**REQ_SA1_F08** – The platform should provide access to irrigation and aerial spraying data **REQ_SA1_F14** – The platform should allow the eligible user to provide irrigation and spraying suggestions **REQ_SA1_F15** – The platform should allow the user to view the irrigation and spraying suggestions **REQ_SA1_NF01** – The IoT-NGIN platform must respect security and privacy requirements
Related KPIs	**KPI_SA1_01** – Reduction in the water needed for irrigation compared to manual irrigation = 20% **KPI_SA1_02** – Reduction in pesticides used for spraying compared to manual irrigation = 20% **KPI_SA1_03** – Increase in quantity of fruits harvested compared to manual irrigation and spraying >/=15%
WP4 – IoT AR toolkit	
Description	The user will be able to access monitoring data of SynField nodes via scanning them and using Augmented Reality (AR) illustration of buttons on the SynField device appearing on the user's device.
Adaptation and fine-tuning	No adaptation need identified at this point.
Deployment	Cloud
Related requirements	**REQ_SA1_F07** – The platform should provide automated irrigation and aerial spraying based on crop disease prediction **REQ_SA1_NF03** – The UC4 Application of IoT-NGIN should support UX features
Related KPIs	**KPI_SA1_01** – Reduction in the water needed for irrigation compared to manual irrigation = 20%

WP5 – GAN-based dataset generation	
Description	UC4 will use synthetic datasets for training the attack detection models, which will identify network level attacks at the SynField infrastructure.
Adaptation and fine-tuning	The Generative Adversarial Network (GAN) based generator model will be trained using network logs of the SynField infrastructure/network.
Deployment	Cloud
Related requirements	**REQ_SA1_NF01** – The IoT-NGIN platform must respect security and privacy requirements
Related KPIs	**KPI_SA1_01** – Reduction in the water needed for irrigation compared to manual irrigation = 20% **KPI_SA1_02** – Reduction in pesticides used for spraying compared to manual irrigation = 20% **KPI_SA1_03** – Increase in quantity of fruits harvested compared to manual irrigation and spraying >/=15%
WP5 – Malicious Attack Detector (MAD)	
Description	This component will identify network-level attacks on the SynField system.
Adaptation and fine-tuning	The ML model should have been trained over network datasets, similar to the network of SynField.
Deployment	IoT/Edge/Cloud
Related requirements	**REQ_SA1_NF01** – The IoT-NGIN platform must respect security and privacy requirements
Related KPIs	**KPI_SA1_01** – Reduction in the water needed for irrigation compared to manual irrigation = 20% **KPI_SA1_02** – Reduction in pesticides used for spraying compared to manual irrigation = 20% **KPI_SA1_03** – Increase in quantity of fruits harvested compared to manual irrigation and spraying >/=15%
WP5 – IoT vulnerability crawler	
Description	This component will identify potential vulnerabilities in SynField nodes, the UAV and the edge nodes.

Adaptation and fine-tuning	No adaptation need identified at this point.
Deployment	Edge/Cloud
Related requirements	**REQ_SA1_NF01** – The IoT-NGIN platform must respect security and privacy requirements
Related KPIs	**KPI_SA1_01** – Reduction in the water needed for irrigation compared to manual irrigation = 20% **KPI_SA1_02** – Reduction in pesticides used for spraying compared to manual irrigation = 20% **KPI_SA1_03** – Increase in quantity of fruits harvested compared to manual irrigation and spraying >/=15%
WP5 – Moving Target Defences (MTDs) network of honeypots	
Description	This module will be used to dynamically set up networks of honeypots in a restricted area, in a subdomain of SynField.
Adaptation and fine-tuning	No adaptation need identified at this point.
Deployment	Edge/Cloud
Related requirements	**REQ_SA1_NF01** – The IoT-NGIN platform must respect security and privacy requirements
Related KPIs	**KPI_SA1_01** – Reduction in the water needed for irrigation compared to manual irrigation = 20% **KPI_SA1_02** – Reduction in pesticides used for spraying compared to manual irrigation = 20% **KPI_SA1_03** – Increase in quantity of fruits harvested compared to manual irrigation and spraying >/=15%

3.2.1.5. Use case sequence diagrams

In the following, a set of sequence diagrams is provided, highlighting the use of equipment and IoT-NGIN technology in the UC. The identified sequence diagram elements are categorized into three domains, namely Cloud, Edge (Near Edge) and Device (Far Edge). The high-level interactions among the IoT-NGIN components and the UC users are also detailed.

In Figure 12, a sequence diagram related to the smart irrigation and Augmented Reality (AR)-based actuation aspect of the UC is provided, the basic interacting elements being as shown in Table 13.

Table 13. Summary of the elements participating in the sequence diagram for the smart irrigation and AR-based actuation case.

Element	Domain	WP	Comments
SynField Platform	Cloud	WP7	The core SynField service of Synelixis, essentially gathering the data from the SynField nodes and controlling their state.
Smart Agri Mobile App	Device	WP7	An AR-enabled mobile application allowing for device identification and interaction with the IoT-NGIN platform.
MLaaS	Cloud/Edge	WP3	The MLaaS framework of IoT-NGIN offering predictions related to the irrigation needs of the field.
IoT Device Discovery	Edge	WP4	Offers device type identification to the Mobile app.
IoT Device Indexing	Edge	WP4	Offers digital twin services to the Synfield nodes.
IoT Device Access Control	Edge	WP4	Offers Access Control services on the digital twins of the Synfield nodes also considering an ambient intelligence perspective (e.g., authentication credentials, permissions and physical proximity to the actual device).
AR Module	Device	WP4	Assists the Smart Agri mobile app, effectively offering AR capabilities.
Farmer	Actor	N/A	The farmer using the Smart Agri Mobile App

As a first step toward enabling the UC, the SynField nodes (not depicted) send data (weather conditions, soil moisture, soil salinity) to the SynField platform which, in turn, forwards this information to the digital twins of the nodes, hosted under the IoT Device Indexing component. At the same time, the MLaaS, being registered as a subscriber to the information updates of the SynField nodes' digital twins, gets this information and produces a flow of irrigation predictions, which are, next, sent to the SynField nodes' digital twins (IoT Device Indexing module). Next, assuming that the farmer is in the visual range of the Synfield nodes and they would like to understand whether to activate an actuator of a given SynField node, they would need to get an access token with enough permissions to allow usage of the IoT-NGIN components. This would be accomplished by interfacing with the IoT Device Access Control module.

As a next step, the farmer would need to securely and uniquely identify the digital twin of the SynField node at hand. To this end, they would first scan the QR code sticker on the SynField node to get the device id from the IoT Device Discovery module (QRCode-based object recognition). Then, they would send a set of images to the IoT Device Discovery module (Computer-Vision-based object recognition) which would, next, forward them to the appropriate deep-learning inference service hosted under the MLaaS framework. The latter would return the correct object type identified. Having, at hand, the device type and the device ID, the farmer, via the Smart Agri Mobile App, is able to issue an access grant to control the particular SynField node digital twin from the IoT Device Access Control module, offering its credentials, the device ID and type, the action they would require to apply as well as their position (for enabling ambient intelligence access control).

Granted access, the Smart Agri Mobile App is now able to query the digital twin hosted under the IoT Device Indexing module context for information about the current readings of the SynField sensors as well as about the irrigation plan predictions. The presentation of this information under an AR framework is facilitated by the AR module. If they would, indeed, like to activate a particular actuator, they would be able to do so by interfacing, once again, with the AR module. The latter would send the actuation command to the SynField node digital twin which would, in turn, communicate the relevant command to the SynField platform to relay the command to the SynField node and trigger the appropriate/selected actuator.

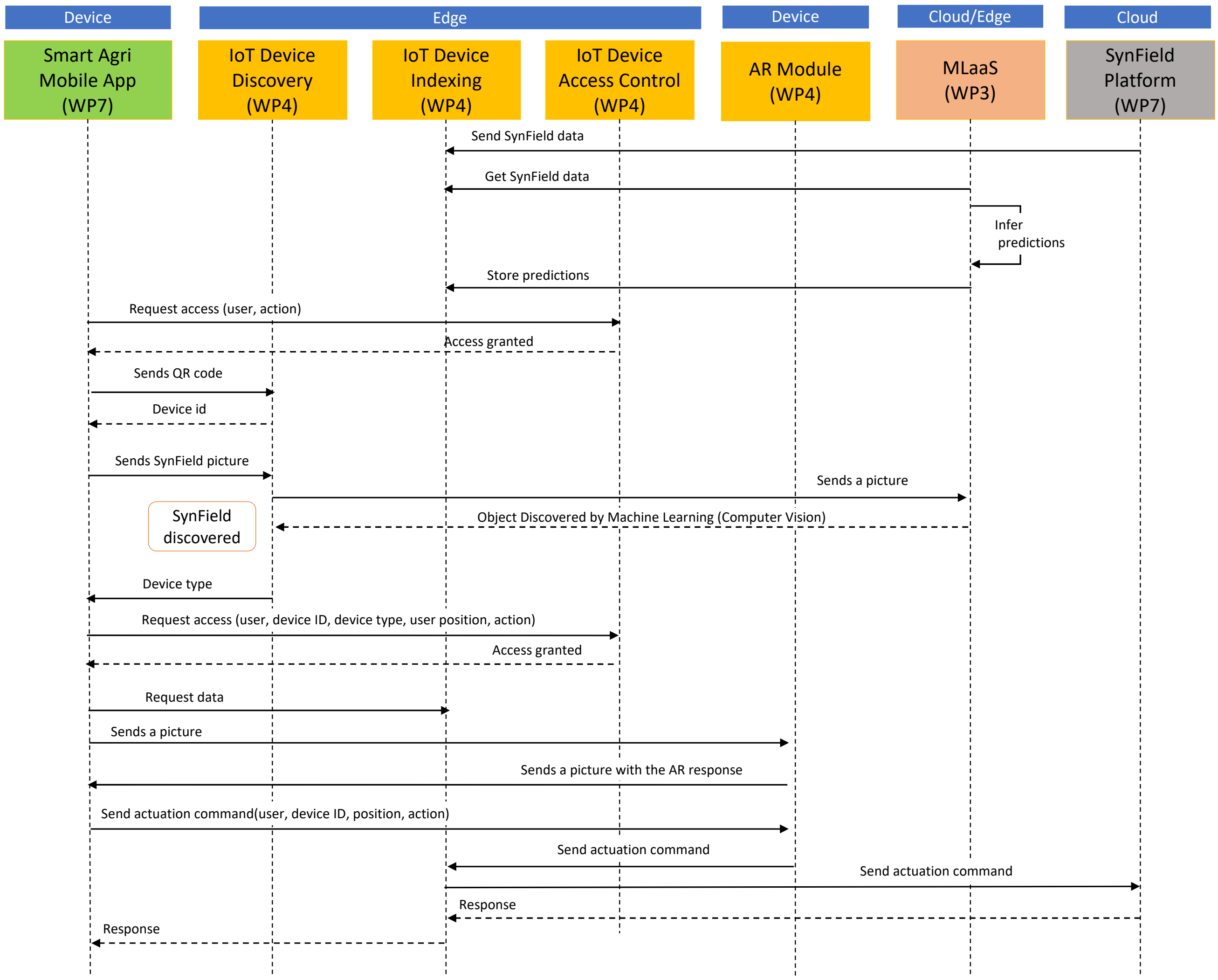


Figure 12. Sequence diagram for smart irrigation and AR-based actuation.

Continuing with the ML-based crop disease prediction case of the UC, Figure 13 depicts the relevant sequence diagram, whereas Table 14 tabulates the elements participating in this sequence diagram.

Table 14. Summary of the elements participating in the sequence diagram for the ML-based crop disease prediction case.

Element	Domain	WP	Comments
SynField Platform	Cloud	WP7	The core SynField service of Synelixis, essentially gathering the data from the SynField nodes and controlling their state.
Smart Agri Mobile App	Device	WP7	An AR-enabled mobile application allowing for device identification and interaction with the IoT-NGIN platform.
MLaaS	Cloud/Edge	WP3	The MLaaS framework of IoT-NGIN offering predictions related to the crop disease.
IoT Device Indexing	Edge	WP4	Offers digital twin services to the Synfield nodes.
IoT Device Access Control	Edge	WP4	Offers Access Control services on the digital twins of the Synfield nodes also considering an ambient intelligence perspective (e.g., authentication credentials, permissions and physical proximity to the actual device).
Privacy-preserving FL	Edge/Cloud	WP3	Model used to train the disease prediction algorithm.
Secure Execution Framework	Edge	WP2	Execution environment of the ML training (possibly also inference) process.
Smart Agri AI developer	Actor	N/A	A ML/AI developer of a smart agriculture application/service.
Farmer	Actor	N/A	The farmer using the Smart Agri Mobile App

The beginning of the action/data flow in this sequence diagram is the same as the previous one, the SynField platform feeding the digital twins of the SynField nodes with data and the MLaaS acquiring this data performing predictions on them and storing the predictions results back to the digital twins. The farmer could, then, gain access to these predictions by first acquiring a valid access token from the IoT Device Access Control module, then querying the IoT Device Indexing (digital twin).

In parallel to this flow, the AI/ML developer developing and maintaining (re-training) the models used for inference by the MLaaS platform would train a new disease prediction model by issuing a relevant command to the MLaaS platform. The latter would, then, spawn a new training process on the Secure Execution Framework. After a while, the model would be trained and stored into the MLaaS model repository and would be at the disposal of the AI/ML developer. The next step includes the deployment of the (updated/new) model. To this end, the AI/ML developer would issue a deployment command to the MLaaS, to deploy a new inference service, served, once again, within the context of the Secure Execution Framework.

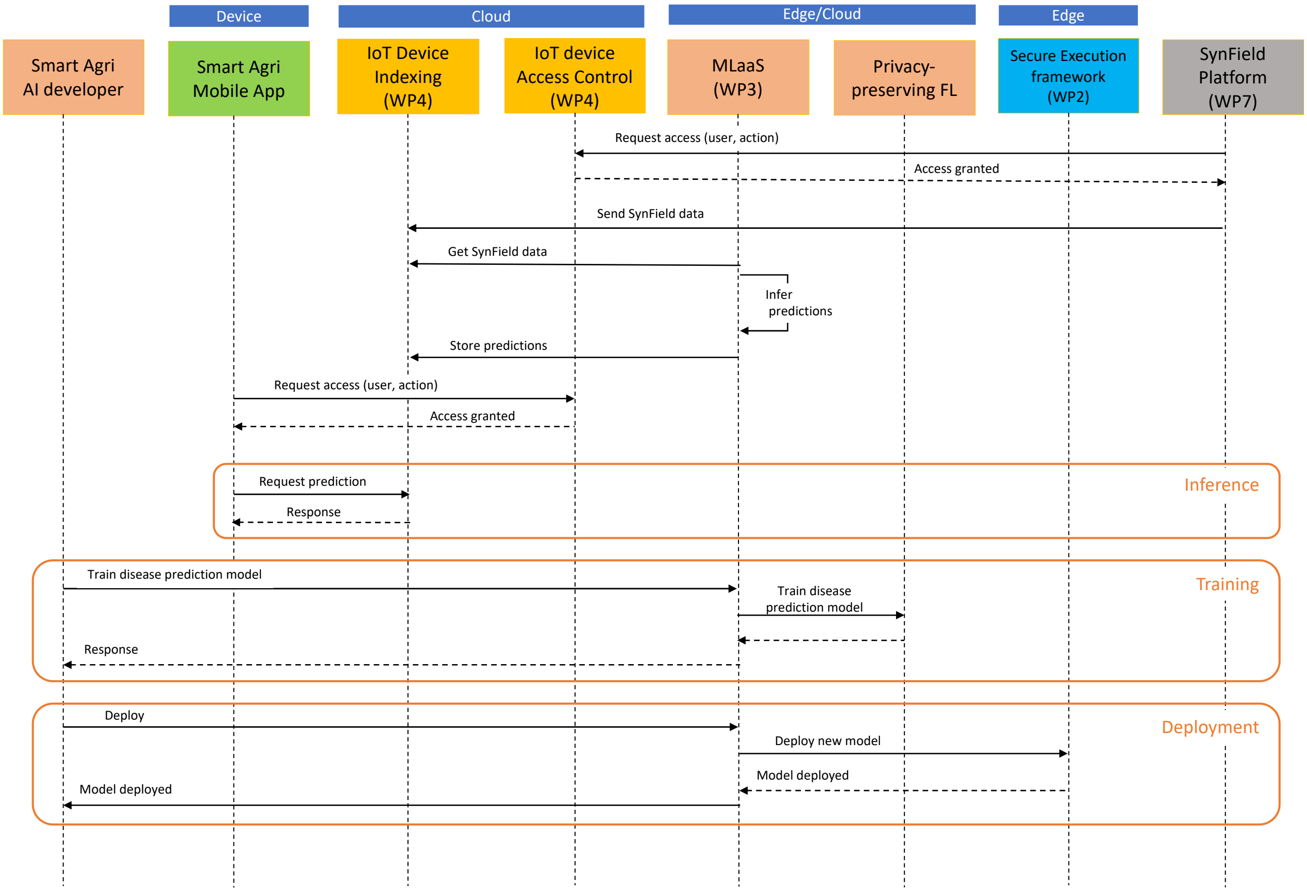


Figure 13. Sequence diagram for ML-based crop disease prediction.

With respect the last sequence diagram, the one describing the interactions taking place in the context of examining the IoT-NGIN cybersecurity features in the Smart Agriculture LL, depicted in Figure 14, Table 15 tabulates the involved elements.

Table 15. Summary of the elements participating in the sequence diagram related to the IoT-NGIN cybersecurity features in Smart Agriculture LL case.

Element	Domain	WP	Comments
IoT Device Indexing	Edge	WP4	Offers digital twin services to the Synfield nodes.
IoT Device Access Control	Edge	WP4	Offers Access Control services on the digital twins of the Synfield nodes also considering an ambient intelligence perspective (e.g., authentication credentials, permissions and physical proximity to the actual device).
MLaaS	Cloud/Edge	WP3	The MLaaS framework of IoT-NGIN offering model training and predictions related to malicious attack detection.

GAN Dataset Generator	Cloud	WP5	Generates data so that, after proper training, attack detection may be effectively operated by the Malicious Attack Detection module.
Malicious Attack Detection	Device/Edge /Cloud	WP5	Identifies network or model attacks.
IoT Vulnerability Crawler	Edge/Cloud	WP5	Scans IoT devices for known vulnerabilities.
MTD Network of Honeypots	Edge/Cloud	WP5	Deploys and reconfigures Honeypots in case vulnerable IoT devices or active attacks get acknowledged by the security-related components.
AI developer	Actor	N/A	A ML/AI developer of a cybersecurity application/service.

The case gets initiated by the GAN Dataset generator getting an access token from the IoT Device Access Control module to use the IoT-NGIN resources and services. Next, it constantly requests data from the storage service of the MLaaS platform, recursively generating new data for training and storing it back, again.

At that point, the AI developer also requests an access token claiming access to the IoT-NGIN services related to the MLaaS platform. After getting this token, she requests the data generated by the GAN Dataset Generator and configures in MLaaS a new training pipeline, in an attempt to create a model that is more efficient than the existing one. After the training has been completed, she deploys the (new/updated) model via the MLaaS platform to the Malicious Attack Detection which, in turn, constantly checks the network for attacks.

At the same time, the IoT Vulnerability Crawler, after getting a service token to be able to query the IoT Device Indexing module, spawns a new vulnerability crawling job, whenever a new device gets admitted into the network. After completing the vulnerability crawling job, the results would be stored back into the IoT Device Indexing module (actually as a property of the digital twin of the IoT device that got scanned).

Simultaneously to the above, the Moving Target Defense (MTD) Network of Honeypots component, after having requested a service token as well, waits for updates in the vulnerability status of the IoT-NGIN-registered IoT devices. Hence, whenever a new vulnerability gets uncovered by the IoT Vulnerability Crawler and gets published as an IoT device status update, the MTD Network of Honeypots examines whether a relevant honeypot is already deployed at the network; if not, then a new relevant honeypot gets deployed (if any relevant one exists). In case a relevant honeypot already exists, the MTD Network of Honeypots will examine whether a reconfiguration is needed, in order to update the existing honeypot deployment.

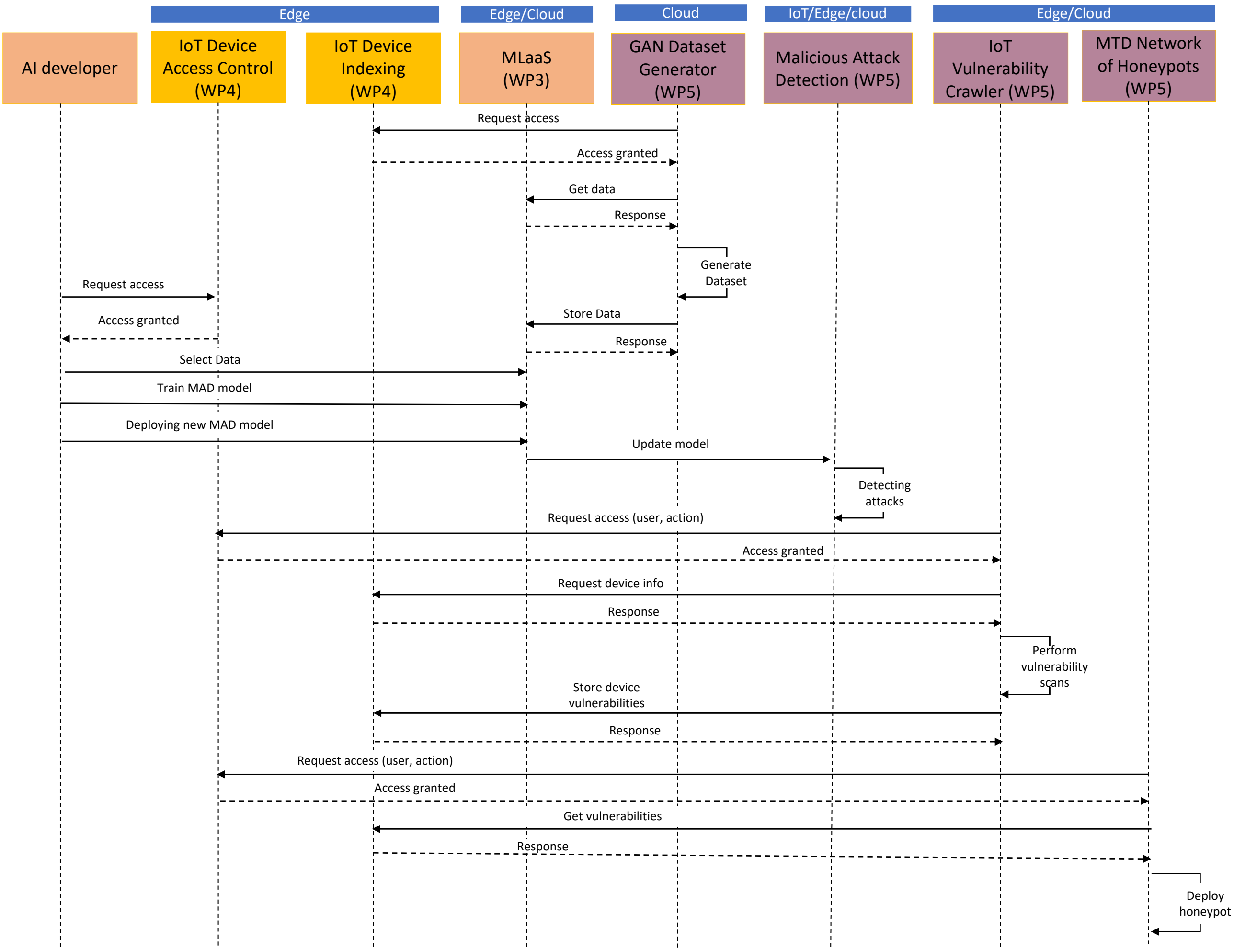


Figure 14. Sequence diagram for IoT-NGIN cybersecurity features in Smart Agriculture LL.

