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Architecture for Scalable, Self-human-centric, Intelligent, Secure, and Tactile next generation IoT

D7.2 Pilot Scenario Implementation – First Version

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Authors

Name	Partner	e-mail
Carlos Guardiola	P01 UPV	carguaga@upv.es
Eduardo Garro	P02 PRO	egarro@prodevelop.es
Estefanía García	P02 PRO	egarcia@prodevelop.es
Adrián Ramos	P02 PRO	aramos@prodevelop.es
Miguel Llàcer	P02 PRO	mllacer@prodevelop.es
Maria Angeles Burgos	P02 PRO	mburgos@prodevelop.es
Piotr Sowiński	P03 SRIPAS	piotr.sowinski@ibspan.waw.pl
Francisco Blanquer	P05 TL	HO.FBLANQUER@terminal-link.com
Nikolaos Vrionis	P06 INF	nvrionis@infolysis.gr
Theoni Dounia	P06 INF	tdounia@infolysis.gr
Anna Dąbrowska	P07 CIOP-PIB	andab@ciop.lodz.pl
Piotr Dymarski	P08 MOW	P.Dymarski@mostostal.waw.pl
Ron Schram	P09 NEWAYS	Ron.Schram@newayselectronics.com
Fotios Konstantinidis	P10 ICCS	fotios.konstantinidis@iccs.gr
Tommi Leino	P11 KONE	tommi.leino@konecranes.com
Sami Piittisjärvi	P11 KONE	sami.piittisjarvi@konecranes.com
Klaus Schusteritz	P12 FORD-WERKE	kschust4@ford.com
Oscar López Pérez	P13 S21SEC	olopez@s21sec.com
Jordi Blasi Uribarri	P13 S21SEC	jblasi@s21sec.com
Lambis Tassakos	P14 TWOT	lambis.tassakos@gmail.com
Zbigniew Kopertowski	P15 OPL	Zbigniew.Kopertowski@orange.com

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Executive Summary

The present document is the first version of the "Pilot Scenario Implementation" and the main objective is to guarantee the successful development of the four pilots of the project, as well as a further ease of integration with the ASSIST-IoT platform enablers.

Each pilot has been divided into one or more trials, based on the business scenarios and use cases identified in WP3 deliverables, all of them trying to solve a real need of industrial stakeholders by means of the application of one or more than one ASSIST-IoT enabler.

The Port Automation pilot will be implemented on the premises of Malta Freeport Terminal. The objective of the pilot is to help container terminal operators to improve the operational efficiency. On the one hand, ASSIST-IoT will provide the ability to make better decisions to container terminal stakeholders by means of improving the availability of information over which the operators can interact with, and, on the other hand, ASSIST-IoT will partially allow automating repeating workflows. Three trials have been identified: (i) Tracking assets in terminal yard, (ii) Automated Container handling Equipment (CHE) cooperation, and (iii) Rubber Tyred Gantry (RTG) remote control with AR support.

The Smart safety of Workers pilot will be implemented on Szczecin building, which is under construction. The pilot is focused on the improvement of health and safety at the construction site by implementing human-centric modular solutions and enablers capable to effectively support the operations. To achieve it, the pilot has identified 3 main trials: (i) Occupation safety and health monitoring, (ii) Safe navigation, and (iii) Health and safety inspection support.

The Vehicle in-service emission diagnostics pilot is centred around emissions and enhanced diagnostics at vehicle fleet level. For this purpose, Ford-Werke GmbH has provided a state-of-the-art current production Ford Kuga, which is located at UPV, to allow the intensive driving and testing planned. ASSIST-IoT is expected to provide an architecture able to ease the many challenges of the pilot: varying sensor sets and driving conditions, coexistent software versions, etc. The pilot will perform an iterative execution of a single trial, which along the project, will include the addition of new features to the existing ones, providing a continuous improvement of the use cases presented in WP3.

The Vehicle exterior condition inspection and documentation pilot aims at supporting humans active in the automotive industry with tasks relevant to the inspection and monitoring of the conditions of the exterior surface of the vehicles. As the scanner is the cornerstone for this pilot owner, TwoTronic will make one available on its premises for project activities. A full ASSIST-IoT technologies ecosystem will be deployed and used for the pilot operation with its tests and evaluation. As the business uses are varying, a single, general business scenario with two use cases has been identified: (i) Vehicle's exterior condition documentation, and (ii) External defects detection support.

D7.2 serves as a continuation of the previous D7.1 Deployment Plan and Operational Framework deliverable. Hence, following the plan defined in D7.1, this deliverable describes the associated implementation activities carried out during the M12-M18 period. More specifically, procurement[1] and configuration activities are described in order to define a proper tracking environment. In addition, development, integration, and verification activities, as well as potential deviations from original planning are also described according to the functionalities of each trial.

Finally, a brief summary of the proposals successfully submitted to the first ASSIST-IoT open call, with special interest over their relationship with WP7 pilot implementation activities is examined, although only from a quantitative analysis, as the final evaluation was not finished in the time of writing this deliverable.

[1] We would like to highlight the limitations that the project partners are facing to procure the different HW elements needed for the proper demonstration of the pilots use cases due to the global chip shortage. It is expected that this shortage will be relieved during the next 18 months of the project, but if not, a technological lower impact can be expected in the final version of the trials.

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List of acronyms

Acronym	Explanation	Acronym	Explanation
AI	Artificial Intelligence	**KPI**	Key Performance Indicator
API	Application Programming Interface	**LAN**	Local Area Network
AR	Augmented Reality	**LED**	Light-Emitting Diode
ASAM	Association for Standardization of Automation and Measuring Systems	**LIDAR**	Light Imaging Detection and Ranging
AV	Audiovisual	**LTE**	Long Term Evolution
BIM	Building Information Modelling	**LTSE**	Long-Term Storage Enabler
BIP	Background IP	**MANO**	Management and Orchestration
BS	Business Scenario	**MB**	Megabytes
CAN	Control Area Network	**MFT**	Malta Freeport Infrastructure
CAS	Crank Angle Synchronous	**MHEV**	Mild Hybrid Electric Vehicle
CCS	Crane Control System	**ML**	Machine Learning
CHE	Container Handling Equipment	**MQ**	Messaging and Queuing
CMS	Crane Management System	**MQTT**	MQ Telemetry Transport
COM	Component Object Model	**MR**	Mixed Reality
CPU	Central Processing Unit	**MTS**	Microsoft Transaction Server
CRIO	Compact Reconfigurable Input/Output System	**NAS**	Network-Attached Storage
DLT	Distributed Ledger Technology	**NFC**	Near Field Communication
DPF	Diesel Particulate Filter	**NG**	Next Generation
ECU	Engine Control Unit	**NTP**	Network Time Protocol
EDBE	Edge Data Broker Enabler	**OCR**	Optical Character Recognition
EU	European Union	**OEM**	Original Equipment Manufacturer
FL	Federated Learning	**OS**	Operating System
FPGA	Field Programmable Gate Arrays	**OSH**	Occupational Safety and Health
GB	Gigabyte	**OTA**	Over-The-Air
GDPR	General Data Protection Regulation	**PAP**	Policy Administration Point
GIS	Geographic Information System	**PASCAL**	Preservation And Storage Centre For Academic Libraries
GPS	Global Positioning System	**PC**	Project Coordinator
GUI	Graphical User Interface	**PCM**	Powertrain Control Module
GWEN	Gateway Edge Nodes	**PCS**	Port Community System
HMD	Head Mounted Display	**PDP**	Policy Decision Point
HMI	Human-to-Machine Interface	**PDS**	Positioning Detecting System
HW	Hardware	**PEMS**	Portable Emissions Measuring Systems
ID	Identifier	**PEP**	Policy Enforcement Point
IDE	Integrated Development Environment	**PIP**	Policy Information Point
IDM	Instructional Device Manager	**PLC**	Programmable Logic Controller
IFC	Industry Foundation Classes	**PPE**	Personal Protective Equipment
IMU	Inertial Measurement Unit	**RAM**	Random Access Memory
IP	Internet Protocol	**RDE**	Real Driving Emission
ISC	In-Service Conformity	**RMG**	Rail Mounted Gantry
ISE	In-Service Emissions	**ROS**	Remote Operation Station
IT	Information Technology	**RPA**	Relative Positive Acceleration
JS	JavaScript	**RTG**	Rubber-Tyred Gantry (crane)
JSON	JavaScript Object Notation	**RTK**	Real Time Kinematics

Acronym	Explanation	Acronym	Explanation
SCR	Selective Catalytic Reduction	**TOS**	Terminal Operating System
SDN	Software Defined Network	**TT**	Terminal Truck
SEC	Security	**UC**	Use Case
SFP	Small Form-factor Pluggable	**USB**	Universal Serial Bus
SFTP	SSH File Transfer Protocol	**UV**	Ultraviolet
SIM	Subscriber Identity Module	**UWB**	Ultra-Wide Band
SQL	Structured Query Language	**VLAN**	Virtual Local Area Network
SSD	Single Shot Detectors	**VM**	Virtual Machine
SSH	Secure Shell Protocol	**VOC**	Visual Object Challenge
STS	Ship-to-Shore	**VR**	Virtual Reality
SUV	Sports Utility Vehicles	**XACML**	eXtensible Access Control Markup Language
SW	Software	**XCP**	Universal Measurement and Calibration Protocol
TB	Terabyte	**XML**	eXtensible Markup Language
TBD	To Be Done/Defined/Determined	**XMLRDT**	XML Radio Data Terminals
TCP	Transmission Control Protocol	**YOLO**	You Only Look Once
TEU	Twenty-foot Equivalent Unit		

1. About this document

The scope of the deliverable is to report about the implementation activities of the pilot It includes trial[2] plans for the procurement, development, integration, and verification activities of each pilot. This deliverable will have a second version on month M27 with the initial results of the validations and the updated versions of implementation activities of each pilot. Reporting work done in this deliverable not only helps to verify that the software and hardware components from ASSIST-IoT meets the requirements elicited in WP3, but it also helps to clarify what activities are behind or advanced with respect to the original schedule and tackle appropriate mitigation measures if needed.

1.1. Deliverable context

Keywords	Lead Editor
Objectives	**O6:** D7.2 documents the three pilots and integrated third parties, addressing the proposed use cases and scenarios, which is the main outcome expected on Objective 6.
Work plan	D7.2 takes inputs from D7.1 [1], as well as from D3.3 [2] deliverables. In addition, the core and transversal enablers that have been defined in WP4 [3] and WP5 [4], have also been collected to generate the pilot-specific architectural diagrams. The implementation activities reported in D7.2 will be further refined in the forthcoming WP7 deliverables, as well as towards the evaluation and assessment work to be carried out within WP8 tasks.
Milestones	This deliverable marks MS4 – Pilots deployed milestone.
Deliverables	This deliverable receives inputs from D3.3, D4.2, D5.3, and D7.1.

1.2. The rationale behind the structure

The deliverable includes four main sections (2 to 5) that report the implementation activities of each pilot scenario of the project. Each pilot section is in turn split into (i) a context review part, which summarises the testbed scenario for the pilots, followed by (ii) a report of the different implementation activities per trial of the pilot (e.g., procurement, development, integration, and verification activities), and ending with (iii) highlights of deviations from the original planning, if any. Section 6 acts as a summary of the first open call submissions, serving as way to identify the most appealing or relevant pilots for the R&D community outside of the project. Finally, Conclusions are drawn in Section 7.

1.3. Outcomes of the deliverable

Like described in the introductory section of this document, D7.2 iterates over D7.1 Deployment Plan and Operational Framework deliverable [1]. Hence, on the one hand D7.2 consequently describes the progress being made in the different Pilot projects within ASSIST-IoT, always in relation to the D7.1 deployment plan, while implicitly ensuring a successful continuation of the Pilots from M18 onwards on the other hand.

In general, as D7.2 is the first in a series of three Pilot evolution reporting documents (D7.3 and D 7.4 are scheduled for M27 and M36, respectively), the deliverable is consequently focusing on the procurement of Pilot specific infrastructure, both hardware and software, and their early setup-phase (considering that only 6 months of actual execution of pilots have occurred). Henceforth, the originally foreseen development, integration, and validation activities are still on their infancy in most of the cases. This was already foreseen via D7.1, therefore no relevant deviations are to be declared.

Regarding pilot specific outcomes, the following ones have been identified:

- Pilot 1 trials #1 and #2 are in good shape. The mobile application over which users will interact with ASSIST-IoT infrastructure is well advanced, and initial successful integration with current MFT

[2] The selection of trial terminology for WP7 activities, instead of the previous ones used in other parts of the project is justified in Section 1.4

systems have been performed. The plan for the next term of the project is to replace the current systems for the Next Generation features of ASSIST-IoT. On the other hand, Pilot 1 Trial #3 is experiencing procurement delays caused by, on the one hand, Konecranes and MFT management matters, and on the other hand by global chip shortage. Nevertheless, the expected delays should not be longer than two-three months with respect to the original plan, which should not pose significant risks to Pilot 1 implementation.

- Pilot 2 testbed has been finally moved from the original Szczecin building to the educational building being constructed on the campus of the University of Warsaw. The efforts carried out during the 6 months period from D7.1, have been on generating comprehensive architectural diagrams of all trials in order to identify the mandatory HW components, as well as the required ASSIST-IoT enablers that should be integrated in the pilot. This has led to a judicious re-organization of the trials of the pilot (instead of 4 there will be 3), and within them (e.g., compared to what was described in D7.1, the number of sub-trials for the "Occupation safety and health monitoring" trial has been reduced from 4 to 3). Unfortunately, in contrast with other pilots, the chip shortage (lack of smart devices and servers) and the finalization of relevant enablers have led to a slow start of the development/integration/validation activities of Trial #1 and Trial #2. However, this is considered at this point as a non-significant deviation, considering that only 6 months of actual pilot have been executed and that, now, every device is agreed and under test, thus implementation activities are already starting at the moment of writing the deliverable. Additional remarks for each trial are listed next:
    - In trial #1, the verification of entry to the construction site will take place on the basis of the camera image, and not on the basis of construction worker wristband, as initially planned.
    - Regarding trial #2, a localization tag is to be used to detect slips, trips, falls and immobility of the construction worker, instead of the fall arrest detector originally planned (i.e., fall-related incident detection will be based on acceleration, not force).
    - Finally, the updated Trial #3 merges the original Safe navigation, and Health and safety inspection support Business Scenarios. It should be noticed that since BIM models, as well as MR devices were already available since M12, this trial is much more advanced than the others.
- Pilot 3A has successfully completed the procurement of relevant measurement hardware, sensor, and software tools, including temporary replacements for not yet available ASSIST-IoT solutions, while at the same time the work on the envisioned software framework was started.
- Pilot 3B Trial #1: Vehicle exterior condition inspection and documentation, several advancements have been performed across the preparation of the already available TwoTronics scanner for the pilot, as well as the setup of the remote server for enabling the access to external partners of the project to integrate and validate the ongoing development activities. It also applies to the provision of a more human-friendly user interface developed by TwoTronics and CERTH. As the rest of the pilots, the hard core of integration activities related to the ASSIST-IoT enablers will take place whenever their Most Valuable Product version is available during the second period of the project.

1.4. Lessons learnt

From the work carried out after the finalization of D7.1, the following insights have been extracted with regards to WP7 activities:

- **Lesson 1:** During the documentation of the different Pilots, it was noticed that deliverable timing, together with the reporting structure inherited from D7.1, slowed down the capacity of pilot stakeholders to focus on development/integration activities, despite all good efforts from partners and lead editors. Therefore, it has been decided that, in order to simplify the Pilot documentation in D7.3 (intermediate version) and D7.4 (final version), some mandatory intermediate milestones will be established, so that more agile documentation requiring less effort spread through bigger time spans will be carried out. It is expected that this decision will improve the pilot completion pace while supporting a frequent documentation of the progress being made in the various Pilots.
- **Lesson 2:** Recurrent discussions regarding the proper terminology to be used in the project in general have been raised during the period from D7.1 and D7.2. This was also further examined in order to set

up a clear differentiation between the WP3 and WP7 scope. These discussions have finally led to the following agreement: While WP3 will still be using "Business scenarios" and "use cases", WP7 deliverables will talk about "trials" (and "sub-trials" if needed). Compared to D7.1, one can notice that D7.1 started using the "demo" word, but according to the below definitions [5], project partners agreed that the activities of WP7 should be defined as ***trials*** (not only demos, which are envisioned within enablers development):

- ***Demo*** **-** a demonstration, or demo, for short, is a **brief overview of the product's features**.
- ***Trial*** **-** is an opportunity for the customer to implement the product in their own environment. The objective is to **give the customer the ability to have hands-on experience with the product and to validate the features and capabilities pitched by the manufacturer in the demo**.

The following figure aims at clearly identifying the nomenclature used in the different parts of the project:

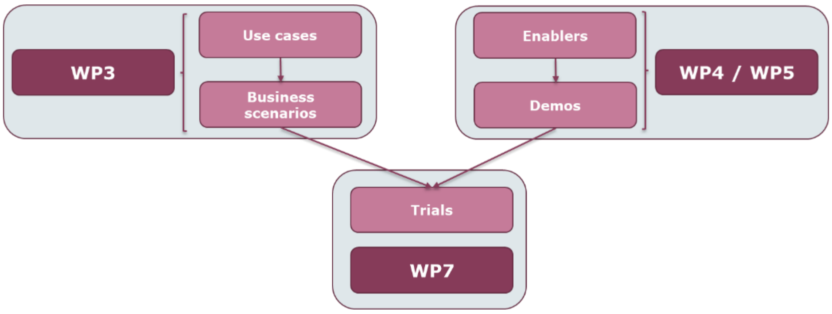

Figure 1. Agreed WP7 terminology

1.5. Version specific notes

It is worth remarking that, resulting from the above-mentioned decision related to naming, some confusion could be generated when reading D7.1 and (its continuation in) D7.2. Both operational and technical scopes of pilots are now clearer, thus the preferred terms (i.e., trials) have been adopted and simplifications/extensions have been put in place. In order to clarify how the classification in D7.1 and the structure of pilots in D7.2 map, the following illustration has been prepared:

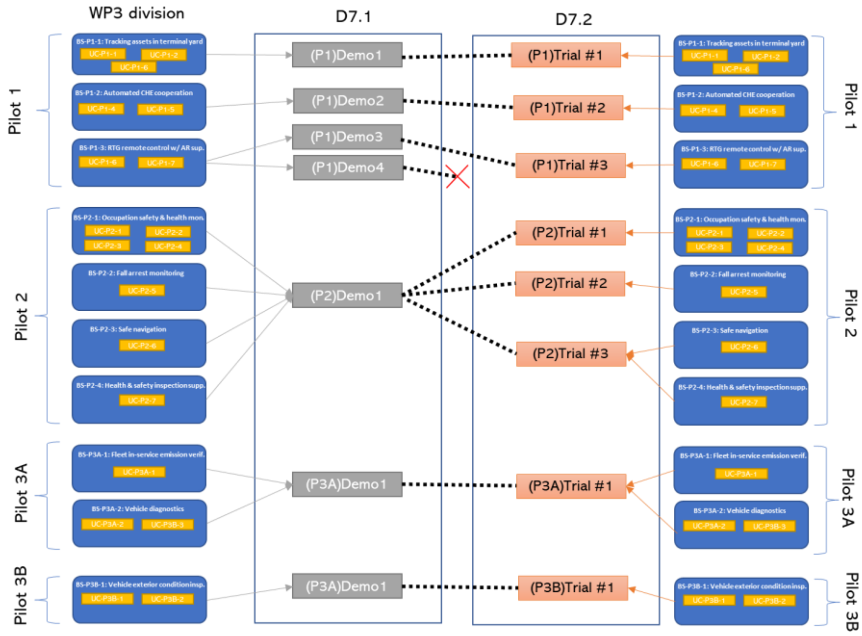

Figure 2. Mapping of terms/classification of pilots between D7.1 and D7.2

1.6. Deviation and corrective actions

The procurement of pilot hardware turned out to be an additional driver in pilot activities, as essential ASSIST-IoT hardware was not available due to several reasons, like explained already in the Executive Summary. This led to the need to develop a temporary replacement infrastructure and consequently resulting in additional tasks to move from the current to the final architecture. As all temporary solutions have been chosen carefully to allow a maximum compatibility with the ASSIST-IoT ecosystem, the current assumption is that that the additional tasks will not cause any critical delays.

An unavoidable fact related to pilots is that they are directly dependent of the advance of enablers. WP4 and WP5 are at the half of their execution, therefore enablers are not (globally) ready to be used in integrated environments, which in some way prevents WP7 from advancing at its own pace. However, according to the project's time plan, MVP versions of the enablers will be ready end of M18. Thus, integration activities (although slightly misaligned with respect to the original planning) will begin with enough time for successfully validating the trials of ASSIST-IoT pilots.

Relevant challenges have been faced on Pilot 2 that were related to an unclarified governance and technical structure of partners in the pilot. This very fact has been discussed with the Coordination and it has been corrected (included in the on-going amendment) by agreeing among Pilot 2 partners that partner P03 IBSPAN (SRIPAS) overtakes the role of "technical leader" of the pilot, taking over a series of software development tasks originally undervalued and that were assigned to non-IT members of the pilot.

1.7. Ethical issues

As not all pilot sites are yet in place, **the detailed list of the filled forms will be included in deliverable D7.3**. Until the time of the current deliverable, no issue has occurred. Any issues (if any) will be reported in the deliverables of WP7 that are closely related to the pilot implementation in a separate section detailing the event(s).

2. Pilot 1: Port Automation

2.1. Context review

The Port Automation pilot will be driven by the Industrial partner Terminal Link Group (TL), which manages more than 13 container terminals and is related with another 12 terminals (from CMA-CGM Terminals) and CMA-CGM shipping line (3rd largest shipping line in the world, with ~500 vessels). Specifically, this scenario will be carried out and validated in the Malta Freeport infrastructure (MFT) [6], which amalgamates the activities of container handling and industrial storage, being a critical node of the European sea logistics.

Figure 3. MFT overall view

Since October 2004, when the container terminal was privatised, more than 300 M€ have been invested in the infrastructure: heavy investment in equipment like Ship-To-Shore (STS) cranes, technological enhancements like the deployment of the Navis N4 TOS, yard expansion, etc. While MFT is investing in industrial assets and heavy machinery, to avoid bottlenecks and improve operational efficiency it is also necessary to invest in smart services like the ones that are going to be developed, deployed, and validated within ASSIST-IoT.

Figure 4. Malta Freeport Container Terminal

The Port Automation Pilot of ASSIST-IoT aims at helping container terminal operators to improve the operational efficiency. ASSIST-IoT will help on making better decisions to container terminal stakeholders by means of improving the availability of information over which the operators can interact with, as well as facilitating the automation of repeating workflows. Three trials were identified in D7.1. Their associated implementation activities during the M12-M18 period are described in the following sections.

2.2. Trial #1: Tracking assets in terminal yard

2.2.1. Scope

This trial aims at enabling the traceability of containers within the port infrastructure to prevent losing them, as well as to enhance the operational efficiency of terminal operators (including not only internal, but also external drivers). To achieve this, the positions of all CHEs within the yard, including external trucks as well, will be tracked. All this information is combined in the Terminal Operating System in order to link the location of all CHEs with the job orders, i.e., containers handled in the yard.

The following figure illustrates de architectural block diagram of Trial #1. As it can be seen, up to 8 ASSIST-IoT enablers have been identified to be part of the trial. Regarding HW, it is expected as described in the following section that the current IoT Gateways used in MFT may be replaced by GWENs (if they meet the computing requirements of the system). They will expose the telemetry information collected in the cranes PLCs, as well as their GPS location coordinates.

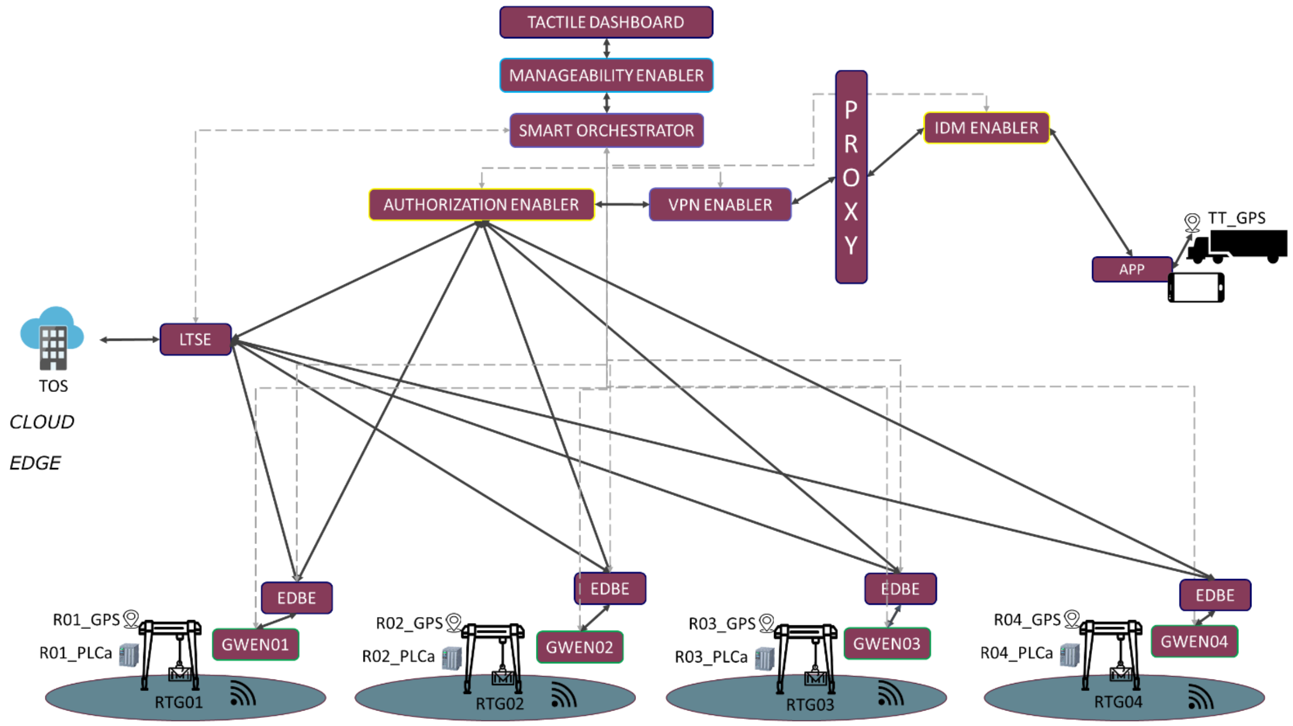

Figure 5. Architectural block diagram of Pilot 1 - Trial #1

2.2.2. Implementation activities reporting

2.2.2.1. Procurement activities

The status of the procurement activities related with this trial of Pilot 1, which were identified in D7.1, is updated next.

Pilot1_SetupAct_ID1 RTG crane: Available and integrated within the pilot. Most of RTG cranes deployed in MFT yard are already connected with a previous IoT system. However, two of them will be subject of testing with the different ASSIST-IoT enablers, as well as specific pilot development activities.

Pilot1_SetupAct_ID2 RTG PLC: Available and integrated within the pilot.

Pilot1_SetupAct_ID3 CAN Bus converter: Discarded.

Pilot1_SetupAct_ID4 IoT Gateways: Available and integrated within the pilot. Currently, Siemens IoT2040 Gateways are available and integrated within the pilot. They will be replaced by GWEN Gateways once they are available.

Figure 6. RTG crane (left), RTG PLCs (centre), IoT Gateway (right) installed on MFT

Pilot1_SetupAct_ID10 IoT-GPS and **Pilot1_SetupAct_ID11 D/RTK-GPS:** Available and integrated within the pilot. It should be noticed that RTG cranes in MFT have installed two types of GPS. However, while a few of them are equipped with industrial-grade D/RTK-GPS, most of them employ a more commercial regular GPS from Banner brand as the latter are more inexpensive.

Figure 7. GPS devices (Novatel D-GPS and regular Banner GPS)

Pilot1_SetupAct_ID12 TT (Terminal Truck): Available and integrated within the pilot.

Pilot1_SetupAct_ID13 RTG PDS: Discarded. Pilot partners have realised that there is no need to have access to the PDS for this trial. Hence, it has been dropped from the original procurement activities of this trial, although the functionality to warning the driver that there is a mistake will be in place.

Pilot1_SetupAct_ID14 TT MTS Server (position): Available and integrated within the pilot

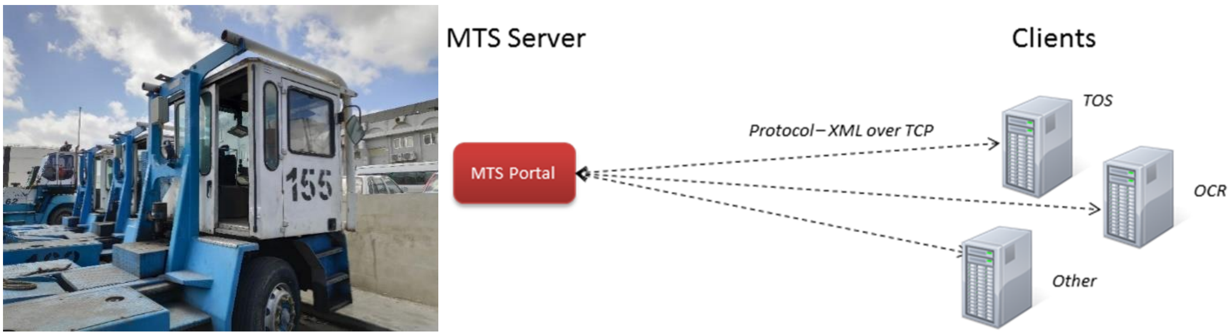

Figure 8. Terminal Truck (TT) (left), MTS server used for obtaining TTs position (right)

Pilot1_SetupAct_ID15 TOS Navis: progress. The TOS is being used in the MFT terminal, being the core system for operational management. Therefore, since the ASSIST-IoT project requires access to it, it should be well coordinated and ensuring that its regular performance will not be affected. However, some overload of resources is affecting to this integration, and it has been agreed to move from current trigger-based integration to a more stable and safer XMLRDT-based one, which is the Navis (TOS brand) own protocol. This will require some time, which was not planned originally, leading to potential deviations on its availability for the project.

Pilot1_SetupAct_ID18 Tablet Honeywell: Available and integrated within the pilot**.** MFT's Terminal Trucks are equipped with tablets from Honeywell brand. For debugging and testing purposes, two of them (Windows-based Honeywell VM3, and Android-based Honeywell VM1A) have been shipped to PRO lab. While the mobile app being developed in Pilot1_DevAct_ID3 is properly installed in the VM3, the default security setup of the VM1A is restricting its access, so that the staff is facing some integration obstacles, which are expected to be solved for the next report.

Pilot1_SetupAct ID19 VM3 GPSs: It has been noticed that VM3 devices do not support GPS, so that the procurement of a VM1A/VM2 compatible new GPS module and antenna is under progress.

2.2.2.2. Development activities

Pilot1_DevAct_ID1-SEC authentication: In progress. Please, refer to Section 2.3.2.2 for more details.

Pilot1_DevAct_ID2-SEC incident management: In progress. Please, refer to Section 2.3.2.2 for more details.

Pilot1_DevAct_ID3 Smartphone application: In progress. PRO is developing a native smartphone application that will become the ASSIST-IoT entry gate for external users (either MFT terminal administrators, internal RTG and TT drivers, as well as external drivers). Next, some screenshots of the workflow of the app are depicted.

When opening the app, the login screen is presented. For the time being, this login management is hardcoded, but it will be replaced by the IdM and Authorization enablers when they are ready.