3.2.1.6. Testing and validation procedures

Technical validation of UC4

UC4 will be validated against 3 scenarios, each one implementing one sequence diagram presented in subsection 3.2.1.5. In the following, Table 16 to Table 18 present the validation scenarios for UC4.

Table 16. UC4 Test scenario 1 "Smart irrigation and AR-based actuation".

Test 1: Smart irrigation and AR-based actuation	
Objective	The objective is to validate the AR functionality of IoT-NGIN the Smart Agriculture LL UC4, in order to visualize monitoring information related to involved SynField node, as well as to trigger irrigation via AR actuation service of IoT-NGIN.
Components	• IoT Device Discovery (IDD) • IoT Device Indexing (IDI)

	• IoT Device Access Control • AR module • MLaaS • Smart Agri Mobile app • SynField platform (by Synelixis)
Features to be tested	• Development of Smart Farm's Digital Twin, realized through the IDI component • Data acquisition from SynField node's Digital Twin • ML-based Image recognition service • Pervasive security in the context of ambient intelligence, granting device access based on user credentials, location information and device recognition • AR visualization of SynField node info on user's mobile device • AR-based actuation, which controls the node's irrigation modules
Requirements addressed	REQ_SA1_F01 REQ_SA1_F02 REQ_SA1_F04 REQ_SA1_F08 REQ_SA1_F10 REQ_SA1_F12 REQ_SA1_F13 REQ_SA1_F14 REQ_SA1_F15 REQ_SA1_F16 REQ_SA1_NF01 REQ_SA1_NF03 REQ_SA1_NF04 REQ_SA1_NF05
Test setup	The IoT-NGIN framework should be deployed and functional. A set of SynField nodes is installed and configured to communicate with the edge node and the SynField platform. The SynField platform must be integrated with IDI, in order to inject sensor measurements, but also receive actuation commands. The ML-based crop disease prediction service queries monitored data on a regular basis, infers predictions and sends them back to IDI. The Smart Agri App is installed on the user's device and user credentials are registered in IDAC module, as eligible to access at least one of the installed SynField nodes. The CV-based image recognition module of the IDD component should be deployed and accessible via the MLaaS platform, based on already trained ML model, able to recognize SynField nodes. Each SynField node is attached with a QR code, which provides the node's id information.
Steps	1. The user approaches a SynField node on which it has no permission to read monitored data or perform any actuation. 2. The user scans the node's QR code through the Smart Agri app. 3. The user streams SynField node's images through the Smart Agri app. 4. The user is not granted access to further use of the Smart Agri app

	5. The user approaches a SynField node which it has permission to access and performs again steps 2-3. 6. The user is granted access to the AR functionality. 7. The user visualizes information about the SynField node, as well as its monitored data and calculated predictions via AR on their device. The user also visualizes an AR button, for triggering irrigation on the SynField node. 8. The user presses the AR button and sends an irrigation command. 9. Irrigation starts on the solenoid valve connected to the SynField node, as dictated by IDI and SynField platform.
KPIs	KPI_SA1_01, KPI_SA1_03, KPI_SA1_04

Table 17. UC4 Test scenario 2 "ML-based crop disease prediction and aerial spraying".

Test 2: ML-based crop disease prediction and aerial spraying	
Objective	The objective of this test is to validate the crop disease prediction functionality of the IoT-NGIN UC4 application, offered through the MLaaS framework of IoT-NGIN and based on sensor readings of SynField nodes, as well as on images acquired via smart agricultural drones.
Components	• IoT Device Indexing • IoT Device Access Control • MLaaS • Privacy-preserving FL • Secure Execution Framework • Smart Agri Mobile App • SynField platform (by Synelixis)

Features to be tested	• ML-based crop disease prediction service development
	  o Training
	  o Deployment
	  o Inference
	• Smart Farm' Digital Twin
	• Aerial spraying
	• Access control

Requirements addressed	REQ_SA1_F01 REQ_SA1_F02 REQ_SA1_F03 REQ_SA1_F04 REQ_SA1_F05 REQ_SA1_F06 REQ_SA1_F07 REQ_SA1_F08 REQ_SA1_F09 REQ_SA1_F10 REQ_SA1_F11

	REQ_SA1_F12 REQ_SA1_F13 REQ_SA1_F14 REQ_SA1_F15 REQ_SA1_F16 REQ_SA1_NF01 REQ_SA1_NF04 REQ_SA1_NF05
Test setup	The IoT-NGIN framework should be installed and functional. The user should be provided with permissions to access and control SynField nodes and UAVs. The SynField platform is integrated with IDI and sends monitored data on a regular basis, but it can also receive control commands through it.
Steps	1. The AI developer accesses through their credentials the MLaaS platform. 2. The AI developer trains the disease prediction model through the MLaaS platform. 3. The AI developer deploys the model through the MLaaS platform. 4. The Smart Farmer accesses the Smart Agri app through their credentials. 5. The Smart Farmer selects the Smart Farm of interest. 6. The Smart accesses the list of IoT devices for the selected farm, namely both SynField nodes and UAVs. 7. The Smart Farmer accesses crop disease prediction outcomes for the selected Smart Farm. 8. The Smart Farmer selects to perform aerial spraying on specific areas of the field 9. The Smart Farmer selects to share a portion of data via the MLaaS platform.
KPIs	KPI_SA1_02, KPI_SA1_03, KPI_SA1_04

Table 18. UC4 Test scenario 3 "Smart agriculture cybersecurity".

Test 3: Smart agriculture cybersecurity	
Objective	The objective of this test is to validate the IoT-NGIN cybersecurity tools in the Smart Agriculture LL, effectively protecting the UC4 operation from IoT cyber-attacks which could compromise the effectiveness of the AI models.
Components	• IoT Device Indexing • IoT Device Access Control • MLaaS • GAN-based Dataset Generator • Malicious Attack Detection • IoT Vulnerability Crawler

	• MTD Network of Honeypots • SynField platform (by Synelixis)
Features to be tested	• Malicious attack detection • Vulnerability scanning of SynField devices • Malicious attack pattern investigation for the Smart Agriculture domain • Smart Farm Digital Twin • MLaaS platform functionality for attack detection models development and deployment • Access control
Requirements addressed	REQ_SA1_F01 REQ_SA1_F12 REQ_SA1_NF01 REQ_SA1_NF02
Test setup	The IoT-NGIN framework should be installed and functional. The user should be provided with permissions to access monitored data. The SynField platform is integrated with IDI and sends monitored data on a regular basis. The malicious attack detection modules are deployed and operate over the SynField data streams. Vulnerability scanning is in place for the SynField devices.
Steps	1. The administrator of the SynField platform signs in and accesses the vulnerability scanning outcomes for the SynField devices. 2. The administrator approves the setup of a new honeypot based on the identified vulnerabilities. 3. The administrator accesses the malicious attack detection reports. 4. The administrator excludes the data of the node under attack from the next training cycle. 5. The administrator resets the attacked node.
KPIs	KPI_SA1_01, KPI_SA1_02, KPI_SA1_03

Validation stages

UC4 will be validated in 3 stages, as presented in the following.

- **Preliminary lab validation:** During this stage, all 3 validation scenarios will be validated in Synelixis' laboratory, using real or simulated datasets, where appropriate. Preliminary lab validation will be conducted for each validation cycle, as IoT-NGIN components or subsystems become available.
- **Closed trial validation:** After the lab validation, the available IoT-NGIN components will be tested under a limited field installation, to ensure that all trial parts, including both equipment and software components are deployed properly and operate smoothly.
- **Final validation:** During the final validation, the complete LL infrastructure available for the UC will be involved in the trial. The 3 validation scenarios will be validated end-to-end in order to receive the final pilot results.

User testing / validation

Besides the validation outcomes that will be provided mainly through system logs, user testing will be performed to ensure that the IoT-NGIN framework operates appropriately. The outcomes will be recorded in a checklist, similar to the indicative list provided in Table 19.

Table 19. Indicative checklist for Test 3 user testing.

Checklist for Test 3 "Smart agriculture cybersecurity"		Yes	No	Comments
1	The SynField nodes are correctly installed on the field.			
2	The SynField platform is accessible online.			
3	The SynField data are correctly sent to IDI.			
4	A new dataset can be created through the GAN-based Dataset Generator.			
5	The MAD module has been trained over this dataset.			
6	The MAD module is deployed via the MLaaS platform.			
7	The MAD module operates over the SynField data.			
8	The MAD module sends predictions to the deployed Digital Twin.			
9	The IoT Vulnerability Crawler can perform scanning on a set of SynField devices.			
10	The scanning outcomes are sent to the deployed Digital Twin.			
11	The user is provided with access relevant to their role.			
12	The logged-in admin user can access the vulnerability scanning outcomes for the SynField devices.			
13	The logged-in admin user can set up a new honeypot.			
14	The logged-in admin user can access the malicious attack detection reports.			
15	The logged-in admin user can exclude the data of the node under attack from the next training cycle.			
16	The logged-in admin user can reset the attacked node.			

3.2.1.7. Execution timeline

The execution timeline of UC4, divided into multiple phases, is detailed in Table 20 below.

Table 20. Execution timeline of UC4.

Phase	Estimated start date	Estimated end date	Notes
Trial set-up and equipment procurement	*M5*	*M18*	Completed

Initial implementation and validation	*M19*	M30	Validation mainly on the basis of the 2nd integrated prototype
Final implementation and validation	*M31*	*M36*	Validation mainly on the basis of the final integrated prototype

3.2.1.8. Initial results

The LL activities in the first period included the preparatory work for UC4. The main outcomes, besides the design of the LL tests have been towards procuring the required equipment that was not available in partners' resources, as well as conducting early integration tests with the IoT-NGIN components. However, since development is in progress for most components, integration has been focused on the IoT Device Indexing module, which will be fed with IoT data.

UC4 equipment procurement

After concretely defining the Use Case description, OPT and SYN have identified the equipment that will be needed for executing the pilot tests, concluding to the list identified in Section 3.2.1.2. Then, a market analysis has been performed on identifying the exact items that are most appropriate for the pilot. The criteria for the selection of the exact pieces have been based on the requirements that relate to the UAV of UC4, as listed in Table 21, as well as on the available budget. Based on these, hardware requirements for UC4's UAV solution have been identified, as listed in Table 22.

Table 21. IoT-NGIN requirements affecting drone selection.

Requirement ID	Requirement description
REQ_SA1_F01	The platform should provide access to measurements
REQ_SA1_F02	The platform should provide options to manage/view sensors/devices
REQ_SA1_F05	The platform should provide predictions of crop diseases, based on ML/FL performed over sensor measurements and drone images/videos
REQ_SA1_F07	The platform should provide automated irrigation and aerial spraying based on crop disease prediction
REQ_SA1_F08	The platform should provide access to irrigation and aerial spraying data
REQ_SA1_F11	The platform must be able to retrieve plant photos via drones
REQ_SA1_F12	The monitoring devices must support network connectivity
REQ_SA1_F13	The monitoring devices must be able to communicate data to and receive control commands from the IoT-NGIN platform

Table 22. Hardware components requirements for UAVs arising from IoT-NGIN components.

Component	Requirement description	Desired value/specification
drone	Hovering precision	Vertical ≤±0.5 m, Horizontal ≤±1.5 m
	Hovering time	≥ 15min
	Payload (without batteries)	≥ 5kg
	Spraying capacity	Desired[6] ≥ 5lt
	integration with third party software and hardware	Yes
camera	Type	Multi-spectral
	memory	≥ 32GB
	Connectivity	USB
	Mounting base	yes
Processing unit	GPU	yes
	RAM	≥ 2GB
	Connectivity	Wi-Fi/Cellular
	SDK	Support at least for TensorFlow, PyTorch, Keras
Power	Power supply	external

Based on the hardware requirements identified in Table 22, the following components have been selected after thorough market analysis for architecting the UAV solution for UC4.

Drone

The DJI MATRICE PRO has been selected and procured as the drone to integrate the additional modules for the UAV solution. A picture of it while conducting preliminary tests on the laboratory is depicted in Figure 15. The selected drone covers the requirements identified in Table 21, except for the spraying capacity. However, the specific drone has been identified as the best value-for-money option, considering that a separate drone spraying system can be integrated.

[6] Otherwise, a third-party spraying tank must be installed on the drone

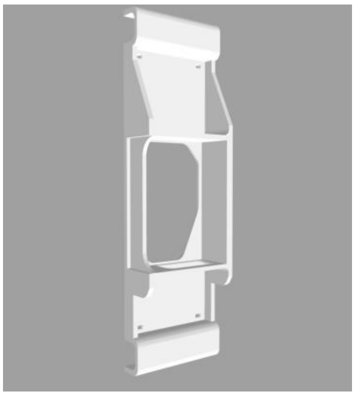
Figure 15. The drone procured for UC5.

Camera

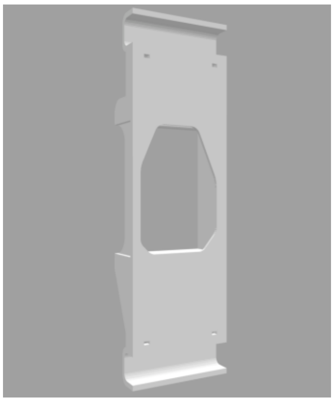
The Parrot Sequoia+ camera has been selected as the multispectral camera of the UAV. Parrot Sequoia+ is the first multispectral camera to provide absolute reflectance measurements without reflectance targets. Moreover, its high resolution (11cm/px at 120m) makes it appropriate for crop disease prediction in Smart Agriculture use cases. It is also flexible in terms of triggering and data acquisition, so it can well support the use case within the IoT-NGIN concept. The camera is depicted in Figure 16.

Figure 16. The multispectral camera for the UAV of UC5.

As integration with the selected drone is not available, a mounting base has been designed and 3d-printed for integrating the camera on the drone. The design of the base is depicted in Figure 17, while the camera mounted on the base and then on the drone is depicted in Figure 18.



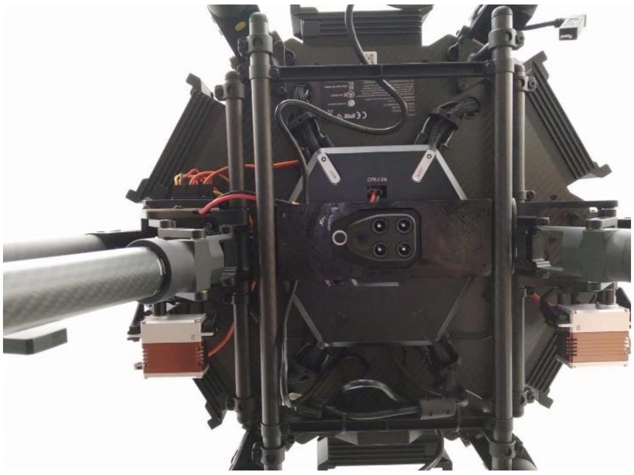
(a) Mounting base design (front)



(b) Mounting base design (rear)

Figure 17. Design of the mounting base for the camera.

(a) camera mounted on the base



(b) Camera mounted on the drone

Figure 18. Camera mounted on the base and the drone.

Early integration activities with IoT-NGIN

In this UC, a Digital Twin of the Smart Farm will be developed, twinning the IoT devices used in the field, namely the SynField nodes and the UAV. Within IoT-NGIN, the IoT Device Indexing (IDI) component supports this functionality. So, the component has been deployed on SYN premises and tested in the context of UC4 for the UAV, considering that it collects images on which it performs inference locally.

For the purposes of the use case, we have registered a new device to IDI, representing the UAV under consideration. We have assumed that the UAV will send batches of the captured images and the crop disease prediction values to IDI, deployed on the edge server. An example of such a batch sent to IDI is depicted in Figure 19 indicating relevant fields, while Figure 20 presents the logs acknowledging the reception of such batches by IDI. Then, IDI would be able to be queried to provide data associated with the UAV, as presented in *Figure 21*.


```
    },
    {
      "location": "-0.218774358582686, -3.262067806732362",
      "image_link": "http://localhost",
      "prediction": [
        {
          "location": "-0.218774358582686, -3.262067806732362",
          "disease_area": [
            {
              "x1": "338",
              "y1": "257"
            },
            {
              "x2": "310",
              "y2": "319"
            }
          ],
          "prediction": 1
        }
      ]
    },
    {
      "location": "2.4821770791793245, -1.3495824053947523",
      "image_link": "http://localhost",
      "prediction": [
        {
          "location": "2.4821770791793245, -1.3495824053947523",
          "disease_area": [
            {
              "x1": "319",
              "y1": "312"
            },
            {
              "x2": "272",
              "y2": "264"
            }
          ],
          "prediction": 0
        }
      ]
    }
  ]
}
```


Figure 19. Example of batch data sent by the UAV to the edge server's IDI component.

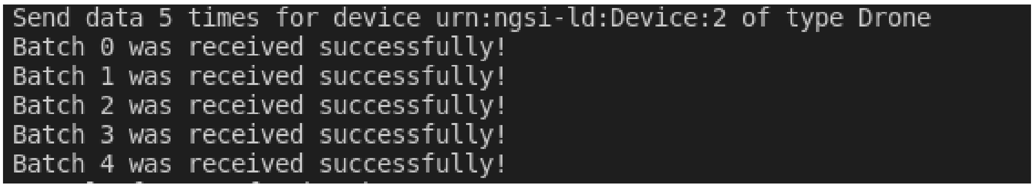


Figure 20. Reception of UAV data by IDI.

Figure 21. IDI's API response to request for the UAV's data.

3.2.2. UC5 – Sensor aided crop harvesting

Manual crop harvesting is quite labour-intensive operation, which often requires significant manpower for both the harvesting process per se, but also for carrying the harvested crops to the loading points. While mechanical harvesting has been introduced as a cost and time-efficient alternative [4], manual harvesting is usually preferred as a more favourable method to products' quality [5]. However, the availability of labour staff can be limited, especially during the harvesting period, when the relevant demand is high. The COVID-19 lockdowns have had a great impact on the availability of labour staff [6] [7], involved also in the harvesting processes. A hybrid approach involving both manual harvesting and mechanical assistance for the carrying operations can bring significant cost and time benefits, without compromising the crops' quality.

IoT-NGIN Use Case #5 "**Sensor aided crop harvesting**" will experiment with such a hybrid, semi-mechanical crop harvesting use case, in which Automated Guided Land Vehicles (AGLV) will support human-workers by autonomously carrying the crates to the loading point. We will experiment with agricultural AGLV serving as carrier machines, which are developed in the scope of IoT-NGIN. AGLVs will be autonomous in the sense that they will be able to locate and avoid workers (for safety reasons), as well as trees or other obstacles (for operational reasons), by automatically changing their trajectory upon detection of a potential collision. The AGLV will be equipped with a camera and sensors, in order to perceive its environment and, based on ML algorithms running directly on the robot, to be able to detect obstacles and identify potential collisions automatically. Moreover, the AGLV will be able to follow given routes, from the crates' location to the loading point. The UC will exploit the IoT-NGIN tools for the ML model development and secure deployment on the device. Moreover, within UC5, the Digital Twin of the AGLVs will be developed, in order to allow access to the acquired data for ML training purposes, but also enable command communication to the device, such as route configuration and model deployment.

3.2.2.1. Trial site description

The infrastructure elements, through which UC5 "Sensor aided crop harvesting" will be executed, will interact as depicted in Figure 22. The use case will be realized in the Smart Agriculture Living Lab, both in lab and outdoor environment, in a vineyard in Peloponnese, Greece.

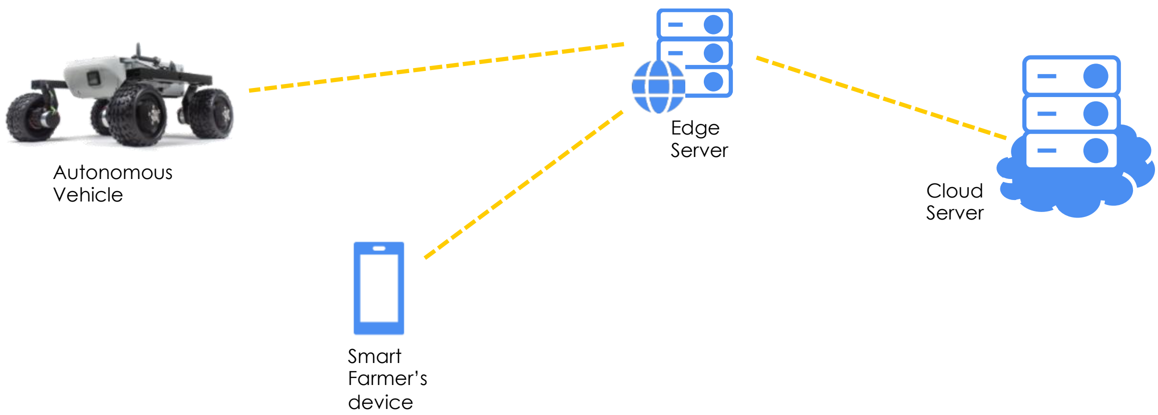


Figure 22. Infrastructure topology for UC5

As depicted in Figure 22, the mobile robot will communicate with an edge server via a wireless interface, such as Wi-Fi or cellular, in order to communicate its data. These will be used for persistence and training purposes of the ML models. Moreover, the Smart Farmer's device, such as mobile phone or tablet, will communicate with the edge server in order to send commands to the AGLV (via the Digital Twin), such as route configuration. Last but not least, the cloud server will be used for heavy computations, such as training processes of ML models, based on data that will be pulled from the edge server.