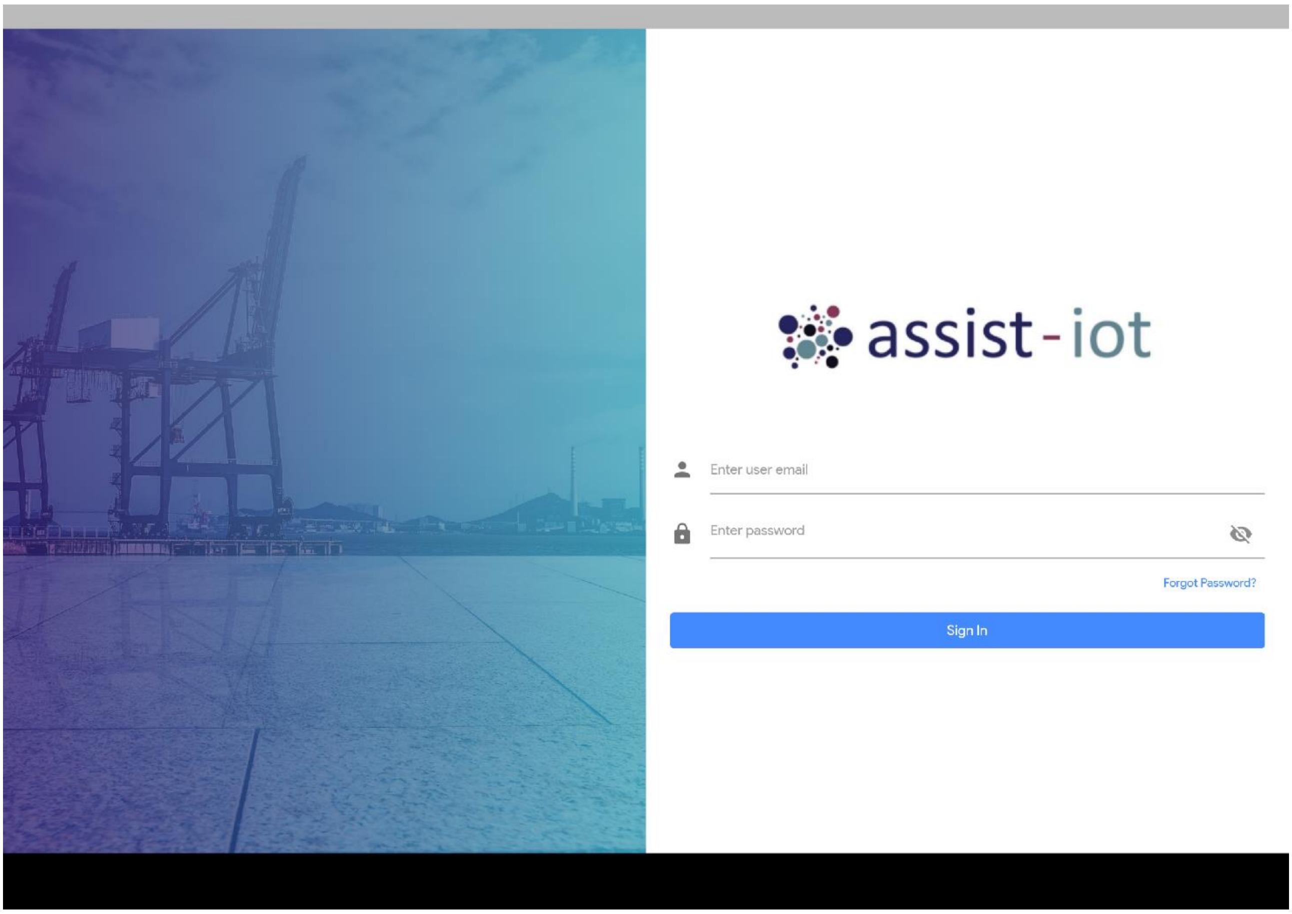

Figure 9. ASSIST-IoT Pilot 1 mobile app Login screen

Once logged-in, the user accesses to the main screen of the app as shown below. It is split in several modules:

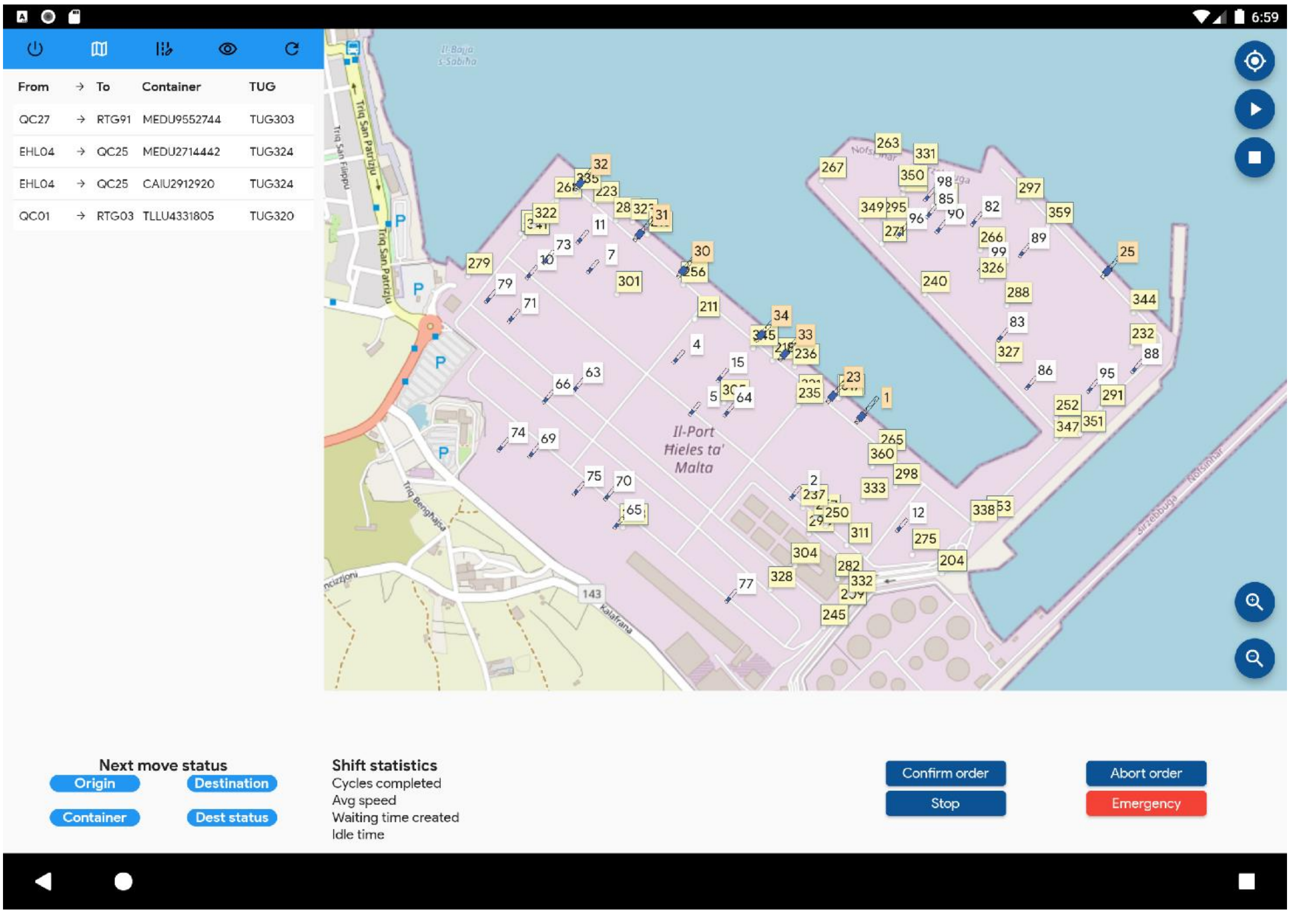

Figure 10. ASSIST-IoT Pilot 1 mobile app Main screen

- In the left pane, the list of working instructions assigned to the truck driver is presented. The bottom part of the left pane provides a human-centric translation from the working instruction message in order to help drivers about their origin and destination, as well as container ID, and the current status of the working instruction itself. This list is obtained by connecting to the TOS (see Pilot1_SetupActID15 above), which will be in between stored in the NoSQL component of the ASSIST-IoT LTSE, when the latter is available.
- At the bottom-right pane of the application, different action buttons such as Confirm order (i.e., working instruction), abort order, stop or emergency will communicate with the TOS when the latter is available for integration.
- The main panel presents the yard map, with the location of the different assets of the terminal. The location recovery of MFT assets is carried out by subscribing (via websockets) to an Apache Kafka system already installed in the terminal, which, in turn receives the location of the RTGs, STSs, and TTs from the IoT Gateways. An extract of the JSON messages received by the backend service of the mobile app is presented below.


```
.{
    "msgTimestamp": "2022-02-08T10:14:45.000Z",
    "che.id": "RTG064",
    "che.id_name": "RTG64",
    "che.type": "RTG",
    "che.family": "RTG62-81",
    "che.brand": "KoneCranes",
    "che.number": 64,
    "msgTimestampEpoch": 1644315285,
    "che.coordinate.gps_banner": [14.5365872, 35.8177024],
    "che.coordinate.che_banner": [14.536628259683084, 35.81774207890946],
    "che.coordinate.spreader_banner": [14.536611767443333, 35.81772614128465],
```

```
    "che.coordinate.gps": [14.5365872, 35.8177024],
    "che.spreader.coordinate": [14.536611767443333, 35.81772614128465],
    "type_register": "Instantaneous"
  }, {
    "msgTimestamp": "2022-02-08T10:14:45.000Z",
    "che.id": "RTG092",
    "che.id_name": "RTG92",
    "che.type": "RTG",
    "che.family": "RTG82-101",
    "che.brand": "KoneCranes",
    "che.number": 92,
    "msgTimestampEpoch": 1644315285,
    "che.coordinate.gps_banner": [14.54452, 35.8173056],
    "che.coordinate.che_banner": [14.544561059477928, 35.81734527890946],
    "che.coordinate.spreader_banner": [14.5445445673206, 35.81732934128465],
    "che.coordinate.gps": [14.54452, 35.8173056],
    "che.spreader.coordinate": [14.5445445673206, 35.81732934128465],
    "type_register": "Instantaneous"
  },
```


Figure 11. Example of ASSIST-IoT Pilot 1 JSON message

Although already explained before, it should be remarked that it is expected that ASSIST-IoT will boost the replacement of current Siemens IoT2040 devices for the NG-IoT ones being developed by Neways (branded as GWEN), which will also include the EDBE by default. The EDBE will be the ASSIST-IoT broker that will communicate with the current Apache Kafka of the terminal.

The next figure presents the expected workflow once a driver selects one of the working instructions listed in the left pane. In the main map pane, it will indicate the guide route considering the origin and destination points extracted from the working instruction selected. The route calculation is still pending due to the lack of a GIS detailed cartography of the terminal. This layout, which is being collected, will include yard distribution in the form of streets, blocks and bays, and will serve to the PGRouting system to indicate the most optimum route. PRO and TL have reached to the Malta Port Authority, as it is the owner of this digital information.

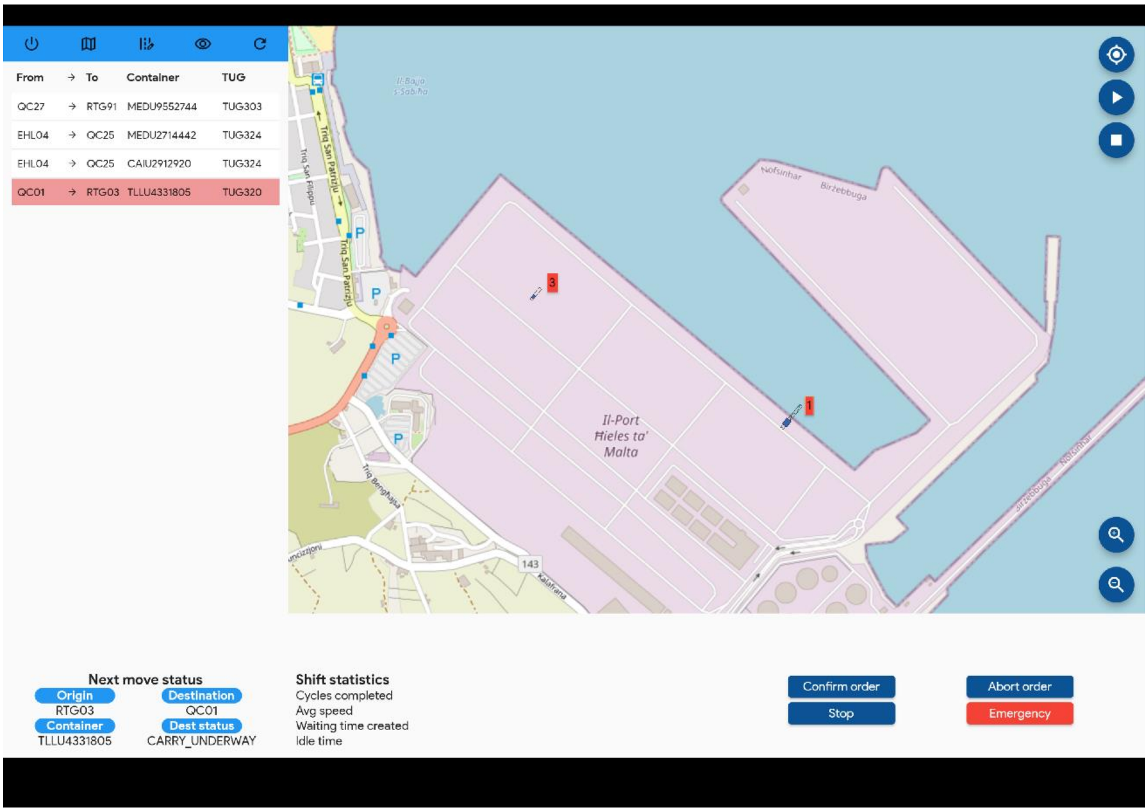

Figure 12. ASSIST-IoT Pilot 1 mobile app Route map screen

2.2.2.1. Integration activities

Integration activities in this pilot are in principle associated to the integration of the different identified ASSIST-IoT enablers (which were highlighted in the architectural diagram of Figure 5). Since these enablers are not fully operational yet, all the integration activities have been postponed for the second term of the project.

Pilot1_IntAct_ID1-SEC T53Ex integration into mobile app: Not started yet. Postponed until cybersecurity enablers are developed, and ready for integration.

Pilot1_IntAct_ID2-SEC incident management: Not started yet. Postponed until cybersecurity enablers are developed, and ready for integration.

Pilot1_IntAct_ID7 T44Ex dashboards and T55Ex integration: Not started yet. Postponed until T44 and T55 enablers are developed, and ready for integration.

Pilot1_IntAct_ID11 integration PDS: Discarded. As mentioned in Section 2.2.2.1, the trials of Pilot 1 will not finally make use of MFT PDS. Thus, Pilot1_IntAct_ID11 has been removed from the original planning.

2.2.2.2. Validation activities

Like development activities, and integration activities, the validation activities related to the ASSIST-IoT enablers have been postponed until they are fully operational and ready for deploying on Pilot 1.

Pilot1_ValAct_ID1-SEC Operation authorization: Not started yet. Postponed until cybersecurity enablers are developed, and ready for integration.

Pilot1_ValAct_ID2-SEC Operation validation: Not started yet. Postponed until cybersecurity enablers are developed, and ready for integration.

Pilot1_ValAct_ID6 Optimal route: Not started yet. Postponed until MFT GIS cartography layout is provided by Malta Port Authority.

2.2.3. Deviations from original planning

Gantt chart summarising the task implementation for Trial #1. Major changes include the withdrawal of Pilot1_SetupAct_ID3, Pilot1_SetupAct_ID13, and Pilot1_IntAct_ID11. Modifications in the time estimation for the remaining tasks as explained in the text above are also shown here.

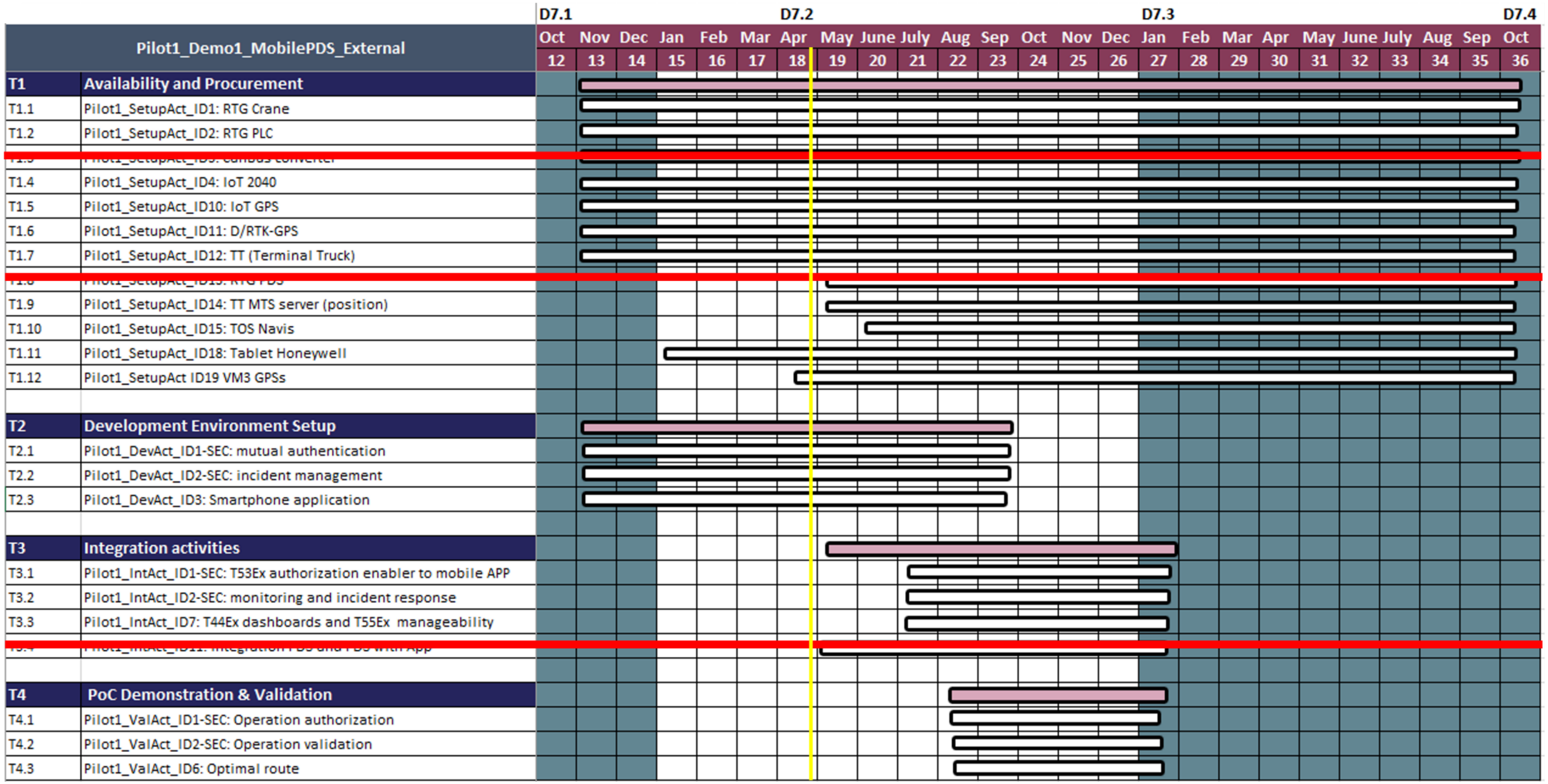

Figure 13. Pilot 1 – Trial #1 updated Gantt chart (M18)

2.3. Trial #2: Automated CHE cooperation

2.3.1. Scope

The scope of Pilot 1 – Trial #2 is to enhance the operational performance by enabling CHEs cooperation from an alignment automation perspective, so containers are moved automatically from RTG cranes to trucks (TT or external). To do so, the machines will first identify and authenticate each other before starting the operation. Then, the RTG will guide the truck to the correct position using LIDAR sensors and UWB location system. The process will be illustrated through positioning guidance lights, as well as a new screen over the ASSIST-IoT mobile app that will be installed in truck driver's cabin.

The following figure illustrates de architectural block diagram of Trial #2. As it can be seen, a short-range M2M communication system is expected for this trial, so that "only" 3 ASSIST-IoT enablers will be required for the trial. Like the previous trial #1, MFT IoT Gateways may be replaced by GWENs. Additionally, LIDAR sensors, and a dedicated UWB communication system will be used to guarantee the authentication on proximity requirement identified in D3.3.

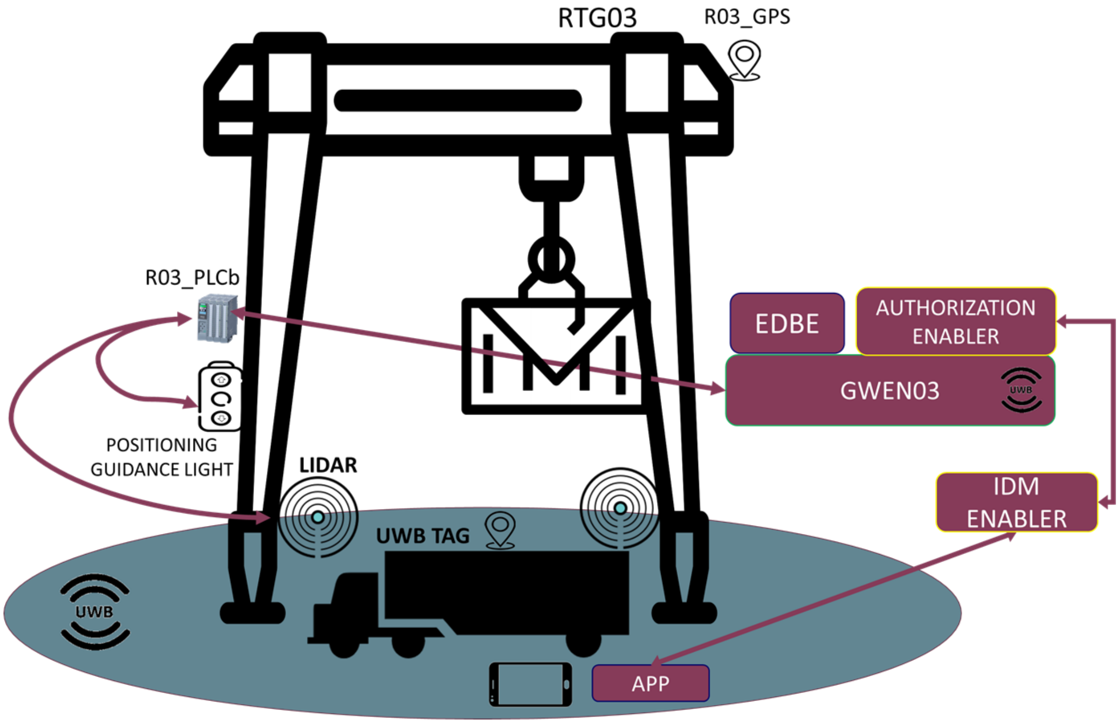

Figure 14. Architectural block diagram of Pilot 1 - Trial #2

2.3.2. Implementation activities reporting

2.3.2.1. Procurement activities

The status of the procurement activities related with this trial of Pilot 1, which were identified in D7.1, is updated next.

Pilot1_SetupAct_ID1 RTG crane: Same SetupAct in Trial #1. Go to Section 2.2.2.1 for more details.

Pilot1_SetupAct_ID2 RTG PLC: Same SetupAct in Trial #1. Go to Section 2.2.2.1 for more details.

Pilot1_SetupAct_ID3 CANBus converter: Discarded. Go to Section 2.2.2.1 for more details.

Pilot1_SetupAct_ID4 IoT Gateways: Same SetupAct in Trial #1. Go to Section 2.2.2.1 for more details.

Pilot1_SetupAct_ID9 LIDAR System: Engineering and purchasing activities ongoing. As a first step on the automation journey of Malta Freeport RTG cranes, ASSIST-IoT partner KONE will install several 3D laser sensors creating a complete LIDAR system for (i) reducing the risk of collision with containers (by constantly monitoring the distance between the RTG spreader and the stack), and (ii) for signalling, by means of guiding lights visible to the truck operators, the desired position where to park the truck. The following figure illustrates how the LIDAR system works. As it can be seen on the right side, the system will be formed by the CCS computer, dedicated crane PLC, truck positioning sensors, and truck guiding lights, which are all internally communicated using PROFINET protocol.

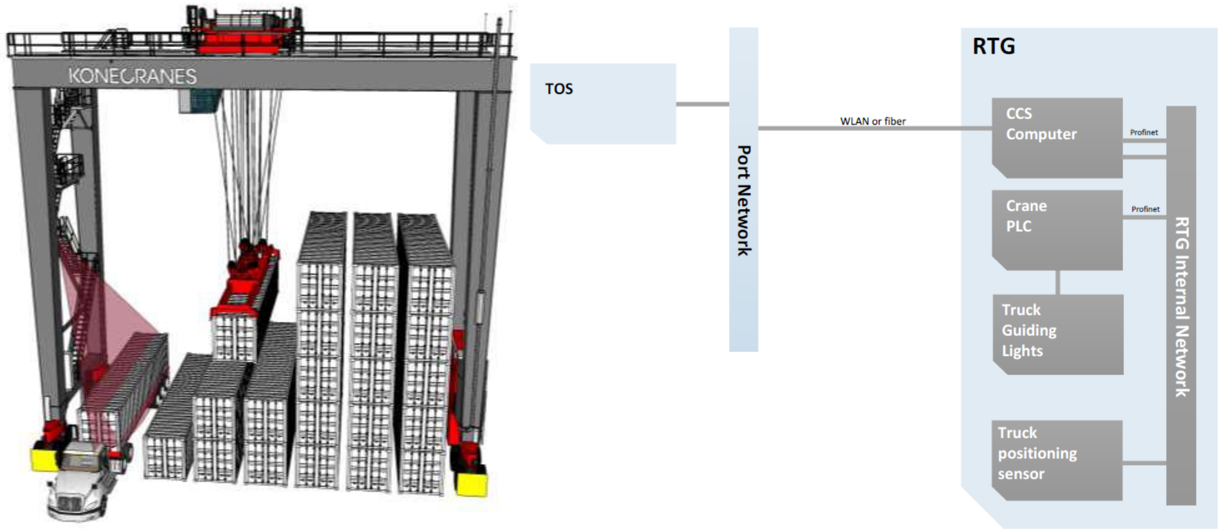

Figure 15. Pilot 1 SetupAct_ID9 illustration (left), hardware schema (right)

Pilot1_SetupAct_ID12 TT (Terminal truck): Same SetupAct in Trial #1. Go to Section 2.2.2.1 for more details.

Pilot1_SetupAct_ID15 TOS Navis: Same SetupAct in Trial #1. Go to Section 2.2.2.1 for more details.

Pilot1_SetupAct_ID18 Tablet Honeywell: Same SetupAct in Trial #1. Go to Section 2.2.2.1 for more details.

In addition, one more procurement activity related to the identification and mutual authentication of CHEs when they are in close proximity has been identified:

Pilot1_SetupAct_ID20 UWB system: For the identification and authentication process triggering, it has been decided to set up an Ultra-Wide Band (UWB) communication system. WiFi or Bluetooth was also possible, but finally, the selected trigger was UWB.

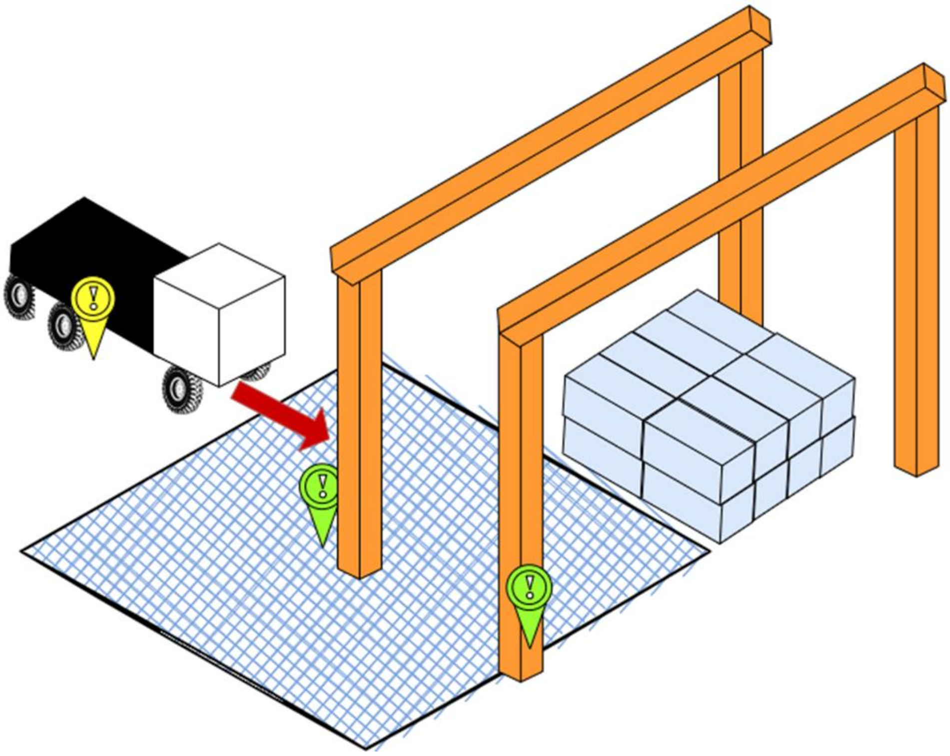

Figure 16. Close-proximity mutual identification/authentication

This short-range system is seen as the NG-IoT alternative to Bluetooth due to its very accurate Real-Time Location capabilities [7]. The Decawave MDEK1001 Development Kit [8] has been selected for the first tests of the trials. It provides the necessary hardware, software and development environment to quickly evaluate UWB features and performance. The evaluation kit includes 12 encased development boards (DWM1001-DEV), as shown in the Figure 17.

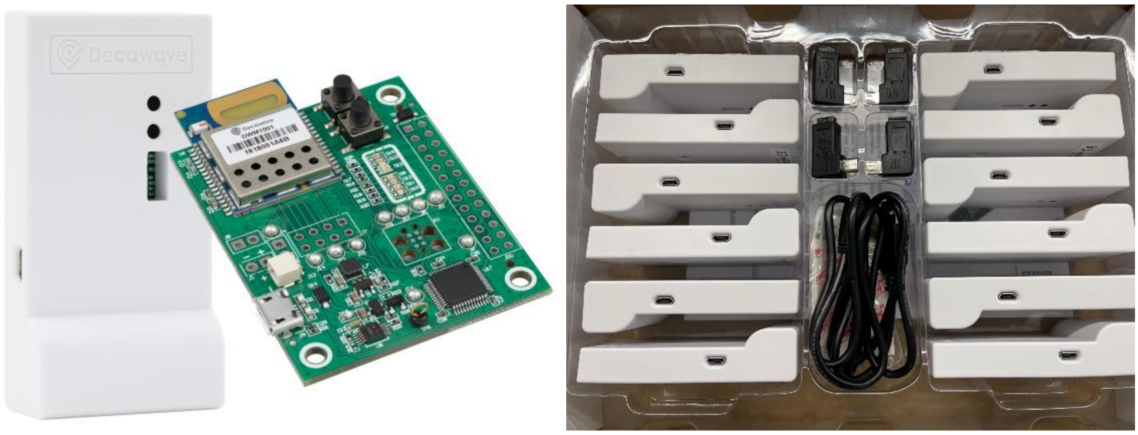

Figure 17. Pilot 1 SetupAct_ID20 Decawave MDEK1001 Development Kit.

2.3.2.2. Development activities

Pilot1_DevAct_ID1-SEC authentication: In progress. This development activity is focused on truck and RTG crane mutual authentication and validation when they are in close proximity. To do so, two sub-development activities are in progress.

1. First, both CHEs should be located in close proximity, which, as explained in Pilot1_SetupAct_ID20, it will be guaranteed by the UWB experiment module described in previous section. The use of the UWB devices will help in increasing security, because the access to the RTG crane telemetry data will be denied until the CHEs are close enough. The first tests have been focused on identifying how the distance between the devices is measured. It has been identified that there are two types of UWB

devices. While sensors defined as UWB tags start up the UWB programme, the UWB anchors are in charge of getting the response of the distance between both. To obtain the response, the UWB anchors have been connected via serial port, through which the logs of the distance between them is obtained. An example of the logs received on the serial port can be seen in the following screenshots, where the identifier of the sensor transmitting the distance, the identifier of the receiving sensor and the distance between both sensors are shown.

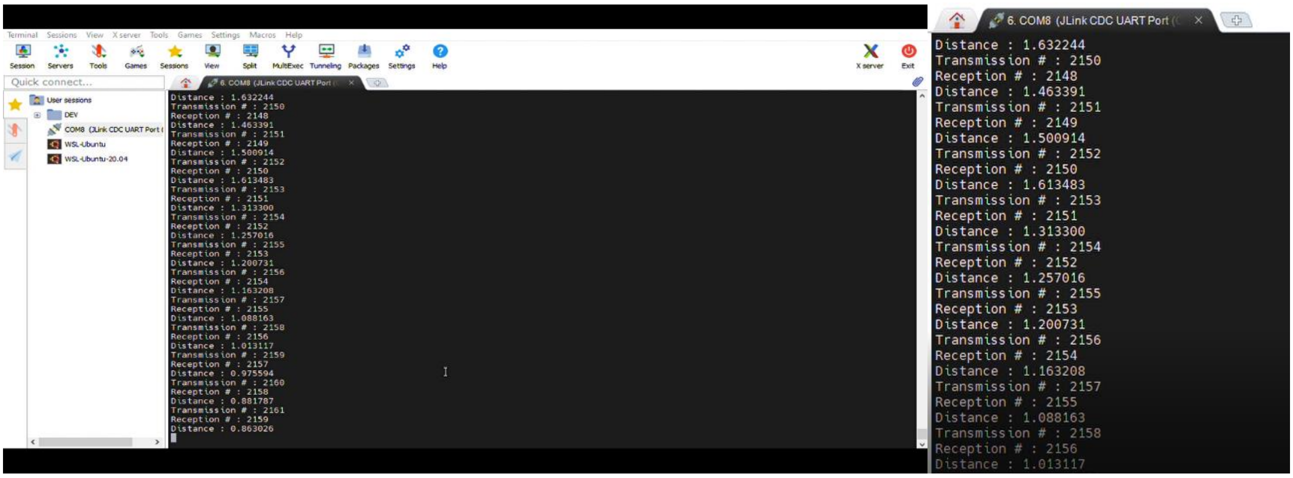

Figure 18. Decawave UWB distance logs

This distance will be used to apply a Kafka subscription to trigger the mobile app installed on the Honeywell (VM1A and/or VM) when the UWB tag mounted over the truck under test for the trial is entering into the geofenced area of the UWB anchor installed in the RTG crane (this will probably require not only two UWB anchors, but four). Consequently, the truck mobile app will start consuming RTG telemetry messages such as truck lane positioning (from LIDAR system, or loading/unloading container status - from spreader's trolley/hoist movement).