3.2.2.2. Required equipment

Table 23 below shows a detailed description of the required equipment for UC5, along with its type and status (whether it is available or still be procured).

Table 23. Detailed description of the required equipment for UC5.

Equipment	Description / Specifications	Type	Status
Robot chassis	Wild Thumper 6-Wheel platform. Each of the six motors are mounted on independent suspension and outfitted with 34:1 steel gearboxes (no more stripped	AGLV	Procured

	gears!). The entire chassis is perforated with 10mm pitched, 4mm diameter mounting holes and there is plenty of room interior to the chassis for batteries, drivers and other support hardware.		
Arduino Mega2560	The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analogue inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.	Microcontroller	Procured
Ultrasonic sensor HC-SR04	HC-SR04 ultrasonic distance sensor. providing 2cm to 400cm of non-contact measurement functionality with a ranging accuracy up to 3mm.	Sensor	Procured
Waveshare photo interrupter sensor	Robot Speed Measuring Module	Sensor	Procured
Processing unit	NVIDIA Jetson Nano 2GB, a small, powerful computer which is able to run multiple neural networks in parallel for applications like image classification, which is desired for the crop disease prediction application.	Processing board	Procured
Zed 2i	IP66 stereo camera, wide-angle 3D AI camera, multiple lens selection with polarizer, built-in IMU, barometer & magnetometer	Camera	Procured
Edge node	Edge server for running Digital Twin functionality. The edge node will host the client-side services of the IoT-NGIN framework.	Edge server	Available
Cloud node	Cloud resources used for permanent storage and ML model aggregation/training activities. Also, here the server-side services of IoT-NGIN will be deployed.	Cloud	Available within the Consortium

3.2.2.3. Data collection

The following dataset(s) have been identified as part of the use case:

- **AGLV sensor measurements:** measurements acquired from sensors installed and configured specifically for the trial on Automated Guided Land Vehicles (AGLVs) will be collected. The data will be used to allow the use of the AGLVs as carrier machines, and to enable them to locate and avoid workers and trees.
- **AGLV camera images:** video images collected from AGLV's camera. The images will be used for obstacle avoidance of the AGLV.

3.2.2.4. Alignment with IoT-NGIN technologies

Table 24 below shows the IoT-NGIN technologies relevant for UC5. For each technology, a description of its role is provided along with any adaptation it might need to be used in the UC, deployment details and related UC requirements and KPIs.

Table 24. Alignment of UC5 with the relevant IoT-NGIN technologies.

WP2 – Secure edge-cloud execution framework	
Description	This framework will be used in order to enable secure deployment and operation of IoT-NGIN services. Indicatively, it will host the obstacle detection models deployed on the mobile robot.
Adaptation and fine-tuning	The Secure Execution framework will be integrated with the MLaaS platform, enabling secure deployment of ML models. As such, no adaptation is needed.
Deployment	Multi-layer, including edge and cloud resources.
Related requirements	**REQ_SA2_F06** – The platform must ensure collected data sovereignty and integrity **REQ_SA2_NF01** – The IoT-NGIN platform must respect security and privacy requirements
Related KPIs	**KPI_SA2_03** – Reduction of the time needed for carrying crates to the loading point, compared to manual carrying >/= 10%
WP3 – MLaaS framework	
Description	The MLaaS framework will be used to provide ML/AI services to the use case, related to ML model training and model serving, in order to support the obstacle avoidance application.
Adaptation and fine-tuning	No adaptation of the MLaaS framework is needed for the purposes of UC5. The obstacle avoidance application will consume the MLaaS services interacting with its API.

Deployment	A project-wide deployment can be used. The use case does not require a dedicated instance of the MLaaS framework.
Related requirements	**REQ_SA2_F01** – Mobile robots must support autonomous operation **REQ_SA2_F10** – The platform must be able to calculate mobile robots' routes in real-time **REQ_SA2_F11** – The platform must be able to identify and avoid obstacles such as humans and trees in real-time
Related KPIs	**KPI_SA2_01** – Collisions of mobile robots with human workers = 0 **KPI_SA2_02** – System reaction in emergency cases < 1 sec
WP3 – Deep Learning, Reinforcement Learning & Transfer Learning	
Description	Deep Learning techniques will be used to train the obstacle avoidance prediction ML models at the cloud node.
Adaptation and fine-tuning	No adaptation need identified at this point.
Deployment	N/A
Related requirements	**REQ_SA2_F01** – Mobile robots must support autonomous operation **REQ_SA2_F10** – The platform must be able to calculate mobile robots' routes in real-time **REQ_SA2_F11** – The platform must be able to identify and avoid obstacles such as humans and trees in real-time
Related KPIs	**KPI_SA2_01** – Collisions of mobile robots with human workers = 0 **KPI_SA2_02** – System reaction in emergency cases < 1 sec
WP4 – IoT device indexing	
Description	This module will allow accessing data collected by the mobile robots, as well as any information accompanying these devices. Moreover, it can be used to dispatch actuation/configuration commands on the robots.
Adaptation and fine-tuning	No adaptation need identified at this point.
Deployment	Edge
Related requirements	**REQ_SA2_F02** – Mobile robots should be able to understand which crates they should carry

	REQ_SA2_F03 – Mobile robots must be able to follow a route or reach a destination **REQ_SA2_F04** – The crates must be identifiable at the loading points via RFID technology **REQ_SA2_F07** – The platform should provide access to collected data **REQ_SA2_F08** – The platform should provide options to manage/view the connected mobile robots **REQ_SA2_F12** – The platform must be able to schedule carrier plans, based on real-time data **REQ_SA2_F13** – Mobile robots must be able to provide data to and receive control commands from the IoT-NGIN platform **REQ_SA2_F14** – The platform UC app should allow the user to view the routes and carrier plans **REQ_SA2_F15** – The platform should allow the user to cancel or manage the carrier plans or routes **REQ_SA2_NF04** – IoT-NGIN should be scalable in terms of adding/removing devices and integrating hundreds of devices
Related KPIs	**KPI_SA2_03** – Reduction of the time needed for carrying crates to the loading point, compared to manual carrying >/= 10%
WP4 – IoT device access control	
Description	This module will provide access management to the mobile robots, before allowing access to monitoring data or control actions.
Adaptation and fine-tuning	No adaptation need identified at this point.
Deployment	Cloud
Related requirements	**REQ_SA2_F06** – The platform must ensure collected data sovereignty and integrity **REQ_SA2_F07** – The platform should provide access to collected data **REQ_SA2_F09** – The platform should provide options to manage users **REQ_SA2_NF01** – The IoT-NGIN platform must respect security and privacy requirements
Related KPIs	**KPI_SA2_01** – Collisions of mobile robots with human workers = 0 **KPI_SA2_02** – System reaction in emergency cases < 1 sec

	KPI_SA2_03 – Reduction of the time needed for carrying crates to the loading point, compared to manual carrying >/= 10%

3.2.2.5. Use case sequence diagrams

In the following, a set of sequence diagrams is provided, highlighting the use of equipment and IoT-NGIN technology in the UC. In accordance to UC4, the identified sequence diagram elements are categorized into three domains, namely Cloud, Edge (Near Edge) and Device (Far Edge). The high-level interactions among the IoT-NGIN components and the UC users are also detailed.

In Figure 23, a sequence diagram related to the sensor-aided crop harvesting is provided, the basic interacting elements being as shown in Table 25.

Table 25. Summary of the elements participating in the sequence diagram related to sensor-aided crop harvesting.

Element	Domain	WP	Comments
AGLV app	Device	WP7	An application allowing the AGLV to interact with IoT-NGIN.
MLaaS	Cloud/Edge	WP3	The MLaaS framework of IoT-NGIN offering deep learning inference services related to obstacle avoidance.
IoT Device Indexing	Edge	WP4	Offers digital twin services to the AGLV.
IoT Device Access Control	Edge	WP4	Offers Access Control services on the digital twins of the AGLV and on the IoT-NGIN services also considering an ambient intelligence perspective (e.g., authentication credentials, permissions and physical proximity to the actual device) whenever appropriate.
Secure Execution Framework	Device	WP2	Execution environment of the ML inference process.
Smart Agri AI developer	Actor	N/A	A ML/AI developer of the algorithms performing the obstacle avoidance analysis.

The interactions among the control and data flow participating elements get initiated by the AGLV requesting a service token from the IoT device Access Control, then sending data to its digital twin, hosted under the framework of the IoT Device Indexing module.

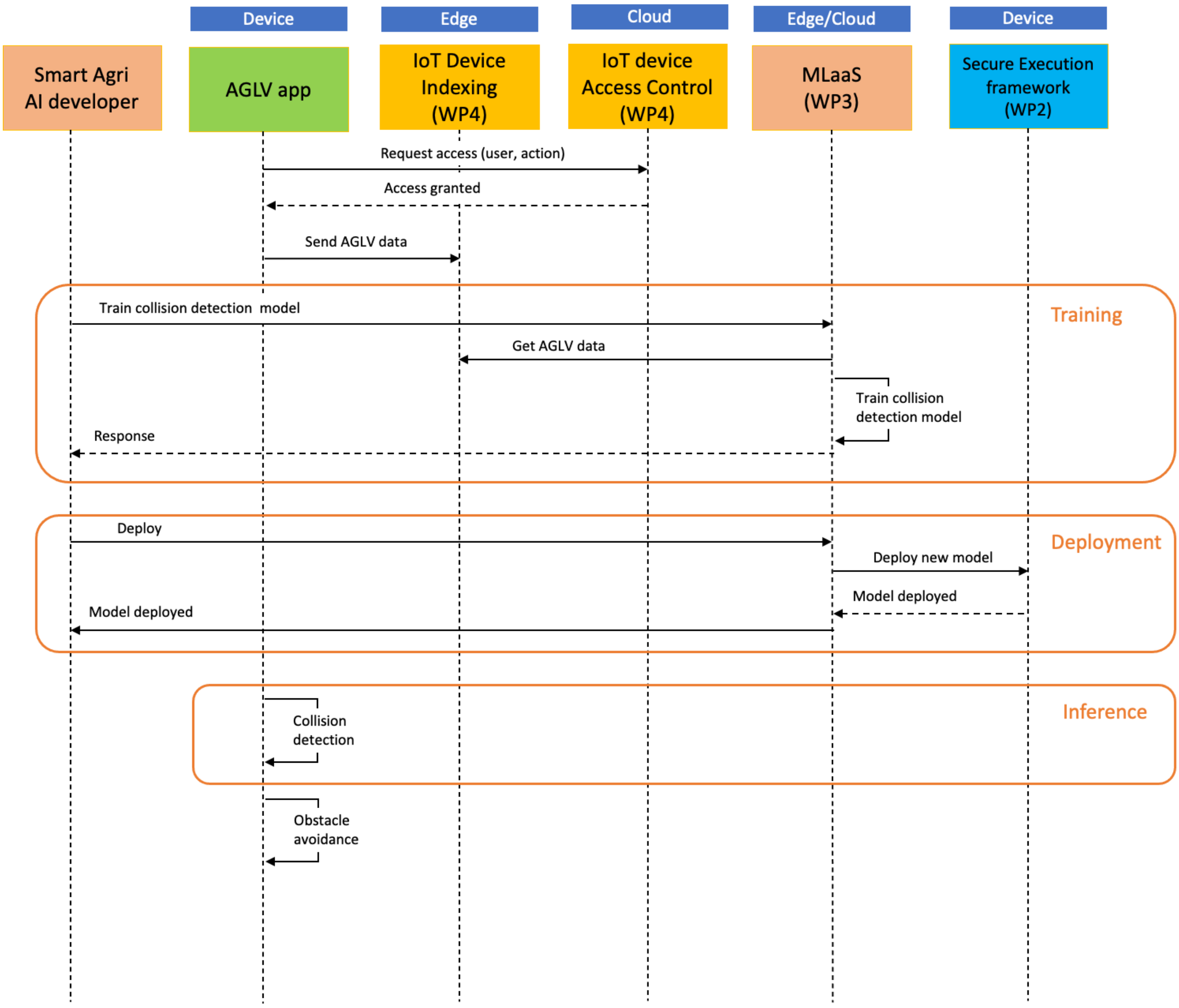


Figure 23. Sequence diagram for ML-based obstacle avoidance.

At the same time, the AI/ML developer, willing to re-train the collision avoidance performance, sends a model training command to the MLaaS framework which, in turn, collects the data and trains an updated model. When this training procedure gets completed, the AI/ML developer, after getting the relevant acknowledgement, continues with the updated model deployment at the Secure Execution Framework operated in the AGLV. The latter should now be able to actually perform the collision avoidance and avoid obstacles hindering its planned course.

3.2.2.6. Testing and validation procedures

Technical validation of UC5

UC5 will be validated against the scenario, presented in Table 26.

Table 26. Test scenario 1 "Obstacle avoidance".

Test 1: Obstacle avoidance	
Objective	The objective is to validate the effectiveness of the obstacle avoidance functionality of IoT-NGIN the Smart Agriculture LL UC5, in order to ensure labour staff safety and safe AGLV movement across the field while carrying crates with harvested crops.
Components	• IoT Device Access Control • IoT Device Indexing • MLaaS • Secure Execution Framework
Features to be tested	• Obstacle detection • Route recalculation • Model training • Access control • Digital Twin of the mobile robot
Requirements addressed	REQ_SA2_F01 REQ_SA2_F02 REQ_SA2_F03 REQ_SA2_F05 REQ_SA2_F06 REQ_SA2_F07 REQ_SA2_F10 REQ_SA2_F11 REQ_SA2_F13 REQ_SA2_F14 REQ_SA2_F15
Test setup	The IoT-NGIN framework should be deployed and functional. A mobile robot is configured with the IoT-NGIN framework and able to communicate with the edge node. The mobile robot must be integrated with IDI, in order to provide its data and receive commands. The AGLV App is installed on the mobile robot, in which the ML-based obstacle avoidance service performs inference on the mobile robot, based on collected data. The Smart Farmer must be registered on IoT-NGIN platform, in order to access AGLV data.
Steps	1. The user signs in the AGLV app. 2. The user configures a new route for the mobile robot. 3. The mobile robot starts its route. 4. Upon detection of obstacle, the mobile robot should change its trajectory. 5. The mobile robot reaches its destination. 6. The user accesses the route information.
KPIs	KPI_SA2_01, KPI_SA2_02, KPI_SA2_03

Validation stages

Similarly to UC4, UC5 will be validated in 3 stages, as presented in subsection 3.2.1.6. Namely: *Preliminary lab validation*, *Closed trial validation* and *Final validation*.

User testing / validation

Moreover, the pilot trial will include functional testing, the outcomes of which will be based on the users' feedback through a checklist, similar to the one presented in Table 19.

3.2.2.7. Execution timeline

The execution timeline of UC5, divided into multiple phases, is detailed in Table 27 below.

Table 27. Execution timeline of UC5.

Phase	Estimated start date	Estimated end date	Notes
Trial set-up and equipment procurement	M5	M18	Completed
Initial implementation and validation	M19	M30	Validation mainly on the basis of the 2nd integrated prototype
Final implementation and validation	M31	M36	Validation mainly on the basis of the final integrated prototype

3.2.2.8. Initial results

The main outcomes of the preparatory activities of UC5, besides the design of the LL tests, have been towards procuring the required equipment that was not available in partners' resources.

UC5 equipment procurement

Following the Use Case description, the required and missing equipment has been identified for executing the pilot tests, as presented in Section 3.2.2.2. We have followed an approach similar to UC4 for the drone selection, considering the IoT-NGIN requirements that relate to the AGLV capabilities and/or functionality (Table 28) and identifying minimum hardware requirements (Table 29).

Table 28. IoT-NGIN requirements affecting AGLV selection.

Requirement ID	Requirement description
REQ_SA2_F01	Mobile robots must support autonomous operation.

REQ_SA2_F02	Mobile robots should be able to understand which crates they should carry.
REQ_SA2_F03	Mobile robots must be able to follow a route or reach a destination.
REQ_SA2_F04	The crates must be identifiable at the loading points via RFID technology.
REQ_SA2_F05	Mobile robots must support network connectivity, such as Wi-Fi or cellular.

Table 29. Hardware components requirements for AGLV arising from IoT-NGIN components.

Component	Requirement description	Desired value/specification
AGLV	Appropriate environment	Outdoor use
	Terrain	Rough
	Max payload	>=15kg
	Design	Flexible to mount several items
camera	Type	Stereo camera
	Connectivity	USB
	Compatibility	Jetson nano
	Mounting base	Yes

Based on the hardware requirements identified in Table 29, the following components have been selected after thorough market analysis for building the AGLV solution for UC5.

AGLV

The Wild Thumper 6-Wheel platform has been identified as a robot chassis platform. We have mounted the 6 motors, as well as the relevant controllers for enabling movement to the left or right. A Pulse Width Modulation (PWM) controller is used for controlling the velocity of the motors, while a digital compass will be used for allowing the AGLV to turn in certain degrees. n addition, distance sensors are used, in order to allow collision avoidance. Thus, a low-level controller has been developed by SYN, in order to allow controlling the motors, sending data to the edge server and communicate with the processing unit (Jetson nano) over a serial interface. Moreover, the controller firmware has been developed, providing PWM-controller support and enabling the motors to stop when distance is less than a defined value (front-sensor when going forward, and back sensor for reverse).

In the following, Figure 24 presents the assembled AGLV solution so far, including both the motor controllers, the PWM controller and the sensors. Moreover, a custom mobile application has been developed in order to facilitate the test activities of the LL by sending control commands received and executed via SYN's low-level microcontroller. In the mobile application, as depicted in Figure 25, the left bar is for controlling the left wheels, while the right bar for controlling the left wheels. Specifically, we could send commands to the AGLV in the following format:

```
[{"TYPE":"COMMAND","MOTORSx":"val","END":"1"}]
```

where:

- MOTORSx:
    - MOTORSL for the left motor
    - MOTORSR for the right motor
    - MOTORSA for all motors
- val: value for the velocity [-100, 200], where negative values refer to rear movement

Moreover, the measurements of sensors connected to the AGLV system can be read as follows:

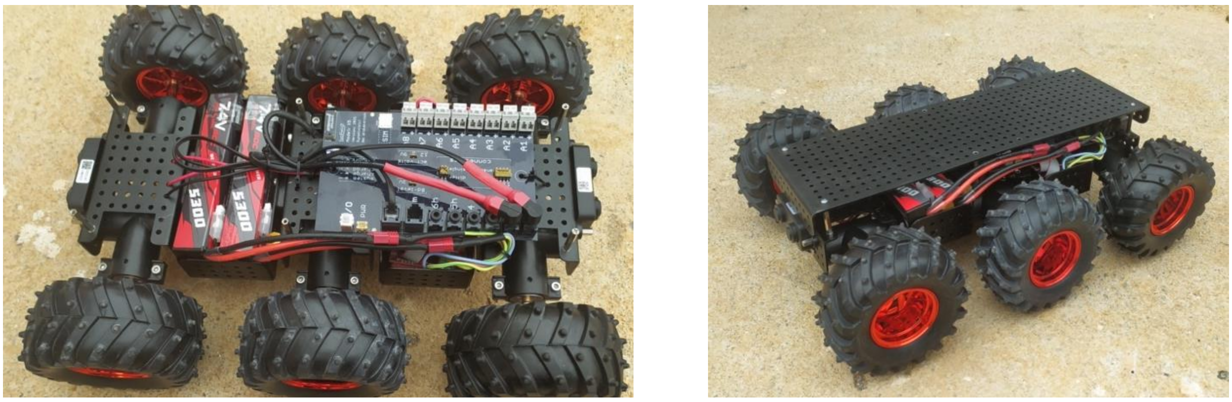
```
[{"TYPE":"COMMAND","GETDATA":"1","END":"1"}]
```

It is possible to send more than one commands in a single command message, e.g. GETDATA & MOTORSL. If the GETDATA command is sent, the AGLV will respond in a message of the following format:

```
[{"TYPE":"DATA","IC0":"1024","ADC0":"145", "END":"1"}],
```

where:

- ICx refer to I2C sensors
- ADCx refer to analogue-sensors
- etc.



(a) *(b)*

Figure 24. AGLV chassis with motors, controllers and power (a) without the lid and (b) with the lid.

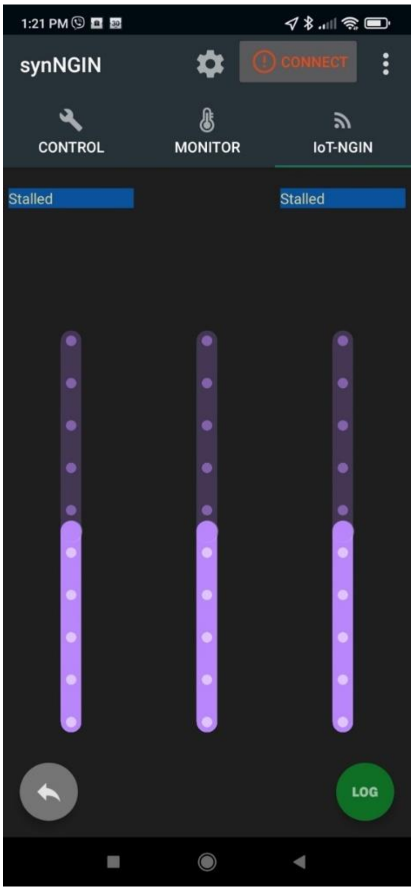


Figure 25. Custom application for controlling the AGLV at the test stages.