2. Second sub-activity is related with the management of pre-defined authentication users (i.e., UWB tags directly linking trucks/truck drivers), and authorization roles. To do so, the integration of cybersecurity enablers is paramount, which are still under development.

Pilot1_DevAct_ID2-SEC incident management: In progress. This development activity is focused on incorporating monitoring and incident response to the cybersecurity operation centre. In particular, it will ensure that the location of the container being handled by ASSIST-IoT RTG cranes matches with the expected position assigned in the TOS working instruction. In case both GPS coordinates do not match, the incident management system will send an alert to the ASSIST-IoT mobile application, which, in turn, will represent the wrong matching by triggering a graphical alert.

Pilot1_DevAct_ID3 Smartphone application: In progress. In addition to the development progress described in Section 0, the multi-platform smartphone application will provide additional contextual information when the truck has reached the RTG crane involved in the working instruction. Two sub-use cases are identified in this trial: RTG-Truck alignment, and Container handing operations reporting.

- ***RTG-Truck alignment***: When arriving at the destination point (and the ASSIST-IoT UWB proximity mechanism allows consuming PLC data), the map view will be replaced by the alignment view. This view will indicate to the driver by means of arrow icons where to move. This information will be acquired by the LIDAR PLCs installed in the crane (see next development activity) and sent to the Apache Kafka topic being consumed by the truck application through the EDBE installed on ASSIST-IoT Gateways.

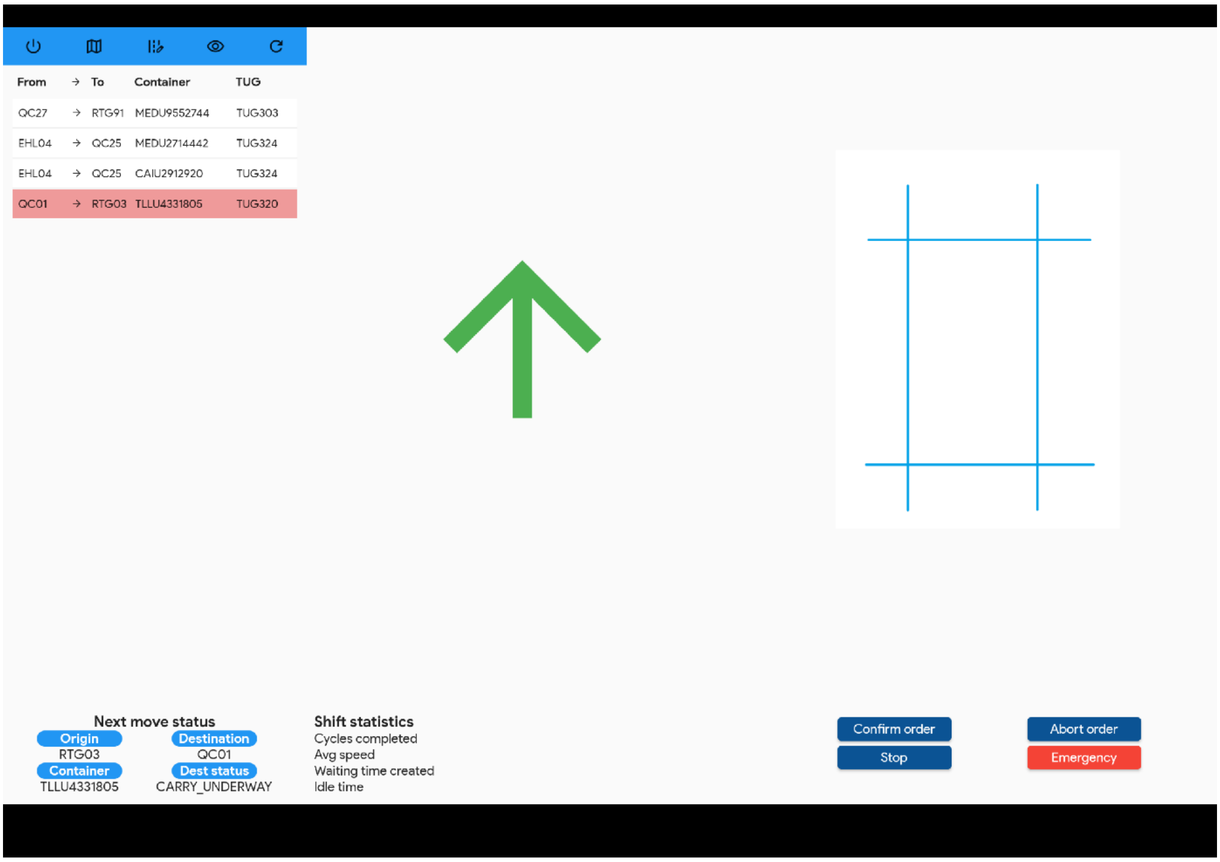

Figure 19. ASSIST-IoT Pilot 1 mobile app RTG-Truck alignment view

- ***Container handling operations reporting***: Once the truck is correctly positioned, a warning message will appear. When the driver presses OK button, the alignment view will change to the container handling view, which makes it easier for the driver inside the truck to see what movements the crane is making above him. This view provides a human-centric GUI of the telemetry data of the trolley and hoist movements of the spreader of the RTG crane under work. This information is obtained in the mobile app via websocket consuming the corresponding Apache Kafka topic produced by the ASSIST-IoT EDBE.

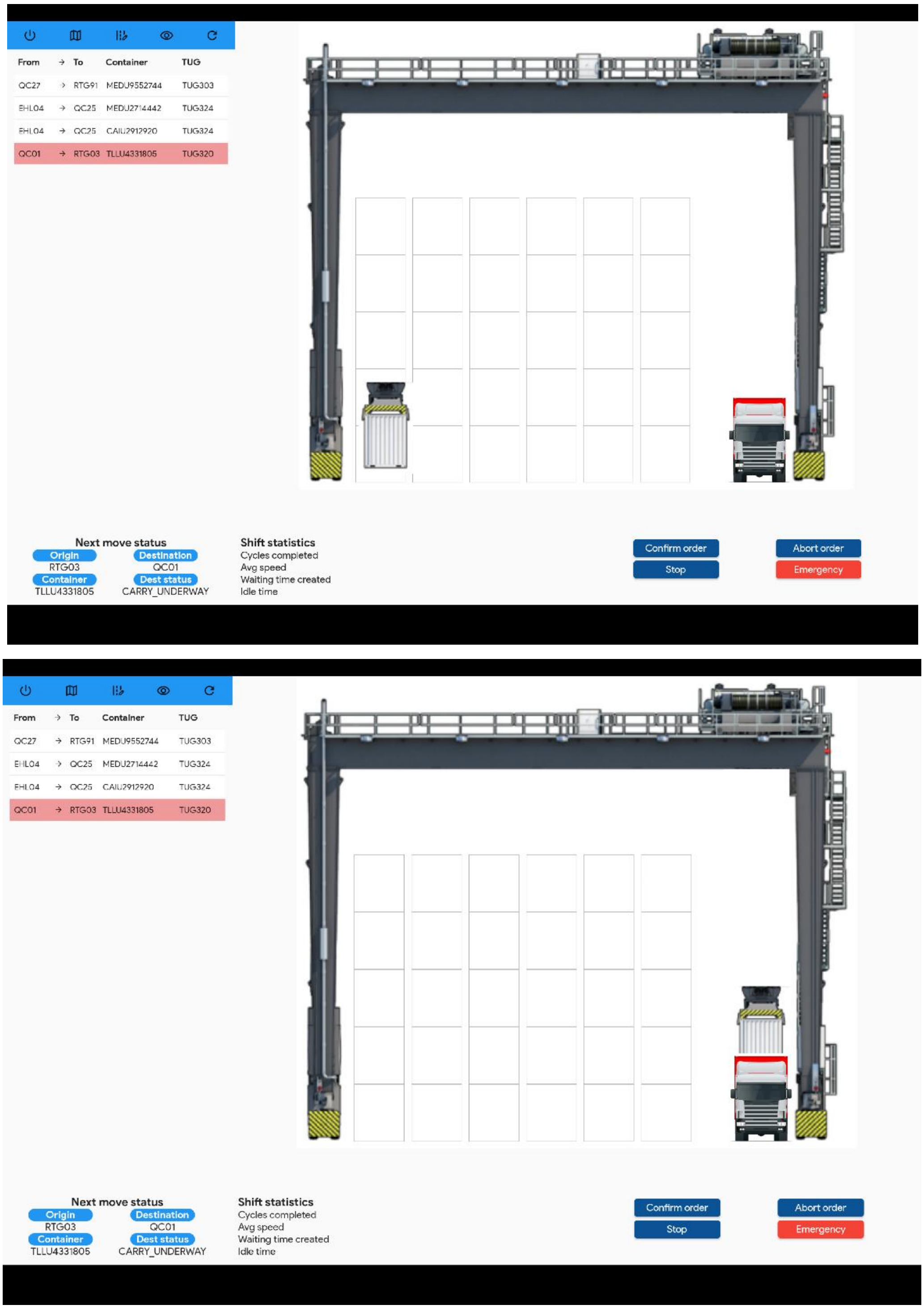

Figure 20. ASSIST-IoT Pilot 1 mobile app Container handling reporting view

Pilot1_DevAct_ID5 LIDAR System: Not started yet. In addition to the aforementioned development activity, the mobile app will also support a human-friendly Graphical User Interface, presenting the truck position within the truck lane by retrieving the PLC messages from the LIDAR system (see Pilot1_SetupAct_ID9 LIDAR System). Since the LIDAR system will not be installed and ready for use in MFT until M23 (or even later, depending on shipping global situation), and in order to speed up this activity, KONE will provide datasets from lab-crane PLCs (truck position in centimeters from approximately +/- 5 meters from the centerline of the crane in order to give reliable data) in the forthcoming weeks.

2.3.2.3. Integration activities

Integration activities in this pilot are in principle associated to the integration of the different identified ASSIST-IoT enablers (which were highlighted in the architectural diagram of Figure 14). Since these enablers are not fully operational yet, all the integration activities have been postponed for the second half of the project.

Pilot1_IntAct_ID1-SEC T53Ex integration into mobile app: Not started yet. Postponed until cybersecurity enablers are developed, and ready for integration.

Pilot1_IntAct_ID2-SEC incident management: Not started yet. Postponed until cybersecurity enablers are developed, and ready for integration.

Pilot1_IntAct_ID6 Commissioning of LIDAR: Not started yet. Postponed until the LIDAR system is shipped to MFT premises (expected for M22).

Pilot1_IntAct_ID7 T44Ex dashboards and T55Ex integration: Not started yet. Postponed until T44 and T55 enablers are developed, and ready for integration.

Pilot1_IntAct_ID6 M2M LIDAR: Not started yet. Postponed until the LIDAR system is shipped to MFT premises (expected for M22).

Pilot1_IntAct_ID11_integration PDS: Discarded. As in Trial #1, Pilot 1 will not finally make use of MFT PDS. Thus, Pilot1_IntAct_ID11 has been removed from the original planning.

2.3.2.4. Validation activities

Like development activities, and integration activities, the validation activities related to the ASSIST-IoT enablers have been postponed until they are fully operational and ready for deploying on Pilot 1.

Pilot1_ValAct_ID1-SEC Operation authorization: Not started yet. Postponed until cybersecurity enablers are developed, and ready for integration.

Pilot1_ValAct_ID2-SEC Operation validation: Not started yet. Postponed until cybersecurity enablers are developed, and ready for integration.

Pilot1_ValAct_ID5 LIDAR Hardware tests: Not started yet. Postponed until the LIDAR system is shipped to MFT premises (expected for M22).

Pilot1_ValAct_ID8 M2M Nearby protocol: In progress. Although some validation tests of data consumption triggering by UWB modules are being carried out in PRO laboratory, additional work is still pending. Furthermore, once the system is properly validated in the lab, it will be sent to MFT for start the debugging process in terminal premises.

2.3.3. Deviations from original planning

Gantt chart summarising the task implementation for Trial #2. Major changes include the withdrawal of Pilot1_SetupAct_ID3_CANBus_converter, and Pilot1_IntAct_ID11. Modifications in the time estimation for the remaining tasks as explained in the text above are also shown here.

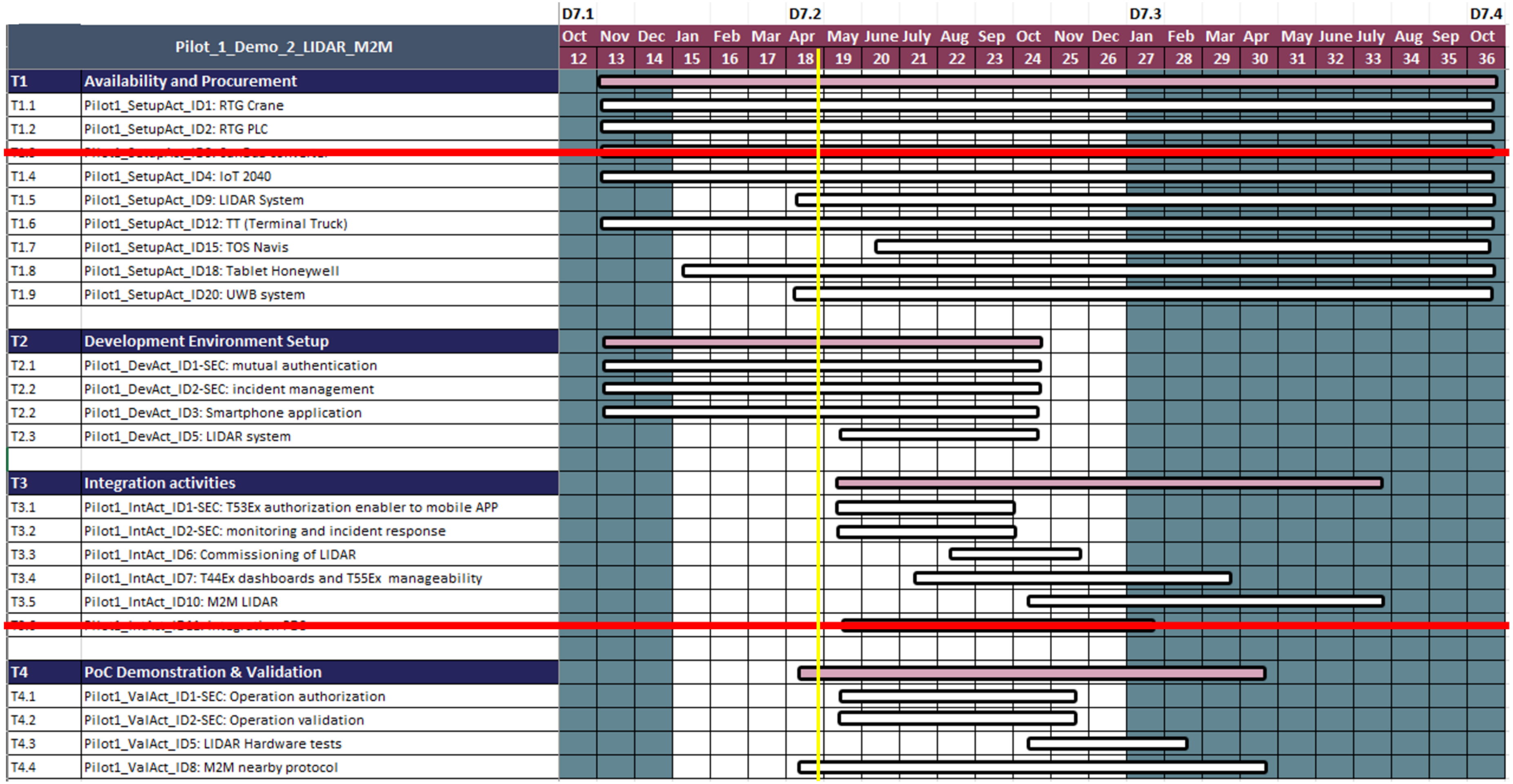

Figure 21. Pilot 1 - Trial #2 updated Gantt chart (M18)

2.4. Trial #3: RTG remote control with AR support

2.4.1. Scope

Trial #3 includes the completely remote operation of RTG cranes, which by means of ASSIST-IoT enablers will on the one hand reduce the deployment costs by enabling the connection between the operator and the RTG via wireless communications, with multiple redundant links and, on the other hand, empower the crane operators with visuals indicating which container should be handled and where should it be placed afterwards in the remote screens.

The following figure illustrates the architectural block diagram of Trial #2. As it can be seen, up to 11 ASSIST-IoT enablers have been identified (it should be noted that some of them will be use-case exclusive, like the Multilink enabler required for the multi-wireless ROS access, or the Video Augmentation enabler required for the object recognition). Regarding HW, several equipment should be installed in MFT in order to provide the ROS capabilities (e.g., A/V system, ROS Desktop, new PLCs, etc.). A detailed description of them was included in D7.1, while D7.2 just updates their implementation status.

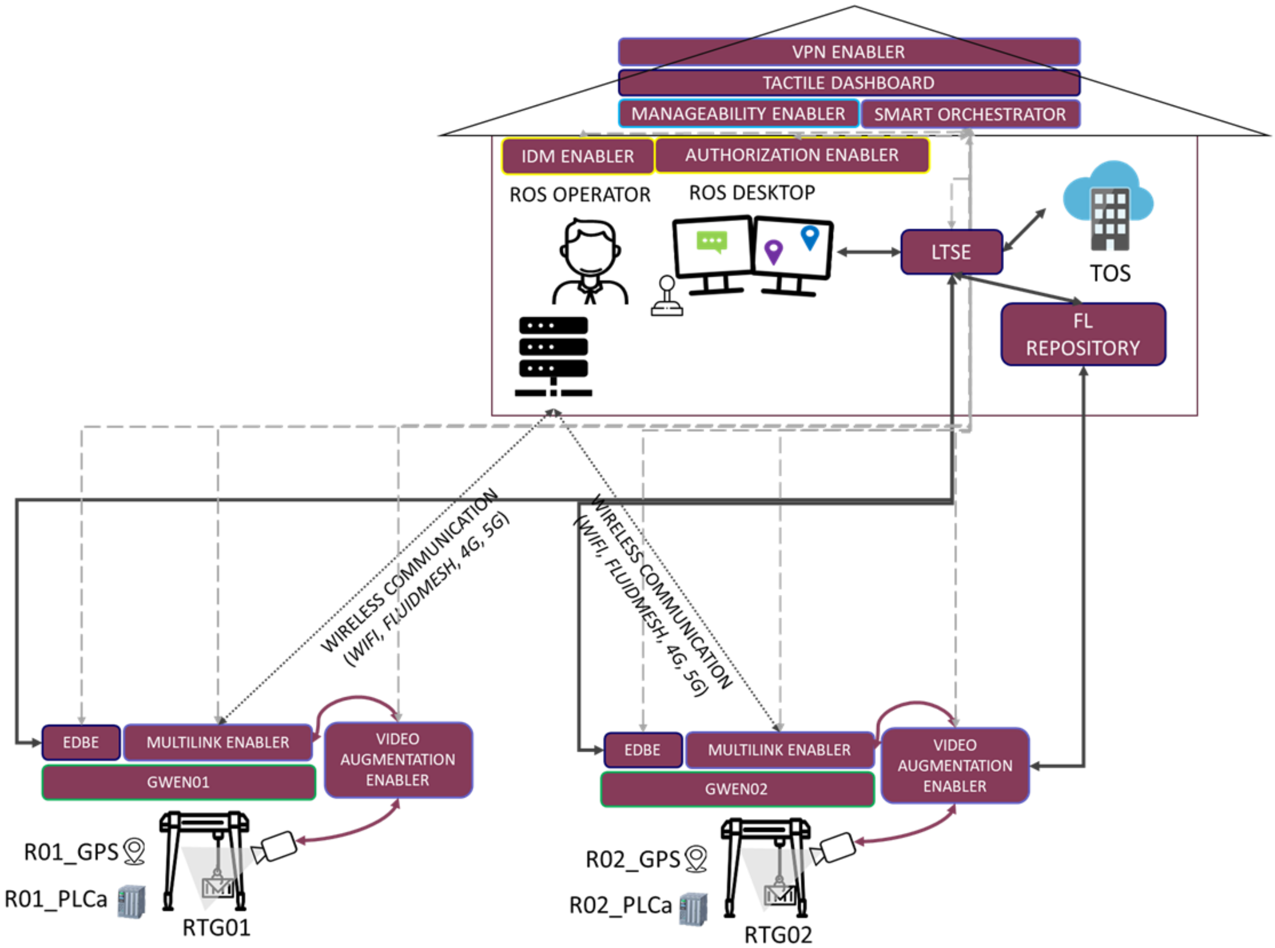

Figure 22. Architectural block diagram of Pilot 1 - Trial #3

2.4.2. Implementation activities reporting

2.4.2.1. Procurement activities

Pilot1_SetupAct_ID1 RTG crane: Same SetupAct in Trial #1. Go to Section 2.2.2.1 for more details.

Pilot1_SetupAct_ID2 RTG PLC: Same SetupAct in Trial #1. Go to Section 2.2.2.1 for more details.

Pilot1_SetupAct_ID5 RTG Audio-visual: Engineering and purchasing activities ongoing.

Pilot1_SetupAct_ID6 RTG Remote Operating Desktop station: Engineering and purchasing activities ongoing.

Pilot1_SetupAct_ID7 RTG Crane task management server: Engineering and purchasing activities ongoing.

Pilot1_SetupAct_ID8 Central PLC: Engineering and purchasing activities ongoing.

Figure 23. RTG Audio-visual system (left), ROS Desktop station (centre), and Central PLC (right)

Pilot1_SetupAct_ID13 RTG PDS: Available and integrated within the pilot. The Remote Operating System requires access to the PDS of the terminal. Therefore, although discarded for the other two previous trials, it will be needed for Pilot 1 trial #3.

Pilot1_SetupAct_ID15 TOS Navis: Same Setup Activity as in Trial #1. Go to Section 2.2.2.1 for more details.

Pilot1_SetupAct_ID16 Fluidmesh: Fluidmesh 3500 ENDO transceivers are already deployed in MFT. However, the current Fluidmesh license acquired by the terminal provides up to 50 Mbps, which has been considered insufficient for supporting the two remote RTG cranes that will be implemented in ASSIST-IoT (60 Mbps per crane is required, i.e., a Fluidmesh license supporting at least bandwidths of 120 Mbps is required). Therefore, although the equipment is available and integrated within the pilot, it will be upgraded in the upcoming months.

Pilot1_SetupAct_ID17 Virtual servers: The 6 dedicated virtual servers originally identified in D7.1 have been reduced to 3: ***AV Server, Diagnostics Server, and NTP & Netmon Server***. The three are already set up by IT department of MFT. However, ongoing discussions with respect to the required number of VLAN needed are still in place. According to the specifications sheet, ***8 VLANs are needed***: (i) CCS/CMS Servers, (ii) AV Servers, (iii) Profinet Control&Safety, (iv) LAN management, (v) CCS/CMS RMG, (vi) CCS/CMS ROS, (vii) AV RMG, (viii) AV ROS. A final telco between network experts of KONE, PRO, and MFT to finally confirm if these are the required needs will be held during M19.

2.4.2.2. Development activities

Pilot1_DevAct_ID4 AI/ML container recognition: In progress. The AI/ML container recognition will help remote crane drivers with the visual guidelines highlighting the container over which he/she has to operate with. The development activity can be split in three parts.

- The first part is related with the collection of images/videos from similar scenarios. KONE has been in charge of this part, and by obtaining A/V tests from their labs and from other customers, they have gathered up to 27 videos from the spreader view, which have been later on split into more than 700 images/screenshots.
- The second part is related with the annotation of the collected images. The open-source Linux-based software LabelImg [9] has been used for that purpose. The annotations are saved as XML files in PASCAL VOC format, which is used by ImageNet, and is also supported in YOLO and CreateML formats. The main labels that are identified in the dataset are “*container*”, “*spreader*”, and “*truck*”.

- The third part uses a customized variant of the general Video Augmentation enabler. The enabler makes use of both Tensorflow Object Detection 2, and OpenCV frameworks. For the time being, several ML models from the pre-trained TensorFlow 2 Zoo Detection library have been tested [10]. The best results have been obtained with the ssd_resnet50_v1_fpn_640x640. An extract of the dataset of the project, as well as the outputs of the trained model are shown in Figure 24. The TotalLoss obtained for that model with the project's current annotated dataset is around 8. According to Tensorflow official documentation, it is advisable to allow the trained model to reach a TotalLoss of at least 2 (ideally 1 and lower) in order to achieve "fair" detection results. Therefore, the development team has considered that a higher accuracy should be obtained. To do so, additional datasets have been requested to KONE, but unfortunately, it is not a straightforward task. As a mitigation measure, it has been proposed to obtain new ones from the MFT remote cameras when they are installed in M22.

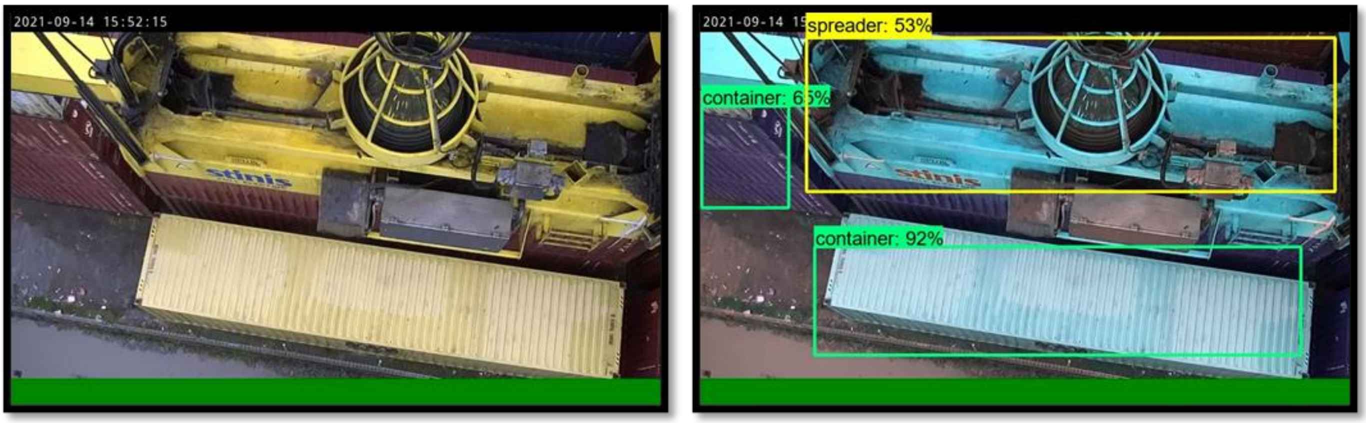

Figure 24. Target visualization screenshot (raw image - left; identified container - right)

Screenshots of the recognized containers, the size of the trained dataset,

2.4.2.3. Integration activities

Pilot1_IntAct_ID3 Network ROS commissioning: Not started yet. Commissioning of the system according to schedule.

Pilot1_IntAct_ID4 Crane PLC and Central PLC: Not started yet. Commissioning of the system according to schedule.

Pilot1_IntAct_ID5 A/V system: Not started yet. Commissioning of the system according to schedule.

Pilot1_IntAct_ID7 T44Ex dashboards and T55Ex integration: Not started yet. Postponed until T44 and T55 enablers are developed, and ready for integration.

Pilot1_IntAct_ID8 T42Ex multilink: Not started yet. Postponed until Multilink enabler is developed, and ready for integration.

Pilot1_IntAct_ID11_integration PDS: Not started yet. Postponed until remote operating ROS system is in place.

Pilot1_IntAct_ID12 AI/ML container recognition: Not started yet, as the AI/ML container recognition is considered not accurate enough. Furthermore, despite initially contemplated its integration into KONE's lab cranes, they are currently out of work due to maintenance and are not expected to be available until summer 2022. Therefore, since the remote A/V system will also be deployed in MFT around that period, it has been considered as a mitigation measure to directly carry out the work over the MFT remote cranes of ASSIST-IoT.

2.4.2.4. Validation activities

Pilot1_ValAct_ID3 ROS tests: Not started yet. Testing of the system according to schedule.

Pilot1_ValAct_ID4 A/V device tests: Not started yet. Testing of the system according to schedule.

Pilot1_ValAct_ID5 LIDAR Hardware tests: Not started yet. Postponed until the LIDAR system is shipped to MFT premises (expected for M22).

Pilot1_ValAct_ID7 Multilink: Not started yet. Postponed until Multilink enabler is developed, and ready for integration.

Pilot1_ValAct_ID9 Video AI/ML software: Not started yet. Although initial tests have been carried out with PRO's equipment, the aim of this activity is to verify the functionality of the AI/ML system in the real environment of MFT.

2.4.3. Deviations from original planning

Gantt chart summarising the task implementation for Trial #3. None of the tasks have been withdrawn in this trial. Delays and modifications in time estimations as explained in the text above are also shown.

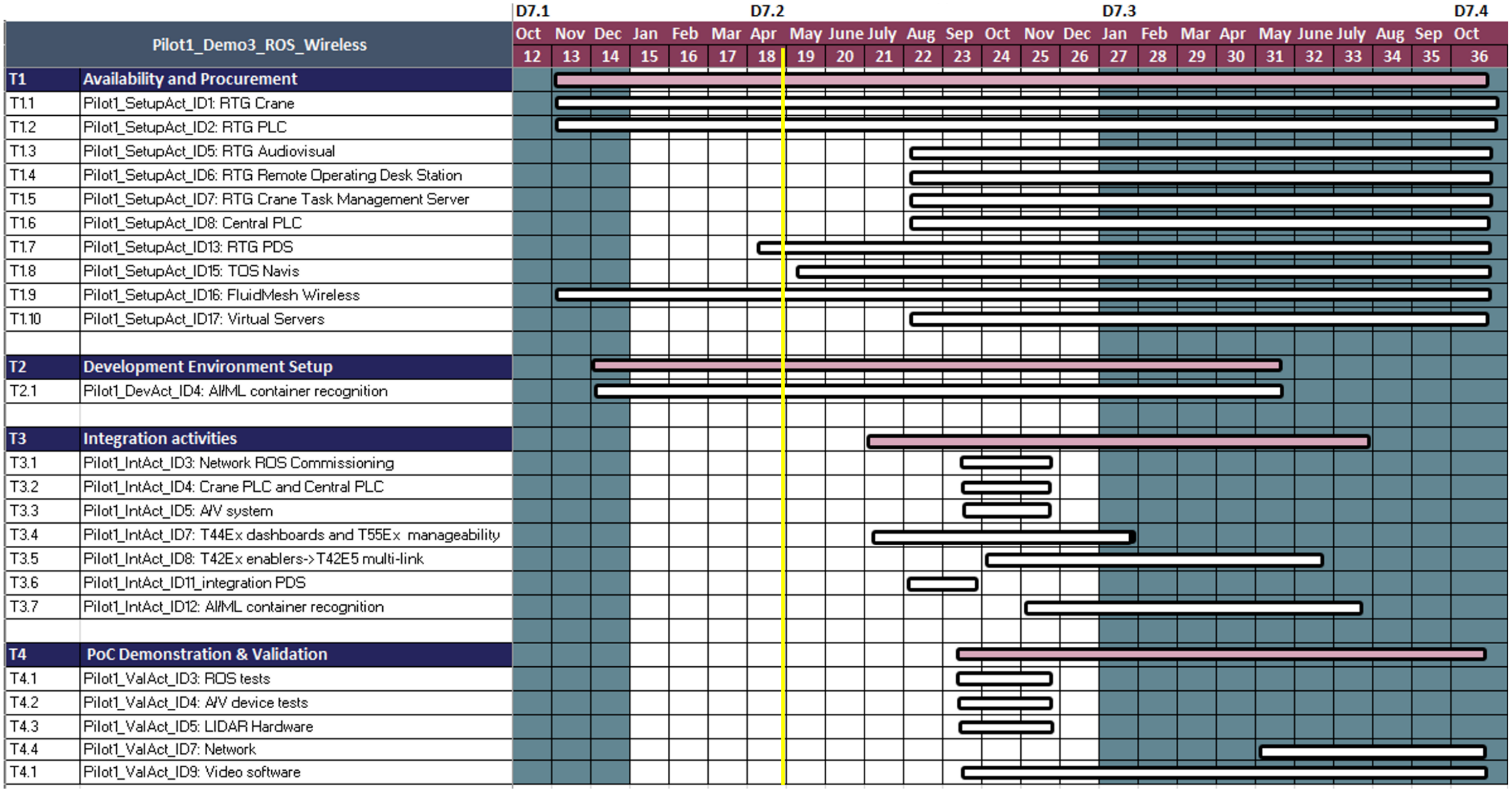

Figure 25. Pilot 1 – Trial #3 updated Gantt chart (M18).

3. Pilot 2: Smart safety of workers

3.1. Context review

Mostostal Warszawa S.A. is one of the largest building companies in Poland. The company is active in all basic sectors of the construction market focusing on steel construction, public buildings, environmental protection projects, as well as roads constructions.