Camera

The Zed 2i stereo-camera procured for the AGLV is presented in Figure 26. The camera has been tested individually with the Jetson Nano board, against the captured images and basic ML models. It will be mounted on the AGLV at a later stage, in order to allow parallel development of the AI services and the AGLV movement and control operation.

Figure 26. Stereo-camera for the AGLV in UC5.

3.3. Industry 4.0 Use Cases Living Lab

3.3.1. UC6 – Human-centred safety in a self-aware indoor factory environment

Humans and robots working together in heavy industrial settings is becoming more and more common. The increment of the number of robots and automated machines and the velocity at which they work increase the productivity of the factory but also the exposure of humans to new hazards. Additionally, the interactions between humans and machines also increases in number and complexity and that is why new technologies based on Ambient Intelligence, Tactile IoT and Augmented Reality are needed to simplify and optimize these interactions.

- **Test case 1: AGV – Human collisions prevention**
  - Predict, identify and avoid collisions between humans and Autonomous Guide Vehicles (AGV).
  - Predict, identify and avoid collisions between Human Driven Vehicles (HDV) and AGVs.
  - Increase performance of human-driven vehicles by reducing emergency braking
  - Reduce scrap caused by falling of containers in an emergency braking.
  - Federate and interwork IoT for localization, high-speed wireless and edge computing and distributed AI to analyse input from multiple sensors and cameras.
- **Test case 2: AR human assistance**
  - Assist factory human workers in the warehouse with the use of AR to recognize specific AGVs and receive relevant information.
  - Deploy an AR interface that will provide information about the position of the AGVs, HDV and humans
  - Deploy an AR interface that will provide information about potential collisions identified in the test case 1

3.3.1.1. Trial site description

The use case will be conducted in the factory that Bosch has in the city of Aranjuez (Spain). In the BOSCH site, AGVs will coexist with other AGVs, human-driven vehicles, human-drawn carts and humans, who will come and go around the workshop (maintenance, logistics, production supervisors, etc.) and production workers that will stay mostly stationary but will also move now and then.

Figure 27 shows the area of the Bosch factory in which the use case will be conducted. There are seven Load Stations (blue rectangles) in which the AGVs will charge some items and drive them to the Unload stations (blue heptagons) where the items will be discharged. The path of the AGVs marked in orange is an approximation of the real path. As it was said before, there are also HDV and walking workers in the working area.

The AGVs, the HDV and the workers will be identified and positioned with different technologies developed in WP4 based on Computer Vision, Ultra-Wide Band (UWB) and Visual Light Positioning (VLP). For this purpose, cameras, VLP LED Panels and UWB beacons will be installed in the ceiling of the factory. The position of these devices shown in Figure 27 is also approximated. There will also be one fixed screen in one of the aisles of the workshop that will show the position of the detected objects as well as the warming of potential collisions. A Wi-Fi Access Point will be also installed in the workshop to bring connectivity to all the devices deployed for the use case. These two components will connect with an edge server installed in a technical room next to the workshop.

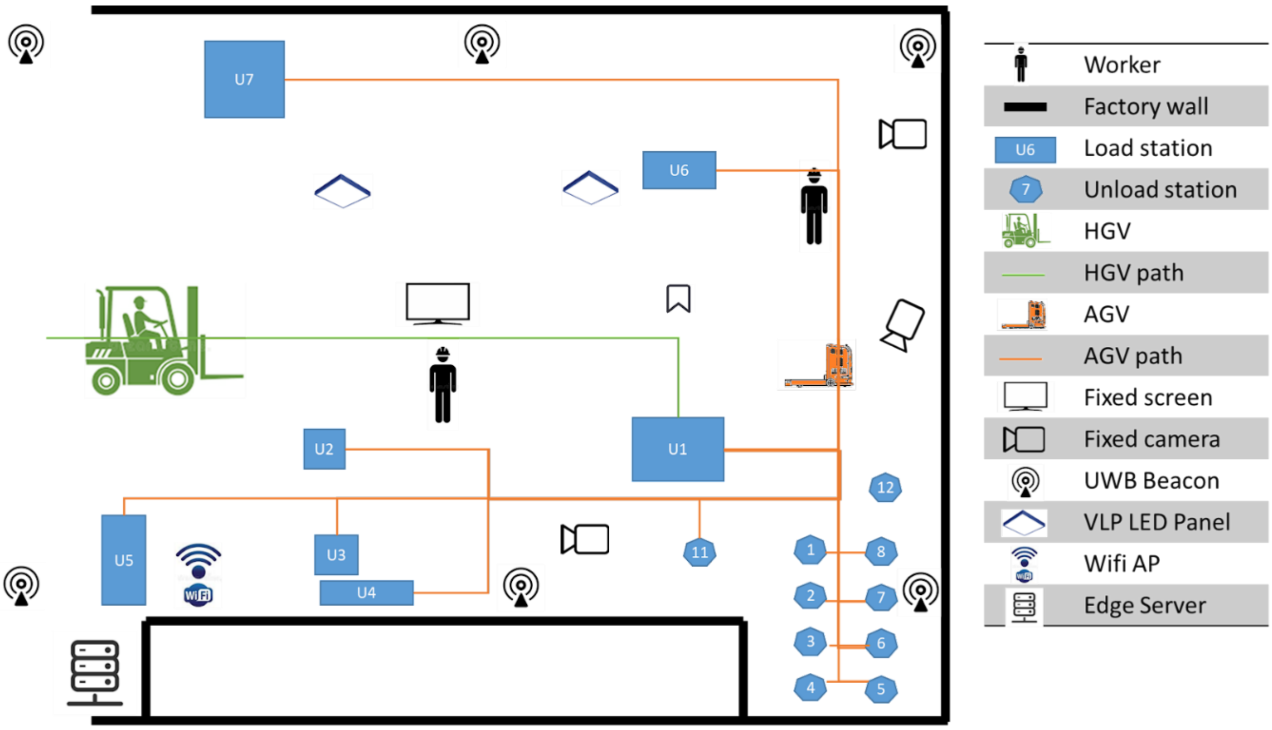


Figure 27. Trial site of UC6 in the BOSCH factory.

Figure 28 gives some more details of the main components that appear in Figure 27. It shows the potential connection interfaces for the cameras, screens, UWB tags and VLP lamps. It also depicts the components onboarded on the AGV and the HDV. The AGV and the HDV will carry an embedded computer board connected to a UWB tag and a VLP receiver, and a Wi-Fi network interfaces. Additionally, the HDV will have a screen to receive potential collisions warnings.

The edge server consists of a high-performance computer with a Graphics Processing Unit (GPU) and the network interface to connect with the Wi-Fi AP and with all the devices connected through ethernet cables. Several virtual machines (VM) will be deployed in this edge server to run the different modules produced in the IoT-NGIN project that will be tested in this use case.

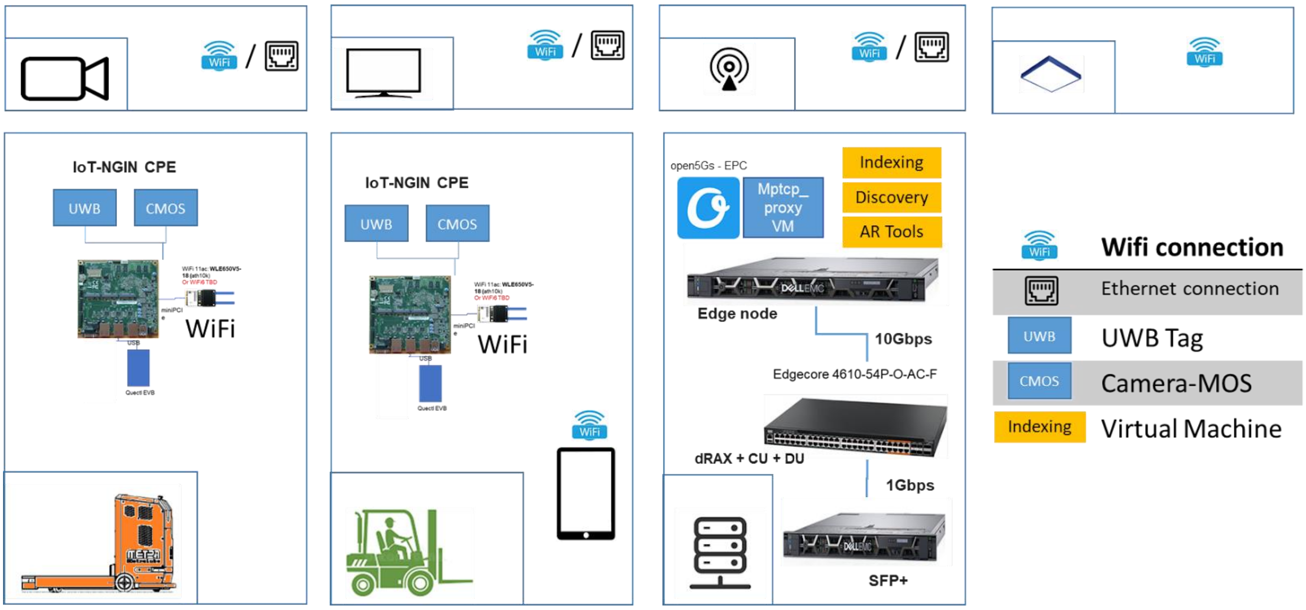


Figure 28. Details of the main components in the trial site of UC6.

3.3.1.2. Required equipment

Table 30 below shows a detailed description of the required equipment for UC6, along with its type and status (whether it is available or still be procured).

Table 30. Detailed description of the required equipment for UC6.

Equipment	Description / Specifications	Type	Status
Autonomous Guided Vehicle	Robot CARY (Metralabs). Dim [mm]: 1040x402x656	Vehicle	Available
Forklift	*TBD*	Vehicle	To be procured
Screen	Laptop MSI Pulse GL66 11UEK-061XES Intel Core i7-11800H/16GB/1TB SSD/RTX 3060/15.6"	Hardware	Available
Camera	3 x Hikvision DS-2DE2A404IW-DE3-W 2-inch 4 MP 4X Powered by DarkFighter IR Network Speed Dome	Sensor	Available
UWB beacon	At least 4x Embedded devices used as a reference for indoor positioning, composed of a UWB transceiver and a computing unit. Will be deployed in the area.	Hardware	Deployed in WP4.Will be adapted for WP7

UWB tag	Embedded device used for indoor positioning, composed of a UWB transceiver and a computing unit.	Sensor	Deployed in WP4. Will be adapted for WP7
VLP LEDs	Light infrastructure used for Visual Light Positioning. Composed of commercial LEDs and an embedded hardware to switch the LEDs and transmit the information to allow positioning. Also, a communication interface (Wi-Fi or BLE) will be deployed to allow remote configuration/tuning.	Hardware	Being deployed in WP4. Will be adapted for WP7
Wi-Fi AP	*TBD*	Hardware	To be procured
Edge server PC	*TBD*	Hardware	To be procured
GPU	A Nvidia RTX 3080 Ti GPU	Hardware	To be procured
VLP receiver	Embedded system composed of a camera, a computing unit and wireless communications to transmit the position in real-time.	Hardware	Being deployed in WP4. Will be adapted for WP7
Jetson Nano	embedded computing board with GPU	Hardware	To be procured

3.3.1.3. Data collection

The following dataset(s) have been identified as part of the use case:

- **Indoor surveillance camera videos:** video images taken from surveillance cameras installed on the ceilings of the factories where the trials will take place. The cameras record the working areas and capture the movement of workers and Automated Guided Vehicles (AGVs) while working in the factory.
- **Workers' indoor trajectories:** data derived from the previous dataset about the location of workers at different time intervals inside the trial factories. The data will be in the form of positioning data with the X and Y coordinates of the factory workers.
- **UWB raw data:** signals collected through Ultra-Wideband (UWB) units installed on AGVs at the factories participating in the trials. These signals will be sent to UWB beacons installed at the factories, which will in turn register the Time of Flight (ToF) of the received signals for further processing.
- **Indoor AGV trajectories:** data derived from the previous dataset about the location of AGVs at different intervals inside the factories participating in the trials. The data will be in the form of positioning data with the X and Y coordinates of the factory AGVs.

3.3.1.4. Alignment with IoT-NGIN technologies

The use case "UC6 – Human-centred safety in a self-aware indoor factory environment" uses technologies developed in two different work packages. It will use the IoT Device Discovery module, the IoT Device Indexing module the IoT Device Access Control module, and the AR repository from WP4 (see D4.2). The IoT Device Discovery module is divided into different methods and three of which will be used in this use case (computer vision, Ultra-Wide Band and Visual Light Positioning). The use case will also need the Machine Learning as a Service framework from WP3. The alignment of UC6 with these technologies is detailed in Table 31.

Table 31. Alignment of UC6 with the relevant IoT-NGIN technologies

WP3 – MLaaS framework	
Description	This technology will be used for the training of the computer vision model based on Deep Learning that will detect the AGVs, HDV and operators working in the Bosch factory
Adaptation and fine-tuning	The algorithm to be train in the MLaaS platform will need to be trained with tag images of the AGVs, HDV and workers of the factory
Deployment	The technology for the training of the model will be deployed in the cloud. The technology for the inference will be deployed in the edge
Related requirements	**REQ_IN1_F03** – All potential obstacles are identified and correctly classified (human, human-driven vehicle, AGV, others). Information on position and movement is provided in real-time **REQ_IN1_NF03** – Edge computing resources shall be robust and horizontally scalable **REQ_IN1_NF04** – Resources must ensure minimum latency **REQ_IN1_NF07** – The algorithm must consider that a human-driven vehicle might be in the factory **REQ_IN1_NF08** – No personal data is gathered or processed, so that it is not possible to identify any person on the shop floor
Related KPIs	**KPI_IN1_01** – Collisions of AGVs with humans or human-guided vehicles = 0 **KPI_IN1_02** – Deviation of actual route time to the planned time < 5% of average planned time
WP4 – IoT device discovery – Computer Vision	
Description	This technology will be used for the recognition and positioning of the AGV, human driven vehicles and human operators working in a defined area of the Bosch factory.

Adaptation and fine-tuning	This technology is based on a trained machine learning algorithm consisting in convolutional neural networks. For this use case, the algorithm will be retrained with the MLaaS module using tagged images of the AGVs, HDV and factory workers.
Deployment	This technology requires the deployment of cameras which will be needed to be installed in specific positions and orientations. The cameras will need to be calibrated. The software for recognition and positioning will be installed in the edge server of the factory.
Related requirements	**REQ_IN1_F03** – All potential obstacles are identified and correctly classified (human, human-driven vehicle, AGV, others). Information on position and movement is provided in real time. **REQ_IN1_F10** – Real-time position tracking **REQ_IN1_NF03** – Edge computing resources shall be robust and horizontally scalable **REQ_IN1_NF04** – Resources must ensure minimum latency **REQ_IN1_NF07** – The algorithm must consider that a human-driven vehicle might be in the factory **REQ_IN1_NF08** – No personal data is gathered or processed, so that it is not possible to identify any person on the shop floor
Related KPIs	**KPI_IN1_01** – Collisions of AGVs with humans or human-guided vehicles = 0 **KPI_IN1_02** – Deviation of actual route time to the planned time < 5% of average planned time
WP4 – IoT device discovery – Non-visual – Ultra-Wide Band (UWB)	
Description	The technology will be used for the positioning of the AGV and forklift vehicle in a defined area of the Bosch factory as one of the IoT Device discovery methods provided by WP4.
Adaptation and fine-tuning	The reference infrastructure devices (UWB beacons) will be installed in the area of the factory. Hardware will be adapted to fit the needs of the scenario and the powering capabilities. The UWB tag will be installed in the AGV/forklift. Hardware adaptations will be performed to fit with the requirements of the scenario. Calibrations of the algorithm might be necessary depending on the features of the scenario. Also, optimizations of the positioning algorithm might be necessary to improve the performance of the system in None-Line-of-Sight (NLOS) situations.
Deployment	As commented, hardware devices (UWB beacons and tags) will be installed in the factory and in the vehicles. The software for positioning (based on distance measurements and trilateration) will run in the embedded location unit.

	Additionally, distance measurements to the different UWB beacons might be sent to the edge server on the factory and saved as csv to allow the application of optimized location algorithms.
Related requirements	**REQ_IN1_F03** – All potential obstacles are identified and correctly classified (human, human-driven vehicle, AGV, others). Information on position and movement is provided in real-time **REQ_IN1_F10** – Real-time position tracking **REQ_IN1_NF04** – Resources must ensure minimum latency **REQ_IN1_NF08** – No personal data is gathered or processed, so that it is not possible to identify any person on the shop floor
Related KPIs	**KPI_IN1_01** – Collisions of AGVs with humans or human-guided vehicles = 0 **KPI_IN1_02** – Deviation of actual route time to the planned time < 5% of average planned time
WP4 – IoT device discovery – Non-visual – Visual Light Positioning	
Description	The technology will be used for the positioning of the AGV in a defined area of the Bosch factory as one of the IoT Device discovery methods provided by WP4.
Adaptation and fine-tuning	The reference infrastructure (VLP LEDs) will be installed in the area of the factory (in the ceiling). Hardware will be adapted to fit the needs of the scenario and the powering capabilities. The VLP receiver will be installed in the AGV. Hardware adaptations will be performed to fit with the requirements of the scenario and allow a good visibility of the ceiling. Calibration of the system and the algorithm will be necessary to adapt to the features of the scenario (e.g., height of the deployment and number of lights).
Deployment	As commented, hardware devices (VLP LEDs and VLP receivers) will be installed in the factory and in the vehicles, respectively. The software for positioning (based on distance measurements and trilateration) will run in the embedded location unit.
Related requirements	**REQ_IN1_F03** – All potential obstacles are identified and correctly classified (human, human-driven vehicle, AGV, others). Information on position and movement is provided in real-time **REQ_IN1_F10** – Real-time position tracking **REQ_IN1_NF04** – Resources must ensure minimum latency **REQ_IN1_NF08** – No personal data is gathered or processed, so that it is not possible to identify any person on the shop floor
Related KPIs	**KPI_IN1_01** – Collisions of AGVs with humans or human-guided vehicles = 0

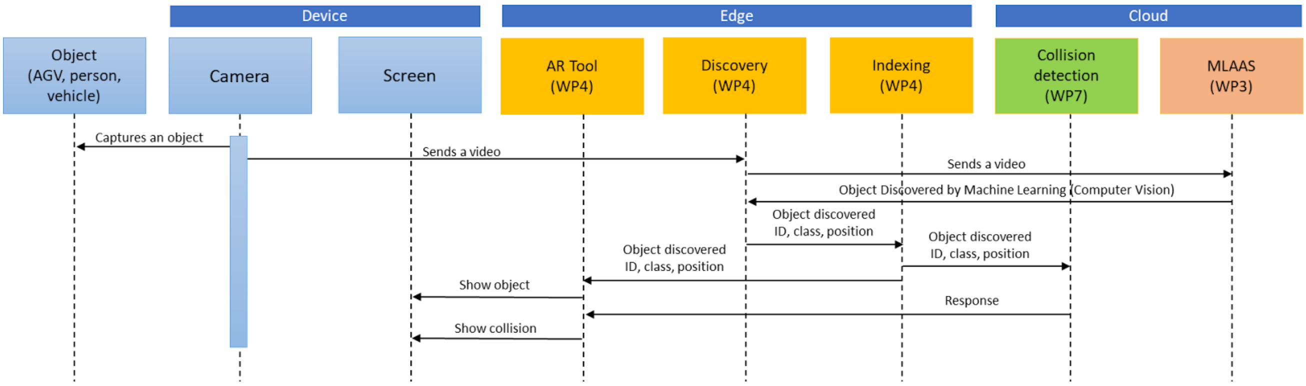
	KPI_IN1_02 – Deviation of actual route time to the planned time < 5% of average planned time
WP4 – IoT device indexing	
Description	This technology will be used for continuous registration of the position, class and ID (or pseudo-ID) of the AGV, HDV and workers discovered by the IoT Device Discovery technologies. This technology will also provide the registered information to the collision detection module and to the AR tools
Adaptation and fine-tuning	The publish-subscribe mechanisms will be adapted to connect the IoT Device Indexing with the IoT Device Discovery, the collision detection module and the AR tools
Deployment	This module will be deployed in the edge server installed in the factory. This module does not require any specific hardware to be deployed
Related requirements	**REQ_IN1_F06** – The service has to provide real-time information of all the moving things and workers in the factory
Related KPIs	**KPI_IN1_01** – Collisions of AGVs with humans or human-guided vehicles = 0 **KPI_IN1_02** – Deviation of actual route time to the planned time < 5% of average planned time
WP4 – IoT device access control	
Description	This module will be use in this use case to manage the access of the users of the AR tools to the information of the discovered devices.
Adaptation and fine-tuning	The IoT device access control will be adapted to interact with the IoT Device Indexing module and the AR APIs of the use case.
Deployment	This module will be deployed in the edge server installed in the factory. This module does not require any specific hardware to be deployed.
Related requirements	**REQ_IN1_NF08** – No personal data is gathered or processed, so that it is not possible to identify any person on the shop floor
Related KPIs	*N/A*
WP4 – IoT AR toolkit	
Description	This technology will be used in the use case to assist the human workers in the assembly line in two different ways • To show the position of the AGVs, workers and objects that are behind the racks and not visible from a specific aisle and prevent accidents.