For the purpose of the pilot, construction of educational building on the campus of the University of Warsaw has been selected in order to integrate the architectural proposal and technologies developed by ASSIST-IoT. The 8-storey building with a total area of 26 600 m2 will provide 30 lecture halls for nearly 400 students at the University of Warsaw. The project is dedicated towards sustainability, by providing energy-saving electrical installations, the use of heat recovery systems and renewable energy sources. The new location in Warsaw guarantees access to the 5G network. The project will be managed by project partner MOW.

The point clouds have been used to compare it with the BIM models. The Common Data Environment (CDE) and BIM models are used to manage the project documentation.

Figure 26. University of Warsaw campus visualization.

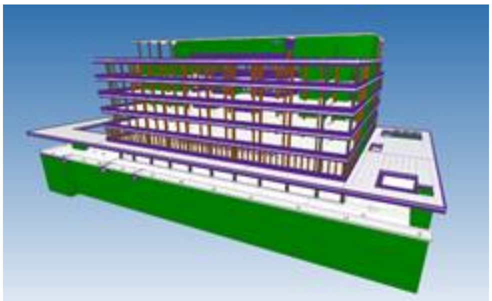

Figure 27. The visualization and BIM model of a demonstration building in Warsaw

3.1.1. Global scope of Pilot 2

This section has been included in Pilot 2 since several discussion among partners conclude that a first description of the architectural diagrams of the trials of this pilot should be provided. In particular, it was agreed to have a common hardware diagram for the entire pilot, shown below, while specific-trial software diagrams are illustrated in their corresponding sections.

All use cases share the same basic computing infrastructure. It consists of several ASSIST-IoT Gateway Edge Nodes (**GWEN**), and a server placed on the worksite. The computing nodes will be connected via WiFi and Ethernet networking. Additional processing may take place in the cloud, accessible via a 5G Internet connection.

Figure 28 presents the connections between the hardware to be used in the pilot. The purpose of this diagram is to illustrate a general principle, rather than specify a rigid network structure. For example, the number of GWENs on the worksite will vary depending on the current size of the building. The various IoT devices will be dynamically connecting to the most suitable GWEN at a given moment. Simply put, the GWENs create a computing and communication backbone for other devices.

The details of the specific IoT devices are discussed in the appropriate trial descriptions below.

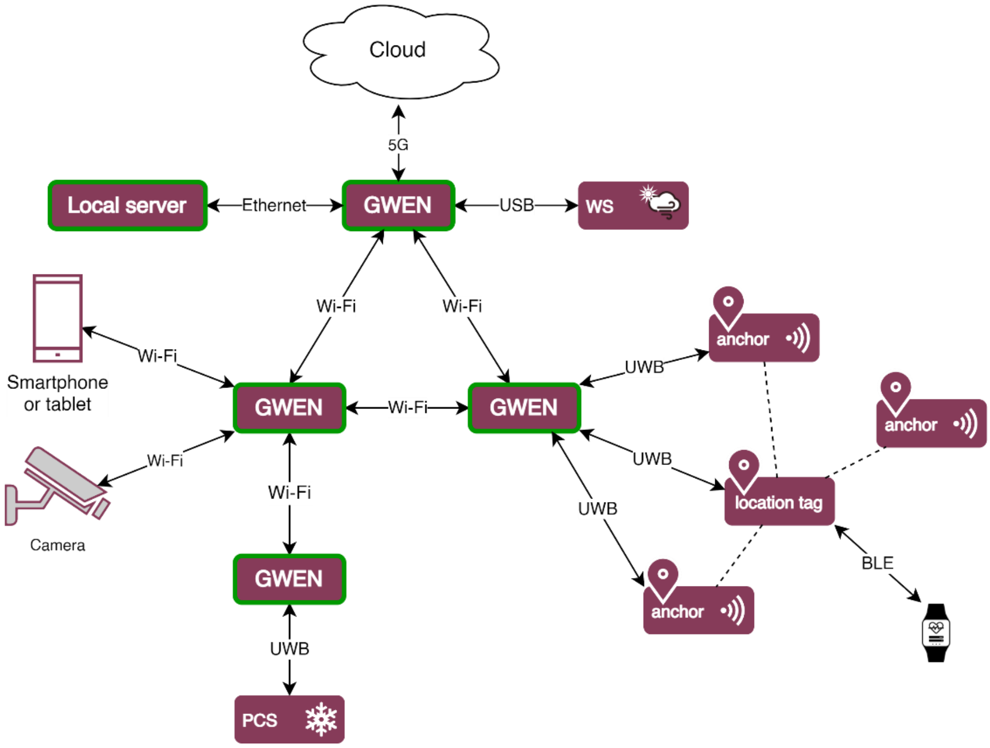

Figure 28. Hardware architectural diagram for Pilot 2

There are several common, custom software components introduced for the purpose of this pilot:

- **Workplace safety controller** – a custom containerized application containing most of the "core" logic for ensuring the safe operation of the construction site.
- **Construction site controller** – a custom component aggregating the information on the assignment of workers on the worksite, their qualifications and training, and assigned equipment (PPE, other smart devices).
- **BIM processor** – software pipeline for extracting the necessary information from IFC files. This process will be performed only once per BIM model revision.
- **Device interface/collector** – custom "thin" components interfacing with the IoT devices running embedded software.

In order for the system to be aware of the workers on the site and their assigned equipment, it must be first configured. Figure 29 presents the workflow for inputting information in the relevant components.

- The OSH manager (or any other authorized person) inputs or imports from a spreadsheet the information about (i) worker training and qualifications, (ii) their assignments and permissions, and (iii) their identification numbers and assigned PPEs and smart devices. The OSH manager is supported with automation tools such as NFC tag readers and optical character recognition (OCR).
- The construction plant operator can independently pair a mobile device to them using their NFC identification tag.
- The information about workers' training and qualifications is stored in the Long-Term Storage enabler.
- The remaining configuration is stored in the Construction site controller, which also receives the semantically annotated worker information.

- The configuration managed by the Construction site controller can be later accesses by the Workplace safety controller to fulfil its tasks.

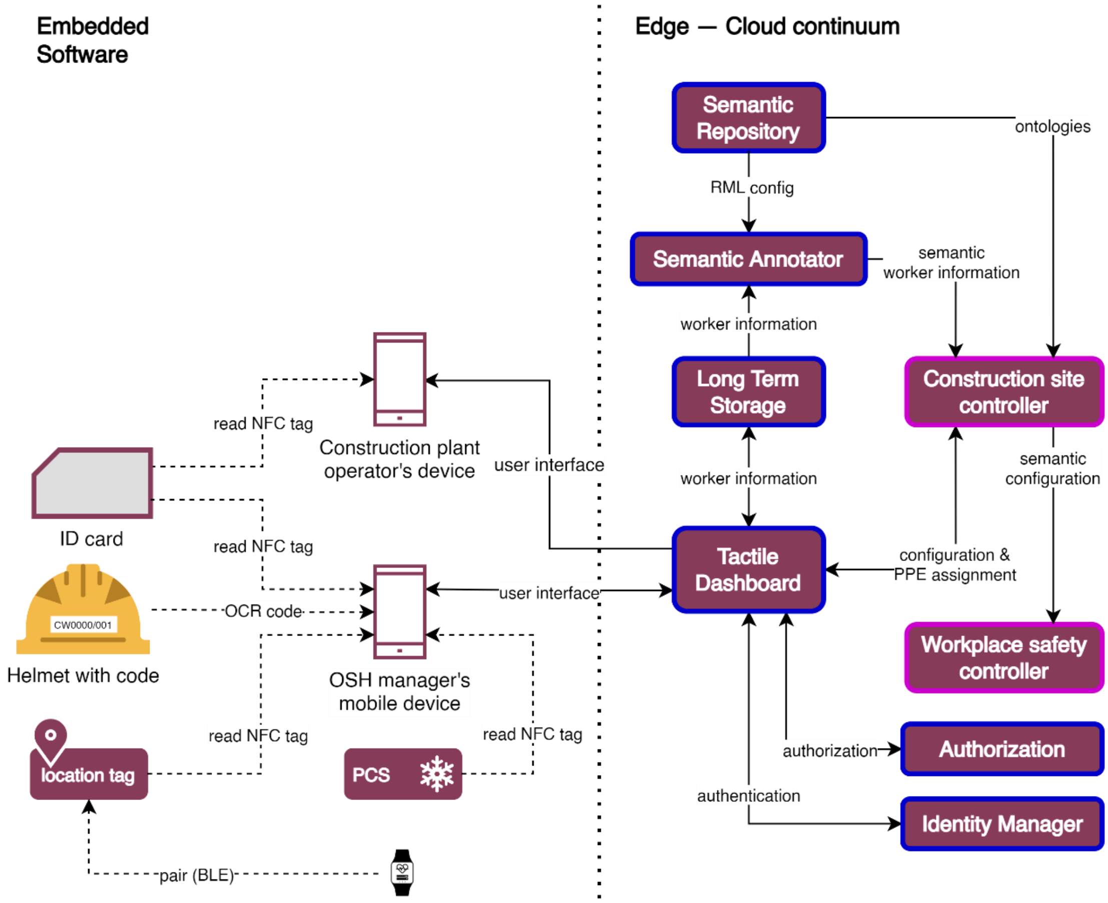

Figure 29. Construction site controller configuration workflow

3.2. Trial #1: Occupational safety and health monitoring

3.2.1. Scope

The Trial aims to increase worker safety through the use of a system that can be split into three parallel sub-trials:

1. **Workers are equipped with locator tags and sensors.** The system will detect if certain worker health parameters have passed a safe threshold by taking readings from sensors located on the worker.
2. **Worker's location will also be monitored**, helping t**o prevent unwarranted access to dangerous areas on the construction site**.
3. The **system will be monitoring the workers and alert supervisors** of potentially unsafe situations.

Workers' health and safety assurance

Detection of abnormalities that are potentially threatening to the workers' health and safety based on measurements from the wristbands and other smart devices. In particular, the following health parameters to be monitored have been selected: heart rate and heart rate variations (for stress diagnosis), temperature (as additional indicator for fatigue diagnosis).

Prevention from overexposure of construction worker to UV radiation will be possible due to the use of a weather station.

On the basis of the measurements of the physiological parameters, two levels of actuation will be performed:

- Indication of stress/fatigue directly to the worker (without involvement of the OSH manager), encouraging to have a break and/or drink some water,
- Indication of serious health issues (e.g., too low, or too high heart rate) and sending of notifications to both the worker and OSH manager (potentially first aid is needed or at least verification of the worker health status). OSH manager should receive only a notification that verification of the worker state is needed, not having access to his/her health data.

Figure 30 presents the overall software architecture for this use case:

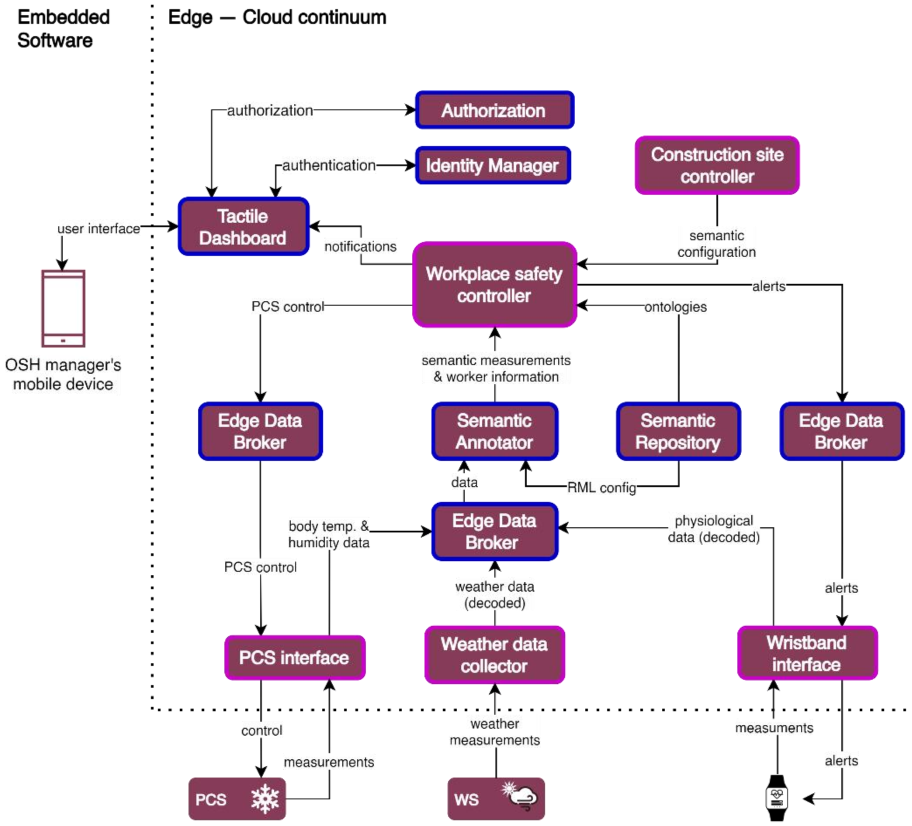

Figure 30. Architectural diagram for Workers' health and safety assurance sub-trial

The previous diagram is explained in the following flow:

- The PCS collects body temperature and humidity measurements. The measurements are collected and decoded by the PCS interface.
- The weather station gathers meteorological data, which is then collected and decoded by the Weather data collector.
- The wristband measures the heart rate of the worker. The measurement is collected and decoded by the Wristband interface.
- All data collected from the IoT devices is relayed via the Edge Data Broker and then annotated semantically.
- The Workplace safety controller matches the measurements to the relevant workers (by the semantic configuration obtained from the Construction site controller). Then, it makes the decisions to (i) alert the worker, (ii) alert the OSH manager, and (iii) change the settings of the PCS.
- The commands to the PCS are relayed back via the Edge Data Broker to the PCS interface and then to the PCS itself. The PCS takes appropriate action, also considering the manual overrides set by the user.
- The alerts to the worker are issued via the Edge Data Broker and the Wristband interface to the wristband. The alerts are communicated visually and with a vibration.
- The alerts/notifications to the OSH manager are sent to the Tactile Dashboard enabler and displayed on the manager's device.

Geofencing boundaries enforcement

Figure 31 presents the overall software architecture for this use case.

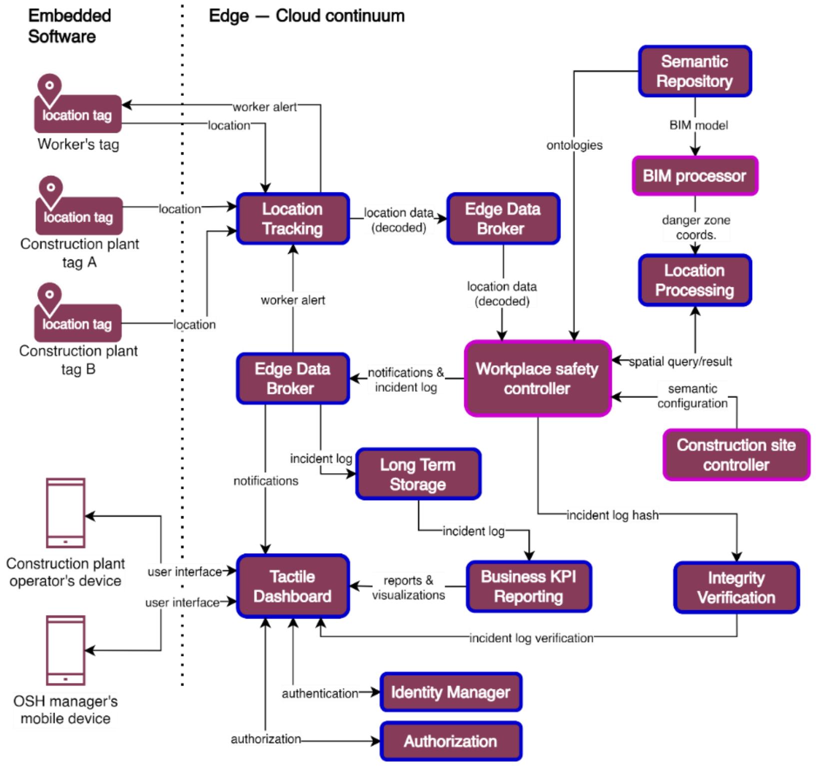

Figure 31. Architectural diagram for Geofencing boundaries enforcement sub-trial

The previous diagram is explained in the following flow:

- The dangerous zones present in the BIM model of the site will be transformed into sets of simple coordinates (cuboid or polyhedron). The coordinates will be then saved in the Location Processing enabler.
- The location and orientation of a construction plant will be determined by a pair of location tags (A and B). Their readings will then be joined by the Workplace safety controller, which will model the virtual dangerous zone around the construction plant. The zone will be then updated in the Location Processing enabler.
- The location of workers in the site will be streamed via the Workplace safety controller to the Location Processing enabler, which will determine whether the worker is in or is approaching a dangerous zone. The result will be streamed back to the Workplace safety controller.
- The Workplace safety controller will be aware of which location tags correspond to which workers. This is needed for, e.g., establishing whether a worker has the necessary qualifications to access a tower crane.
- Appropriate notifications and alerts will be generated by the Workplace safety controller and streamed to:
  - the endangered worker,
  - the construction plant operator if the worker is in the plant's dangerous zone,
  - the OSH manager.
- The incident will be logged and stored in the Long-Term Storage enabler. Additionally, the Integrity Verification enabler will provide non-reputability of the incident log.
- The interface for the mobile devices will be provided by the Tactile Dashboard enabler

Construction site access control

Figure 32 presents the overall architecture for this use case.

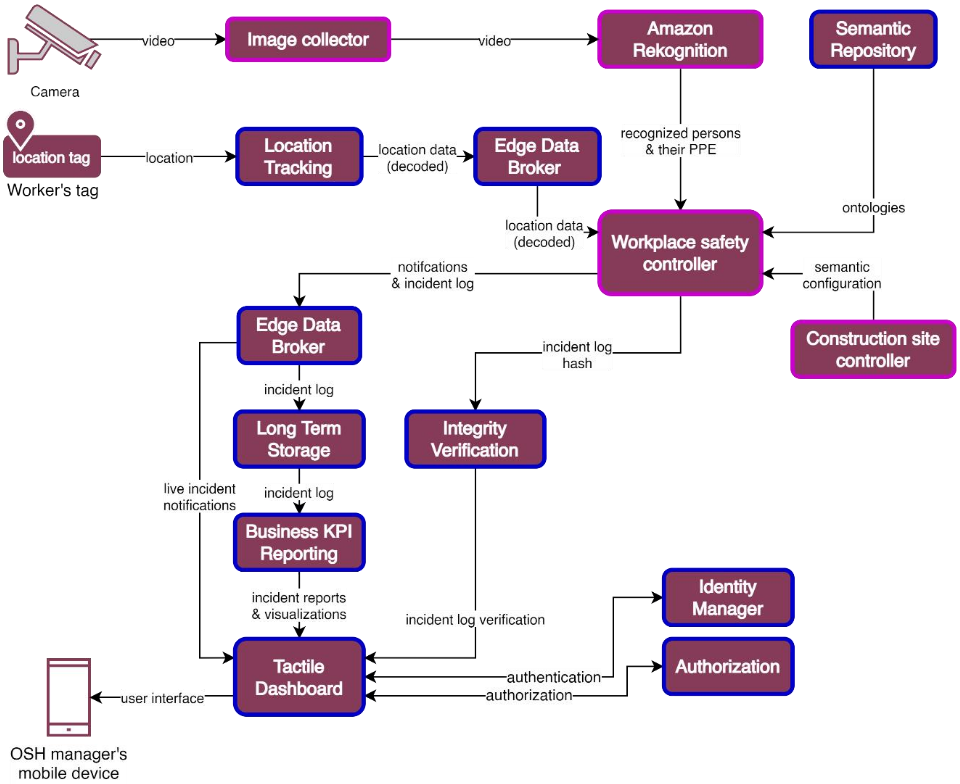

Figure 32. Architectural diagram for Construction site access control sub-trial

The previous diagram is explained in the following flow:

- A high-quality video camera will observe key points on the worksite. The video stream will be collected by the Image collector and relayed via a 5G connection to the cloud for image processing.
- In the cloud (located within the EU and compliant will all relevant privacy regulations), the Amazon Rekognition AI image processing solution will be used [11]. It can identify persons within a video stream, along with their PPE.
- The information on the recognized persons and their PPE will be retrieved by the Workplace safety controller. It will be aggregated with location data (see Geofencing boundaries enforcement sub-trial) and the semantic configuration from the Construction site controller.
- The Workplace safety controller will then decide whether (i1) there are persons who are not wearing the appropriate PPE, (ii) all workers can be identified via the location tags, and (iii) they have the necessary qualifications and medical examinations to enter the worksite.
- In case of any irregularity, the incident will be logged, and a notification issued to the OSH manager, via a similar workflow to that of Geofencing boundaries enforcement sub-trial.

3.2.2. Implementation activities reporting

3.2.2.1. Procurement activities

Pilot2_SetupAct_ID2 Construction site: The testbed has been finally moved from the original Szczecin building to the educational building being constructed on the campus of the University of Warsaw. The main reason was in order to guarantee the availability of Orange 5G network. Furthermore, it eases all the future logistics matters, since the construction site located in Warsaw is closer to all three Polish partners. The first visit at the construction site was organized on March 10, 2022. Some photos taken from that visit are listed below.

Figure 33. Photos captured during the on-site visit to the construction place.

Pilot2_SetupAct_ID2 BIM models: The design construction model is available. A couple of screenshots from the IFC software are presented below.

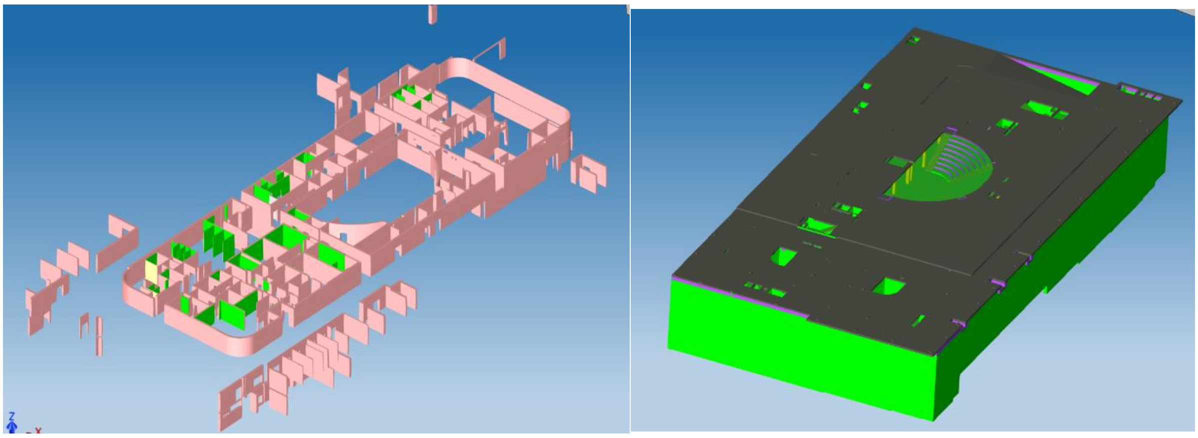

Figure 34. Mostostal University of Warsaw BIM models.

Pilot2_SetupAct_ID2 BIM models and safety areas: Several test danger zones were modelled in order to check the possibility of obtaining data from the BIM model. An extract of the designed safety areas over the BIM models is illustrated in the next figure.

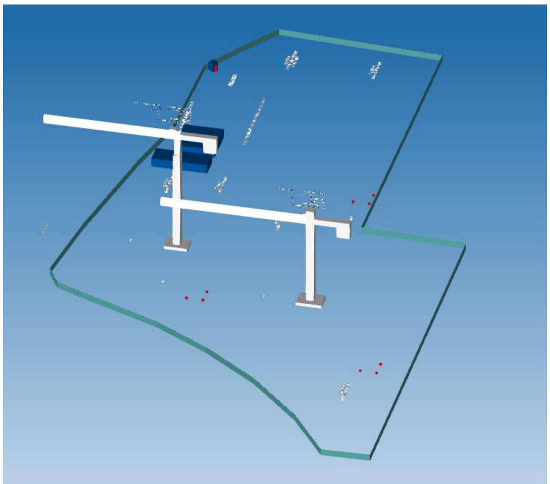

Figure 35.Safety areas depicted for the University of Warsaw BIM model.

Pilot2_SetupAct_ID3 4G/5G network: The first coverage tests of 5G network coverage on the construction site were completed positively.

Pilot2_SetupAct_ID7 GWEN: Software and hardware in development.

Pilot2_SetupAct_ID13 UWB anchors: Software and hardware in development.

Pilot2_SetupAct_ID15 UWB tags: Software and hardware in development.

Pilot2_SetupAct_ID16 Smart devices: Devices were identified after a market survey. Procurement of all of them will begin soon. Going into details:

- **Wristband:** The initial selection of the wristband to be used is the open source PineTime smartwatch [12]. Its main advantages are (i) good documentation and the ability to use custom software, (ii) long battery life, (iii) dustproof and water resistant (IP67), (iv) relatively low cost, and (v) vibrations and colour display for communicating with the worker. The main disadvantage is the lack of any long-range wireless communication interface, such as WiFi or UWB. Therefore, the wristband's communication will be relayed via the location tag, which does have an UWB interface. Other alternative solutions were examined, but they were deemed either too costly or did not allow access to the raw physiological measurements of the worker. Many solutions available on the market process the measurements in the manufacturer's cloud, which jeopardizes the privacy of the worker's data. Thus, these options were also discarded.
- **Weather station:** The weather station selected for use in the trial is Davis Instruments Vantage Pro2 Plus [13] with a USB data logger. The communication protocol of the station is well-documented. The weather station collects the following parameters: Barometric pressure, Relative humidity, Wind speed and direction, Rainfall, Solar radiation, Air temperature, Ultraviolet (UV) radiation.
- **Access control unit**: It is mounted at the entrance, controlling the authorized access to the construction plant.

Figure 36. PineTime smartwatch (left), Davis Instruments Vantage Pro2 Plus weather station (right)

Figure 37. The entrance gates to the office area and the path to the entrance to the construction part.

Pilot2_SetupAct_ID19 Measuring equipment: Available and ready for further activities. Using PCS will include implementation of a solution for reducing thermal discomfort developed in another project (BIP-15, in D9.6). The developed solution is an active personal cooling system with thermoelectric coolers (Peltier modules) integrated with clothing. The idea behind the system is to adjust the cooling power to the individual needs of the user based on the desired temperature in the undergarment microclimate to ensure thermal comfort. The active cooling system is able to reduce the local skin temperature by up to 3°C after six hours of system operation during little physical activity of the user. After implementation with ASSIST-IoT adjustment of the cooling power will be made based on the temperature in the undergarment microclimate, heart rate and data collected from the weather station.

3.2.2.2. Development activities

Pilot2_DevAct_ID1-SEC Identification: Not started yet.

Pilot2_DevAct_ID2-SEC incident management: Not started yet.

Pilot2_DevAct_ID1 Stress and fatigue detection algorithm: Preliminary design of the algorithm drafted, but its official development has not started yet.

Pilot2_DevAct_ID2 Medical validity and personal info tracking software: Design drafted, in development.

Pilot2_DevAct_ID10 Location events detection algorithm: Preliminary design of the algorithm drafted. Development starting soon.

3.2.2.3. Integration activities

Pilot2_IntAct_ID1-SEC Identification integration: Not started yet.

Pilot2_IntAct_ID2-SEC incident management: Not started yet.

Pilot2_IntAct_ID3 Stress and fatigue detection algorithms integration: Not started yet.

Pilot2_IntAct_ID4 Location events detection integration: Not started yet.

Pilot2_IntAct_ID8 BIM ontologies integration: Identified ontologies to be used. Integration not started yet.

Pilot2_IntAct_ID10 GWEN integration: In progress.

Pilot2_IntAct_ID11 UWB anchor nodes integration: Not started yet.

Pilot2_IntAct_ID12 Worker UWB tag integration: Not started yet.

Pilot2_IntAct_ID14 Network integration: Preliminary network design drafted. Integration has not started yet.

Pilot2_IntAct_ID15 Integration of T44Ex/T55Ex enablers: In progress. Identified the enablers that will need to be integrated with the pilot. Started establishing communication interfaces to be used. Initial mock-ups of the application already sketched (see figure below).

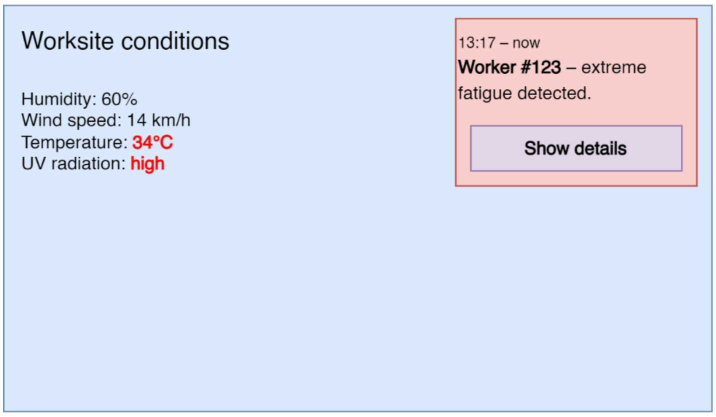

Figure 38. Mock-up of the OSH manager's interface

3.2.2.4. Validation activities

Pilot2_ValAct_ID1-SEC Operation authorization: Not started yet.

Pilot2_ValAct_ID3 Hardware testing: Not started yet.

Pilot2_ValAct_ID4 Software testing: Not started yet.

Pilot2_ValAct_ID6 System testing: Not started yet.

Pilot2_ValAct_ID9 UWB infrastructure validation: Not started yet.

Pilot2_ValAct_ID10 5G Network testing: Not started yet.

3.2.3. Deviations from original planning

The “Occupation safety and health monitoring” business scenario (BS-P2-1), described in the Deliverable 7.1, is now named “Occupational safety and health monitoring” trial. Compared to what was described in D7.1, the number of sub-trials has been reduced from 4 to 3. In particular, the slip/falls monitoring has been removed, and transfer to Trial #2. Original UC-P2-2 and UC-P2-3 have been combined to form the sub-trial "Geofencing boundaries enforcement". They have been merged due to the use of the same location tracking device. Finally, the verification of entry to the construction site of the third sub-trial, will take place on the basis of the camera image, and not on the basis of construction worker wristband, as initially planned. It will include construction workers.

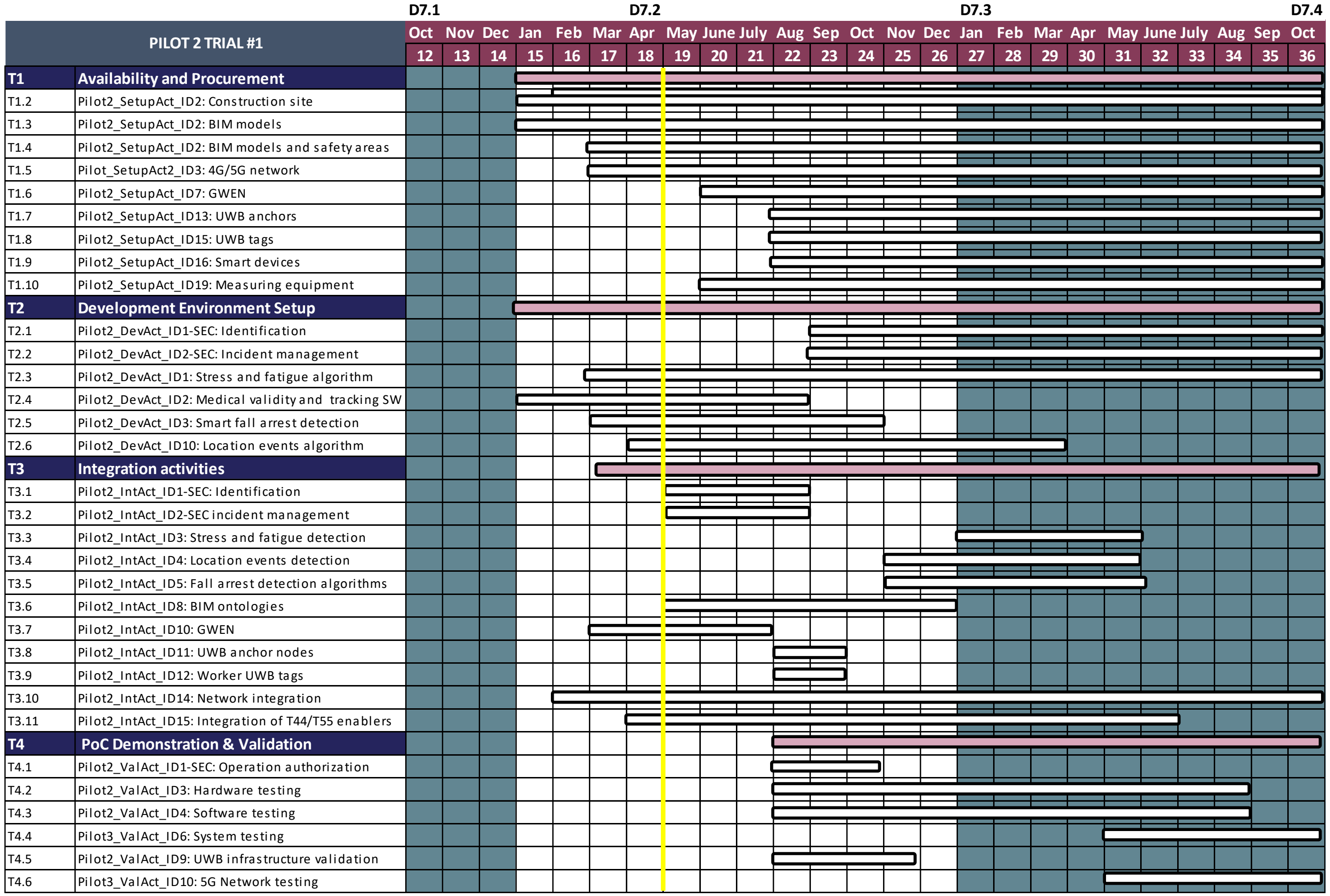

Figure 39. Pilot 2 – Trial #1 updated Gantt chart (M18)

3.3. Trial #2: Fall-related incident identification

3.3.1. Scope

The main purpose of this Trial is to detect fall-related incidents. This Trial focuses on the detection of construction worker's slips, trips, falls and immobility. If either a fall from a height is arrested by the protective equipment or construction worker is falling as a consequence of slipping, tripping or loss of consciousness, the incident should be detected and automatically reported, along with the location and the identity of the worker, in order to be further investigated. If the worker remains suspended from the fall arrest equipment, an alert should be raised, and help should be sent to the location of the incident immediately. The place of the incident is known due to the localization tag placed on the worker.