	• To provide information of the AGVs to the operators of the assembly line through an AR interface.
Adaptation and fine-tuning	The AR software will need to be adapted for this use case • The AR software will get the position and the ID of different objects from the Indexing Module and show them with AR in a fixed screen installed in one of the aisles of the factory. • The AR software will show information of the AGVs detected by the IoT Device Discovery module. The information of the AGVs will be read from external files.
Deployment	The AR software will be deployed in edge devices. • It will be deployed in a fixed tablet or laptop to show the position of the objects (AGVs, forklift, workers, etc.). • It will be deployed in a cell phone with a camera to show information of the AGVs
Related requirements	**REQ_IN1_F06** – The service has to provide real-time information of all the moving things and workers in the factory **REQ_IN1_F03** – All potential obstacles are identified and correctly classified (human, human-driven vehicle, AGV, others). Information on position and movement is provided in real-time **REQ_IN1_NF07** – The algorithm must consider that a human-driven vehicle might be in the factory **REQ_IN1_NF08** – No personal data is gathered or processed, so that it is not possible to identify any person on the shop floor
Related KPIs	**KPI_IN1_01** – Collisions of AGVs with humans or human-guided vehicles = 0 **KPI_IN1_02** – Deviation of actual route time to the planned time < 5% of average planned time

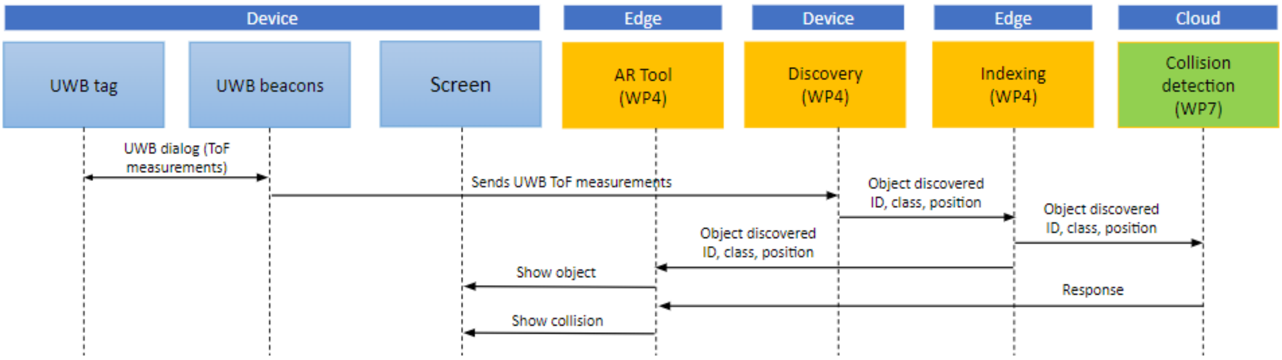
3.3.1.5. Use case sequence diagrams

The sequence diagrams in this section represent 4 main scenarios in the use case, being split into the two test cases described at the beginning of Section 3.3.1as follows:

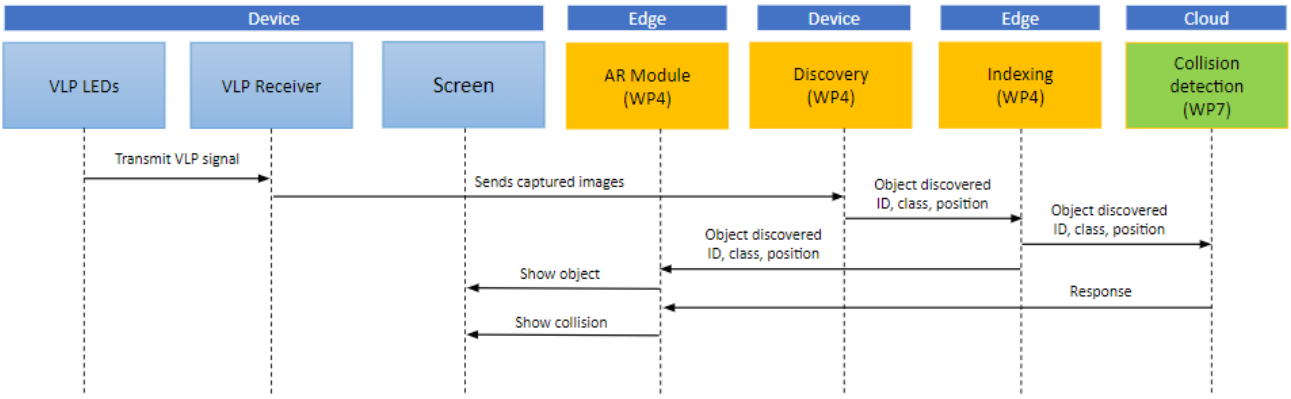
- **Test case 1: AGV – Human collisions prevention** (Figure 29)
  - IoT device discovered by camera
  - IoT device discovered by UWB
  - IoT device discovered by VLP
- **Test case 2: AR human assistance** (Figure 30)
  - AR device interaction



(a) IoT device discovered by computer vision



(b) IoT device discovered by UWB



(c) IoT device discovered by VLP

Figure 29. Sequence diagram of UC6 – Test case 1 – Human collisions prevention.

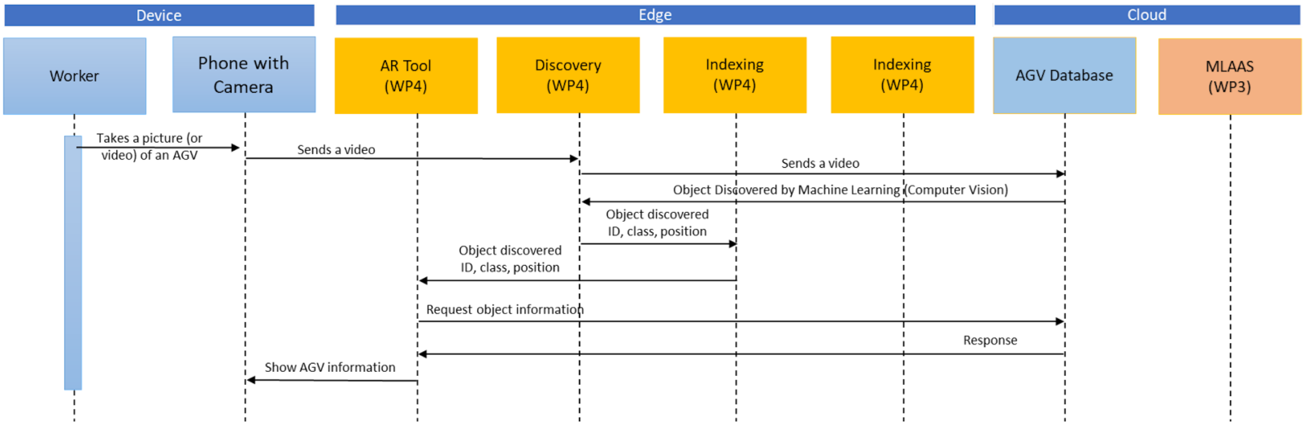


Figure 30. Sequence diagram of UC6 – Test case 2 – AR human assistance.

3.3.1.6. Testing and validation procedures

Validation of the IoT Device Discovery by Computer Vision

This technology will be validated by analysing the following several metrics:

- Accuracy of the object detection: with the Intersection over union and the mean average precision (see D4.2)
- Accuracy of the object tracking: calculating the Multiple Object Tracking Accuracy and the Multi Object Tracking Precision
- Area covered by the cameras
- Minimum object size detection: minimum size of the object in pixels
- Accuracy of the object positioning: in meters and compared by a ground truth.
- Frame rate: number of images processed per second
- The validation will be done in three different stages. The first test will be done in a lab in I2CAT, and the second and final validations will be in the Bosch factory in Aranjuez.

Validation of the IoT Device Discovery by Ultra-Wide Band

This technology will be validated by analysing the following metrics:

- Accuracy of the position of the object: Based the average measurements obtained for fixed well-known positions precisely measured.
- Accuracy of the object tracking: Based on a replicable path defined in the area as ground truth.
- Anchors density: Number of anchors and area covered by the solution.
- Update capacity: Number of locations per minute.

Validation of the IoT Device Discovery by Visual Light Positioning

This technology will be validated by analysing the following metrics:

- Accuracy of the position of the object: Based the average measurements obtained for fixed well-known positions precisely measured.
- Accuracy of the object tracking: Based on a replicable path defined in the area as ground truth.

- Area covered by the VLP system.
- Lights density: Distance between lights (LEDs) necessary for the positioning.
- Update capacity: Number of locations per minute.

Validation of the IoT Device Indexing

This module does not require any specific hardware for this use case. The validation will be done testing the interoperability of the module with the IoT Device Discovery module and the AR tools of the use case. This validation will be done first in the i2cat servers and then in the edge server installed in the factory for the use case.

Validation of the Collision Detection

This technology will be validated by analysing the following metrics:

- Collision detection time: the time needed by the module to analyse the trajectories of the vehicles and workers to detect a potential collision.
- Collision detection refresh frequency: the frequency at which the potential collisions are checked by the module. In other words, how many times per second the Collision Detection module can be executed.
- Time to collision warming: how much time in advance the warming is received by the end user before the potential collision occurs (depending on the velocity of the vehicles).

Validation of the AR interaction tools

These tools will be validated by testing that the AR software is correctly working in the edge devices (tablet, laptop and cell phone). Then, the interoperability of the APIs with the IoT Device Indexing, IoT Device Discovery and Collision Detection modules will be tested. Finally, the AR software deployed in the edge devices will be tested in the factory with real AGVs and people walking around the working area.

Validation of the MLaaS framework

This technology will be validated together with the IoT Device Discovery module based on Computer vision.

3.3.1.7. Execution timeline

The execution timeline of UC6, divided into multiple phases, is detailed in Table 32 below.

Table 32. Execution timeline of UC6.

Phase	Estimated start date	Estimated end date	Notes
Trial set-up and equipment procurement	M16	M18	- AGVs routes and area covered defined - Sensors location, anchors and powering defined - Server location and connectivity defined

			- Initial test measurements - Equipment procurement
Initial implementation and validation	M20	M24	- Sensors deployment in final position - Objects position measurements tested and validated - 5G and Wi-Fi AP installation
Intermediate implementation and validation	M30	M36	- Indexing module deployment - Collision detection module deployment - Full demo validated
Final implementation and validation	M16	M18	- AGVs routes and area covered defined - Sensors location, anchors and powering defined - Server location and connectivity defined - Initial test measurements - Equipment procurement

3.3.1.8. Initial results

Some initial tests have been performed to validate the UWB-based IoT Device Discovery. The details of the test are explained hereafter.

Hardware

For the deployment two type of devices have been deployed in the scenario:

- UWB Anchors, which are the static elements that make up the UWB infrastructure and the location area.
- The UWB tag, as the mobile element to be located.

At the hardware level, both devices (anchor and tag) contain the same elements:

- The communication module: The DWM1001 Development Board, which includes the UWB transceiver DW1001C and a Nordic Semiconductor nRF52832.
- The processing module: An Espressif ESP32 development board.
- A Li-ion rechargeable battery.

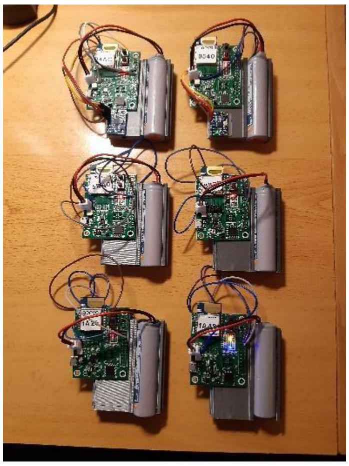


Figure 31. Devices employed in the UWB tests.

Scenario

The UWB-based Real Time Location System (RTLS) developed by i2CAT has been tested in an industrial bay located in the city of Barcelona. This building can be considered as a realistic scenario, as it is similar to the characteristics of the targeted BOSCH facilities from Trial 4 in terms of dimensions and presence of obstacles.

A UWB network has been deployed by means of 4 anchors that form a trapezoid altogether, thus creating a location area of 283.28 m2 (see Figure 2). The reference system uses the position of the anchor master as origin (0, 0) and uses the clock of this device to synchronize the rest of elements of the network.

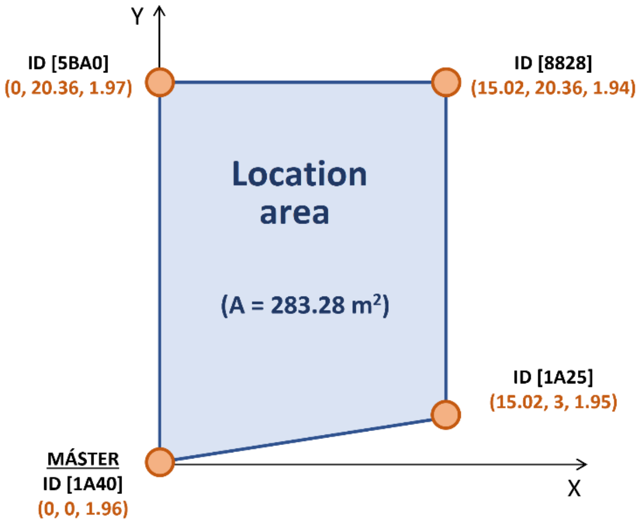


Figure 32. Location area of the test.

The height of the anchors was established at 2 meters using portable poles to make the deployment easier. It is worth noting though that this 'z' dimension is not used in final results, so that the tag location is only expressed in 2 dimensions (that is, 'x' and 'y').

The devices were configured to perform up to 5 ranging measurements per second. The resulting information was sent through the Wi-Fi interface to a purpose-oriented cloud platform for the analysis and verification of the measurements.

Metallic shelves were also deployed in the test area in order to emulate some obstacles that hinder the signal propagation between the anchors and the tags. Concretely, the UWB tags were placed in the ground between the two shelves in-line with a separation of 80cm between each other (as illustrated in Figure 33).

Results of the location test

Figure 33 shows the obtained results in the 5 different considered positions. Whereas blue crosses represent each one of the estimated tag positions, red circles show the average of these estimations for each considered position. Real tag and anchor positions are represented with yellow and purple circles, respectively. Lastly, Table 33 compiles the most significant information in a quantitative way.

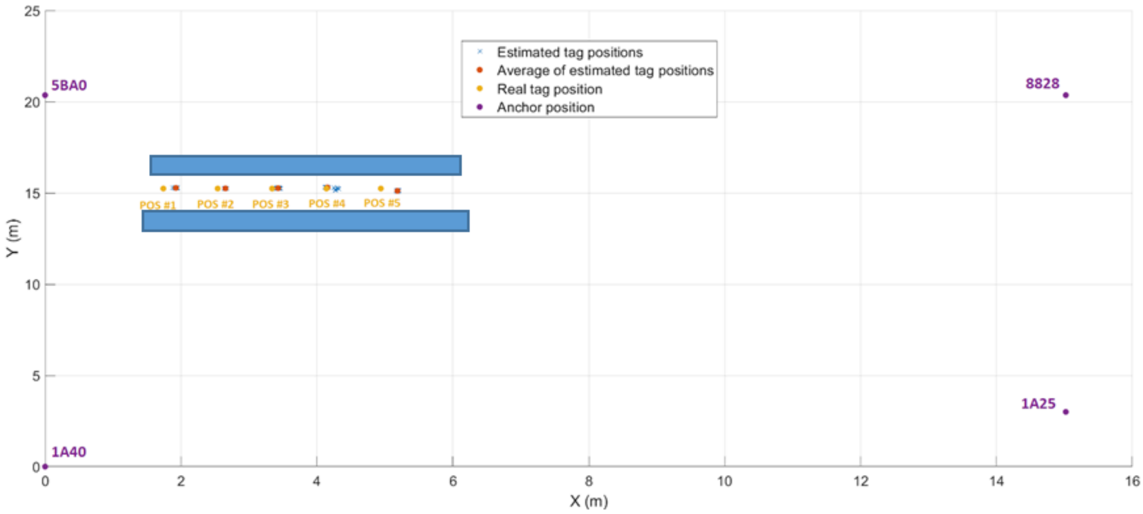


Figure 33. Estimated tag positions resulting from the location system.

Table 33. Summary of results from the IoT Device Discovery test.

Positions	Real tag position		Nr of samples	Average of estimated tag positions		Standard deviation of estimated tag positions		2D-Error (cm)
	X (m)	Y (m)		X (m)	Y (m)	X (cm)	Y (cm)	
Pos #1	1.74	15.24	181	1.9243	15.2788	0.91	0.55	18.83
Pos #2	2.54	15.24	159	2.6539	15.2477	0.62	0.49	11.41
Pos #3	3.34	15.24	161	3.4290	15.2627	0.91	0.66	9.18
Pos #4	4.14	15.24	54	4.1547	15.2993	4.96	3.29	6.12
Pos #5	4.94	15.24	162	5.1853	15.1184	0.78	0.68	27.38

In all cases, the average position generated by the location system is very close to the real position of the tag. In fact, the average error is always below 30 cm (ranging from 6 to 28 cm in function of the considered position), thus proving the high accuracy of the developed localization system.

The precision of the collected samples (considering precision as the quality of two or more measurements of being closer each other regardless their accuracy) has been computed by means of the standard deviation. In all cases except for position #4, data provides high precision, with X-Y standard deviation lower than 1 cm.

As for position #4, the scarce number of collected samples and the observed variability in some of them has affected its precision, being the standard deviation in X and Y axis of 4.96 and 3.29 cm, respectively. In any case, and as it was previously described, average accuracy in position #4 was not impacted by the lesser number of collected samples.

3.3.2. UC7 – Human-centred Augmented Reality assisted build-to-order assembly (ABB Facility)

The AR use case will be located at ABB's facilities and involves the assembly and wiring of ABB's drive cabinet products. Digital models of the cabinets are developed which contain both mechanical and electronic CAD data. These digital models are used to visualize the different assembly phases to the assembly worker in the proprietary Smart Wiring™ software created by EPLAN. The models are also used to create an AR application for training, sales, and/or maintenance purposes.

3.3.2.1. Trial site description

The use case will take place at ABB's Helsinki factory site in the cabinet production facility. The main UC component is the digital model created by combining MCAD data (generated by Creo™ software) and ECAD data (generated by EPLAN's software suite). The digital model is then used to visualize assembly steps in EPLAN's Smart Wiring™ software, and to create an AR application utilizing the repository of software tools provided by T4.4.

3.3.2.2. Required equipment

Table 34 below shows a detailed description of the required equipment for UC7, along with its type and status (whether it is available or still be procured).

Table 34. Detailed description of the required equipment for UC7.

Equipment	Description / Specifications	Type	Status
Server / Edge server	Capable of running containers / Kubernetes and NGIN components.	Server	To be procured
Mobile device	Mobile phone / tablet with camera. Capable of running the AR app.	End device	Available
AR IDE / SDK	A framework for developing the AR application. Should have tools for importing CAD models.	Software	To be procured

Smart Wiring™	Proprietary system tracking the wiring status during assembly.	Software	Available

3.3.2.3. Data collection

The following dataset has been identified as part of the UC:

- **CAD data:** digital model of the drive cabinet that will be used to visualize assembly steps in the Smart Wiring™ software and in AR application development.

3.3.2.4. Alignment with IoT-NGIN technologies

Table 35 below shows the IoT-NGIN technologies relevant for UC7. For each technology, a description of its role is provided along with any adaptation it might need to be used in the UC, deployment details and related UC requirements and KPIs.

Table 35. Alignment of UC7 with the relevant IoT-NGIN technologies.

WP4 – IoT device discovery – Non-visual (QR code)	
Description	Cabinet has a QR-code which can be scanned using a mobile app to identify the type of cabinet in question and fetch the relevant information from a server.
Adaptation and fine-tuning	N/A
Deployment	Deployed to local private server.
Related requirements	**REQ_IN2_F02** – The application must provide information through touch screens and public displays on the shop floor **REQ_IN2_F03** – The application needs a GUI that always shows the relevant data and adjusts itself to the current state **REQ_IN2_F12** – The user can choose the different views as well as the process data and charts to be displayed **REQ_IN2_NF05** – No personal data is gathered or processed, so that it is not possible to identify any person on the shop floor
Related KPIs	N/A
WP4 – IoT AR toolkit	
Description	The AR software & tools provided by task 4.4 will be used to create an AR application which utilizes the digital model of the cabinet. The AR application

	can manipulate the digital model and can be used for training, sales and/or maintenance purposes.
Adaptation and fine-tuning	Need for CAD-model importing. The CAD model developed in the use case needs to be imported into the AR application development environment. E.G. Unity, Unreal Engine, and Vuforia Studio have existing proprietary tools for importing CAD-models.
Deployment	The AR application will run on mobile devices as an app.
Related requirements	**REQ_IN2_F03** – The application needs a GUI that always shows the relevant data and adjusts itself to the current state **REQ_IN2_F05** – The application has to recognize every stage and components needed to complete every stage of the assembly line **REQ_IN2_F08** – The modalities of the service will be training employers, assembly line and customizable phase **REQ_IN2_F11** – It is possible to customize the GUI of the application for different user groups and different phases: Production, process, asset and energy **REQ_IN2_NF05** – No personal data is gathered or processed, so that it is not possible to identify any person on the shop floor
Related KPIs	N/A

3.3.2.5. Use case sequence diagrams

Figure 34 below shows a sequence diagram of UC7, depicting the involved actors in the UC and their interactions with the relevant IoT-NGIN technologies and components.

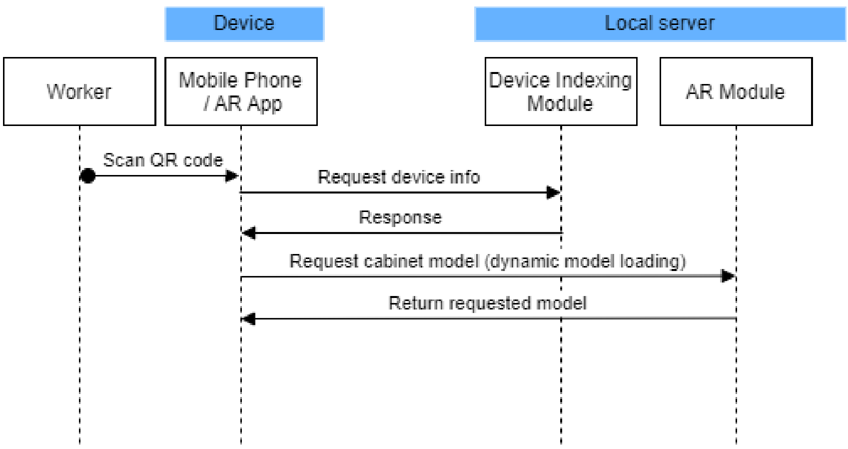


Figure 34. Sequence diagram of UC7.

3.3.2.6. Testing and validation procedures

Technical validation of the UC

- The AR module and tools developed in T4.4 will be validated via the development of the AR app.
- QR codes will be used to identify the drive cabinet with the mobile app, validating at least part of the device discovery / indexing module.

Validation stages

- Initial validation and testing will be done by the development team in a controlled environment.
- Final validation will be done in a live production line with production personnel.

User experience testing / validation

- Factory / Assembly workers will validate the use of the digital models in the Smart Wiring software and the use of the AR app
- A survey will be conducted to evaluate the user experience and whether the new tools have improved productivity, quality and overall working conditions.

3.3.2.7. Execution timeline

The execution timeline of UC7, divided into multiple phases, is detailed in Table 36 below.

Table 36. Execution timeline of UC7.

Phase	Estimated start date	Estimated end date	Notes
Trial set-up and equipment procurement	M13	M21	- Server setup - AR tools (IDE / SDK)
Initial implementation and validation	M16	M20	- First complete digital model
Intermediate implementation and validation	M21	M27	- Initial version of AR app. NGIN components running on local server.
Final implementation and validation	M27	M34	

3.3.2.8. Initial results

An initial digital model has been developed for one of the drive cabinet models. Model importing to AR has been tested with Unity[7] and Vuforia Studio[8]. The import was successful with both IDEs, however Unity provided more powerful tools for programmatically manipulating the individual mechanical and electrical components of the model, e.g., highlighting or hiding a specific component or part.

3.3.3. UC8 – Digital powertrain and condition monitoring

In the context of this use case, the term powertrain is used to describe the equipment involved in transforming energy provided by a power source into useful work done by some machine. In industrial applications, such equipment typically includes an AC motor and a variable speed drive responsible for its control. Aside from direct process control, data gathered in such powertrain applications is also used for higher-level supervisory tasks and condition monitoring. The goal in this use case is to leverage IoT-devices, 5G telecommunication and cloud platforms to utilize novel ideas in the area of data engineering, analytics and condition monitoring.

3.3.3.1. Trial site description

The use case will take place at ABB's laboratory for high power drives located in Helsinki. The lab has up to 6 powertrains with varying sizes of motors. The complete setup for a single powertrain is depicted in Figure 35.

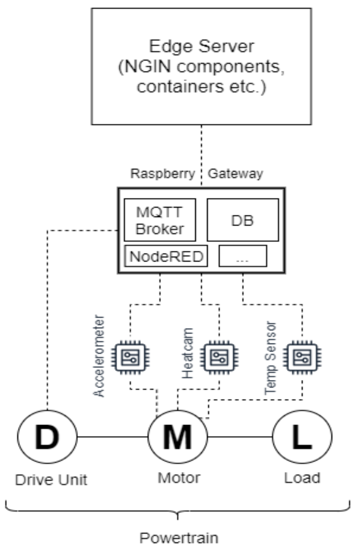


Figure 35. Powertrain setup for UC8 at ABB's facilities.

[7] Augmented Reality Development Software – Unity : https://unity.com/unity/features/ar
[8] Vuforia Studio Augmented Reality for Industrial Enterprise – PTC: https://www.ptc.com/en/products/vuforia/vuforia-studio

3.3.3.2. Required equipment

Table 37 below shows a detailed description of the required equipment for UC8, along with its type and status (whether it is available or still be procured).

Table 37. Detailed description of the required equipment for UC8.

Equipment	Description / Specifications	Type	Status
Edge server	Capable of running containers/Kubernetes and IoT-NGIN components.	Server	To be procured
Raspberry PI gateway	Used to collect the various sensor data gathered from a powertrain ensemble.	Gateway	Available
Drive Units	Drive units used for motor control. Include IoT-panels which can be used to send data via 4G/5G.	End device, sensor	Available
Motors	The powertrains in the lab consist of 2 motors, one acts as the application load, while the other is controlled by the drive device being examined.	End device	Available
Smart Sensor	A Bluetooth Low Energy (BLE) sensor that can be attached to the side of a motor. Connected to the raspberry PI gateway.	Sensor	Available
PLC (accelerometers + temperature sensors)	A Programmable Logic Controller (PLC) device used to connect accelerometers and temperature sensors.	Sensor / HW	Available
Heat camera	A BLE sensor that generates a 2D heatmap view. Connected to the raspberry PI gateway.	Sensor	Available

3.3.3.3. Data collection

The following dataset(s) have been identified as part of the use case:

- **Drive data:** drive operating data gathered via its IoT-Panel: speed, torque, current, voltage, etc., used for operation and condition monitoring.
- **Smart sensor data:** acceleration and temperature related KPI values.
- **PLC data:** high frequency accelerometer data and temperature data.

3.3.3.4. Alignment with IoT-NGIN technologies

Table 38 below shows the IoT-NGIN technologies relevant for UC8. For each technology, a description of its role is provided along with any adaptation it might need to be used in the UC, deployment details and related UC requirements and KPIs.

Table 38. Alignment of UC8 with the relevant IoT-NGIN technologies.

WP3 – MLaaS framework	
Description	Sensor data gathered from the powertrain(s) will be for machine learning purposes. The goal is to detect incipient faults from the gathered sensor data.
Adaptation and fine-tuning	The various sensor data related to a powertrain will be gathered to a Raspberry PI gateway device. The gateway device can manipulate & process the data freely and forward it in a suitable format to the big data and ML framework components.
Deployment	Edge and cloud. Initially a single powertrain will be deployed and used for training. Later on, combining data from multiple powertrains and/or model sharing will be attempted.
Related requirements	**REQ_IN3_F03** – IoT-NGIN should provide a framework to implement federated learning **REQ_IN3_NF01** – Support for batch data processing
Related KPIs	**KPI_IN3_01** – Different types of sensors' data to be analysed > 5 **KPI_IN3_02** – Number of implemented ML models >/= 3
WP3 – Polyglot model sharing component	
Description	There is a large install base of drive units globally. Model sharing could be used to implement 'big data' machine learning scenarios, utilizing data from multiple different drives (/powertrains).
Adaptation and fine-tuning	Data gathered from identical drive units may differ due to differences in operating point and mechanical setup (motor type, bearing type etc.)
Deployment	In this use case, model sharing will be tested out using the drive units available in ABB's laboratory facility.
Related requirements	**REQ_IN3_F02** – IoT-device data must be protected so that only the owner of the device has access to the data. **REQ_IN3_F03** – IoT-NGIN should provide a framework to implement federated learning

Related KPIs	**KPI_IN3_03** – Number of digital twins to be created using an IoT-NGIN conformant pipeline > 3
WP4 – IoT device discovery and indexing	
Description	Drive devices and/or gateway devices need to be registered and made available to other IoT-NGIN components and use case specific applications (In this case a condition monitoring application)
Adaptation and fine-tuning	The registering and availability of devices should also leverage the semantic twin concept developed in T5.5, which will be used in this use case.
Deployment	Edge server
Related requirements	**REQ_IN3_F01** – IoT-device data must be accessible to device owner from edge node to generate a holistic view **REQ_IN3_F02** – IoT-device data must be protected so that only the owner of the device has access to the data.
Related KPIs	**KPI_IN3_03** – Number of digital twins to be created using an IoT-NGIN conformant pipeline > 3
WP5 – Semantic Twins	
Description	Semantic Twins (previously referred to as Meta-Level Digital Twins) will be used to create a condition monitoring application. The application will be able to browse and process twin documents in order to access relevant data and APIs for condition monitoring purposes.
Adaptation and fine-tuning	N/A
Deployment	Local deployment / edge.
Related requirements	**REQ_IN3_F01** – IoT-device data must be accessible to device owner from edge node to generate a holistic view **REQ_IN3_F02** – IoT-device data must be protected so that only the owner of the device has access to the data. **REQ_IN3_F03** – IoT-NGIN should provide a framework to implement federated learning **REQ_IN3_NF01** – Support for batch data processing
Related KPIs	**KPI_IN3_03** – Number of digital twins to be created using an IoT-NGIN conformant pipeline > 3

3.3.3.5. Use case sequence diagrams

Figure 36 below shows a sequence diagram of UC8, depicting the involved actors and their interactions with the relevant IoT-NGIN technologies.

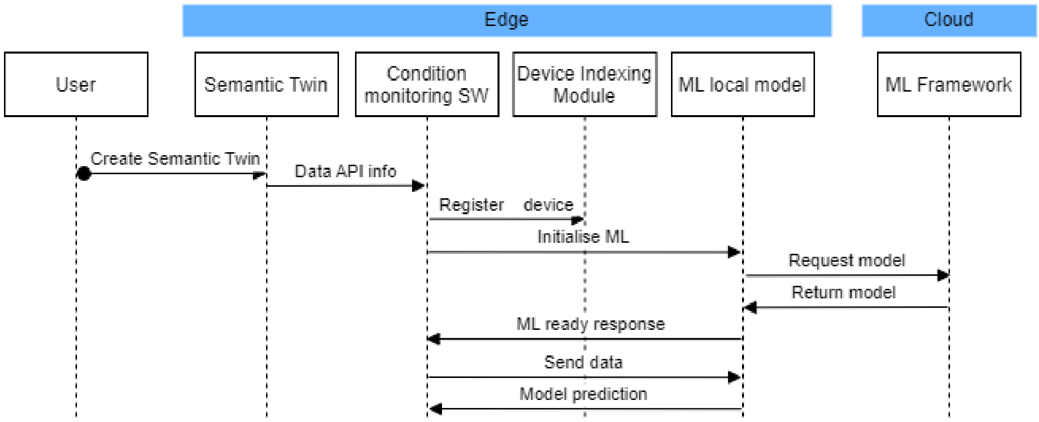


Figure 36. Sequence diagram of UC8.

3.3.3.6. Testing and validation procedures

Technical validation of the UC

- The machine learning technologies developed in IoT-NGIN will be validated in this use case. KPI_IN3_01 states that >5 different types of sensor data will be analysed, and KPI_IN3_02 specifies that 3 or more machine learning models will be applied.
- Devices and data will be made available digitally utilizing the results of tasks 4.2 and 5.5. KPI_IN3_03 specifies that digital representations of more than 3 powertrains will be produced in this use case.

Validation stages

- Individual components will first be validated and tested in development environments without actual physical equipment.
- Final validation will be done in the high-power laboratory using live equipment.

3.3.3.7. Execution timeline

The execution timeline of UC8, divided into multiple phases, is detailed in Table 39 below.

Table 39. Execution timeline of UC8.

Phase	Estimated start date	Estimated end date	Notes
Trial set-up and equipment procurement	M10	M16	- IoT-panel FW modifications

			- Procuring hardware and data handling implementations on gateway device
Initial implementation and validation	M16	M20	- Procure edge server - Complete semantic twin document of a powertrain and initial deployment of a semantic twin pipeline/architecture.
Intermediate implementation and validation	M21	M27	- Deploy ML components. - Integration of semantic twin with other IoT-NGIN components.
Final implementation and validation	M27	M34	

3.3.3.8. Initial results

At this stage of the use case, the following preliminary results have been obtained:

- Firmware modifications have been done to the IoT-panels of the drive units so that data can be gathered flexibly and utilized by IoT-NGIN components.
- A raspberry PI gateway device has been prepared, which can process and then forward data to IoT-NGIN components, avoiding possible integration problems down the line.
- An initial twin document has been prepared describing data endpoints of a powertrain ensemble using the W3C WoT model.

3.4. Smart Energy Grid Monitoring / Control Living Lab

3.4.1. UC9 – Move from reacting to acting in smart grid monitoring and control

In UC 9, data provided by sensors placed among the electrical distribution grid, such as Phaser Measurement Units (PMUs) and smart meters are used to monitor grid parameters in real time. An alarm is provided when parameters are out of limits and appropriate action is taken to restore the service to optimal values.

3.4.1.1. Trial site description

The Living Lab is located in Terni, in the centre of Italy, and will be conducted on the electrical distribution grid, managed by ASM Terni. ASM is a multi-utility and covers the role of DSO. Several sensors are located into Terni smart grid, such as smart meters, phasor measurement units and power quality analysers. Data are managed by a SCADA system, that collect all data and allow efficiently sharing with partners. One of the problems faced by the Distribution System Operators (DSO), especially with the spread of distributed generation, is to ensure that power quality is always adequate, and this is one of the goals of this UC.

3.4.1.2. Required equipment

Table 40 below shows a detailed description of the required equipment for UC9, along with its type and status (whether it is available or still be procured).

Table 40. Detailed description of the required equipment for UC9.

Equipment	Description / Specifications	Type	Status
Portion of the electrical distribution grid	The portion of the grid used for the test is a MV grid with 14 buses.	Infrastructure	Available
ASM server	It is a SCADA system made by Wonderware, able to monitor in real time hundreds of sensors and to store historical data.	Server	Available
Smart Meter	About 100 electrical smart meters, able to monitor active and reactive power and voltage in several buses of the grid	Sensor	Available
PMU	2 phasor measurement units, able to monitor active and reactive power, voltage, phase angle, harmonic content, etc.	Sensor	Available

3.4.1.3. Data collection

The following datasets have been identified as part of the use case:

- **Smart Meter eXtension (SMX) dataset:** Measurements of voltage, currents, and power derived by ASM energy units, collected through an MQTT protocol via public IP and / or LAN/VPN connections. To ensure secure access to the dataset, credentials will be required.
- **Phaser Measurement Units (PMU) dataset:** Measurements of voltage, currents, and power derived by ASM energy units, collected through HTTP protocol only via LAN/VPN connections, which provide built-in security access features.

3.4.1.4. Alignment with IoT-NGIN technologies

Table 41 below shows the IoT-NGIN technologies relevant for UC9. For each technology, a description of its role is provided along with any adaptation it might need to be used in the UC, deployment details and related UC requirements and KPIs.

Table 41. Alignment of UC9 with the relevant IoT-NGIN technologies.

WP3 – MLaaS framework	
Description	The MLaaS framework will be used for electrical grid operation optimization, i.e., optimizing the operation of the digital twin and determining which flexibility tool can be used.
Adaptation and fine-tuning	The technology will be developed using specific machine learning tools for optimizing electricity grids.
Deployment	The service will be carried out on the cloud and will be based on the data that is communicated by ASM and the digital twin implemented in another service. It will act on the parameters of the digital twin in order to optimize them according to the needs of the DSO.
Related requirements	**REQ_SE1_F02** – High-tech power sensors should be useful to elaborate on new strategies, in order to improve the power quality in a secure way. Smart Meter should help this process
Related KPIs	**KPI_UC9_4** – Reduce the probability of Smart Grid failure due to voltage instability at least = 25 % reduction in comparison with daily average value **KPI_UC9_5** – Increase urban Electrical Vehicles charging efficiency = 20 % in comparison with daily average value
WP3 – Deep Learning, Reinforcement Learning & Transfer Learning	
Description	ML techniques will be used for the generation and consumption forecasting for the Digital Twin to predict when there will be surges, under-voltages or other faults based on load and generation
Adaptation and fine-tuning	Based on the extensive historical data, a forecast of generation or consumption at network nodes will be assessed.
Deployment	This service will be deployed on cloud, using historical data of electrical sensors
Related requirements	**REQ_SE1_F02** – High-tech power sensors should be useful to elaborate on new strategies, in order to improve the power quality in a secure way. Smart Meter should help this process
Related KPIs	**KPI_UC9_4** – Reduce the probability of Smart Grid failure due to voltage instability at least = 25 % reduction in comparison with daily average value
WP5 – Malicious Attack Detector (MAD) and GAN based dataset generation	

Description	Malicious attack detection at the network level, applied to the data management platform of IoT-NGIN
Adaptation and fine-tuning	Systems will be used to detect attacks and protect the platform from a cybersecurity perspective.
Deployment	Cybersecurity services produced within the data management platform will be tested
Related requirements	**REQ_SE1_NF02** – Secure communication of sensitive data related to the infrastructure should be provided
Related KPIs	N/A
WP5 – Semantic Twins	
Description	A digital model of the electricity grid will be created for real-time monitoring of the distribution grid. The Digital Twin will be automatically updated on the basis of the values measured by the sensors, and will allow the electrical grid parameters to be simulated correctly.
Adaptation and fine-tuning	The digital twin of the electricity grid will be realized using electricity grid simulation software, exploiting the topological data provided by ASM and the real time data produced by the sensors.
Deployment	The digital twin will be the basic structure on which simulations will be carried out and algorithms for optimizing and monitoring the electricity grid will be developed. It will take real time data from sensors via the MQTT protocol and forecast energy consumed and produced via the AI modelling technical service.
Related requirements	**REQ_SE1_F01** – Based on sampled data, phasors are calculated with high precision and the synchronization process should be very fast. Indeed, innovative reconfiguration and self-healing schemas should rely on appropriate measurements
Related KPIs	**KPI_UC9_4** – Reduce the probability of Smart Grid failure due to voltage instability at least = 25 % reduction in comparison with daily average value **KPI_UC9_5** – Increase urban Electrical Vehicles charging efficiency = 20 % in comparison with daily average value
WP5 – Privacy-preserving Self-Sovereign Identities (SSIs)	
Description	SSIs will enable pervasive security and implement methods to control access to the digital twin of the grid.

Adaptation and fine-tuning	No adaptation need identified at this point.
Deployment	N/A
Related requirements	**REQ_SE1_NF02** – Secure communication of sensitive data related to the infrastructure should be provided
Related KPIs	**KPI_UC9_3** – Event detection time using the digital twin concept < 50 ms
WP5 – IoT vulnerability crawler	
Description	This component will identify potential vulnerabilities in ASM sensors
Adaptation and fine-tuning	No adaptation need identified at this point.
Deployment	Edge/Cloud
Related requirements	**REQ_SE1_NF02** – Secure communication of sensitive data related to the infrastructure should be provided
Related KPIs	**KPI_UC9_3** – Event detection time using the digital twin concept < 50 ms

3.4.1.5. Use case sequence diagrams

Figure 37 below shows a sequence diagram of UC9, depicting the involved actors and devices and their interactions with the relevant IoT-NGIN technologies.

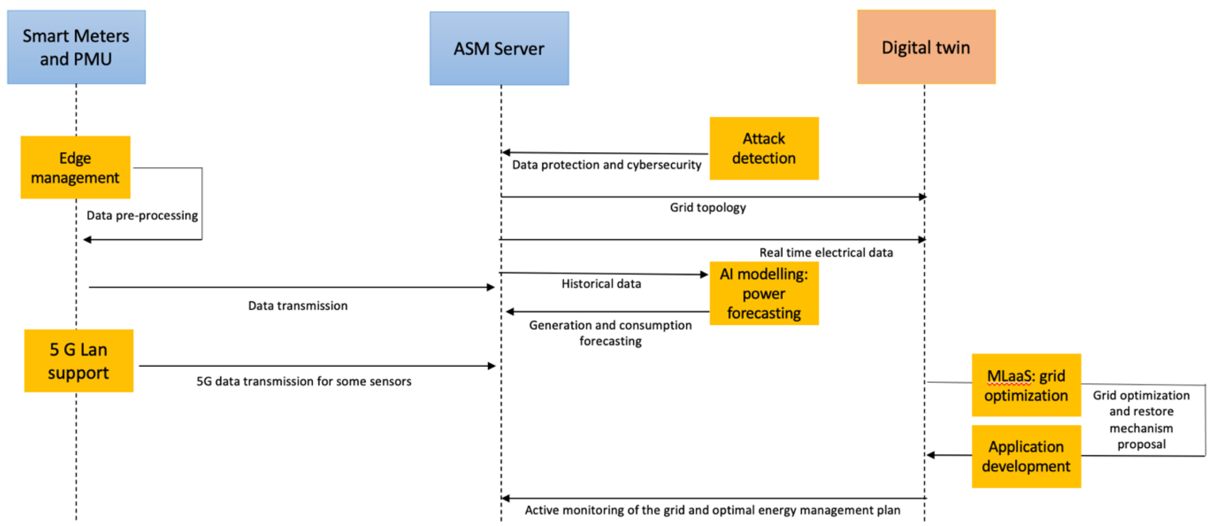


Figure 37. Sequence diagram of UC9.

3.4.1.6. Testing and validation procedures

UC 9 will be validated in the Terni electricity distribution network, combining technical partner support with network management by the DSO. In particular, data transmission, both in terms of granularity and quantity of information reported, will be evaluated, as well as the benefits from the point of view of the electricity network, i.e., identification of malfunctions and energy flexibility.

The validation will take place directly in the field, as it is a simulative activity where real data are already available. The validation phases can be the following:

- Sharing of real time and historical data
- Implementation of a digital twin of the network
- Generation and consumption forecast
- Cybersecurity analysis
- Optimisation of operation and simulation of the benefits of adopting service recovery strategies.

3.4.1.7. Execution timeline

The execution timeline of UC9, divided into multiple phases, is detailed in Table 42 below.

Table 42. Execution timeline of UC9.

Phase	Estimated start date	Estimated end date	Notes
Trial set-up and equipment procurement	M8	M15	-
Initial implementation and validation	M16	M20	-
Intermediate implementation and validation	M21	M26	-
Final implementation and validation	M27	M34	-

3.4.1.8. Initial results

During this first period of UC management, the following results have been achieved:

- The infrastructure has been defined and all sensors are placed in the Living Lab and transmit data in real time. A database with historical data is also in place.
- A new SCADA system was implemented, which collects the data produced by the different sensors and allows a more effective sharing of real-time and historical data with partners.
- The necessary technical services for UC have been identified.
- Collaboration with ATOS for load and generation forecasting and for the analysis of electricity grid optimisation was initiated.
- Collaboration with SYN and INTRA for the cybersecurity was initiated

- Collaboration with SYN for the digital twin of the grid was initiated
- Started discussions with AALTO for self-sovereign identities, to be used for the digital twin

3.4.2. UC10 – Driver-friendly dispatchable EV charging

The actors involved in the UC10 are EV Users, Charging Station Managers and DSO. The objective of this use case is to charge EVs with renewable energy, with the aim to power e-Mobility with green energy and help DSO to keep the grid stable in a condition of high penetration of distributed intermittent renewable energy plants.

3.4.2.1. Trial site description

UC10 trial site is in Terni, an industrial city in the centre of Italy. In particular, the use case will be hosted in ASM Smart Grid Active Network; ASM is the Terni municipal electricity and gas distribution network operator. Four energy substations and 180 kW PV arrays monitored in real-time will provide needed information for developing and testing a driver-friendly dispatchable EV charging mechanism in collaboration with EMOT, an Italian charging station manufacturer and e-Mobility services provider that monitors and manages electric vehicles and charging stations deployed in Terni living lab.

3.4.2.2. Required equipment

Table 43 below shows a detailed description of the required equipment for UC10, along with its type and status (whether it is available or still be procured).

Table 43. Detailed description of the required equipment for UC10.