Figure 40 presents the software architecture for this use case.

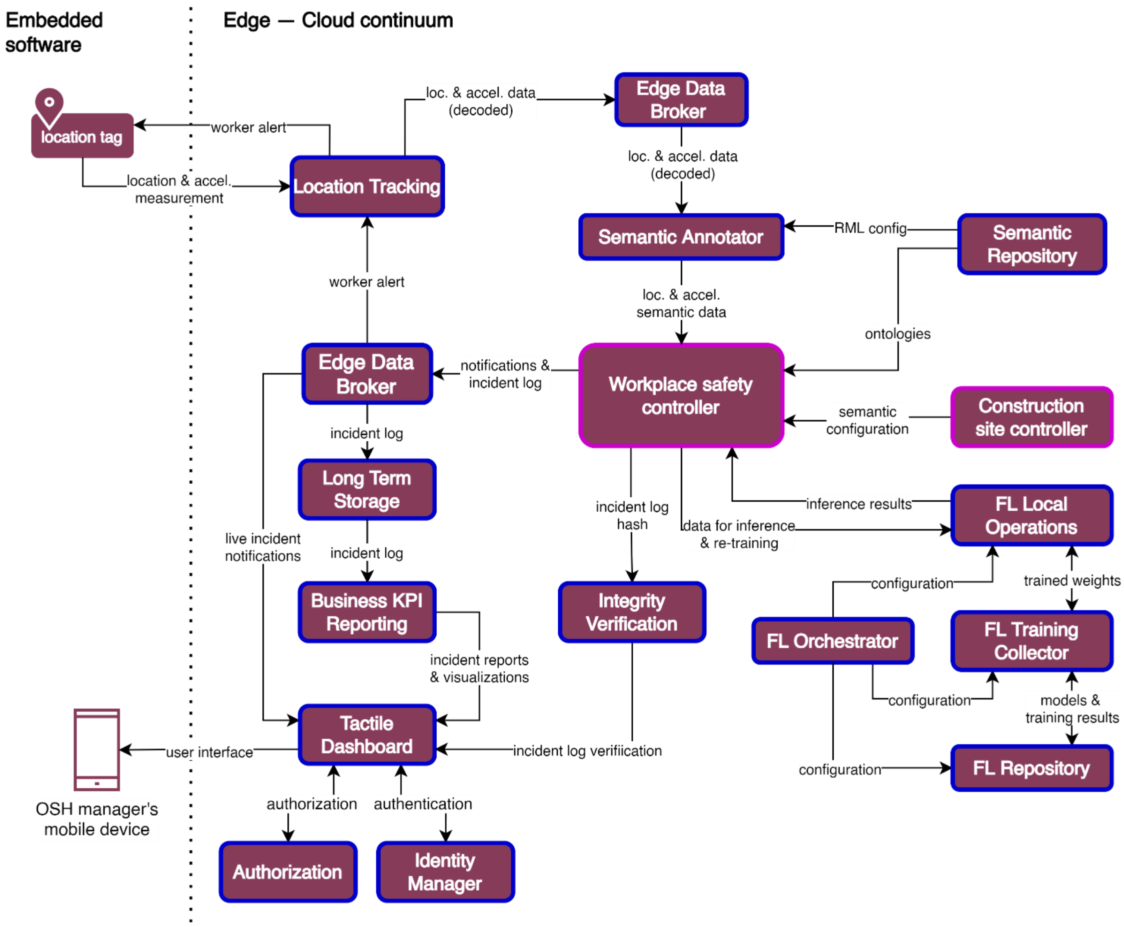

Figure 40. Architectural diagram for Fall-related incident identification trial

The previous diagram is explained in the following flow:

- Location and acceleration measurements will be gathered from worker's location tags by the Location Tracking enabler.
- The readings will be then annotated semantically by the Semantic Annotation enabler.
- The Workplace safety manager will operate the FL Local Operations enabler to (i) perform inference on the gathered live data, and to (ii) re-train the machine learning model. The model will be tasked with detecting worker's slips, trips, falls, and immobility.
- The Workplace safety manager will issue appropriate notifications, alerts, and incident logs.

- The live and historical information will be presented to the OSH manager via the Tactile Dashboard enabler and the Business KPI Reporting enabler. The integrity of the logs will be assured by the Integrity Verification enabler.

3.3.2. Implementation activities reporting

3.3.2.1. Procurement activities

Pilot2_SetupAct_ID2 Construction site: Same SetupAct in Trial #1. Go to Section 3.2.2.1 for more details.

Pilot2_SetupAct_ID2 BIM models: Same SetupAct in Trial #1. Go to Section 3.2.2.1 for more details.

Pilot2_SetupAct_ID3 4G/5G network: Same SetupAct in Trial #1. Go to Section 3.2.2.1 for more details.

Pilot2_SetupAct_ID7 GWEN: Same SetupAct in Trial #1. Go to Section 3.2.2.1 for more details.

Pilot2_SetupAct_ID13 UWB anchors: Same SetupAct in Trial #1. Go to Section 3.2.2.1 for more details.

Pilot2_SetupAct_ID15 UWB tags: Same SetupAct in Trial #1. Go to Section 3.2.2.1 for more details.

Pilot2_SetupAct_ID16 Smart devices: A localization tag will be used to detect slips, trips, falls and immobility of the construction worker, not a fall arrest detector as planned at the beginning. This change is a result of the fact that through the tag being developed by NEWAYS, the trial will be able to identify fall arrest situations. Thus, there is no need for a separate device for this purpose. In particular, the ASSIST-IoT localisation tag contains a buzzer and red LED to indicate to the person that he/she is in a restricted area. Other features that have been included in the localization tag are Push button and an IMU sensor (Inertial Measurement Unit). Push button is used to alert the system that a dangerous situation has been detected by pressing a button by worker. A fall-related incident can be detected by the integrated IMU. This means that when a worker falls on the floor, this can be detected and the appropriate information about this may be provided.

Pilot2_SetupAct_ID19 Measuring equipment: Same SetupAct in Trial #1. Go to Section 3.2.2.1 for more details.

3.3.2.2. Development activities

Pilot2_DevAct_ID1-SEC Identification: Same DevAct in Trial #1. Go to Section 3.2.2.2 for more details.

Pilot2_DevAct_ID2-SEC incident management: Same DevAct in Trial #1. Go to Section 3.2.2.2 for more details.

Pilot2_DevAct_ID1 Stress and fatigue detection algorithm: Same DevAct in Trial #1. Go to Section 3.2.2.2 for more details.

Pilot2_DevAct_ID2 Medical validity and personal info tracking software: Same DevAct in Trial #1. Go to Section 3.2.2.2 for more details.

Pilot2_DevAct_ID3 Smart fall arrest detection: Algorithm and solution architecture designed. The solution will be ML-based and data-driven. Currently working on designing the data collection procedure. Data augmentation algorithm is also in development.

Pilot2_DevAct_ID10 Location events detection algorithm: Same DevAct in Trial #1. Go to Section 3.2.2.2 for more details.

Pilot2_DevAct_ID14 Anchor node firmware: Not started yet.

Pilot2_DevAct_ID17 Fall detect tag device firmware: Not started yet.

3.3.2.3. Integration activities

Pilot2_IntAct_ID1-SEC Identification integration: Same IntAct in Trial #1. Go to Section 3.2.2.3 for more details.

Pilot2_IntAct_ID2-SEC incident management: Same IntAct in Trial #1. Go to Section 3.2.2.3 for more details.

Pilot2_IntAct_ID3 Stress and fatigue detection algorithms integration: Same IntAct in Trial #1. Go to Section 3.2.2.3 for more details.

Pilot2_IntAct_ID4 Location events detection integration: Same IntAct in Trial #1. Go to Section 3.2.2.3 for more details.

Pilot2_IntAct_ID5 Fall arrest detection algorithms integration: Not started yet.

Pilot2_IntAct_ID8 BIM ontologies integration: Same IntAct in Trial #1. Go to Section 3.2.2.3 for more details.

Pilot2_IntAct_ID10 GWEN integration: Same IntAct in Trial #1. Go to Section 3.2.2.3 for more details.

Pilot2_IntAct_ID11 UWB anchor nodes integration: Same IntAct in Trial #1. Go to Section 3.2.2.3 for more details.

Pilot2_IntAct_ID12 Fall tags integration: Not started yet.

Pilot2_IntAct_ID14 Network integration: Same IntAct in Trial #1. Go to Section 3.2.2.3 for more details.

Pilot2_IntAct_ID15 Integration of T44Ex/T55Ex enablers: Initial mock-ups of the application already sketched (see figure below).

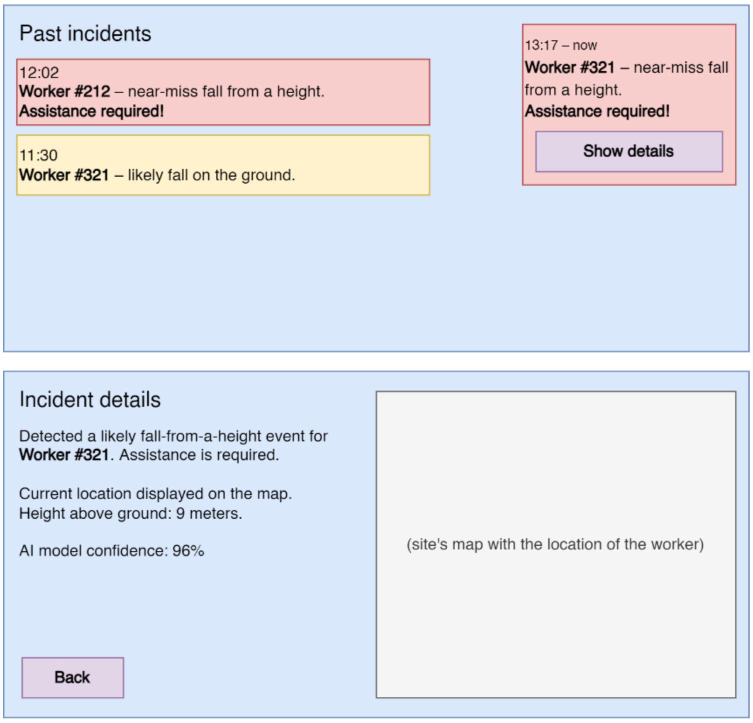

Figure 41. Mock-up of the OSH manager's interface

3.3.2.4. Validation activities

Pilot2_ValAct_ID1-SEC Operation authorization: Same ValAct in Trial #1. Go to Section 3.2.2.4 for more details.

Pilot2_ValAct_ID3 Trial #2 Hardware testing: Not started yet.

Pilot2_ValAct_ID4 Trial #2 Software testing: Not started yet.

Pilot2_ValAct_ID6 Trial #2 System testing: Not started yet.

Pilot2_ValAct_ID9 UWB infrastructure validation: Same ValAct in Trial #1. Go to Section 3.2.2.4 for more details.

Pilot2_ValAct_ID10 5G Network testing: Same ValAct in Trial #1. Go to Section 3.2.2.4 for more details.

3.3.3. Deviations from original planning

The name of this trial has been changed from D7.1 to "Fall-related incident identification" due to the change in the nature of the detected events. The use case number is 1 and applies detection of slips, trips, falls and immobility of the construction worker. UC-P2-6 on safe navigation has been moved to Trial #3 due to its similar nature. A localization tag will be used to detect slips, trips, falls and immobility of the construction worker, not a fall arrest detector as planned at the beginning. This change is a result of the fact that through the tag being developed by NEWAYS we will be able to identify fall arrest situations and a separate device for this purpose is not needed as all functionalities will be kept. The use of the localisation tag changed the analysed parameter. Fall-related incident detection will be based on acceleration, not force.

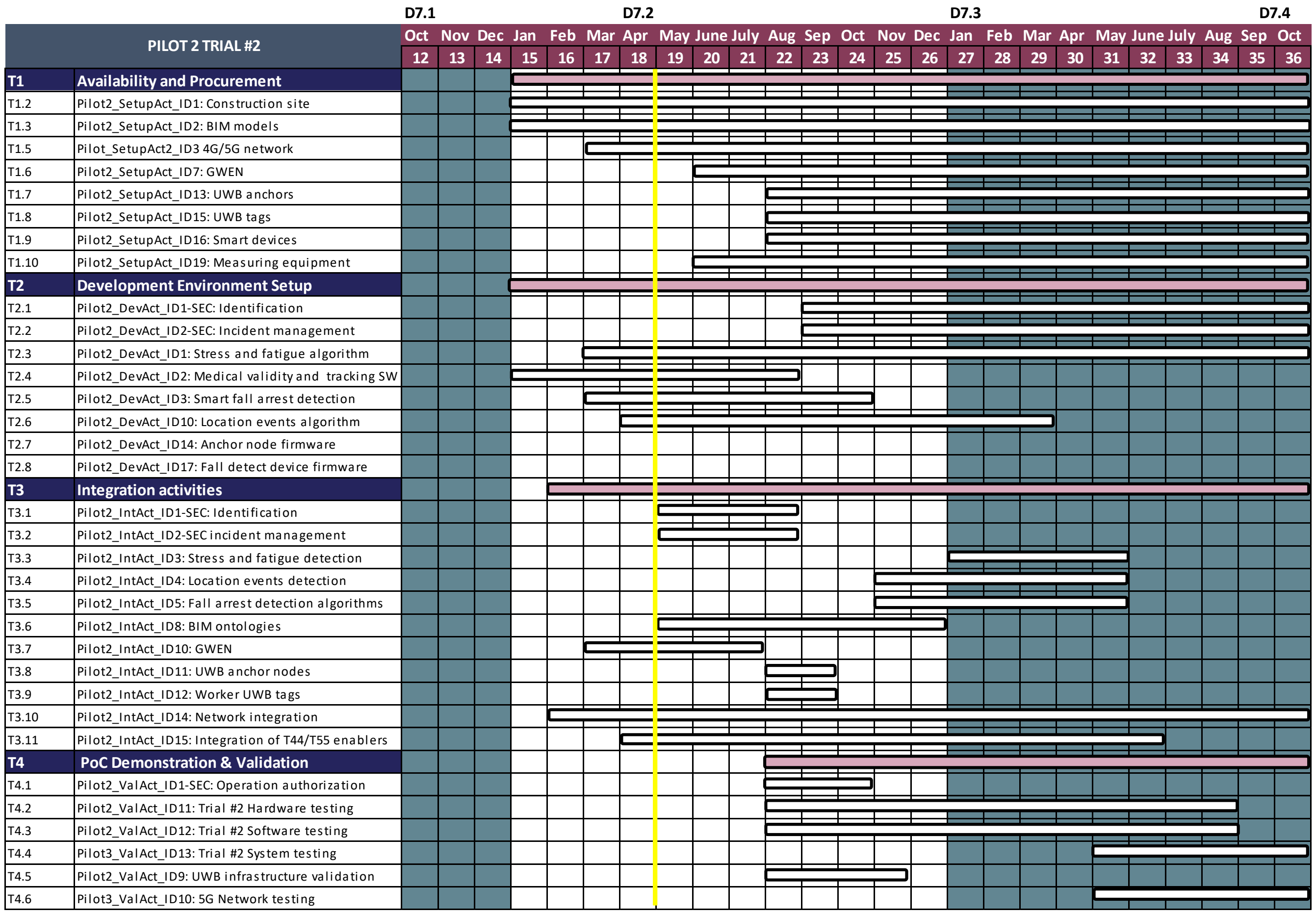

Figure 42. Pilot 2 – Trial #2 updated Gantt chart (M18)

3.4. Trial #3: Health and safety inspection support

3.4.1. Scope

A challenge that OSH mangers face on a construction site is to properly assess and communicate evacuation paths. Typically, physical markers are located throughout the construction site that give workers information regarding escape routes, however there is a risk that these markers are not kept up to date. This trial has a goal of testing innovative AR solutions to provide this information by utilizing data provided by BIM models.

The nature of construction sites leads to a high turnover of blue-collar workers due to the variety of tasks and disciplines involved. It is crucial to be able to easily locate and identify all workers, to ensure that they are authorized to be present on site. In the case of an individual disregarding health and safety protocols, it is crucial to support the OSH mangers in worker identification as well as checking whether permissions are up to date.

This trial has been split in two sub-trials:

Safe navigation instructions

Figure 43 presents the overall software architecture for this sub-trial.

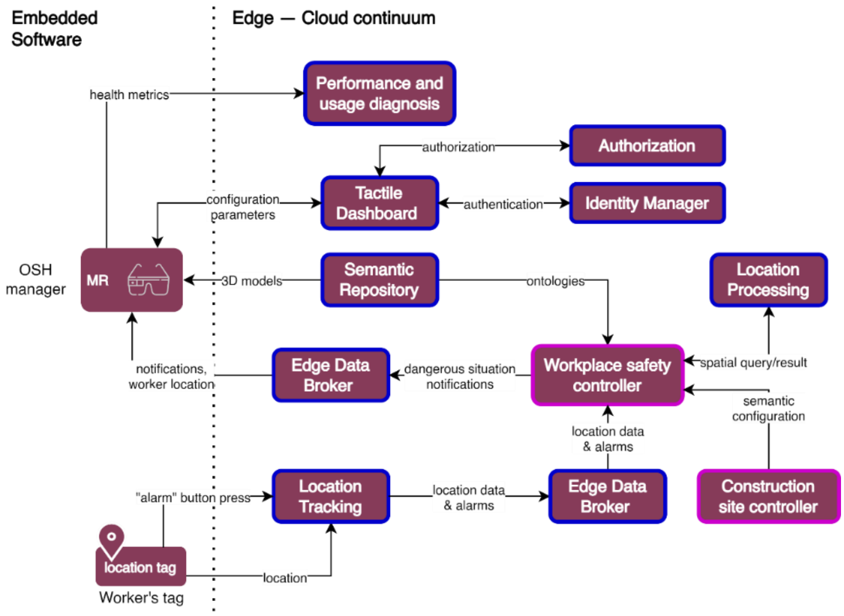

Figure 43. Architectural diagram for Safe navigation instructions sub-trial

The previous diagram is explained in the following flow:

- The MR device will display 3D models of the construction site enhanced with information about escape routes and key evacuation infrastructure.
- From the workers' location tags, their location will be gathered by the Location Tracking enabler. Additionally, the "alarm" button presses will be recorded. The data will be relayed over the Edge Data Broker to the Workplace safety controller.
- The Workplace safety controller will aggregate the location and alarm data and, using the Location Processing enabler, will establish whether there is a dangerous situation on the worksite. This may include, e.g., congestion along the escape routes, or a large quantity of alarms in one location.
- The Workplace safety controller will issue relevant notifications about dangerous situations to the MR device of the OSH manager.

Health and safety inspection support

The scope of this sub-trial is to conduct inspections to ensure that the OSH inspectors have checked all the necessary requirements for the inspected activities, and they have addressed and reported incidents. Through the MR enabler (using a Head Mounded Device-HMD), the OSH inspector receives contextual visual information related to the activities taking place at their location (such as, the number of workers at close proximity and their training records).

Figure 44 presents the overall software architecture for this sub-trial.

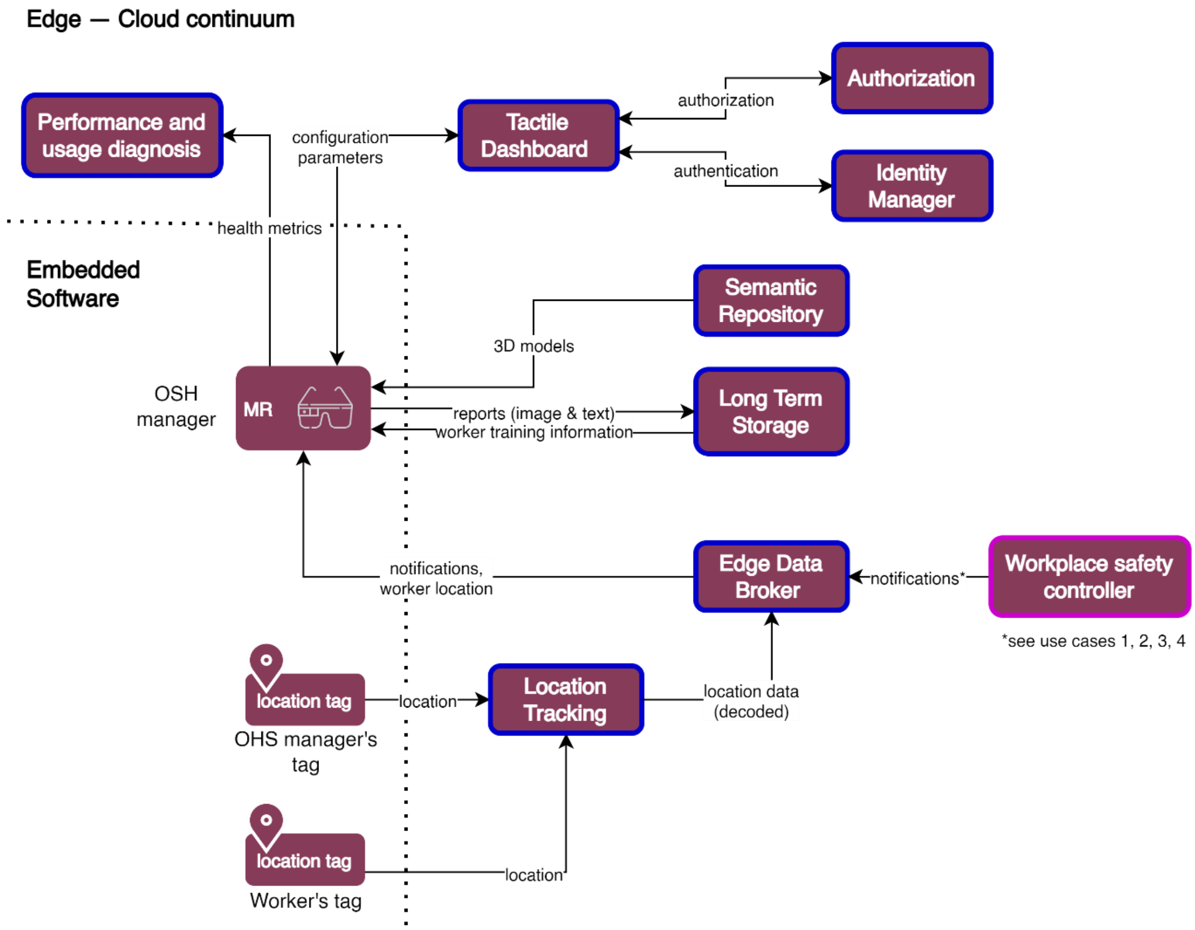

Figure 44. Architectural diagram for Health and safety inspection support sub-trial

3.4.2. Implementation activities reporting

3.4.2.1. Procurement activities

Pilot2_SetupAct_ID1 Microsoft HoloLens: The HoloLens glasses have been purchased, and the first tests of the customized BIM models over the purchase equipment have been successfully carried out.

Figure 45. Microsoft HoloLens 2 is a pair of mixed reality smart glasses.

Pilot2_SetupAct_ID2 Construction site: Same SetupAct in Trial #1. Go to Section 3.2.2.1 for more details.

Pilot2_SetupAct_ID2 BIM models: Same SetupAct in Trial #1. Go to Section 3.2.2.1 for more details.

Pilot2_SetupAct_ID2 BIM models and safety areas: Same SetupAct in Trial #1. Go to Section 3.2.2.1 for more details.

Pilot2_SetupAct_ID3 4G/5G network: Same SetupAct in Trial #1. Go to Section 3.2.2.1 for more details.

Pilot2_SetupAct_ID7 GWEN: Same SetupAct in Trial #1. Go to Section 3.2.2.1 for more details.

Pilot2_SetupAct_ID13 UWB anchors: Same SetupAct in Trial #1. Go to Section 3.2.2.1 for more details.

Pilot2_SetupAct_ID15 UWB tags: Same SetupAct in Trial #1. Go to Section 3.2.2.1 for more details.

Pilot2_SetupAct_ID16 Smart devices: Same SetupAct in Trial #1. Go to Section 3.2.2.1 for more details.

Pilot2_SetupAct_ID19 Measuring equipment: Same SetupAct in Trial #1. Go to Section 3.2.2.1 for more details.

3.4.2.2. Development activities

Pilot2_DevAct_ID1-SEC Identification: Same DevAct in Trial #1. Go to Section 3.2.2.2 for more details.

Pilot2_DevAct_ID2-SEC incident management: Same DevAct in Trial #1. Go to Section 3.2.2.2 for more details.

Pilot2_DevAct_ID4 Save navigation and evacuation: …

Pilot2_DevAct_ID9 MR-based BIM visualisation: The BIM visualisation functionality relies on the loading of the BIM model in a way that can be visualized through the MR device. The OSH inspector can manipulate the most-updated BIM model at each location. This development activity includes:

- loading of the BIM model into the MR enabler installed in the HoloLens HMDs.
- manipulation of the BIM model (including scaling and rotation).

The BIM owner should transform the IFC model to an MR-compatible format (*.dae) and upload it in the Semantic repository, as the procedure cannot be automated.

The current status of this development activity is BIM visualization (95%), Manipulation techniques (90%).

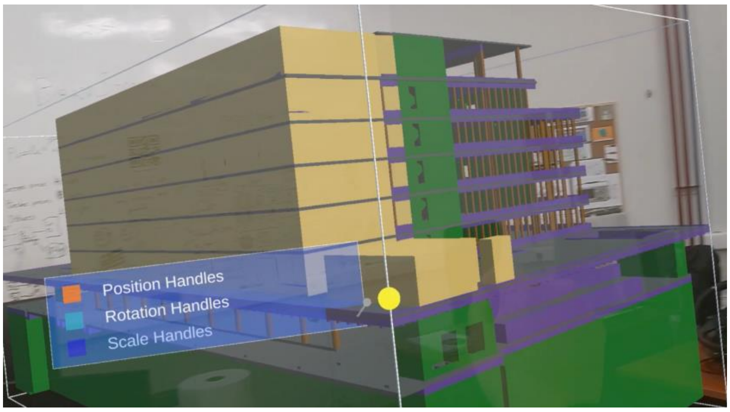

Figure 46. The BIM model visualized through the MR glasses upon conversion to the required format through the laboratory facilities.

Pilot2_DevAct_ID10 Location events detection algorithm: Same DevAct in Trial #1. Go to Section 3.2.2.2 for more details.

Pilot2_DevAct_ID18 MR-based data visualisation: This activity refers to the visualization of the worker-related information, upon identification from the OSH inspector using the MR device, such as medical and training records and includes:

- identification of the workers at close proximity.
- information to be visualized (Name of the company, Name and Surname of the worker, the expiration dates of their training, medical tests, and permissions, as well as the person responsible for H&S, etc.).

The BIM owner should transform the IFC model to an MR-compatible format (*.dae) and upload it in the Semantic repository, as the procedure cannot be automated.

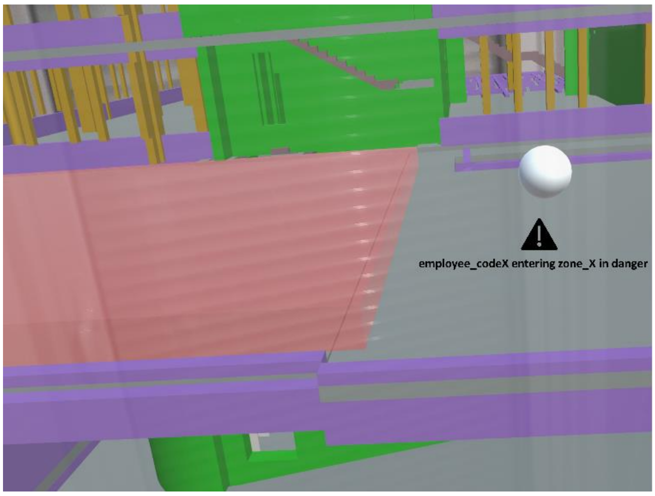

Figure 47. A worker (symbolized with a white ball) is about to enter a dangerous zone (red rectangle), and the MR interface notifies the OSH inspector about the type of incident, the ID of the worker, and their location.

The current status of this development activity is Mock-ups (90%), BIM visualisation (90%), Identification of the worker (0%). As an additional enhancement, project partners will explore the possibility of easily identifying the workers in case they are located in the same spot and the location accuracy is limited.

Pilot2_DevAct_ID19 MR-based reporting: The scope of this activity is to develop the inspection report module, where the OSH inspector can produce a human-centric report when they identify misalignments during the inspection procedure. The inspection report module includes:

- including information about the report (such as the Project, Serial Nr, Control list, Item on checklist, workplace, Workflow, Date of reporting, Deadline, Create by, Responsible).
- including information about the action or incident (such as the Corrective action required, the ID of the person who created it, the assigned person, the Topic, and a Deadline).
- capturing and attaching photos from the MR device.
- submitting report functionality.

The current status of this development activity is Mock-ups (90%), Table visualisation (90%), Media input (100%). As it can be noticed, the MR-based functionality is almost ready, but its duration will mainly depend on the integration with ASSIST-IoT LTSE enabler.

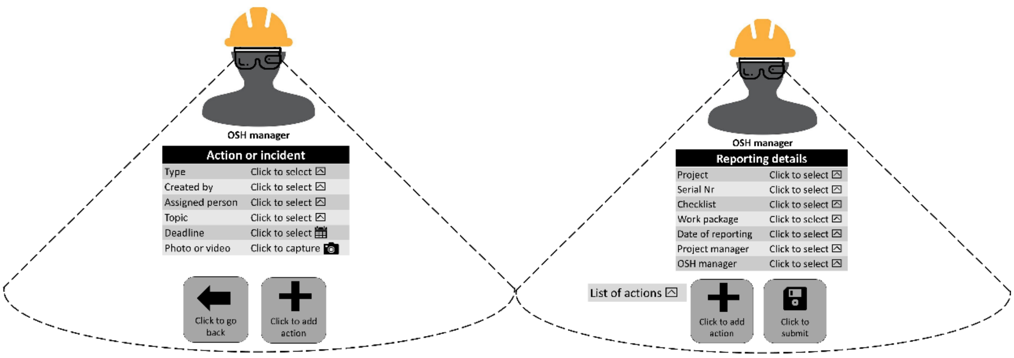

Figure 48. Mock-ups template for inserting the general reporting information (left), and Mock-ups template for enlisting an action or an incident (right)

Pilot2_DevAct_ID20 MR-based danger zone visualisation: In this development activity, as the locations of the construction workers are continuously monitored, as soon as they reach dangerous zones, their jeopardized location will be visualized to the BIM model through the MR HMD. The development activity includes:

- visualization of danger zone restriction.

- localization of construction worker through integration with the location management system.
- visualization of the position of the construction worker, that are located in danger zones, within the BIM.

The current status of this development activity is Danger zone restriction visualization (100%), Visualization of the position's worker within BIM (60%).

Figure 49. The BIM model visualized through the MR glasses with the dangerous zones in yellow.

Pilot2_DevAct_ID21 MR-based alerts visualisation: This development activity includes the alerts and notifications that the inspector receives in case a dangerous event within the construction site via the MR device. The alerting module includes:

- Compatibility with MQTT protocol messages.
- Integration with edge data broker to receive the alerts.
- Visualisation of the various alerts coming from other system (such as the fall arrest monitoring system, weather station, fatigue monitoring, location management system about danger zones unauthorised access, construction worker's emergency button).

The current status of this development activity is Mock-ups about alert visualisation (30%), compatibility with MQTT protocols (100%), integration with Edge data broker (60%), visualisation of the alerts (20%).

3.4.2.3. Integration activities

Pilot2_IntAct_ID1-SEC Identification integration: Same IntAct in Trial #1. Go to Section 3.2.2.3 for more details.

Pilot2_IntAct_ID2-SEC incident management: Same IntAct in Trial #1. Go to Section 3.2.2.3 for more details.

Pilot2_IntAct_ID4 Location events detection integration: Same IntAct in Trial #1. Go to Section 3.2.2.3 for more details.

Pilot2_IntAct_ID7 3D model BIM integration: Almost ready, as explained in previous MR-based development activities.

Pilot2_IntAct_ID8 BIM ontologies integration: Same IntAct in Trial #1. Go to Section 3.2.2.3 for more details.

Pilot2_IntAct_ID9 MR device integration: Not started yet.

Pilot2_IntAct_ID11 UWB anchor nodes integration: Same IntAct in Trial #1. Go to Section 3.2.2.3 for more details.

Pilot2_IntAct_ID12 Worker UWB tags integration: Same IntAct in Trial #1. Go to Section 3.2.2.3 for more details.

Pilot2_IntAct_ID14 Network integration: Same IntAct in Trial #1. Go to Section 3.2.2.3 for more details.

Pilot2_IntAct_ID15 Integration of T44Ex/T55Ex enablers: Same IntAct in Trial #1. Go to Section 3.2.2.3 for more details.

3.4.2.4. Validation activities

Pilot2_ValAct_ID1-SEC Operation authorization: Same ValAct in Trial #1. Go to Section 3.2.2.4 for more details.

Pilot2_ValAct_ID14: Trial #3 Hardware testing: Not started yet.

Pilot2_ValAct_ID15: Trial #3 Software testing: Not started yet.

Pilot3_ValAct_ID16: Trial #3 System testing: Not started yet.

Pilot2_ValAct_ID9 UWB infrastructure validation: Same ValAct in Trial #1. Go to Section 3.2.2.4 for more details.

Pilot2_ValAct_ID10 5G Network testing: Same ValAct in Trial #1. Go to Section 3.2.2.4 for more details.

3.4.3. Deviations from original planning

The following Gantt chart provides an update of Pilot 2 Trial #3. In particular, upon detailed discussions with OSH managers and Mostostal personnel, the trial has been enhanced with two more functionalities compared to D7.1. Therefore, the original single Pilot2_DeAct_ID9 (M10-M33) related to MR-based BIM visualisation has been split in several Development Activities. The rest of the Pilot plan remains the same.

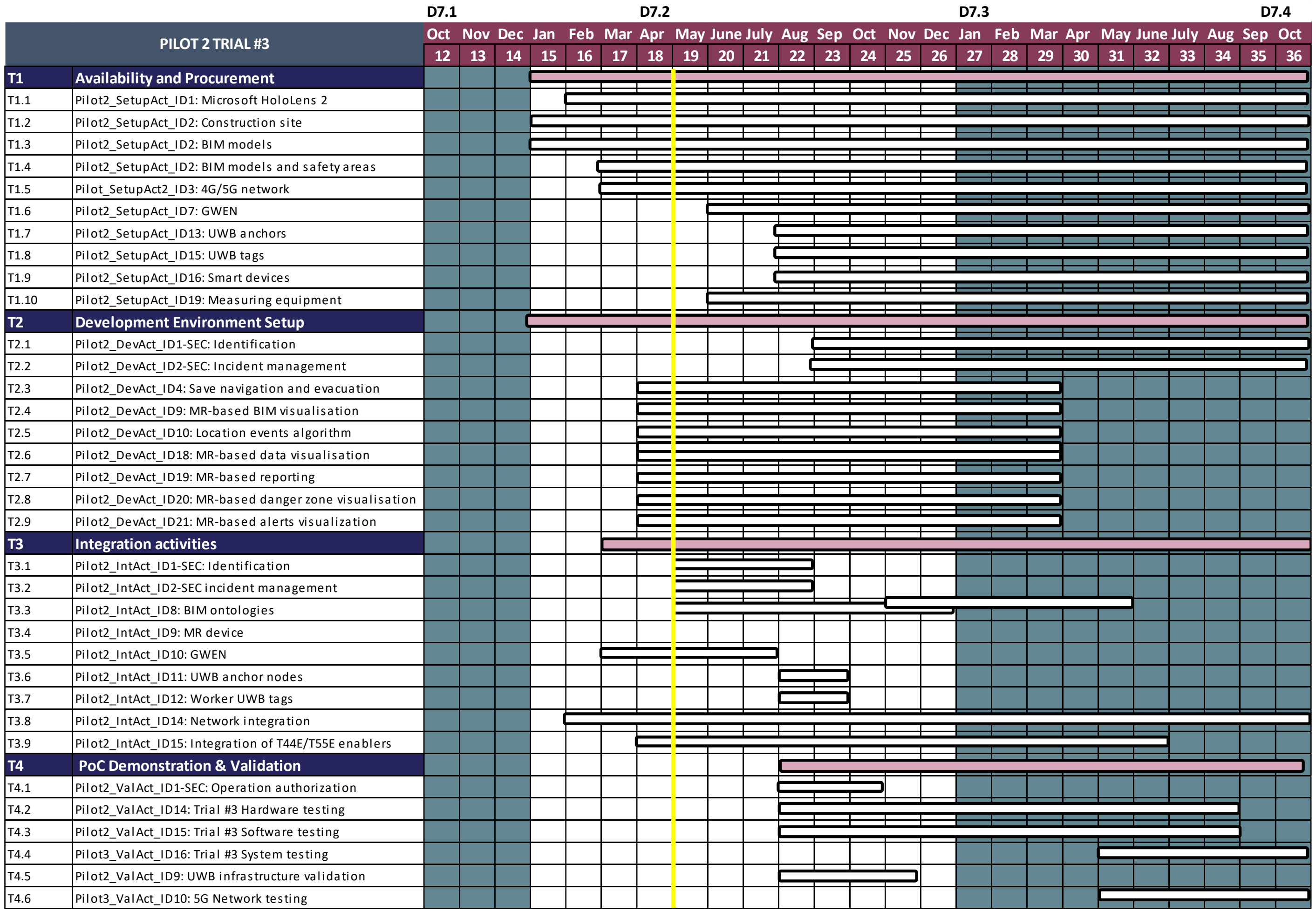

Figure 50. Pilot 2 – Trial #3 updated Gantt chart (M18)

4. Pilot 3A: Vehicle in-service emission diagnostics

4.1. Context review

This pilot is driven by the industrial partner FORD, that is a leader Original Equipment Manufacturers (OEMs) of passenger cars, with over a 5 million vehicles produced per year. FORD provides a state-of the-art hybrid electrical vehicle (see later) with an open access Electronic Control Unit (ECU) which will be integrated into ASSIST-IoT reference architecture, thus allowing remote access to powertrain parameters and over-the-air update of diagnostics firmware. The Cohesive vehicle monitoring, and diagnostics pilot will demonstrate the benefits of the ASSIST-IoT approach for the case of vehicle fleet diagnostics, where inputs coming from different sources are combined for providing an incremental and cohesive evaluation of the vehicle condition.

As mentioned, Pilot 3A is centered around emissions and enhanced diagnostics at vehicle fleet level. For this purpose, Ford-Werke GmbH has provided a state-of-the-art current production Ford Kuga, which is located at UPV, to allow the intensive driving and testing planned within Pilot 3A. The Ford Kuga is a compact Sports Utility Vehicle (SUV) in the C-size segment, which was built in the Ford Body and Assembly plant in Valencia, Spain. It is sold with a large variety of options, including various Gasoline and Diesel propulsion systems and, depending on the variant, can be offered as a Plug-In Hybrid or Mild-Hybrid.

Figure 51. FORD Vehicle provided for the Pilot

The implementation of the ASSIST-IoT reference architecture in this pilot will enhance the capabilities of automotive OEMs to monitor the emission levels of vehicles which are already in operation (ISE, in-service emissions). Monitoring the fleet emission levels will allow the implementation of timely corrective actions, if needed, in order to restore them to the accepted limits. Ensuring fleet ISE meets the certification limits during their lifetime will imply a *de facto* fulfilment of the EU regulations, which are to be verified through in-service conformity (ISC) mechanism.

The pilot has been designed as a single Trial that will evolve along the project, adding new features to the existing ones, providing a continuous improvement of the same trial (Trial #1). Three demonstration tasks have been prepared, each of them adding new features to the pilot implementation and correcting and improving the previous iterations.

4.2. Trial#1: Fleet in-service emission verification

4.2.1. Scope

The first part of the Pilot 3A focuses on vehicle emissions with special attention on nitrogen oxides (NOx). Compared to Petrol-driven propulsion systems, Diesel propulsion systems are naturally emitting higher amounts of NOx, driving the need for technical solutions on vehicle manufacturer side, like emission aftertreatment, to ensure these NOx levels are below the legal thresholds. Therefore, to ensure a challenging real-world test environment, it was decided to use a vehicle with a 2.0L EcoBlue Diesel engine and MHEV capabilities. Details of the vehicle were provided in D7.1, together with the different hardware and software elements used in the pilot.

Emissions (here especially NOx) can either be measured on the outside of the vehicle, e.g., with the help of a so-called Portable Emission Measuring Systems (PEMS), which is attached to the back of the vehicle during driving and is directly measuring the emissions of the vehicle. This PEMS unit is only useful during designated test drives and neither from size nor from cost perspective a reasonable solution for a vehicle fleet. Another method is to utilize the internal sensors of the vehicle, which are giving enough data to allow vehicle operation within the current legal limits. As these standard production NOx sensors are not accurate enough to account for the likely changes to be seen in the post-EU6 emission legislation context, the idea is to add additional sensors to increase accuracy over vehicle lifetime to the desired level.

The second aspect covered within Pilot 3A is the enhanced diagnostic functions in the propulsion system domain. ASSIST-IoT will be utilized to run in-depth diagnostic routines and enhanced data logging functionalities, supported by ML/AI capabilities, which ASSIST-IoT offers. These enhanced diagnostic functions will bring innovative, close to real-time insight into the vehicle, significantly reducing the time to analyze unknown failures. In the pilot implementation, different sensors are available to the ASSIST-IoT framework: series sensor of the engine, series vehicular sensors (available through the vehicle CAN line), additional high fidelity (HiFi) emissions sensors, plus the possibility of including any sensor provided by third parties. A state-of-the-art acquisition system will be used for gathering all these data, and to allow modifications into the vehicle control software.

Henceforth, following the structure established in WP3 and D7.1, the pilot has identified two business scenarios, which are detailed in D3.3 and whose short summary is presented next:

BS-P3A-1: Fleet in-service emission verification: This business scenario is focused on determining, from the real-life operation of the vehicles, NOx and CO2 emission metrics and deriving fleet emission metrics on vehicle fleet level. The partners in charge of this Business Scenario consider that a given quantity of the vehicles may be fitted with additional, high- precision, emission sensors, thus making possible to determine the drift of the series sensors. In addition to the vehicle monitoring and fleet In-Service Emissions (ISE) distribution reporting, the business scenario also covers the update of the PCM calibration in order to recover desired emission levels (when possible), and the detection of vehicles which are outliers of the emission distribution. Note that the studied scenario has certain particularities: the vehicle is mobile by definition, which challenges network stability and even availability (e.g., underground parking lots or remote countryside areas); and, in addition to obvious data protection, cybersecurity must ensure that no malicious code is injected in the vehicle, since it could have significant consequences. Figure 52 provides a view of the main actors and architectural blocks present in the use case of this business scenario.

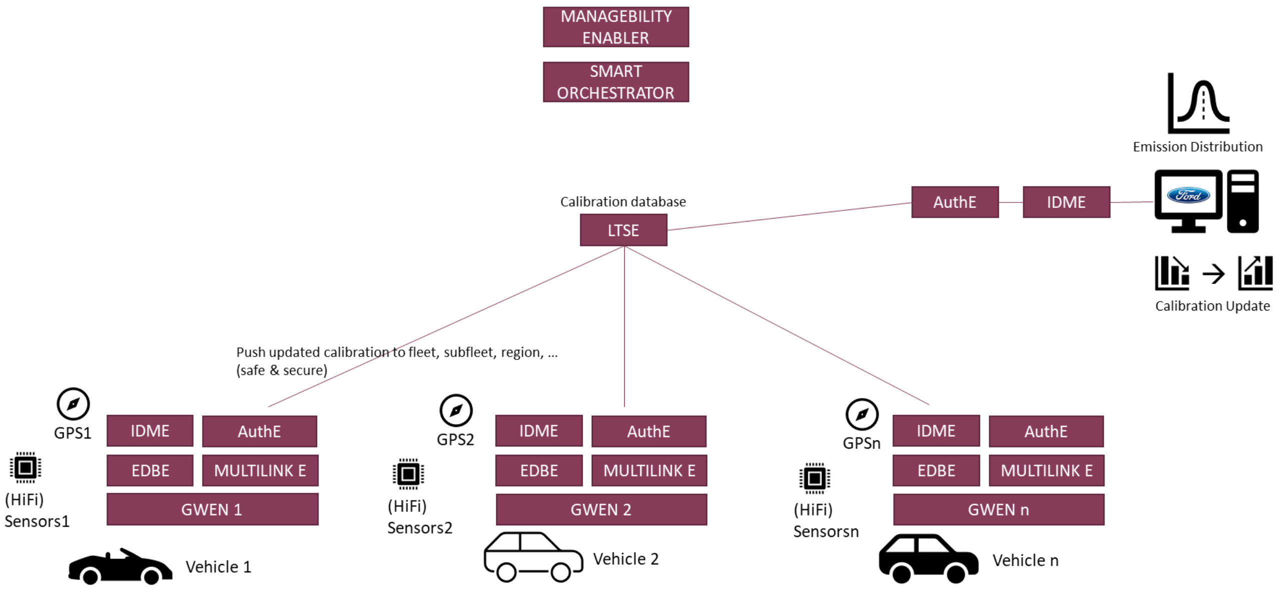

Figure 52. BS-P3A-1: Fleet in-service emission verification

BS-P3A-2: Vehicle diagnostics: This business scenario covers the identification of the fault source for vehicles tagged as non-compliant (either by the ISE monitoring in BS-P3A-1, by the driver, or by a service technician).

The scenario is developed into two use cases: the first is devoted to the identification of the fault cause by deploying a series of fault detection methods which are deployed to the edge; the second business case is centered on the development of such fault detection methods. Figure 53 provides a view of the main actors and architectural blocks present in the use cases of this business scenario.

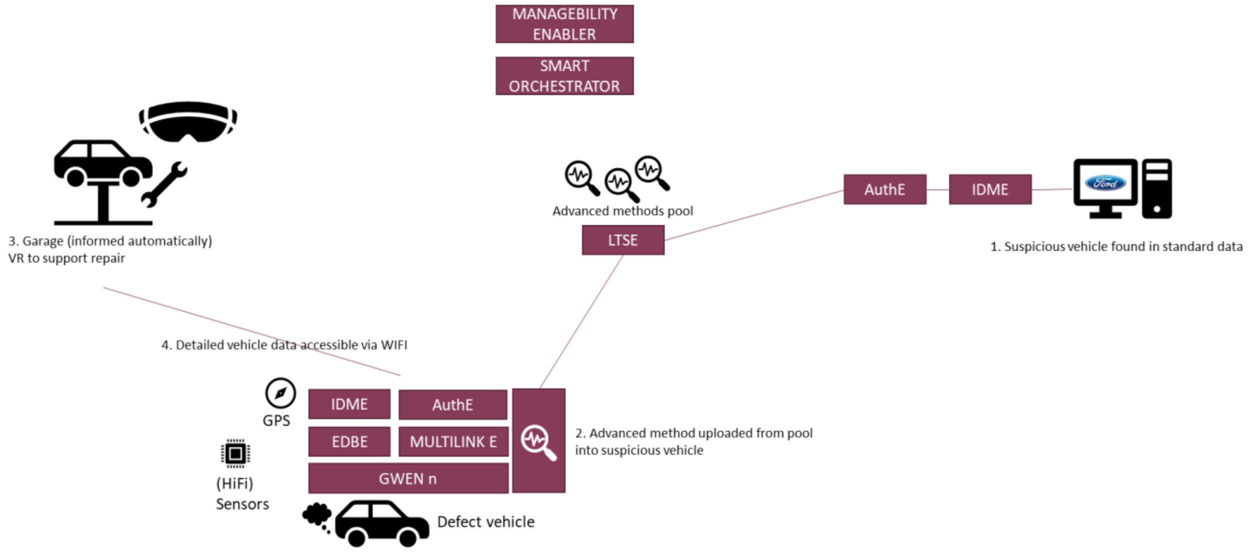

Figure 53. BS-P3A-2: Vehicle diagnostics

4.2.2. Implementation activities reporting

This chapter will document the work in progress for pilot 3A, focusing on vehicle emission and diagnostics. The original planning was defined in *D7.1 Deployment Plan and Operational Framework*, and in the present document the state of development of the different tasks is reviewed, tracking their evolution according to the foreseen planning. Note that the reported period corresponds to M12-M18 (see planning in Figure 79). As this is the initial part of the pilot implementation, most of the works are focused on system setup, which is needed to ensure a flawless integration of the ASSIST-IoT infrastructure, once the different hardware and software packages are available. Therefore, during this initial period of the pilot project, already available resources are used as placeholders for the target ASSIST-IoT infrastructure. The main part of the documentation is dealing with the setup of the Ford Kuga test vehicle in Valencia, whereas a minor yet equally important part is dealing with the preparation of strategies and software for later integration in the vehicle. Therefore, the first and foremost activities in Pilot 3A are targeting procurement activities (*Pilot3A_SetupAct_IDXX*), the setup of the vehicle and the integration of sensor signals (*Pilot3A_DevAct_ID1*), data handling within the vehicular network (*Pilot3A_DevAct_ID2*), over-the-air update mechanism for the SW (*Pilot3A_DevAct_ID3*), the setup of the remote server (*Pilot3A_DevAct_ID4*), and the development of SW tools for onboard exploitation of the data (*Pilot3A_DevAct_ID5* and *Pilot3A_DevAct_ID6*).

4.2.2.1. Procurement activities

The identified procurement activities for the pilot, from D7.1, are listed below with their current state. The general description of the elements was provided on D7.1 and will not be repeated here.

Pilot3a_SetupAct_ID1 Ford KUGA 2.0 mHEV Available and integrated within the pilot

Pilot3a_SetupAct_ID2 Open PCM with A8: Available and integrated within the pilot

Pilot3a_SetupAct_ID3 PCM SW and calibration Available and integrated within the pilot

Pilot3a_SetupAct_ID4 ATI VISION Available and integrated within the pilot

Pilot3a_SetupAct_ID5 ATI KVASER USBcan Pro Available and integrated within the pilot

Pilot3a_SetupAct_ID6 NI CRIO 9049 Available and integrated within the pilot

Pilot3a_SetupAct_ID7 HiFi sensors	Available and integrated within the pilot
Pilot3a_SetupAct_ID8 Vehicle onboard PC	Available and integrated within the pilot
Pilot3a_SetupAct_ID9 Dashboard communication	***[planned for M22]***
Pilot3a_SetupAct_ID10 AR system	***[planned for M19]***
Pilot3a_SetupAct_ID11 Remote servers	Available and integrated within the pilot
Pilot3a_SetupAct_ID12 Raspberry Pi	Available and integrated within the pilot

In addition to these identified activities, GWEN hardware is also being procured, for migrating the system to the ASSIST-IoT hardware whenever available. Because of SW compatibility between the current Raspberry Pi based development and GWEN, migration is expected to be straightforward.

4.2.2.2. Development activities

Pilot3a_DevAct_ID1 Vehicle setup. Stock Ford KUGA 2.0 mHEV (2020) vehicle (Pilot3a_SetupAct_ID1) has been made available for the project. In order to setup the vehicle for the project purposes the following actions were needed:

- **Implementation of the open access PCM.** As described before, the vehicle propulsion system control is handled in the Powertrain Control Module (PCM) of the vehicle. Therefore, establishing access to internal PCM data in order to get a detailed understanding about current vehicle emissions, engine status, driving situation, is a key requirement for this project. This also applies to and propulsion system controls related diagnostics, which will be covered in the second trial of Pilot 3A.

  Due to security reasons a direct access to internal PCM data is prevented in series production, therefore the original PCM had to be exchanged with a development ECU (Pilot3a_SetupAct_ID2**)**, that allows reading of PCM internal parameters and measurement data. Also writing and saving of calibration parameters is possible, for any sub-set of parameters and as a batch-upload also for the whole calibration at once.

  The implementation of the PCM can be described by two tasks. First the mechanical installation, with the actual exchange of the modules and the routing of CAN wires from the PCM to the desired measurement and calibration devices, and second, the setup of the measurement infrastructure, selection of appropriate data labels and smart saving routines to allow easy data access in the later stage of the pilot project. The latter will be described in Pilot3a_DevAct_ID2**.**

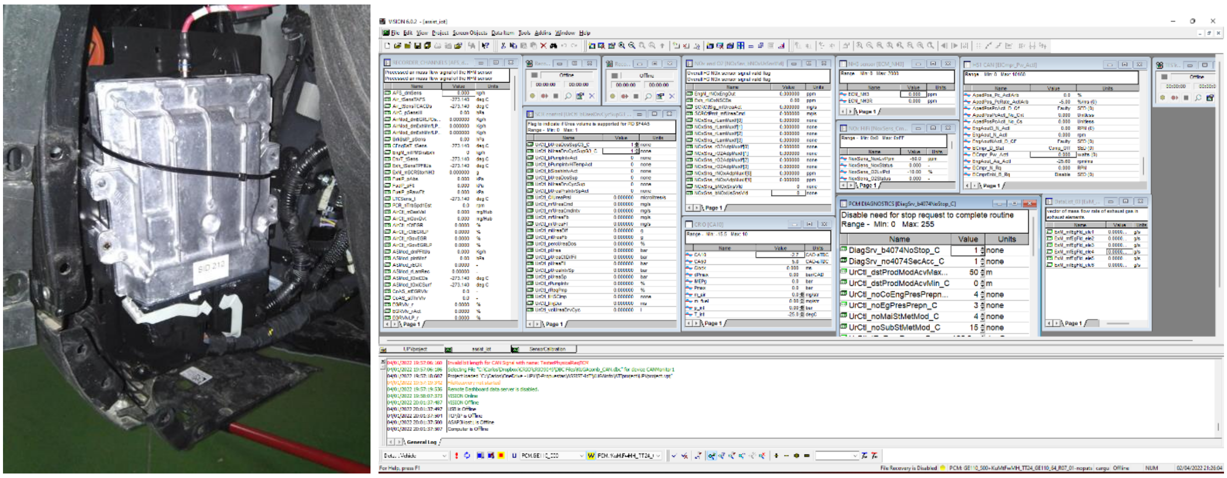

Figure 54. Left: research grade open PCM installed in the vehicle. Right: view of the SW used (ATI VISION) for accessing PCM measurements and internal calculations

- **Implementation of additional sensors, including HiFi-sensors.** As an addition to the PCM and the built-in vehicle standard sensors, additional sensors have been installed in order to a) confirm and b) to enhance the standard vehicle data gathering.

For the case of emission measurement, two previously mentioned HiFi-sensors were installed in the exhaust pipe, close to the standard vehicle sensors, to allow an easy comparison of the sensor output signals and simply because of space and access restrictions in the other parts of the exhaust system, where an installation might have made sense. As a positive side effect, it can be noted, that the newly installed sensors allow a precise sensing after engine start earlier compared to the standard sensors, due to a manipulated internal heating strategy, solely for prototyping purposes.

Figure 55. HiFi exhaust concentration sensors fitting in the vehicle exhaust. The one in the centre corresponds to the series sensors. Centre; under-hood setup of HiFi sensor electronics. Right: details of coaxial BNC connectors for routing the sensors' signals to the control system

- **Alternate power supply.** Due to the fact that the test vehicle is a standard production car, it is not intended to provide voltage to additional sensors and measurement equipment. Especially as measurements have to be set up before the propulsion system is running and providing electrical power with the vehicle generator, where battery voltage drainage is a significant problem. Therefore, it was decided to install an electromechanical relay to guard the battery, which is used to disconnect any measurement equipment from the battery immediately after the power supply is no longer needed for measurements and processing of data. Additionally, to increase the buffer capacity of the main vehicle battery during high transient voltage situations, a second battery was installed in the trunk of the car, mainly to support operation in cold weather start up conditions, and to avoid voltage drop during engine start. The power system was protected with fuses and automatic switches, and a manual actuated relay (activated from a switch from the vehicle interior) was provided. Systems powered by the alternate power supply are the HiFi sensors and the electronic system enclosure described below.

Figure 56. Left: Additional battery in the trunk. Centre: automatic relay for alternate power system isolation. Right: manual switch for the system

- **Implementation of the electronic communication and acquisition system.** A dedicated enclosure was installed in the trunk, in order to provide a dust protected environment for setting up the different additional electronics needed for the project (except for those elements placed under-hood).

Figure 57. Left: electronic system enclosure in the trunk. Right: general view of the system with identified elements

In addition to electrical protections and din rail connector blocks, the enclosure allowed the setup of the following systems:

a. **5V, 6A regulated power supply**, for providing safe voltage levels for those electronics that may not be supplied from the battery (note that the battery is charged by the car alternator thus having a significant variation in the voltage level).

b. **A digital isolation** custom design, based on a digital isolator MAX22245BAWA+, for avoiding any effect on the camshaft and crankshaft series sensors when they are measured by any external system. This is a critical aspect since any disruption in the sensor measurement by the PCM would cause the engine to stop because synchronism loose.

c. **NI cRIO 9049** (Pilot3a_SetupAct_ID6**)** has been installed for supporting the additional sensor integration activities, and to provide support for Open Call projects needing additional computation power or needing extended data acquisition capabilities. The cRIO allows an easy implementation of sensors, especially analogue ones, which otherwise would demand dedicated electronics to allow data transfer to the PC and the ASSIST-IoT edge node. This is an acceptable compromise as sensor implementation on ASSIST-IoT level would create a lot of additional workloads and, at the same time, would not provide any additional results.

   In the current state of the implementation, the system is able to synchronize with the engine series crank angle sensor for performing crank angle synchronous (CAS) data acquisition of up to 4 simultaneous channels (16 bit), and 16 simultaneous channels at 100 kHz. All data is streamed to an SSD disk for backup, and it is also real time processed. The results of the processing are published to the CAN bus. A series of methods have been set in placed for interacting with this real time system: TCP-IP, network shared variables, and CAN.

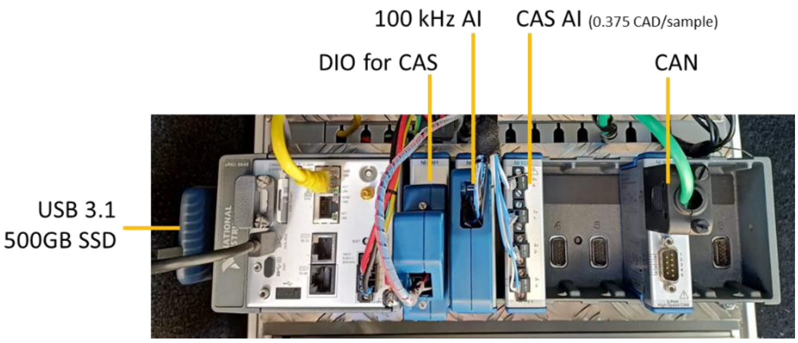

Figure 58. NI cRIO 9049 configuration with identified elements

a. **Teltonika RUT955**. To allow communication over various mobile networks, an industrial grade mobile network router was installed in the car. The router provides 4 LAN connections, a WiFi access point (with dual antennas), and connects to mobile network (4G –up to 150 Mbps, 3G – up to 42 Mbps, 2G – up to 236.8 kbps) with dual SIM. In addition, it also allows GPS measurement. This setup is also a placeholder until the final ASSIST-IoT solution is available.

Figure 59. Left, centre: Teltonika RUT955 router. Right: details of GPS, WiFi and 4G antennas

a. **Raspberry Pi 4B 8 GB.** To prevent delays in the development of the pilot as much as possible, it was decided to install a placeholder for ASSIST-IoT edge node hardware, which is still under development at this point in time of the project (M18). This preliminary placeholder hardware is based on a Raspberry Pi with CAN Shield, which is a Ford in-house development. It has to be noted that within the current planning the CAN shield is considered to be an alternative solution, as Pilot 3A data transfer is built around the usage of the so called Drivelets, which are small measurement files containing all relevant data for a short defined driven distance. The Drivelet concept is described later in this chapter in more detail. The idea behind the usage of the Raspberry Pi is that a later exchange of hardware should be possible with a reasonable effort – in an ideal world, only the Pilot 3A related Python scripts are copied from the Raspberry Pi to the ASSIST-IoT edge node once the latter is installed in the vehicle.

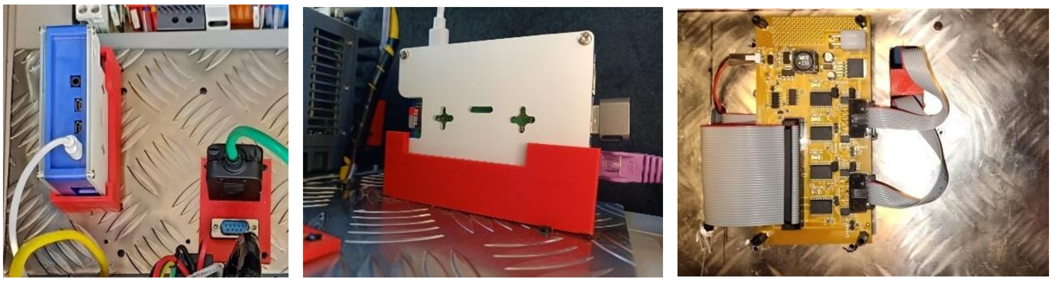

Figure 60. Left, centre: Raspberry Pi in the enclosure, and connection to CAN bus. Right: lower view of the CAN shield

b. Finally, while not installed, room has been provisioned for the ASSIST-IoT GWEN placement inside the enclosure.

- **PC with USB CAN dongle.** While the project is centred in IoT, a PC (Pilot3a_SetupAct_ID8) is needed in this pilot since it is currently the only supported way of interfacing with the open PCM. The PC uses ATI VISION software (Pilot3a_SetupAct_ID4) and interfaces with the rest of the elements in the setup via Ethernet or CAN. For the latter, an ATI KVASER USBcan Pro (Pilot3a_SetupAct_ID5) was installed.

Figure 61. Left: Control PC, showing the connection with the open PCM (red USB cable) and with the CAN interface (black USB). Right: dual channel USBcan Pro 2xHS v2

- **Wiring,** including power wiring, CAN bus (two different lines where distributed, one that of the series vehicle, and an additional one with the HiFi sensors and the NI cRIO measurements), Ethernet and sensor signals (from the engine compartment to the acquisition system in the trunk).

Pilot3a_DevAct_ID2 Development of vehicle data server. This activity tackles the integration of the different elements (open PCM, NI CRIO, HiFi sensors, etc.) in a cohesive acquisition framework, which serves data to the ASSIST-IoT hardware (either via CAN stream or as a series of short MDF4 files). The activity also included the system automation. Main actions needed for the task were:

- **Network setup.** The different subsystems within Pilot 3A have been interconnected as sketched in the diagram below. As it may be appreciated, several networks have been made available:

    a. Vehicular CAN network, which is connected to the HS1 line of the vehicle, granting access to a variety of messages provided by the different ECUs within the line. As per today, this bus is only connected to the PC via the ATI KVASER. However, wiring is ready for adding other systems to the bus. The line works with 500 kbauds.

    b. Sensors CAN network, where the different sensors (either the HiFi emission sensors or the additional sensors connected to the NI CRIO) publish their measurements; the PC is able to retrieve all these data by its second CAN measurement channel. The line also works with 500 kbauds.

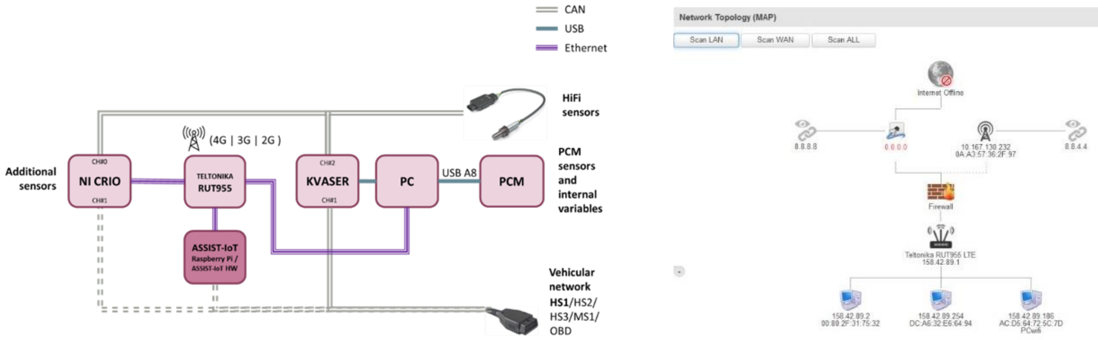

Figure 62. Left: Deployed networks. Right: detail of LAN network topology as obtained from the router

    a. LAN network, where the PC, the CRIO and the ASSIST-IoT hardware (currently the Raspberry Pi 4B) are interconnected. Since the router also supports WiFi connectivity, it is possible to access the network in a wireless mode.