Equipment	Description / Specifications	Type	Status
ASM server	It is a SCADA system made by Wonderware, able to monitor in real time hundreds of sensors and to store historical data.	Server	Available
EMOT server	Server with 4 core CPU + 8 GB RAM	Server	Available
Smart Meter	About 100 electrical smart meters, able to monitor active and reactive power and voltage in several buses of the grid	Sensor	Available
PMU	2 phasor measurement units, able to monitor active and reactive power, voltage, phase angle, harmonic content, etc.	Sensor	Available

PQA	6 power quality analysers, able to monitor active and reactive power, voltage, harmonic content, etc.	Sensors	Available
Electric Vehicle	4 x Renault ZOE, 2 x Nissan LEAF	Vehicle	Available
OBD	OBD is a IoT component; OBD connects to the diagnostic interface from which it can extract the information from the electric vehicle control unit	Sensor	Available
Charging Station	3 x Emotion EVO (22 kW), 1 x Emotion FAST (50 kw)	Hardware	Available
Raspberry Pi 3	Single-board computer installed inside of the charging stations to enable real-time monitoring and remote management	Hardware	Available
Emotion Spotlink	Electric Vehicle and Charging station Monitoring and Management Platform	Software	Available
Camera	Camera to perform object detection	Sensor	Available
Smartphone	Smartphone to perform augmented reality interaction with charging station	Hardware	Available
DSO Platform	Living Lab Grid Monitoring and Management Platform	Software	Available

3.4.2.3. Data collection

The following dataset(s) have been identified as part of the use case:

- **Power Quality Analysers (PQA) dataset:** Measurements of voltage, currents, and power derived by ASM energy units, collected through HTTP protocol only via LAN/VPN connections, which provide built-in security access features.
- **Charging station data:** Real-time and historical data collected from the charging stations deployed in the trial site (Terni, Italy). The data will include information about the charging station and each charging session, without any identifying information about the use of the station.
- **Electric vehicle data:** Real-Time and historical data collected from electric vehicles deployed in the trial site (Terni, Italy). The data will include battery capacity, power and life, and data about the vehicles' movement and trajectories, such as latitude, longitude, and speed.

3.4.2.4. Alignment with IoT-NGIN technologies

Table 44 below shows the IoT-NGIN technologies relevant for UC10. For each technology, a description of its role is provided along with any adaptation it might need to be used in the UC, deployment details and related UC requirements and KPIs.

Table 44. Alignment of UC10 with the relevant IoT-NGIN technologies.

WP3 – MLaaS framework – Grid forecasting	
Description	Data collected from smart meters will be used to train machine learning, obtaining a grid status forecasting system able to provide day-ahead prediction about DSO energy flexibility needs.
Adaptation and fine-tuning	The technology will be developed using specific machine learning tools to obtain an action strategy for grid balancing, i.e., an indication of how much energy flexibility is needed (kWh) and at what time of the day.
Deployment	The service will be carried out on the cloud and will be based on the data that is communicated by ASM.
Related requirements	**REQ_SE2_F10** – DSO shall be able to forecast electricity production / consumption and estimate flexibility need
Related KPIs	**KPI_UC10_3** – Reduction of reverse power flows ~ 10 kWh/day **KPI_UC10_4** – Increase EV charging efficiency, money saved: 0.05 €/kWh **KPI_UC10_5** – Increase EV charging efficiency, renewable energy > 50%
WP3 – MLaaS framework – EV flexibility provision forecasting	
Description	Data collected from electric vehicle On-Board Diagnostics (OBDs) will be used to train machine learning, obtaining a forecasting system able to provide day-ahead prediction about EV potential energy flexibility provision.
Adaptation and fine-tuning	The technology will be developed using specific machine learning tools to obtain an action strategy for flexibility provision, i.e., an indication of how much energy flexibility will be available (kWh) at DSO needed time.
Deployment	The service will be carried out on the cloud and will be based on the data that is communicated by EMOT.
Related requirements	**REQ_SE2_F07** – Charging station must provide energy data to be involved in DR campaigns; data shall be stored for result evaluation
Related KPIs	**KPI_UC10_3** – Reduction of reverse power flows ~ 10 kWh/day

	KPI_UC10_4 – Increase EV charging efficiency, money saved: 0.05 €/kWh **KPI_UC10_5** – Increase EV charging efficiency, renewable energy > 50%
WP4 – IoT device discovery and indexing	
Description	The IoT device discovery and indexing modules will be used to allow charging station detection via a camera installed on the electric vehicles.
Adaptation and fine-tuning	Computer vision models will be trained over charging station videos provided by EMOT.
Deployment	Cloud
Related requirements	**REQ_SE2_F02** – e-Mobility platform shall be enabled for user registrations **REQ_SE2_F05** – Charging station must be connected to the internet to be integrated into the platform **REQ_SE2_F06** – Electric vehicle must be connected to the internet to be integrated into the platform
Related KPIs	**KPI_UC10_4** – Increase EV charging efficiency, money saved: 0.05 €/kWh **KPI_UC10_5** – Increase EV charging efficiency, renewable energy > 50%
WP4 – IoT device access control	
Description	The IoT device access control module will enable augmented reality interaction between charging station and electric vehicle, after the charging station detection is done.
Adaptation and fine-tuning	Device Access Control Module provides access management to EMOT e-Mobility platform
Deployment	Cloud
Related requirements	**REQ_SE2_F02** – e-Mobility platform shall be enabled for user registrations **REQ_SE2_F05** – Charging station must be connected to the internet to be integrated into the platform **REQ_SE2_F06** – Electric vehicle must be connected to the internet to be integrated into the platform
Related KPIs	**KPI_UC10_4** – Increase EV charging efficiency, money saved: 0.05 €/kWh **KPI_UC10_5** – Increase EV charging efficiency, renewable energy > 50%
WP4 – IoT AR toolkit	

Description	The IoT AR toolkit will enable novel interaction between electric vehicle users and charging point operator, allowing charging session management in AR mode.
Adaptation and fine-tuning	AR tool will be adapted for smartphones application
Deployment	Cloud
Related requirements	**REQ_SE2_F02** – e-Mobility platform shall be enabled for user registrations **REQ_SE2_F05** – Charging station must be connected to the internet to be integrated into the platform **REQ_SE2_F06** – Electric vehicle must be connected to the internet to be integrated into the platform
Related KPIs	**KPI_UC10_4** – Increase EV charging efficiency, money saved: 0.05 €/kWh **KPI_UC10_5** – Increase EV charging efficiency, renewable energy > 50%
WP5 – IoT vulnerability crawler	
Description	This component will identify potential vulnerabilities in EV charging stations
Adaptation and fine-tuning	No adaptation need identified at this point.
Deployment	Edge/Cloud
Related requirements	**REQ_SE2_NF06** – Data shall be consistent, reliable, transparent and accessible only to authorized users **REQ_SE2_NF07** – Store data in a safe and tamperproof manner
Related KPIs	**KPI_UC10_1** – Time granularity for monitoring < 1 s **KPI_UC10_2** – Interaction capability > 100.000 measurement/minute
WP5 – Privacy preserving Self-Sovereign Identities (SSIs) and Interledger applications	
Description	SSIs will enable pervasive security and implement methods to control access to the EV charging stations. On the other hand, decentralized interledger bridge will enable information exchanging among different DLTs to store key information related to DR campaign from a light DLT into a more secure DLT. This will help to manage payments between different platforms for micropayments and smart contracts.

Adaptation and fine-tuning	No adaptation need identified at this point.
Deployment	N/A
Related requirements	**REQ_SE2_NF06** – Data shall be consistent, reliable, transparent and accessible only to authorized users **REQ_SE2_NF07** – Store data in a safe and tamperproof manner
Related KPIs	**KPI_UC10_1** – Time granularity for monitoring < 1 s **KPI_UC10_2** – Interaction capability > 100.000 measurement/minute
WP5 – Malicious Attack Detector (MAD) and GAN-based dataset generation	
Description	Malicious attack detection at the network level, applied to the data management platform of IoT-NGIN
Adaptation and fine-tuning	Systems will be used to detect attacks and protect the platform from a cybersecurity perspective.
Deployment	Cybersecurity services produced within the data management platform will be tested
Related requirements	**REQ_SE2_NF06** – Data shall be consistent, reliable, transparent and accessible only to authorized users **REQ_SE2_NF07** – Store data in a safe and tamperproof manner
Related KPIs	**KPI_UC10_1** – Time granularity for monitoring < 1 s **KPI_UC10_2** – Interaction capability > 100.000 measurement/minute

3.4.2.5. Use case sequence diagrams

This section contains two sequence diagrams describing the interactions of the different actors and devices involved in the use case with IoT-NGIN technologies in the context of UC10. In particular, the sequence diagrams correspond to the following:

- Figure 38 depicts the DR module and its interactions
- Figure 39 depicts the AR module and its interactions

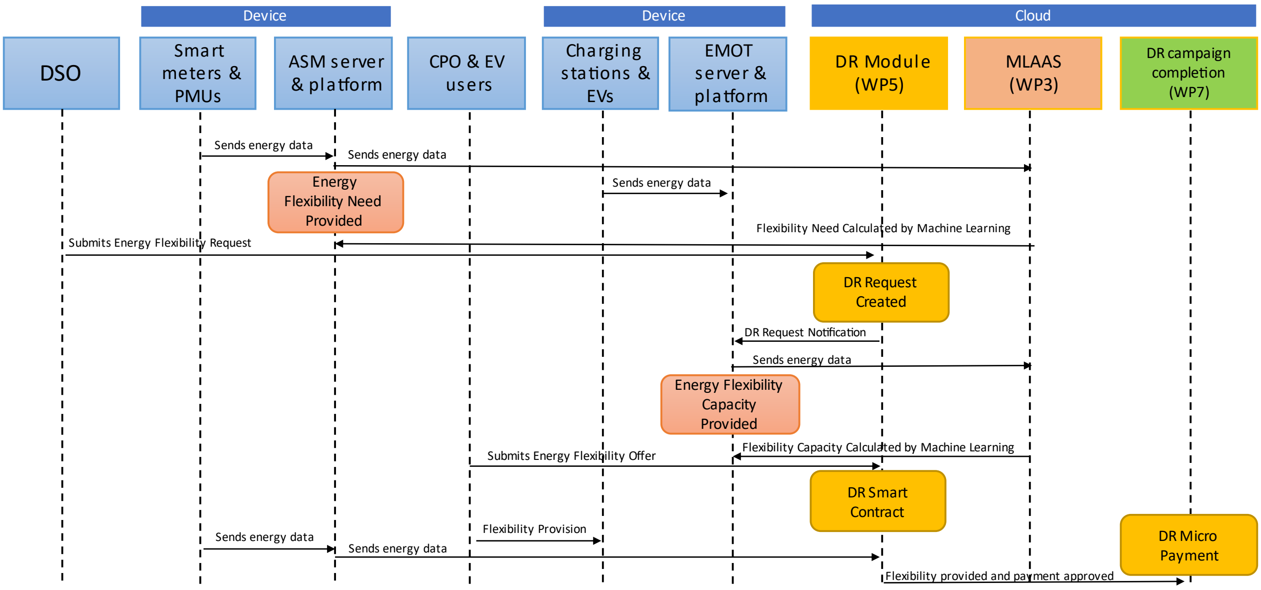


Figure 38. Sequence diagram of UC10 – DR module and interactions.

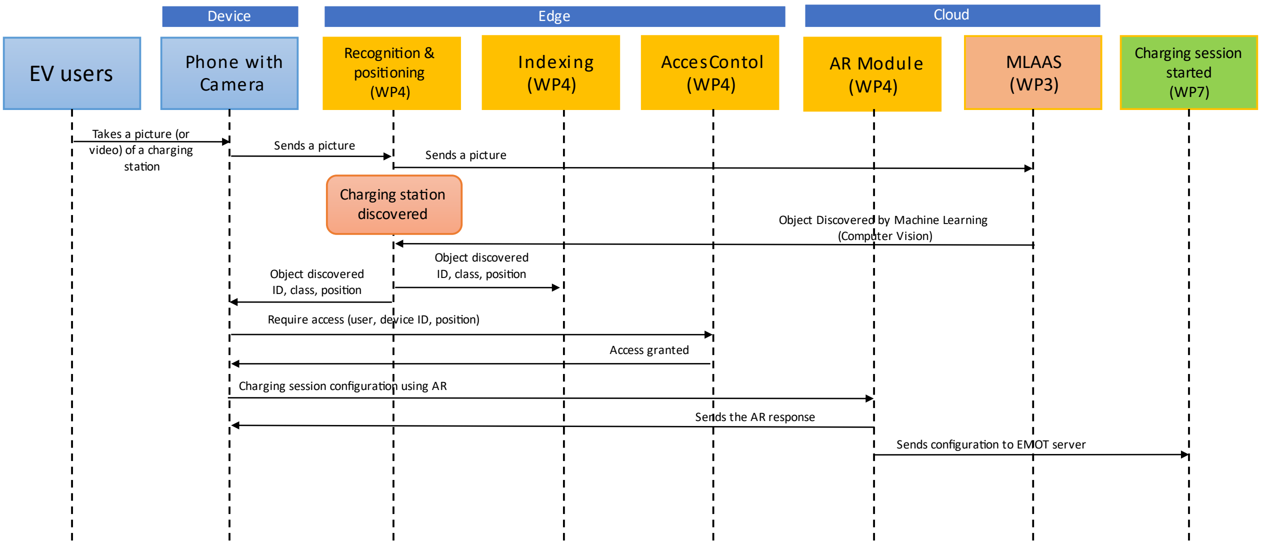


Figure 39. Sequence diagram of UC10 – AR module and interactions.

3.4.2.6. Testing and validation procedures

UC10 will be validated in the Italian Living Lab focusing on the interaction between grid operator, charging point operator and EV users via a DR mechanism. DSO will provide real-time data collected from smart meters and PMUs distributed into the grid; elaborating those data, via ML tool, will be obtained the necessary amount of energy flexibility. Via DR API, a flexibility request will be sent from DSO platform to e-Mobility platform.

Thanks to ML forecasting system will be acquired a prediction of EV energy flexibility provision potential amount, allowing to understand if and how it is possible to satisfy DSO request. If acceptable, the necessary number of electric vehicles are selected to be involved in the DR campaign, a flexibility provision confirmation response is sent to the DSO via the DR API and a smart contract is performed. Thereafter, electric vehicles will be directed to provide energy flexibility at the indicated charging stations at the settled day time.

Through the smart meters distributed into the grid will be possible to verify that the supply of flexibility has been provided correctly and following the verification the micro-payment will be performed. In addition to testing and validation, a novel AR interaction mechanism between charging station and electric vehicle will be tested and validated in Italian living lab; deployed electric vehicles will be equipped with a camera to train ML tool to detect charging station. Charging station discovery and indexing will trigger the control in AR mode.

3.4.2.7. Execution timeline

The execution timeline of UC10, divided into multiple phases, is detailed in Table 45 below.

Table 45. Execution timeline of UC10.

Phase	Estimated start date	Estimated end date	Notes
Trial set-up and equipment procurement	M8	M15	
Initial implementation and validation	M16	M20	
Intermediate implementation and validation	M21	M26	
Final implementation and validation	M27	M34	

3.4.2.8. Initial results

UC10 initial results are related mainly to the site set-up. As described in Section 3.4.2.2, the following equipment have been procured:

- A dedicated server for DSO operation
- A dedicated server for e-Mobility operation
- Smart meters
- PMUs
- Electric vehicles
- OBDs and charging stations.
- Started collaboration with technical partners

Furthermore, living lab data were started to be collected from field devices and processed for machine learning training.

4. Data Management Plan updates

The Data Management Plan (DMP) of IoT-NGIN was presented in detail in *D7.1 – Data Management Plan*. The deliverable provided the guiding principles of the DMP of IoT-NGIN, such as H2020's Open Research Data Pilot, IPR, data security, personal data protection, along with how FAIR data principles will be followed as well as a preliminary description of the datasets identified at that point in the different Living Labs and use cases of the project.

This section can be considered as a follow-up to the DMP and includes updates to the information provided in the previous deliverable. Two main aspects of the DMP will be reviewed. Firstly, the datasets identified as part of the different Living Labs and use case will be updated and any missing information from the previous deliverable will be completed, e.g., metadata, unique identifiers, IP and licenses, etc. (Section 4.1). Secondly, the choice of the Open Data repository that will be used to publish all datasets made available openly will be explained and its alignment with the DMP guiding principles and FARI data principles will be justified (Section 4.2).

4.1. Collected datasets

Data collection is one of the most important aspects of the IoT-NGIN Living Labs and their corresponding use cases. This aspect was part of the questionnaire sent out to trial partners, with a specific section asking partners for details about the datasets identified as part of their trial, as explained in the Section 2.3 of the methodology. Table 1 summarizes the datasets that have been identified so far in the different Living Labs, with the most relevant information about each dataset included. Datasets that will eventually be open and available in the Open Data repository are highlighted in green.

Table 46. Summary of the datasets identified in the IoT-NGIN Living Labs and use cases.

Dataset Number	Dataset Name	Open / Restricted	Reasons for Restriction
Trial 2 - Human-Centred Twin Smart Cities Living Lab			
2.1	On-location camera feed	Restricted / Open	GDPR - Open after anonymization and after end of project
2.2	Radar imagery	Restricted / Open	GDPR - Open after anonymization and after end of project
2.3	Social network feeds	Restricted	GDPR - sensitive personal information
Trial 3 - Smart Agriculture IoT Living Lab			
3.1	AGLV sensor measurements	Open	Open after end of project

3.2	Field sensor measurements	Restricted / Open	IPR – Open after aggregation and after end of project
3.3	Drone camera images	Restricted / Open	IPR / GDPR – Open after anonymization and after end of project
3.4	AGLV camera images	Restricted / Open	IPR / GDPR – Open after anonymization and after end of project
Trial 4 - Industry 4.0 Use Cases Living Lab (BOSCH)			
4.1	Indoor surveillance camera videos	Restricted	GDPR - sensitive personal information
4.2	Workers' indoor trajectories	Restricted / Open	GDPR - Open after anonymization and after end of project
4.3	UWB raw data	Open	Open after end of project
4.4	Indoor AGV trajectories	Open	Open after end of project
Trial 5 - Industry 4.0 Use Cases Living Lab (ABB)			
5.1	CAD data	Restricted	IPR / data security and privacy
5.2	Drive Data	Restricted	IPR / data security and privacy
5.3	Smart Sensor data	Restricted	IPR / data security and privacy
5.4	PLC Data	Restricted	IPR / data security and privacy
Trial 6 - Smart Energy Grid Monitoring / Control Living Lab			
6.1	Smart Meter eXtension (SMX) dataset	Restricted	IPR / data security and privacy
6.2	Power Quality Analysers (PQA) dataset	Restricted	IPR / data security and privacy
6.3	Phaser Measurement Units (PMU) dataset	Restricted	IPR / data security and privacy
6.4	Charging station data	Restricted / Open	GDPR - Open after anonymization and after end of project
6.5	Electric vehicle data	Restricted / Open	GDPR - Open after anonymization and after end of project

Aside from this summary, more detailed, updated information about the datasets can be found in the two annexes of this deliverable. *Annex I. Data Inventory Table* provides information about the description, data controller, data format, data size, data origin and data purpose of each identified dataset. On the other hand, *Annex II. FAIR Data Considerations* describes aspects related to FAIR data principles of each dataset, such as the metadata that will be used to describe the dataset, its unique identifiers, storage medium, standard vocabularies and access level, methods and restrictions used in the dataset or its corresponding metadata.

4.2. Open Data repository – Zenodo

The consortium of IoT-NGIN has decided to use Zenodo as the Open Data repository that will be used to publish all datasets of the project that will be openly accessible. Zenodo[9] is an Open Data portal maintained by OpenAIRE and CERN that allows researchers to upload any type of data (publications, datasets, videos, presentations, posters, etc.) and provides tools to link them together.

Another option that was considered was to create a project-specific open data repository to make datasets available. This option was then discarded because creating another *silo* of project-specific data does not comply with FAIR data principles, nor is it the main objective of H2020's Open Research Data Pilot. The consortium considers that using an already-existing, widely used repository such as Zenodo is more aligned with these principles.

Zenodo follows FAIR data principles by design, making it an excellent choice to publish the openly accessible data of IoT-NGIN. Zenodo is aligned with the FAIR data principles as follows:

1. Making data **Findable**, including provisions for metadata
    - Data are assigned a globally unique and persistent identifier. Zenodo issues a DOI for every published record in the repository.
    - Data are described with rich metadata. Zenodo's metadata is compliant with DataCite's Metadata Schema[10] minimum and recommended terms, with a few additional enrichments.
    - Data are registered or indexed in a searchable resource. Metadata of each record is indexed and searchable directly in Zenodo's search engine immediately after publishing, as well as sent to DataCite servers during DOI registration and indexed there.
2. Making data openly **Accessible**
    - Data are retrievable by their identifier using a standardized communications protocol. Metadata for individual records as well as record collections are

[9] Zenodo: https://zenodo.org/
[10] DataCite Schema: https://schema.datacite.org/

harvestable using the OAI-PMH[11] protocol by the record identifier and the collection name. Metadata is also retrievable through a public REST API[12].

  - Metadata are accessible, even when the data are no longer available. Zenodo stores metadata in high-availability database servers at CERN, which are separate to the data itself, and will retain the metadata for the entire lifetime of the repository (currently at least 20 years at the host laboratory CERN).

3. Making data **Interoperable**
   - Zenodo uses JSON Schema[13] as internal representation of metadata and offers export to other popular formats such as Dublin Core[14] or MARCXML[15].
   - For certain terms, Zenodo refers to open, external and commonly used vocabularies, e.g., license (Open Definition[16]), funders (FundRef[17]) and grants (OpenAIRE[18]).
4. Increasing data **Reuse** (through clarifying licenses)
   - Each record contains a minimum of DataCite's mandatory terms, with optionally additional DataCite recommended terms and Zenodo's enrichments.
   - Data are released with a clear and accessible data usage license. License is one of the mandatory terms in Zenodo's metadata and is referring to an Open Definition license.
   - Data are associated with detailed provenance. All data and metadata uploaded is traceable to a registered Zenodo user. Additionally, metadata can optionally describe the original authors of the published work.

Furthermore, using a well-established repository such as Zenodo offers better capabilities for other aspects of data sharing such as data security and long-time data archiving. According to the official documentation, each upload to Zenodo has two backup replicas located on different disk servers and two independent MD5 checksums used for change detection and automatic recovery of file corruption. This is supplemented with a variety of security mechanisms such as secure protocols (e.g. HTTPS and SSL), cryptographic algorithms for sensitive information such as passwords (currently PBKDF2+SHA512) and the CERN Security Baseline for Servers to guarantee the security of access to the published IoT-NGIN data.