- **System operation and automation.** Main devices in the Pilot3A setup are the PC, the CRIO and the ASSIST-IoT hardware. It was decided to program each one of them as a master system, in the sense that, while may interact with the rest of the systems in the network, it does not depend on the connection with the rest and will not stop or freeze its operation in case of any issue in the usual workflow. For the case of the CRIO, it publishes its measurements and real time calculations in the sensors CAN network, while streams to disk the raw values for backup. The PC compacts all data from the PCM and the two CAN networks in a single MF4 file, which is later made available to the ASSIST-IoT hardware. The ASSIST-IoT hardware processes the files as they are made available by the PC. Requests between the systems are made via network variables, SSH, and/or TCP-IP protocol.

    The PC also contains the interface functions. The HMI (shown below) provides basic information on the system operation and allows to start and stop the system. The same HMI program interacts with ATI VISION via its Windows API, so it can trigger and stop the recording, to vary the PCM calibration, and to add or remove measurement channels (these aspects will be reviewed in the next tasks). It also communicates with the CRIO via network shared variables, and such connection is used for starting and stopping data recording tasks in the CRIO. The depicted HMI is not intended to be the final HMI for the driver within the project pilot, but a high order control of the system from research perspective.

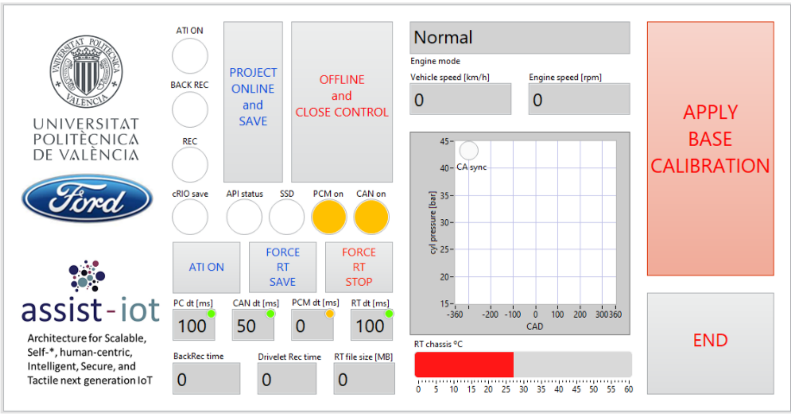

Figure 63. HMI

- **Drivelets.** While vehicle inter-module communication is usually based on data streams, in recent years mainly based on CAN data, for this project a different innovative approach has been chosen. Instead of providing a constant data stream to the ASSIST-IoT edge node, distinct measurement files are prepared and forwarded on frequent basis. The drivelet corresponds to a segment of driving in urban operation, the drivelet is defined as the driving segment between an engine start and stop, while in highway driving is a 5 km segment.

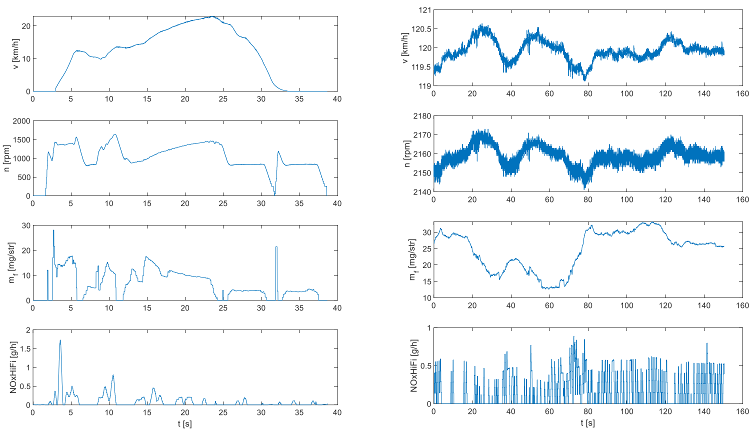

Figure 64. Left: drivelet in urban operation; right: drivelet in highway operation

This approach has several positive effects in the context of Pilot 3A:

a. *Simplified signal pre-processing and filtering:* from a computing perspective and when compared with a data stream, drivelet approach allows an easy access to simultaneous measurements from different channels. Evenly important, due to the fact, that the access to PCM internal data is restricted in this prototype environment, a processing step is needed to make the raw PCM data accessible for any later data analysis, therefore it is a consequent solution to filter incoming data for emission relevant signals in parallel.

b. *Post vehicle shutdown processing capabilities:* It is currently unknown how large the computational load will become to analyse incoming emission and diagnostic data. Therefore, it makes sense to save compressed data in a short or mid-term storage location on the edge node and allow processing of data even after the vehicle was parked, if needed.

c. *Long term storage and database opportunities:* If interesting data segments are identified, they can be handled without any further processing by the Long-Term Storage Enabler, in order to make the drivelets available for later in-detail analysis. Additionally, and most importantly, the drivelets could be easily marked with virtual tags to simplify the search for certain driving situations. This would allow to establish a database for single vehicles, but also for a fleet of vehicles.

In the current setup, the ATI VISION software running in the PC is in charge of gathering all the information: from the PCM (with a list of defined measurement channels i.e., variables to be measured), to the different CAN networks (connected via the ATI KVASER hardware), hence providing HiFi and additional sensors measurements. All data coming from those sources are compacted into a single MF4 (following ASAM standard format). The recording of the variables is periodically stopped and restarted, thus providing a new drivelet file which is locally stored in the MF4.

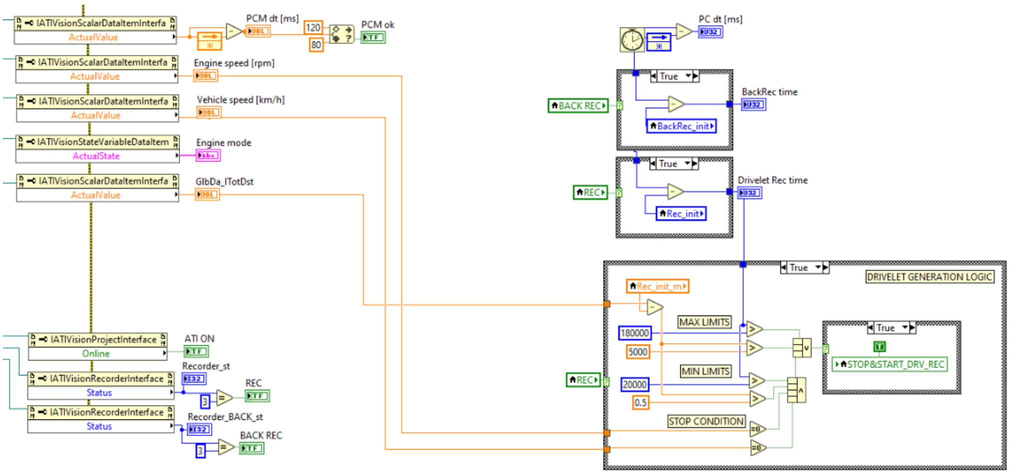

Figure 65. Code for the drivelet generation logic.

- **Data transfer flow.** Whenever a new drivelet is recorded, it is transferred to the ASSIST-IoT hardware (currently the Raspberry Pi) using the Ethernet LAN. File transfer is done using a dedicated program running in the background which detects if a new file is available in the client (PC), compares it with the version already existent in the server (Raspberry Pi) and uploads it. This same program is also used for transferring the data from the edge to the cloud (in this case the edge node acts as the client).

  Current SW version in the vehicle automates all the described steps so the ASSIST-IoT edge node receives drivelets files as they are being generated by the driving profile. In uncompressed MF4 format, they are at most 56 MB files for 254 PCM measurement channels at 100 Hz, and 74 CAN measurement channels (up to 100 Hz). If compressed, maximum size per drivelet is around 3 MB for the same number of channels. While the file could be compressed before transferring to the ASSIST-IoT edge node, the original format is preferred as the needed time is lower.

  In addition to the online operation of the system, all drivelets are stored and backed up for providing a dataset which can be used for other tasks in the project or for emulating the operation of the vehicle (by just dropping drivelet files into the ASSIST-IoT edge node folder with the expected time interval). The drivelet data repository covers to date more than 5000 driving segments, with a mix use (urban and highway).

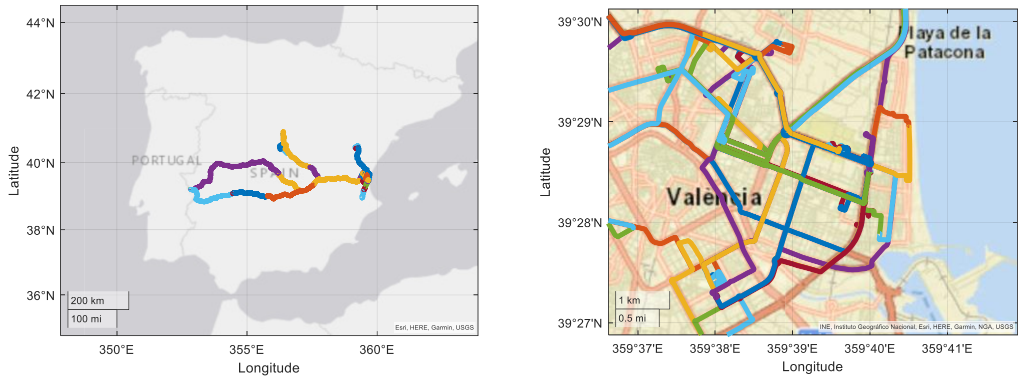

Figure 66. Left: Geographical coverage of drivelet data base. Right: zoom in Valencia, where UPV is located.

<u>Pilot3a_DevAct_ID3 Development of OTA update server and update mechanism.</u> In addition to fulfil data acquisition tasks, the system must allow the modification of the PCM calibration. Making use of the existing API which allows to interact with the PCM software, the following methods have been integrated:

- **OTA update of the PCM calibration.** Given a request (local or remote), the system downloads the new calibration file and, once the engine is stopped (the driver disconnects the contact), an update of the calibration is done. The functionality has been successfully tested and is ready for integration within the ASSIST-IoT framework. This functionality will be used at several steps in the project as, for example, for restoring sensor calibration. Note that the HMI has an "Apply base calibration" button, which allows the driver to restore the original calibration during the project tests. This mechanism has been included as a safety measure.

  It is also possible to modify a single value of the calibration without replacing the complete PCM file. While this feature has not been implemented in an OTA scenario, the functionality has been widely tested and can be readily integrated if needed.

- **OTA update of the measurement channel list.** Given a request (local or remote), the system may add or remove measurement channels (i.e., variables) from the recording list. This is an interesting feature for allow a dynamic definition of the measurements, so that the OEM control engineer can actively decide which channels must be measured.

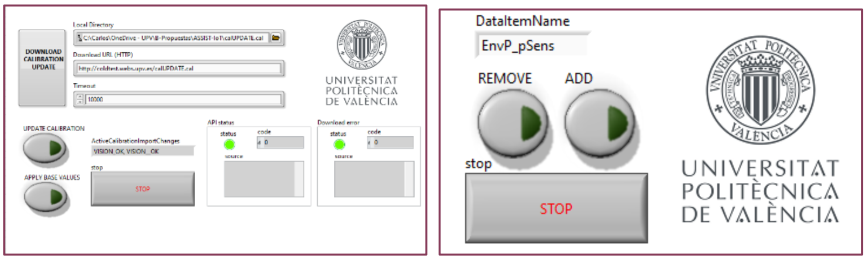

Figure 67. Left: test implementation for OTA updating of the complete calibration of the vehicle. Right: test implementation for OTA modification of the list of measured channels in the drivelets

<u>Pilot3a_DevAct_ID4 Setup of the remote server</u>: The cloud computing cluster consists of (i) three servers (each of them with 2x Intel Xeon Gold 6320R, 512 GB RAM and 1 TB SSD), (ii) two high-performance switches (with 48 x 10 Gbps SFP+), and (iii) two Network-attached storage (NAS) servers, each of them with 16 TB SSD. The cluster is being enhanced with an additional server with the same characteristics, also managing 8 high-performance GPUs. The server is available for the use in the pilot 3A.

In the current state of the project, the cluster is used to automatically back up the files as they are being measured in the vehicle. The client, coded in JS, opens a socket with the server placed in the edge node or the cloud. As it starts sending the data files, the server answers with an acknowledgement to confirm the reception and the data file creation in the server. Some errors can occur, for instance, the vehicle can have low internet coverage and lose the connection between the edge client and the server deployed in the cloud server. To handle these errors, the client has a monitoring mechanism to check the files not sent completely and those not sent yet.

The server implements an API route where the written files and their size can be listed by sending a request to the server, as depicted in Figure 68, where in addition to the client (left), the request to the server is shown (right).

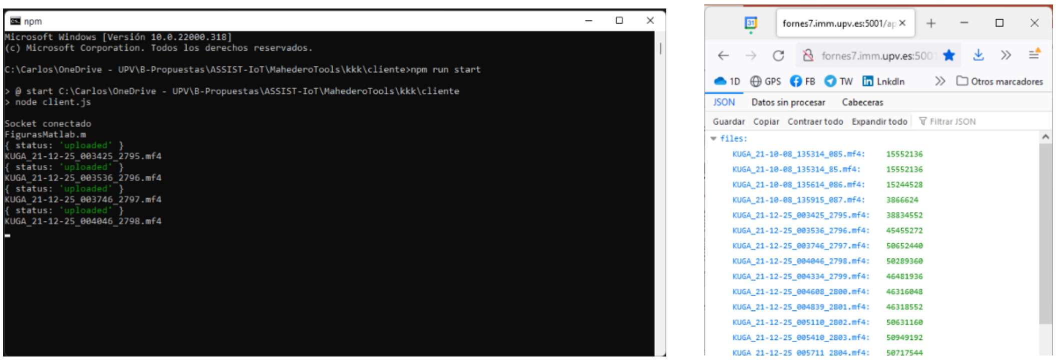

Figure 68. MF4 file uploading. Left: client (edge) view. Right: verification of the file list in the server

<u>Pilot3a_DevAct_ID5 Development of data analytics for fleet ISE:</u> One of the main requirements of the Pilot 3A use cases is to assess the vehicle emission footprint while in real operation. For that, a series of software tools have been developed, centred in the processing of the individual drivelet files. Underlying idea is to get general consumption and emission metrics for the driving segment under consideration, together with some ambient and driving profile metrics that can serve for understanding the actual driving conditions under which the emissions have been generated. This last aspect allows to conveniently filter and consider from a statistical basis the outliers to the distribution.

This task has used the library of drivelets measured in real driving conditions, together with backup files of complete driving profiles (long MF4 files with the complete driving trajectory). Main tasks of the activity have been:

- **Identification and pre-processing of relevant input and output channels.** Relevant variables (i.e., measurement channels) in the PCM and the vehicular CAN network were identified. These were recorded, together with the CAN signals from the HiFi sensors. Because of data with different acquisition frequency was present, time interpolation and cycle-to-cycle interpolation methods were applied. Once the values were interpolated to the PCM signals time base, resulting data turned into a set of vectors of the same length.

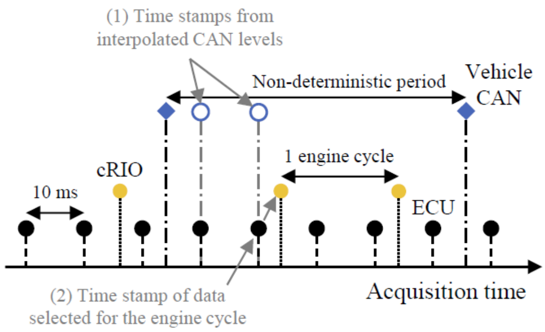

Figure 69. Time stamp of the different measurement channels: PCM at 100 ms (black), CAN signals (blue) and cycle variables provided by the external acquisition system (yellow)

Special care was also taken for solving cases where a specific signal was not available, or when the sensor value was not available (particularly for emission sensors, which have a long light off period).

- **Development of RDE-like metrics for the drivelet.** In addition to some normal metrics, as average speed for the drivelet, or average fuel consumption, RDE-like metrics were calculated for each driving segment. For that, and following the enacted procedure, velocity data was subsampled to 1 Hz, acceleration was estimated from its time derivative, and the following quantities were calculated for the drivelet:

  a. $(v \cdot a)_{95}$, which is the 95% quantile of the product velocity per acceleration when the acceleration is higher than 0.1 m/s^2.

  b. Relative positive acceleration (RPA), which is the average value of the product velocity per acceleration when the acceleration is higher than 0.1 m/s^2.

  These quantities are defined as in the regulation, except that the binning methodology is not used: since the drivelets are short segments, it makes no sense to bin the data according to the average velocity. In addition, RDE regulation limits for RPA and $(v \cdot a)_{95}$ was also computed, thus allowing referencing the measured value with the interval considered in the legislation.

- **Analysis of engine mode effect on the emission profile.** The engine exhibits several operation modes with different objectives. The four main modes are: aftertreatment heating mode (including cold operation), normal operation, DPF regeneration, and engine start. Because different injection strategies are used and the aftertreatment is operating in different conditions, the tailpipe emissions are impacted. For example: high temperature during periodic DPF regeneration forces SCR to operate off-design; or while operating in aftertreatment heating mode, the catalysts have not reached their light off temperature. Hence, tailpipe emissions for those cases should by necessity to be higher than in normal operation; this is necessary and is part of the normal operation of the system. Accordingly, drivelets must be classified according to the predominant mode in the driving segment (usually one single mode).

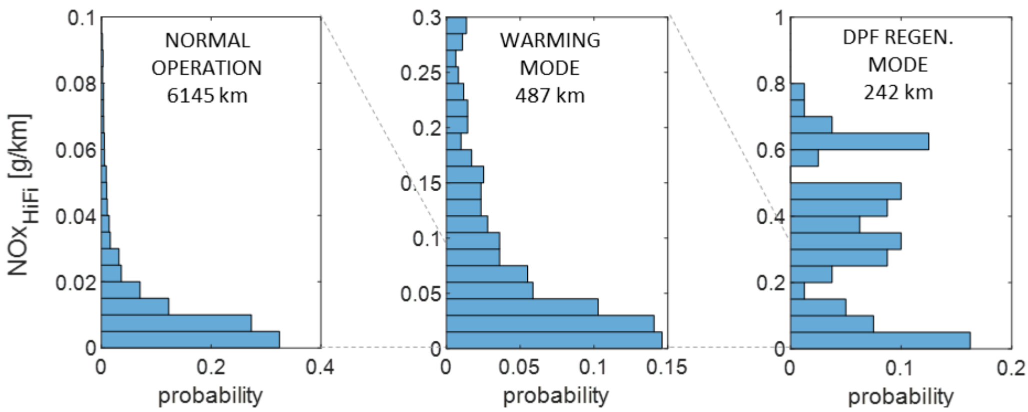

Figure 70. Specific emission distribution for the drivelets in different operation modes. Note that most of the drivelets correspond to the normal operation mode, accounting for up to 90% of the travelled distance

- **Determination of the emission metrics.** Sensor signals must be combined in the form of observers for deriving the value of the NOx emission for the drivelet, from measured mass flow, estimated fuel flow, and exhaust NOx concentration. In this sense, the availability of the NOx signal is a requirement. However, due to energy-efficiency in the operation of the system, tailpipe series sensor usually takes several minutes to be ready following an engine cold start (conservative heating strategies are in place). To get an insight on the operation of the system during the first seconds of the operation (when the SC temperature does not allow to have an effective NOx reduction), the HiFi sensor was provided of an accelerated heating strategy. This way, the signal is ready after a few seconds. To estimate the impact of the sensor signal not being ready, the distance travelled with the sensor signal available is also calculated (and compared with the total distance for the drivelet).

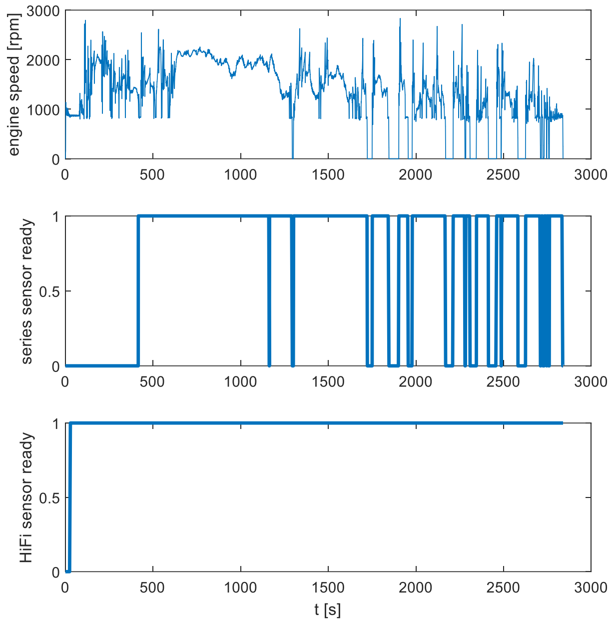

Figure 71. Example of NOx measurement activation for the series sensor (centre) and HiFi sensor (bottom) in a ~30 min drive. Note that series sensor signal is only available after more than 400 s of driving

Cumulating the drivelet emissions -either for a given distance window or for the complete life of the vehicle,- one can derive the emission level (in g/km) of the vehicle. Short distance averaging serves for detecting drift in the vehicle performance.

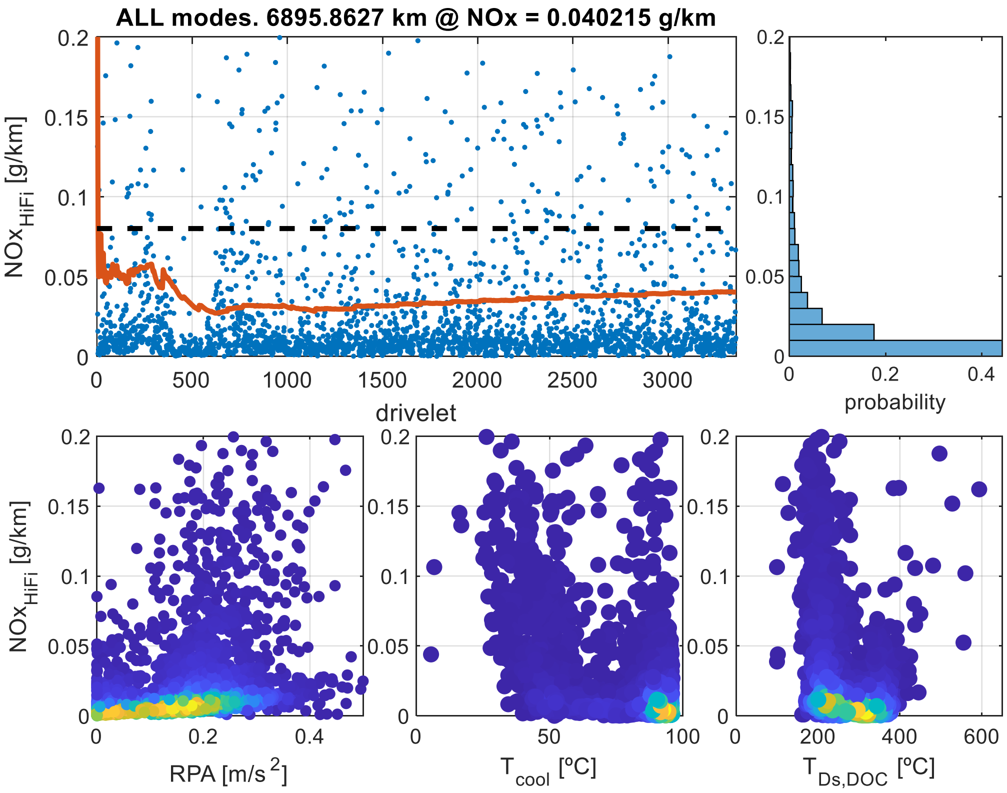

Figure 72. Top left: NOx emissions per each drivelet and cumulated emissions, as measured with the HiFi sensor. Top right: histogram of the specific emissions per drivelet. Bottom: density plots of the emissions with the relative positive acceleration (left), the coolant temperature (centre), and the SCR inlet temperature (right).

Pilot3a_DevAct_ID6 Development of learning methods for calibration update. This ongoing task covers the adaptations of models along the vehicle life, together with corrective actions for -when possible- recovering nominal performance. In its current state, the activity has been centred in detecting drift on the series NOx sensor by comparing its value with the HiFi sensor. In addition, general tools for adaptive modelling (using lookup tables) are also being tailored to the application.

- **NOx sensor drift detection for each drivelet.** In order to detect the drift from tailpipe NOx emission sensors, the system compares the signal of the sensor with that of the HiFi sensor. Because the signal has a nonlinear filtering (negative values are set to zero, as shown in Figure 73), raw signal is preferred for running the comparison.

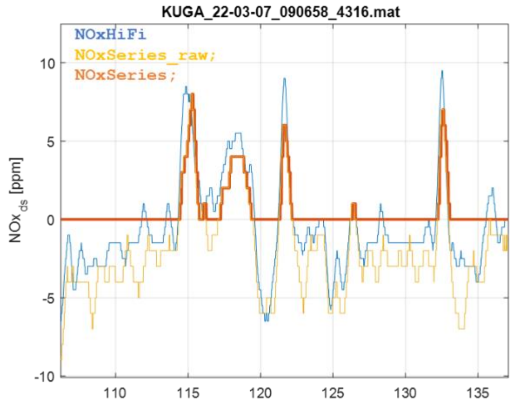

Figure 73. Comparison of raw and filtered values for the series NOx sensor with the HiFi sensor

For each drivelet, a piecewise affine model is fitted by least square minimization of the error. Because the range of the sensor measurement strongly depends on the considered drivelet, the model is defined with three break points at 20%, 50% and 80% quantiles. Those three points are later fed to the recursive model fitting function.

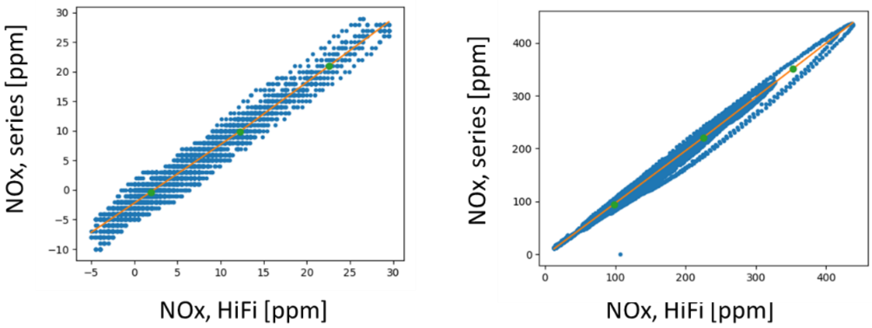

Figure 74. Local fit of the piecewise affine model for two drivelets exhibiting significant differences in range

- **Recursive model fitting.** The recursive model fitting is in charge of combining the data fits for each drivelet into a single model. It works with in an iterative procedure updating the model every time new data is presented to the method. The method may be run either in the edge node (for merging the drivelets into a single global NOx sensor model), or at the cloud, combining data coming from different vehicles for deriving a model for a given fleet.

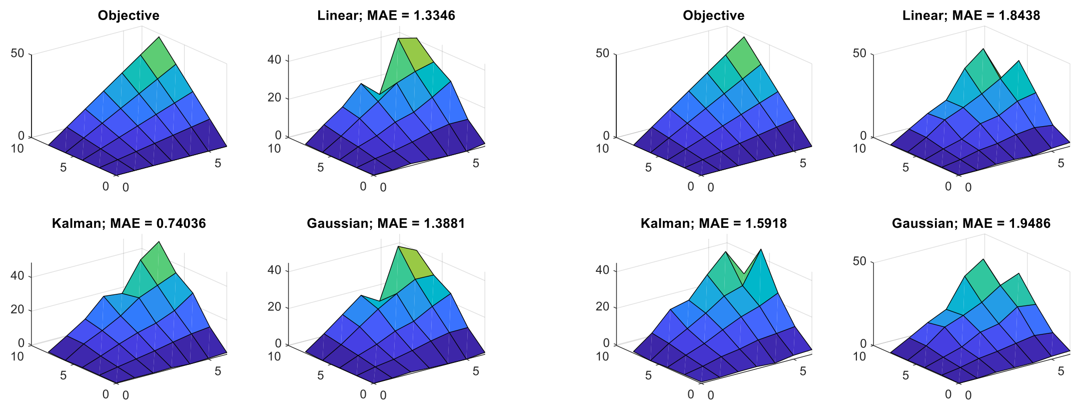

Figure 75. Learned lookup table after 200 noise free (left) and noisy (right) simulated measurements for the three programmed learning methods (linear, Gaussian, and steady state Kalman filter).

Three learning mechanisms have been programme [14], [15], [16]), all of them allowing to recursively fit either 1D lookup tables (i.e., piecewise affine linear models) or 2D lookup tables (i.e., piecewise affine bilinear models). Figure 75 shows an example of the capacity of the system for learning a given surface when sufficient iterations are run, even in the presence of measurement noise.

The learning approach has been used, now as a 1D model, for fitting a global model to the NOx sensor bias, as shown in Figure 76. The model is able to adapt itself to data and has the capability to adapt to time varying bias (i.e., drift).

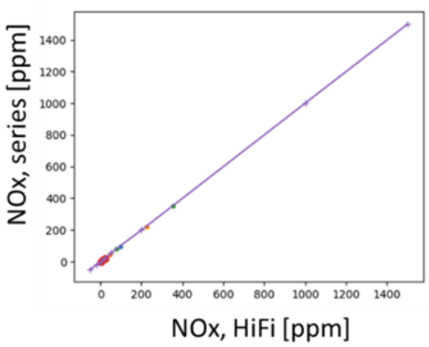

Figure 76. Recursive fit of a piecewise affine model for NOx sensors data. Model break points are marked with crosses, new data for the fit are the red circles, and data from precedent iterations are marked with different colours

Pilot3a_DevAct_ID7 Development of diagnostic models for different failures ***[planned for M23]***

Pilot3a_DevAct_ID8 Development of driver interface device ***[planned for M23]***

Pilot3a_DevAct_ID9 Development of AR assistance for vehicle servicing ***[planned for M26]***

Pilot3a_DevAct_ID10 Development of learning methods for diagnostics algorithms ***[planned for M26]***

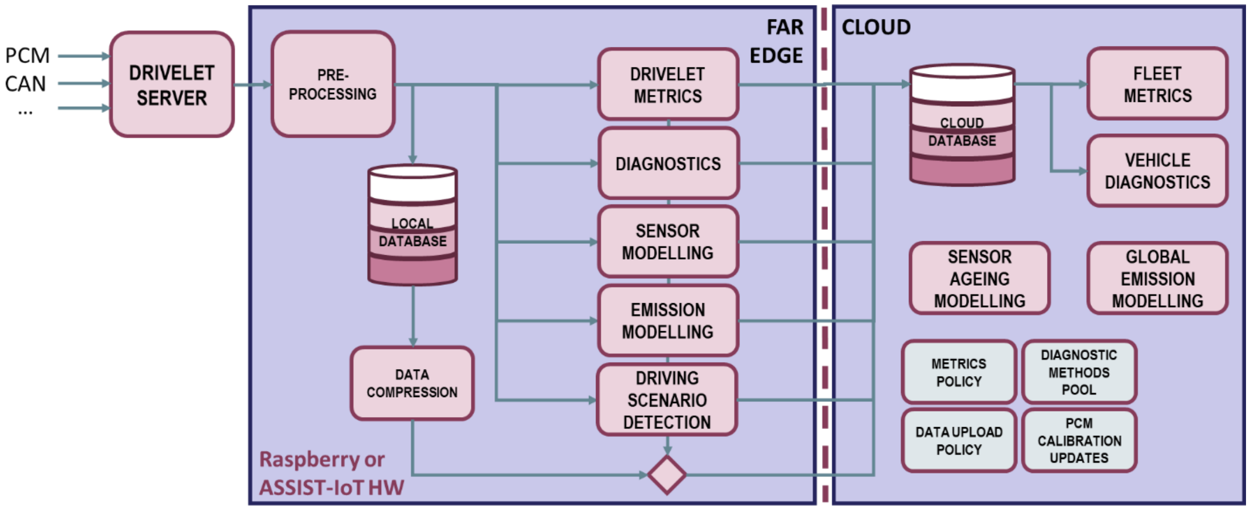

Figure 77. Schematic of software concept under development.

Figure 77 shows the main software components being addressed in the pilot. A first functional software has been developed and integrated into the edge node with the following functionalities:

- **Data file loading and pre-processing.** The system waits for a MF4 file to be available, opens it and stores the relevant variables into memory. Interpolation and resampling functions allow to use a common time base for all signals.
- **Drivelet metrics.** Metrics are computed for the drivelets, attending to different criteria:
  a. Overall data about the drivelet (operation temperature, ambient conditions, GPS position).
  b. Average driving metrics.
  c. RDE metrics.
- **Engine mode detection.** Detection of distance and time spent it each engine mode.
- **Emission metrics.** Metrics are computed for the drivelets, using both series and HiFi sensors.
- **NOx sensor drift detection.** Model for the bias is fitted for the drivelet data, resulting in three new points which may be fed to the global fitting.
- **Recursive update of NOx sensor drift model.** The new points are integrated into a single, new model using a steady state Kalman filter approach.
- **Results integration into SQL database**. Using *pewee* library, the results from the previous calculations are compacted into the local SQL, which is running within a Docker container in the ASSIST-IoT edge node.
- **Compression** of the file and storage into a folder. So far this uses direct data compression, while subsampling and selection reduction in the number of channels to store has not been implemented.
- **Verification** of the number of files in storage, and space saving policy application.
- **Upload** selected compressed files to cloud. This is done by a parallel process in the server. Actually, this piece of SW is the same as the one used for transferring the data form the PC to the ASSIST-IoT edge node, except that this time the client is running in the edge node, and the server is at the cloud side.
- Send request to PC for **PCM update** from calibration repository. This is currently done via TCP-IP.
- Send request to PC for **update of the measurement channel list**. This is currently done via TCP-IP.
- And wait until next drivelet file is available.