Zenodo also uses an 18-petabyte disk cluster to store the data uploads, and a PostgresSQL instance to store the metadata with 12-hourly backup cycle with one backup sent to tape storage once a week. In the future, and depending on access patterns to the data, Zenodo might move the archival and/or the online copy to CERN's offline long-term tape storage

[11] OAI 2.0 Request Results: https://zenodo.org/oai2d
[12] Developers Zenodo: https://developers.zenodo.org/
[13] JSON Schema: https://json-schema.org/
[14] DCMI: https://www.dublincore.org/
[15] MARC in XML: https://www.loc.gov/marc/marcxml.html
[16] The Open Definition: https://opendefinition.org/
[17] Funder Registry – Crossref: https://www.crossref.org/services/funder-registry/
[18] OpenAIRE API: https://graph.openaire.eu/develop/

system, guaranteeing the long-term archiving and availability of IoT-NGIN data significantly beyond the project's lifetime.

One of the few limitations of using a generic repository such as Zenodo is the ability to offer customized access and services to the project's data. This may include, for example, domain-specific metadata, vocabularies and formats, custom APIs, and visualizations aiding in the exploration of the data. Should the need arise for such services not covered by Zenodo during the remainder of the project's lifetime, the consortium will adapt to these needs by reconsidering the possibility of creating a custom Open Data repository and / or offering the datasets in a dedicated section on the project's official website.

5. Conclusions

This deliverable included a summary of the progress made in the IoT-NGIN Living Labs, related to the trial site setup, equipment procurement, alignment with IoT-NGIN technologies, definition of testing and validation processing and any other initial results obtained so far. Furthermore, it also included an update to the project's DMP originally submitted in M6. The DMP was updated in terms of the datasets identified so far as part of the project Living Labs as well as the choice of the Open Data repository to be used to publish these datasets.

After finalizing the early stage of trial set-up and definition, next steps will focus on starting the implementation of the different Living Labs. Given the wide variety of Living Labs in IoT-NGIN, each trial will follow its own execution timeline and stages, as defined in this deliverable. Nonetheless, intermediate updates about the results of all Living Labs are expected by M30 of the project and will be summarized in *D7.3 – IoT-NGIN Living Labs use cases intermediate results.*

On the other hand, no further updates about the DMP are expected at this point. All relevant information about the trial datasets, such as technical characteristics, data controller, access levels and other FAIR data considerations, has already been included in this deliverable. Should the need arise to make any addition or correction to the DMP at the end of the project, these updates will be included in the deliverable *D7.4 – IoT-NGIN Living Labs use cases Assessment and Replication guidelines*, due at M36.

References

[1] IoT-NGIN, "D1.1 - Definition analysis of use cases and GDPR Compliance," H2020 957246 - IoT-NGIN Deliverable Report, 2021.

[2] IoT-NGIN, "D7.1 - Data Management Plan (DMP)," H2020 957246 - IoT-NGIN Deliverable Report, 2021.

[3] Food and Agriculture Organization, "Climate change fans spread of pests and threatens plants and crops, new FAO study," 2021. [Online]. Available: https://www.fao.org/news/story/en/item/1402920/icode/.

[4] F. Domingues and J. S. d. Aguila, "The cost of grape mechanical harvesting is more economical than the manual harvest?," in *39th World Congress of Vine and Wine*, 2016.

[5] Food and Agriculture Organization of the United Nations (FAO), " COVID-19 Series / Improving the Storability and Availability of Pulses by Reducing Post-Harvest Losses," [Online]. Available: http://www.fao.org/food-loss-reduction/news/detail/en/c/1271760/. [Accessed 2020].

[6] European Seed, "Vegetable Growers Looking to Accelerate Switch to Mechanical Harvesting Due to Coronavirus Crisis," 2020. [Online]. Available: https://european-seed.com/2020/06/vegetable-growers-looking-to-accelerate-switch-to-mechanical-harvesting-due-to-coronavirus-crisis/.

[7] AgriLinks, "Climate-Smart Agriculture Could Offset COVID-19's Impact on Bangladeshi Farmers," 2020. [Online]. Available: https://www.agrilinks.org/post/climate-smart-agriculture-could-offset-covid-19s-impact-bangladeshi-farmers.

Annex I. Data Inventory Table

Data Inventory Table									
Dataset no.	Dataset Name	Data Description	Use Case	Data Controller	Data Format	Data Size	Data Origin[19]	Data Purpose	Ethical Issues[20]
Trial 2 - Human-centred Twin Smart Cities Living Lab									
2.1	**On-location camera feed**	On-location cameras will be installed to monitor the movement of vehicles and pedestrians in the site of the living lab. The produced data will be aggregated to count the number of the different types of objects passing through the living lab location at a given time.	UC1, UC2	FVH	Video files, XLS, XML, JSON	≈ KBs	Observational: from on-location cameras.	On-location video analysis (edge computing) to aggregate the number of vehicles and pedestrians in the videos.	Yes
2.2	**Radar imagery**	Radar imagery will be used to detect cars in a given area and count the totals of different types of vehicles passing through an area at a given time.	UC1, UC2	FVH	Video files, XLS, XML, JSON	≈ KBs	Observational: from radars.	Detection of vehicles in a particular area to produce aggregates of the number of detected vehicles.	Yes

[19] **Data Origin** should be one of the following:

- **Observational:** Data captured in real time, often not reproducible (e.g. sensor readings, images, telemetries, sample data).
- **Experimental:** Data from lab equipment, often reproducible, but with high costs (e.g. chromatograms, magnetic fields readings).
- **Simulation:** Data generated by computational models (e.g. climate models, economic models, materials models).
- **Derived / Compiled:** Data coming from analysis or compilation. Reproducible but with high costs (e.g. results of text and data mining, compiled databases).
- **Reference / Canonical:** Collection or conglomeration of smaller datasets published and curated (e.g. chemical structures, gene sequence databanks, spatial data portals).

[20] **Ethical Issues?** a (Y/N) answer indicating whether the data has any potential ethical issues, particularly related to protected personal data.

Data Inventory Table									
Dataset no.	Dataset Name	Data Description	Use Case	Data Controller	Data Format	Data Size	Data Origin[19]	Data Purpose	Ethical Issues[20]
2.3	**Social network feeds**	The social network feeds of the volunteers in the living lab will be collected to retrieve routes, commute times and features of the provided commuting solution.	UC3	FVH	Text (DOC, PDF), XLS	≈ KBs	Derived: from social network feeds of volunteer participants.	Analysis of routes, commute times and features of the provided commuting solution.	Yes
Trial 3 - Smart Agriculture IoT Living Lab									
3.1	**AGLV sensor measurements**	Measurements acquired from sensors installed and configured specifically for the trial on Automated Guided Land Vehicles (AGLVs) will be collected. The data will be used to allow the use of the AGLVs as carrier machines, and to enable them to locate and avoid workers and trees.	UC5	OPT	CSV, JSON	≈ MBs per month	Observational: from AGLV sensors.	Analysis of measurements from AGLV sensors to aid in the harvesting of crops within the trial site(s).	No
3.2	**Field sensor measurements**	Data collected from SynField IoT platform and integrated sensors, including micro-climate data (air temperature, air humidity, wind direction, wind speed, rain volume, rain intensity) and soil and crop data (leaf wetness, soil type, soil temperature, soil humidity, soil conductivity). This dataset will be used to calculate the crop growing degree days (ripening indicator).	UC4	SYN	CSV, JSON	≈ 300 KBs per day per SynField node	Observational: from field sensors.	Conduct tests related to smart irrigation and precision aerial spraying within the trial site(s).	No
3.3	**Drone camera images**	Images collected from multi-spectral cameras on drones. The images will be associated with time	UC4	SYN	Image (JPG, TIFF)	≈ 500 MBs per day per drone	Observational: from multi-	Collect images of crop leaves at the trial site(s) to test crop disease prediction.	Yes

Data Inventory Table									
Dataset no.	Dataset Name	Data Description	Use Case	Data Controller	Data Format	Data Size	Data Origin[19]	Data Purpose	Ethical Issues[20]
		information and geospatial/location information provided by GPS.					spectral drone cameras.		
3.4	**AGLV camera images**	Video images collected from AGLV's camera. The images will be used for obstacle avoidance of the AGLV.	UC5	SYN	Video (SVO)	≈ 40GB per day of operation	Observational: From AGLV cameras	Collect images of fields to train an d validate the obstacle avoidance algorithms.	Yes
Trial 4 - Industry 4.0 Use Cases Living Lab (BOSCH)									
4.1	**Indoor surveillance camera videos**	Video images taken from surveillance cameras installed on the ceilings of the factories where the trials will take place. The cameras record the working areas and capture the movement of workers and Automated Guided Vehicles (AGVs) while working in the factory.	UC6	BOSCH / I2CAT	Image files	≈ 10,000 HD images	Observational: from indoor surveillance cameras.	Train and validate computer vision algorithms in detecting workers throughout the shop floor of the trial site based on the collected images.	Yes
4.2	**Workers' indoor trajectories**	Data derived from dataset 4.1 about the location of workers at different time intervals inside the trial factories. The data will be in the form of positioning data with the X and Y coordinates of the factory workers.	UC6	BOSCH / I2CAT	CSV	≈ 1 GB (17M position points)	Derived: from analyzing images of dataset 4.1.	Analyze the trajectories of workers within the shop floor of the trial site to predict and avoid AGV-human collisions.	Yes
4.3	**UWB raw data**	Signals collected through Ultra-Wideband (UWB) units installed on AGVs at the factories participating in the trials. These signals will be sent to UWB beacons installed at the factories,	UC6	BOSCH / I2CAT	CSV	≈ 2 GB (100M UWB signals)	Observational: from UWB units installed on AGVs.	Collect positions of AGVs at different points in time throughout the shop floor / working area of the trial sites.	No

Data Inventory Table									
Dataset no.	Dataset Name	Data Description	Use Case	Data Controller	Data Format	Data Size	Data Origin[19]	Data Purpose	Ethical Issues[20]
		which will in turn register the Time of Flight (ToF) of the received signals for further processing.							
4.4	**Indoor AGV trajectories**	Data derived from the dataset 4.3 about the location of AGVs at different intervals inside the factories participating in the trials. The data will be in the form of positioning data with the X and Y coordinates of the factory AGVs.	UC6	BOSCH / I2CAT	CSV	≈ 2 GB (100M UWB signals)	Derived: from analyzing UWB signals in dataset 4.3.	Analyze the trajectories of AGVs within the shop floor of the trial site to predict and avoid AGV-AGV and AGV-human collisions.	No
Trial 5 - Industry 4.0 Use Cases Living Lab (ABB)									
5.1	**CAD data**	Digital model of drive cabinet.	UC7	ABB	CAD (.step / .stp)	≈ 150 MB	Experimental: Combination of CREO MCAD and EPLAN ECAD data.	The digital model will be used to visualize assembly steps in the Smart Wiring™ software and in AR application development.	No
5.2	**Drive Data**	Drive operating data gathered via its IoT-Panel: speed, torque, current, voltage etc.	UC8	ABB	JSON	≈ KBs per day	Observational: sensor readings	Device operation and condition monitoring.	No
5.3	**Smart Sensor data**	Acceleration and temperature related KPI values	UC8	ABB	JSON / OPC UA	≈ KBs per day	Observational: sensor readings	Condition monitoring	No
5.4	**PLC Data**	High frequency accelerometer data and temperature data.	UC8	ABB	CSV / JSON	400 KB per measure ment	Observational: sensor readings	Condition monitoring	No

Data Inventory Table									
Dataset no.	Dataset Name	Data Description	Use Case	Data Controller	Data Format	Data Size	Data Origin[19]	Data Purpose	Ethical Issues[20]
Trial 6 - Smart Energy Grid Monitoring / Control Living Lab									
6.1	**Smart Meter eXtension (SMX) dataset**	Measurements of voltage, currents, and power derived by ASM energy units, collected through an MQTT protocol via public IP and / or LAN/VPN connections. To ensure secure access to the dataset, credentials will be required.	UC9, UC10	ASM	JSON	≈ 1 MB per day	Observational: from ASM energy units.	Provide timely alarms when the system approaches unstable operational boundaries by collecting measurements that indicate the health of the grid.	No
6.2	**Power Quality Analyzers (PQA) dataset**	Measurements of voltage, currents, and power derived by ASM energy units, collected through HTTP protocol only via LAN/VPN connections, which provide built-in security access features.	UC10	ASM	CSV / JSON	≈ 1 KB per day	Observational: from ASM energy units.	Provide timely alarms when the system approaches unstable operational boundaries by collecting measurements that indicate the health of the grid.	No
6.3	**Phaser Measurement Units (PMU) dataset**	Measurements of voltage, currents, and power derived by ASM energy units, collected through HTTP protocol only via LAN/VPN connections, which provide built-in security access features.	UC9	ASM	JSON	≈ 1 MB per day	Observational: from ASM energy units.	Provide timely alarms when the system approaches unstable operational boundaries by collecting measurements that indicate the health of the grid.	No
6.4	**Charging station data**	Real-time and historical data collected from the charging stations deployed in the trial site (Terni, Italy). The data will include information about the charging station and each charging session, without any identifying information about the use of the station.	UC10	EMOT	JSON	≈ KBs per day	Observational: from EMOT charging stations.	Conducting driver-friendly, dispatchable charging of EVs based on energy demand-response with human-centered micro-contracts and micro-payments.	No

Data Inventory Table									
Dataset no.	Dataset Name	Data Description	Use Case	Data Controller	Data Format	Data Size	Data Origin[19]	Data Purpose	Ethical Issues[20]
6.5	**Electric vehicle data**	Real-Time and historical data collected from electric vehicles deployed in the trial site (Terni, Italy). The data will include battery capacity, power and life, along with data about the movement and trajectories of the vehicles, such as latitude, longitude and speed.	UC10	EMOT	JSON	≈ KBs per day	Observational: from EMOT electric vehicles.	Conducting driver-friendly, dispatchable charging of EVs based on energy demand-response with human-centered micro-contracts and micro-payments.	No

Annex II. FAIR Data Considerations

FAIR Data Considerations										
Dataset no.	Dataset Name	Findability		Accessibility			Interoperability	Reusability	
		Metadata Description	Permanent Identifiers	Storage Medium	Access Level[21]	Access Methods	Standard Vocabularies	IP / License	Access / Reuse Restrictions[22]
Trial 2 - Human-centred Twin Smart Cities Living Lab									
2.1	**On-location camera feed**	*TBD*	DOI	FVH / AALTO secured servers (internal) Open Access repository (external)	Restricted / Open	API and / or file sharing (internal) Open Access repository (external)	DataCite, DCAT, Dublin Core, schema.org	CC	GDPR - Open after anonymization and after end of project
2.2	**Radar imagery**	*TBD*	DOI	FVH / AALTO secured servers (internal) Open Access repository (external)	Restricted / Open	API and / or file sharing (internal) Open Access repository (external)	DataCite, DCAT, Dublin Core, schema.org	CC	GDPR - Open after anonymization and after end of project
2.3	**Social network feeds**	*TBD*	*N/A*	FVH / AALTO secured servers (internal) Open Access repository (external)	Restricted	API and / or file sharing (internal) Open Access repository (external)	*N/A*	*N/A*	GDPR - sensitive personal information

[21] **Access Level** should be one of the following:

- **Open:** the data is made publicly available to third parties, with or without restrictions (as indicated in the **Access / Reuse Restrictions** column).
- **Restricted:** the data is only available to members of the IoT-NGIN consortium, and the EU Commission for revision and evaluation purposes if needed.

[22] **Access / Reuse Restrictions** in the case of data with Restricted access, indicates one or more of the following: (1) limitations and restrictions to **access** the data, and if they are linked to a specific timeframe. (2) Restrictions on the **reuse** of the data by third-parties after the end of the project (e.g. confidentiality agreements) and if any embargo period is required.

FAIR Data Considerations									
Dataset no.	Dataset Name	Findability		Accessibility			Interoperability	Reusability	
		Metadata Description	Permanent Identifiers	Storage Medium	Access Level[21]	Access Methods	Standard Vocabularies	IP / License	Access / Reuse Restrictions[22]
Trial 3 - Smart Agriculture IoT Living Lab									
3.1	**AGLV sensor measurements**	Location, timestamp	DOI	OPT IoT platform database (internal) Open Access repository (external)	Open	API (internal) Open Access repository (external)	DataCite, DCAT, Dublin Core, schema.org	ODC	Open after end of project
3.2	**Field sensor measurements**	Location, timestamp, SynField node	DOI	SynField IoT platform database (internal) Open Access repository (external)	Restricted / Open	API and / or file sharing (internal) Open Access repository (external)	DataCite, DCAT, Dublin Core, schema.org	ODC	IPR – Open after aggregation and after end of project
3.3	**Drone camera images**	Location, timestamp	DOI	SYN cloud services (internal) Open Access repository (external)	Restricted / Open	API and / or file sharing (internal) Open Access repository (external)	DataCite, DCAT, Dublin Core, schema.org	ODC	IPR / GDPR – Open after anonymization and after end of project
3.4	**AGLV camera images**	Location, timestamp	DOI	SYN cloud services (internal) Open Access repository (external)	Restricted / Open	API and / or file sharing (internal) Open Access repository (external)	DataCite, DCAT, Dublin Core, schema.org	ODC	IPR / GDPR – Open after anonymization and after end of project
Trial 4 - Industry 4.0 Use Cases Living Lab (BOSCH)									

FAIR Data Considerations									
Dataset no.	Dataset Name	Findability		Accessibility			Interoperability	Reusability	
		Metadata Description	Permanent Identifiers	Storage Medium	Access Level[21]	Access Methods	Standard Vocabularies	IP / License	Access / Reuse Restrictions[22]
4.1	**Indoor surveillance camera videos**	Timestamp, number of AGVs, number of workers	*N/A*	Secure cloud file server (internal)	Restricted	File sharing (internal)	*N/A*	ODC	GDPR - sensitive personal information
4.2	**Workers' indoor trajectories**	*TBD*	DOI	Secure cloud file server (internal) Open Access repository (external)	Restricted / Open	File sharing (internal) Open Access repository (external)	DataCite, DCAT, Dublin Core, schema.org	ODC	GDPR - Open after anonymization and after end of project
4.3	**UWB raw data**	Timestamp, UWD beacon position, AGV position	DOI	Secure cloud file server (internal) Open Access repository (external)	Open	File sharing (internal) Open Access repository (external)	DataCite, DCAT, Dublin Core, schema.org	ODC	Open after end of project
4.4	**Indoor AGV trajectories**	*TBD*	DOI	Secure cloud file server (internal) Open Access repository (external)	Open	File sharing (internal) Open Access repository (external)	DataCite, DCAT, Dublin Core, schema.org	ODC	Open after end of project
Trial 5 - Industry 4.0 Use Cases Living Lab (ABB)									
5.1	**CAD data**	*.stp file (CAD model)*	*N/A*	ABB servers (internal)	Restricted	Authorized credentials through VPN (internal)	*N/A*	*N/A*	IPR / data security and privacy

FAIR Data Considerations										
Dataset no.	Dataset Name	Findability		Accessibility			Interoperability	Reusability	
		Metadata Description	Permanent Identifiers	Storage Medium	Access Level[21]	Access Methods	Standard Vocabularies	IP / License	Access / Reuse Restrictions[22]
5.2	**Drive data**	Drive signals such as speed, torque, current…	*N/A*	ABB servers (internal)	Restricted	File sharing (internal)	*N/A*	*N/A*	IPR / data security and privacy
5.3	**Smart Sensor data**	KPI values related to motor condition	*N/A*	ABB servers (internal)	Restricted	File sharing (internal)	*N/A*	*N/A*	IPR / data security and privacy
5.4	**PLC Data**	High frequency accelerometer data	*N/A*	ABB servers (internal)	Restricted	File sharing (internal)	*N/A*	*N/A*	IPR / data security and privacy
Trial 6 - Smart Energy Grid Monitoring / Control Living Lab									
6.1	**Smart Meter eXtension (SMX) dataset**	Active power, Reactive power, 1ph Voltage, 2ph voltage, 3ph voltage	*N/A*	ASM servers (internal)	Restricted	Authorized credentials through VPN (internal)	*N/A*	*N/A*	IPR / data security and privacy
6.2	**Power Quality Analyzers (PQA) dataset**	Active power, Reactive power, 1ph Voltage, 2ph voltage, 3ph voltage	*N/A*	ASM servers (internal)	Restricted	Authorized credentials through VPN (internal)	*N/A*	*N/A*	IPR / data security and privacy

FAIR Data Considerations									
Dataset no.	Dataset Name	Findability		Accessibility			Interoperability	Reusability	
		Metadata Description	Permanent Identifiers	Storage Medium	Access Level[21]	Access Methods	Standard Vocabularies	IP / License	Access / Reuse Restrictions[22]
6.3	**Phaser Measurement Units (PMU) dataset**	Voltage magnitude, current magnitude, Voltage Phase, current phase, frequency, homopolar voltage magnitude, homopolar current magnitude, voltage phase, homopolar current phase	*N/A*	ASM servers (internal)	Restricted	Authorized credentials through VPN (internal)	*N/A*	*N/A*	IPR / data security and privacy
6.4	**Charging station data**	Charging Station ID, Power Output, Socket ID, Socket Status, Charging Session ID, Start Time, End Time, Energy, Cost	DOI	EMOT servers (internal) Open Access repository (external)	Restricted / Open	API and / or file sharing (internal)	DataCite, DCAT, Dublin Core, schema.org	CC	GDPR - Open after anonymization and after end of project

FAIR Data Considerations									
Dataset no.	Dataset Name	Findability		Accessibility			Interoperability	Reusability	
		Metadata Description	Permanent Identifiers	Storage Medium	Access Level[21]	Access Methods	Standard Vocabularies	IP / License	Access / Reuse Restrictions[22]
6.5	**Electric vehicle data**	Electric Vehicle ID, Electric Vehicle Model, Connector Type, Battery Capacity, Battery Power, Timestamp, SoC, Latitude, Longitude, Speed Kilometers, Autonomy, Odometer	DOI	EMOT servers (internal) Open Access repository (external)	Restricted / Open	API and / or file sharing (internal)	DataCite, DCAT, Dublin Core, schema.org	CC	GDPR - Open after anonymization and after end of project