Main pieces of code have been programmed as python scripts, while the data transfer is managed by a node.js program running in parallel, and the SQL database is within a Docker container. So far, no cloud system has been provisioned nor data is sent to cloud (other than file backups). This will be done in a later step using the ASSIST-IoT enablers.

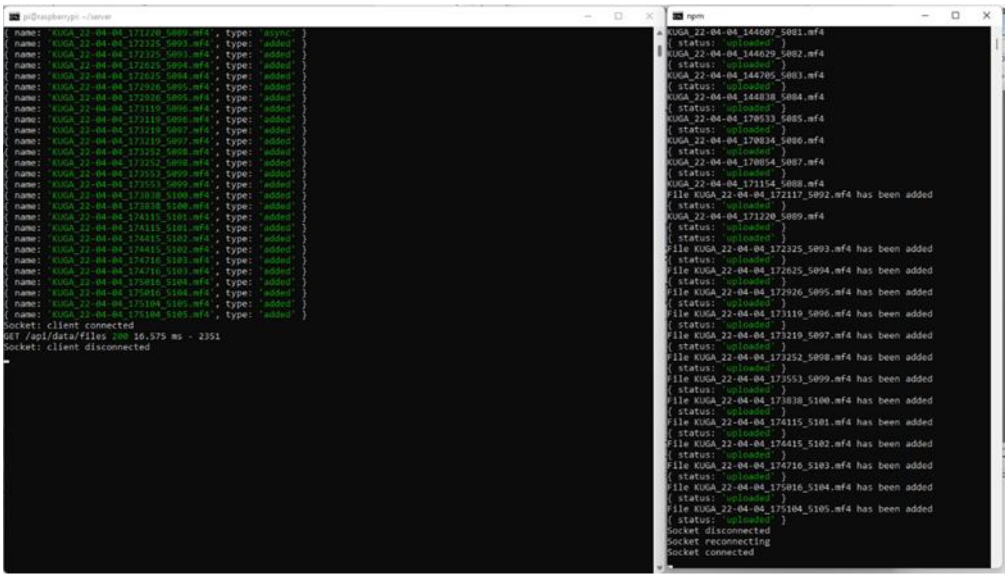

Figure 78. Data transfer between the PC (right panel) and the Raspberry Pi (left panel is an SSH session on it). Files generated in the PC are sent to the Raspberry Pi as they are being created

4.2.2.3. Integration activities

Integration activities are associated to the integration of the different identified ASSIST-IoT enablers (which were highlighted in the architectural diagram in the "Scope" section above). Since these enablers are not fully operational yet, all the integration activities will be carried out during the second half of the project

Pilot3a_IntAct_ID1-Integ.of smart Net. And Cont. (T4.2) and Self-*(T5.1) enablers: Not started yet. Postponed until smart network and self-* enablers are developed, and ready for integration.

Pilot3a_IntAct_ID2-Integration of semantic data management (T4.3) enablers: Not started yet. Postponed until data management plane enablers are developed, and ready for integration.

Pilot3a_IntAct_ID3-Integ.of data broker: Not started yet. Postponed until EDBE is developed, and ready for integration.

Pilot3a_IntAct_ID4-Integ.of LTSE, application and services (T4.4) enablers: Not started yet. Postponed until application plane enablers are developed, and ready for integration.

Pilot3a_IntAct_ID5-Integ.of FL (T5.2) enablers: Not started yet. Postponed till Federated Learning enablers are developed, and ready for integration.

Pilot3a_IntAct_ID6-Integ.of cybersecurity (T5.3) enablers: Not started yet. Postponed cyber-security enablers are developed, and ready for integration.

Pilot3a_IntAct_ID7-Integration of DLT-based (T5.4) enablers: Not started yet. Postponed until DLT-related enablers are developed, and ready for integration.

4.2.2.4. Validation activities

Demonstration policy. Along the project, the pilot will be evolved with new features added to the existing ones, providing a continuous improvement of the same trial (Trial #1). Three demonstration tasks have been prepared: Pilot3A_ValAct_ID1, Pilot3A_ValAct_ID2 and Pilot3A_ValAct_ID3, each of them adding new features to the pilot implementation, and correcting and improving the previous iterations:

- ***Demonstration task #1:*** *Pilot3A_ValAct_ID1* will focus on the validation and demonstration of the Main execution flow of UC-P3A-1 Fleet in-service conformity verification (i.e., analytics of ISE emissions).
- ***Demonstration task #2:*** *Pilot3A_ValAct_ID2* will be centered in the validation and demonstration of the Alternative execution flow of UC-P3A-1 Fleet in-service conformity verification (i.e., calibration

update mechanisms for recovering ISE levels), plus an update of the Main execution flow of the use case. At this step of the project, it is expected that all the identified enablers may be integrated, as described in the integration activities list.

- ***Demonstration task #3:*** *Pilot3A_ValAct_ID3* will be used for demonstrating the implementation of use cases related with the vehicle diagnostics: UC-P3A-2 Vehicle Diagnostics-Vehicle's non-conformance causes identification, and UC-P3A-3 Vehicle Diagnostics-Updating the diagnostics methods pool. In addition, the update of the UC-P3A-1 will be validated

Pilot3A_ValAct_ID1 demonstration: Fleet in-service emission verification. This activity is focused on the validation and demonstration of the Main execution flow of UC-P3A-1 Fleet in-service conformity verification (i.e., analytics of ISE emissions). In the current state of the implementation, only edge components have been verified.

4.2.3. Deviations from original planning

Figure 79 provides the original planning of Pilot 3A implementation for the reported time framework. It must be noticed that as not all ASSIST-IoT software and hardware enablers were sufficiently mature on M18 of the pilot project, expected integration activities should be delayed and were not ready for integration into the first demonstration activity (*Pilot3a_ValAct_ID1 UC-P3A-1 demonstration*). To keep the *Pilot3a_ValAct_ID1 UC-P3A-1 demonstration* activity in place, it was decided to provide a first functional implementation of the capabilities in a mock-up system, keeping in mind portability to the ASSIST-IoT framework in a latter step. As such, containerized elements are used, and compatible software has been selected for the development of the different software elements. Other than that, there are no significant deviations to be expected within the emissions part of Pilot 3A. However, it should be noted, that the original approach to calculate fleet level emissions with standard programming techniques will be enhanced with the usage of the ASSIST-IoT machine learning and federated learning enablers in later steps of the project. On the one hand from research perspective, this is considered to be an interesting innovative approach and, on the other hand, this addition to the original planning can be used to showcase the capabilities of ASSIST-IoT.

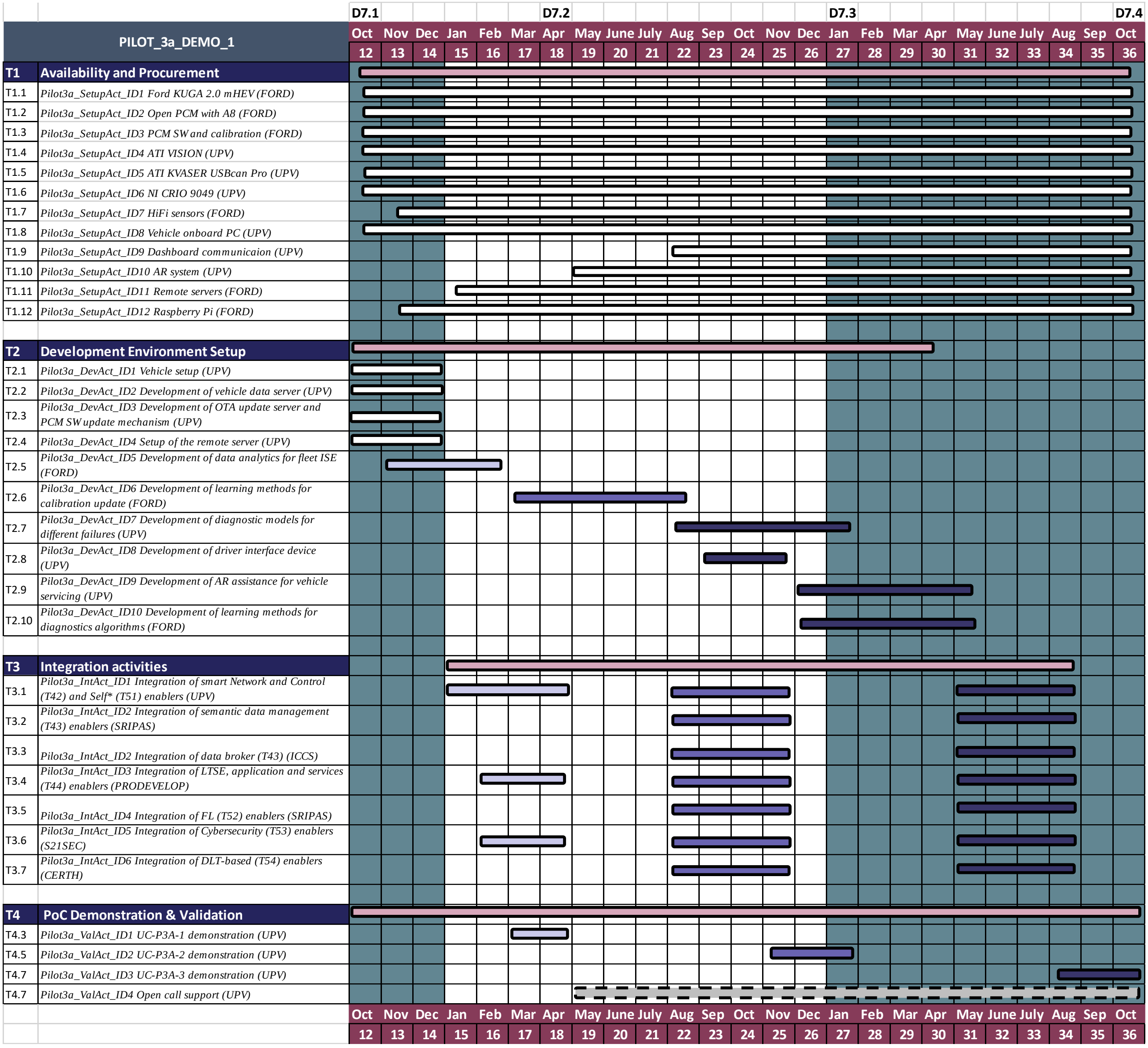

Figure 79. Pilot 3A general planning for M12-M18 period, as per D7.1

5. Pilot 3B: Vehicle exterior condition inspection and documentation

5.1. Context review

The Pilot 3B of ASSIST-IoT aims at helping vehicle inspectors to improve operational efficiency during their job of documenting the vehicle's exterior condition and reviewing them for potential surface damages of the vehicles. More and more automotive organizations not only discover the benefits of a digitalization of their processes, but they are simultaneously under the real pressure to improve their productivity. First promising results in the field of AI-based, automated surface inspection also open the perspectives of the deployment of these technologies into these markets with additional productivity enhancements. The following picture shows a digital vehicle scanner at an OEM branch used as a pilot environment to check the mentioned possibilities under real operational conditions.

Figure 80 Vehicle scanner as pilot outdoor installation at final customer

Several experience and insight gains are being gathered with this pilot, simultaneously conducted with the first half of the ASSIST-IoT project. Particularly, the real operational aspects in the end-user's everyday operations as well as the realistic performance requirements for the technology are being continuously validated and checked under realistic conditions. Additionally, a vast volume of images are acquired early in the project to be used for damage annotations, absolutely needed for the AI-training of the inspection AI-engines in the next phase of the ASSIST-IoT project. They are needed for the traditional AI-approaches, for the innovative FL-methods of ASSIST-IoT as well as for an objective comparison of the deployment of these technologies.

The fundamental, agile plan to conduct the Pilot 3B activities is use an appropriately modified scanner system as starting application and build a new architecture using the upcoming ASSIST-IoT enablers over the time. This has the advantage to be operationally for many project aspects from the project beginning and win necessary impact for R&D activities, not needing the whole system up and running, and on the other hand having an adaptable, fully operational platform to continuously validate new project results and adapt accordingly. This is also realistic, as only a part of the underlying scanner ecosystem is newly developed by the ASSIST-IoT R&D efforts and must collaborate with basic-, application-oriented functionalities, not relevant, but necessary for the proper system functionality. This principle is schematically given in the next figure.

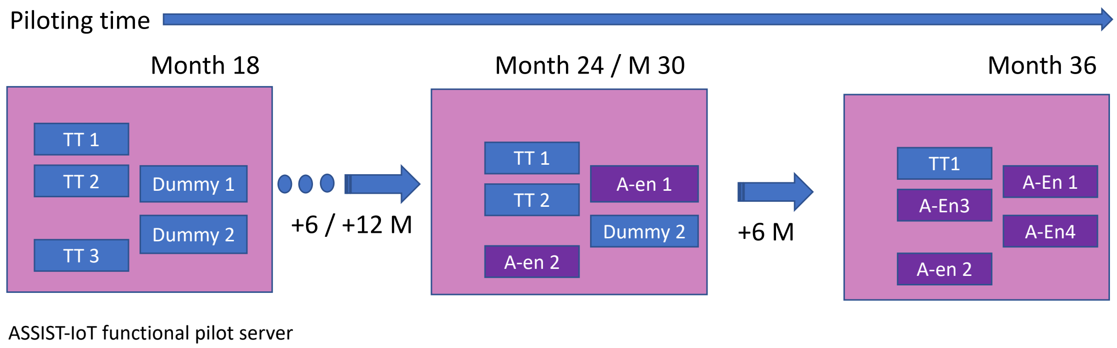

Figure 81 Pilot 3B evolving ASSIST-IoT functionality over time (TT x: TwoTronics own developed modules, Dummy x: dummy place holder modules; A-en x: ASSIST-IoT enablers modules)

5.2. Trial #1: Vehicle exterior condition inspection and documentation

5.2.1. Scope

In this trial two main application functionalities are being developed and investigated in the ASSIST-IoT project framework: (i) the documentation of the exterior condition of the scanned vehicles; and (ii) the AI-based support for automatic inspection.

Documentation of the exterior condition of the scanned vehicles

For the scanned vehicle documentation following aspects are essential: data (images + meta data) - acquisition, - storage, - retrieval, and visualization to support the user to review himself potential damages or review potential claims of the end customers and vehicle owners. The real-time acquisition system determines the actual vehicle position, controls the LED-based adaptive lighting system according to the actual illumination conditions, process the color image processing also applying compression/decompression approaches and it is supported by an intelligent storage system with local buffering to cope with varying process speeds following the actual processes demands (in different hours of the day / month, different vehicle traffic volume is occurring). Finally, the system control unit triggers the communication system (including adaptive image packaging - de-packaging) to transfer the data into a local or cloud-based, long-term storage system. This storage system in different configuration scenarios the different aspects of the various applications. For example, it can be local and short for a few days' storage in short rent-a-car cases or centralized and long for long-leasing contracts (thousand vehicles for a time period of 2-3 years). For all this data / images an ergonomic and fast human-centered retrieval and visualization has also to be implemented. In this concept the real storage location is transparent for the user (edge, local organization, enterprise cloud) and the associated frontend-software must handle hundred thousand of images, offers advanced, application-centered visualization and display with optional focus on existing damages and AI-proposals. Additionally, a special part of this frontend must support the review and the annotation of the scanned images to create the badly needed ground truth training data for the AI-algorithms.

AI-based support for automatic inspection

Additionally, to the manual review and inspection of the images an automated, AI-based inspection is wished. Whilst potential performances and usability of traditional AI-approaches are being investigated for the individual business scenario needs, more recent, so-called federated learning methods are also being developed in the project, so that they can show the advantages of a modern IoT-architecture like the one, proposed by ASSIST-IoT. To these advantages belong more data privacy with its better user system acceptance, less data transfer volumes with reduced communication costs, better utilization of existing computing resources on the edge reducing implementation costs and better integration of the users into the processes (human-centered approach). Questions and challenges here is whether the FL-approach can offer AI-performances at least comparable with the other AI-approaches, how the end-users will accept the higher interoperability with the digitalization processes and how the validation of the AI-results can be achieved in an efficient way. The trial aims to provide answers to all these questions.

Note: Since the enablers functionalities are still not fully defined due to their ongoing development, this pilot has postponed the architectural diagrams of the testbed with the ASSIST-IoT enablers to the future D7.3.

5.2.2. Implementation activities reporting

5.2.2.1. Procurement activities

The procurement activities are naturally being suffered from the current global supply chain problems. We were lucky to have recently got a substantial number of the most critical part of the scanner, which are the colour, high-resolution cameras forming the core of the sensor-subsystem. A not planned effort level at the project beginning is now spent to establish an active monitoring and implementation process for components procurement. This is necessary due to the agile approach of the project, where changes and improvements are part of the planned activities.

The arrival of the new colour cameras allowed to build a test environment for the sensor-subsystem and perform several low-level system tests. They are particularly needed since new camera firmware has been released for the used cameras (from the Canadian company FLIR), particularly in the context of their new feature of compression / decompression of the acquired images. It is supporting higher image acquisition rates, despite their high-resolution sensor. Thus, up to 10 frames per second (FPS) could be achieved with the 24 MP resolution, or 15 FPS for the 12 MP version.

We are facing delivery problems with the LIDAR-sensor from a major manufacturer. In the moment there is one spare available to continue with testing, but a new delivery is not foreseen before coming September 2022. This may cause problems for further going integration- or test- activities. As a contingency measure we may use a slightly different version of the LIDAR-sensor, which may be less powerful for industrial usage, but good enough for our pilot needs.

A major component for the AI-development is here the central internet-based server supporting both a large, permanent volume of the vehicle images and their meta data as well as offering fast communication possibilities for connected scanners on the one hand and for users on the other hand. The later can be

- end-users requesting AI-based inspection results,
- an AI-R&D team developing the AI / ML algorithms &
- annotation teams reviewing and marking damages on the vehicle images

In this context a major change is the decision to move from the internal server at TwoTronic-premises to a server hosted in an external, professional computing services centre. This centre is in Europe (Germany), thus fulfilling the European GDPR-rules for data protection and security. The services have been procured since February 2022 and the system has been setup in March 2022 for the first activities. A first sound set of 5.000 images and their damage annotations from two different scanners for two damage categories has been provided for the relevant FL-R&D project activities.

Several NVIDIA graphics cards have also been acquired for the AI-training and execution. They will be used in both edge as well as cloud corners allowing for interesting comparisons for important overall architectural aspects towards a well-balanced overall ecosystem architecture.

The situation for the various system components is given in more details in the following paragraphs:

Pilot3b_SetupAct_ID1 Physical scanner @ TwoTronic available

Pilot3b_SetupAct_ID2 Local Intelligent Storage System available

Pilot3b_SetupAct_ID3 Real time system controller available

Pilot3b_SetupAct_ID4 Web-based frontend & visualisation software available, test-version as MVP

Pilot3b_SetupAct_ID5 AI-based automated surface inspection hardware + annotation SW available

Pilot3b_SetupAct_ID6 Pilot scanners @ end-users available, producing new images

Pilot3b_SetupAct_ID7 Vehicles & corresponding annotations available (5.000 images + annotations)

Pilot3b_SetupAct_ID8 End-user tables & mobile devices available as commodity components

5.2.2.2. Development activities

Pilot3B_DevAct_ID1 / Scanner preparation & setup

The pilot scanner with the configuration size "small" has been built at TwoTronic with the defined main components as defined in the original plan. It has 2 cameras per side and can be used in indoor as well as outdoor mode, thus flexibly supporting subsequently changing needs of the project.

Additionally, a car size scanner is used at a collaborating, pilot customer to provide thousands of vehicle images for the AI-training needs but also to check the real application requirements. It is a passenger car service and repair garage of a large OEM-manufacturer. It also serves to check the digitalisation of its processes using the developed functionalities as well as their impact on his productivity improvements.

Figure 82. Master side of TwoTronic-scanner with LIDAR sensor, enhanced LED-illumination, and deflectometry-stripes on wheels

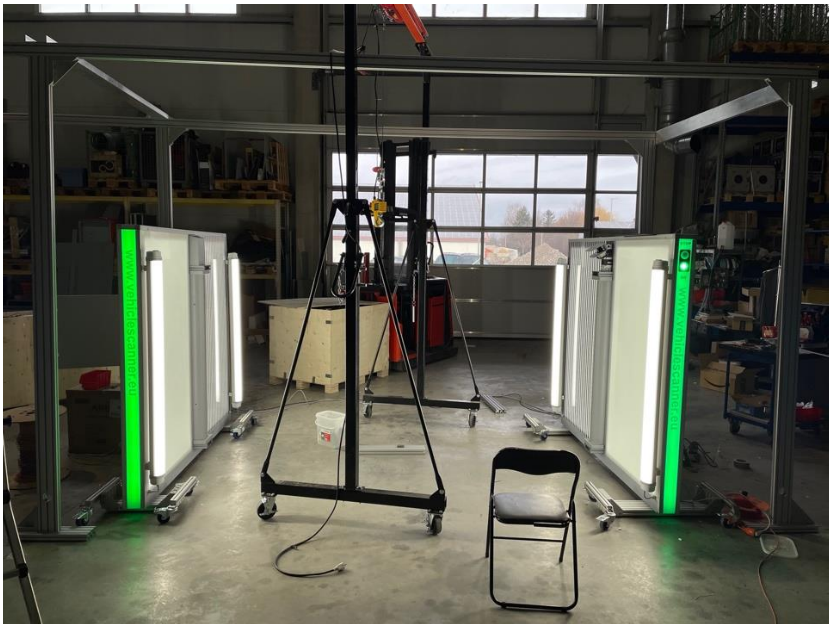

Figure 83. Experimental TwoTronic scanner - small size

The system has got designed enhanced power units (shown next picture) to support modern, powerful graphic cards for edge-based AI-execution of the acquired images. Following several benchmarking experiments, it is concluded to use graphic series from the NVIDIA product family. The used cabinet and the overall embedded system can now also host different card sizes (beyond multiple Giga-ETN interconnections), supporting scalability for the upcoming project computational needs on the edge This is needed for the planned FL-AI execution for both operational inspection as well as training.

Figure 84. Electric cabinet for the pilot scanner with enhanced electric

Several implementation possibilities have been checked to implement a minimal, two levels permanent storage system for the edge or near-edge node. To support a modern, hybrid-architecture as the one, proposed by the ASSIST-IoT, we are defining a new internal edge-node architecture with enhanced interactions internally and externally. The embedded computing system has now enhanced status engines with database-supported information, can orchestrate several scan processing & communication channels with different bandwidth and priority characteristics and can autonomously serve minimal, visualisation supported user-interactions for basic system setup and maintenance activities including remote access and diagnostic possibilities.

The new, refined real time system controller design is shown in the next figure, and contains the following main components:

- sensing system incl. illumination and vehicle positioning system
- real-time image acquisition & control system
- image processing support including a scalable graphics subsystem
- an optional industrial image processing support for additional quality assurance tasks
- a communication module supporting various connectivity options, like cables, Wi-Fi & 4G/5G routers
- a temporary front-storage system supported by an edge-data base
- a local, intelligent storage & retrieval system as optional, permanent storage & retrieval instance

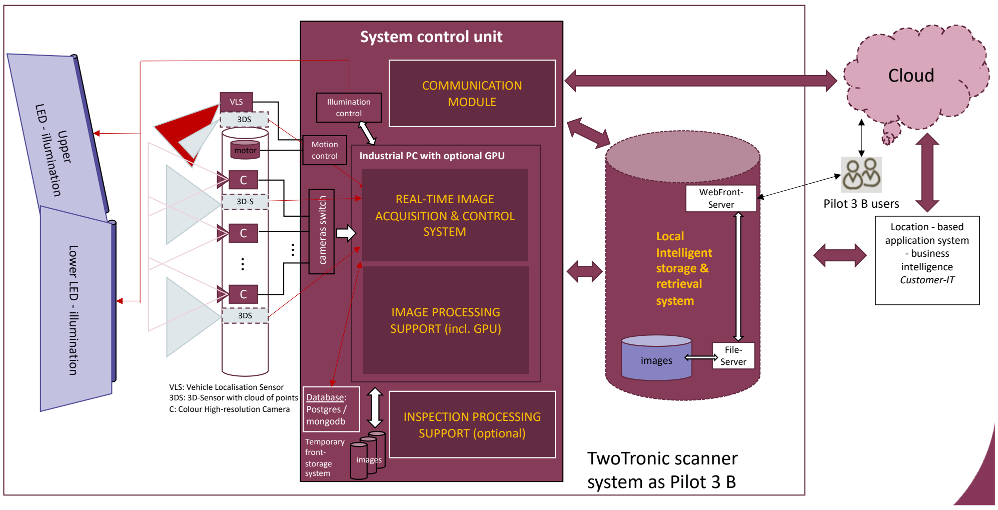

Figure 85. Refined architecture of the scanner real-time control unit

In the Pilot 3B a "small"-sized scanner with two cameras pro side (left / right) is used (see corresponding figure 43) at the TwoTronic premises. The acquired vehicle images from scanned passenger cars driven by the TwoTronic team drivers, together with their corresponding, necessary meta data are saved either into the embedded, temporary storage or into the additional local storage and retrieval system. The communication module is configured to transport the data from the temporary front-storage system to the local intelligent storage & retrieval system as well as to the new TwoTronic cloud server. The generated meta data include various system parameters like scanner-size, -ID & -location, scan epoch-stamp / generated by the real-time controller, vehicle license plate, scan time and other application-motivated information. The new Web-based Frontend software can be installed either on the embedded PC (as a minimal scenario) or on the associated local intelligent storage system. It provides the necessary retrieval and visualization services for the users. It can also be installed in the cloud, offering either an additional or alternative option to the associated local intelligent storage system. These different implementation possibilities support study of the advantages and disadvantages of the edge-, cloud- or even hybrid approaches towards a better design for a well-balanced architecture. The last one is shown in the next figure (44), where the full-blown configuration possibilities are shown including the usually existing business intelligence of the customers. It goes far beyond the examination of the vehicle exterior conditions, as it also includes several service, repair and update contracts of the consumers to the car garages, like spare parts logistics, repair contract details etc.

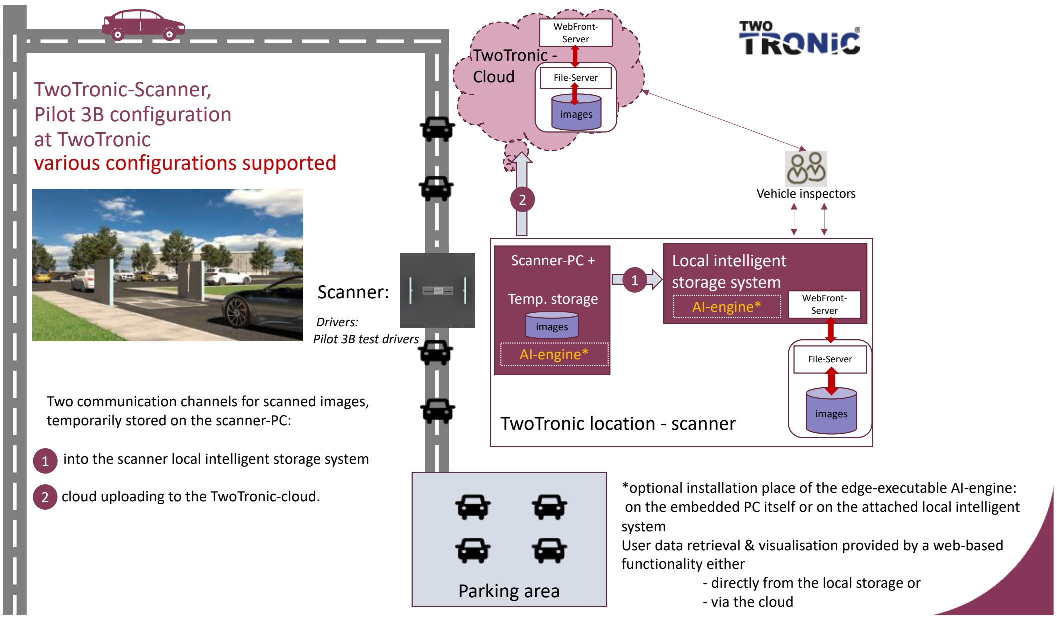

Figure 86. Pilot 3B scanner at TwoTronic - structure and information flow for a simple scanner configuration

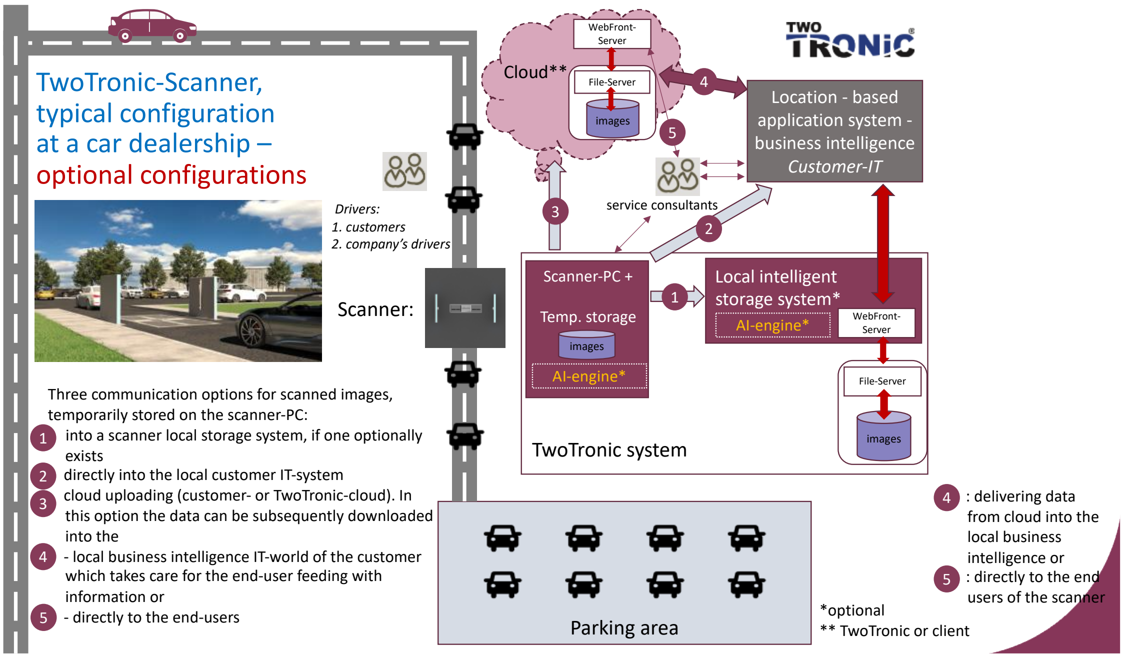

Figure 87. Pilot 3B scanner at pilot customer - information flow for documentation and AI-based inspection

<u>Pilot3B_DevAct_ID2 Design and set up the remote server for the activities in the pilot site</u>

For the AI-R&D work some concrete activities have to be conducted. At least one scanner must be set up and be passed by at least hundreds of vehicles, several thousands of the acquired vehicle images must be saved and finally processed by an annotation team according to the damage specifications. Thus, all three above mentioned R&D activities are depended on each other, and a clearly organised supply chain must be set up for these activities.

To that purpose, a first pilot scanner has been agreed with an external pilot partner to function as source for the badly needed vehicle images, working inside the everyday operation processes at his location. A second one has been built at TwoTronic-side, to test system-level refinements towards a new, ASSIST-IoT supporting operation mode. Several communication tests have been conducted to support the efficient transfer of the vehicle images on the cloud server.

A scalable cloud environment to support the AI-R&D activities has been also established. This is already configured and setup for operations in the following internal structure (see the following figure).

- Two scanner uploading channels (one for TwoTronic-location, one for pilot end-customer)
- Two Virtual Machines (VM2 + VM3), one separately for each scanner. Each VM has a web-based front-end system, supported by a database and a corresponding file server. Whilst the web-based front end takes care of the User Graphical Interface and the user-access aspects of a given scanner, it serves the corresponding user-requests for scan data by forwarding them to the underlying fileserver, who administrates all scan data of a particular scanner.
- A large network file system with selectable storage areas for working, testing & validation)
- One channel access type for AI-R&D teams
- One channel access type for AI-annotation teams
- One channel access for end-users (lie vehicle exterior inspectors)
- Security provision for user access is also made by the CloudFlare-provided mechanisms
- Several computing elements support processing, storage, communication, and AI-intensive operations (graphical subsystems) in a scalable way with interoperability

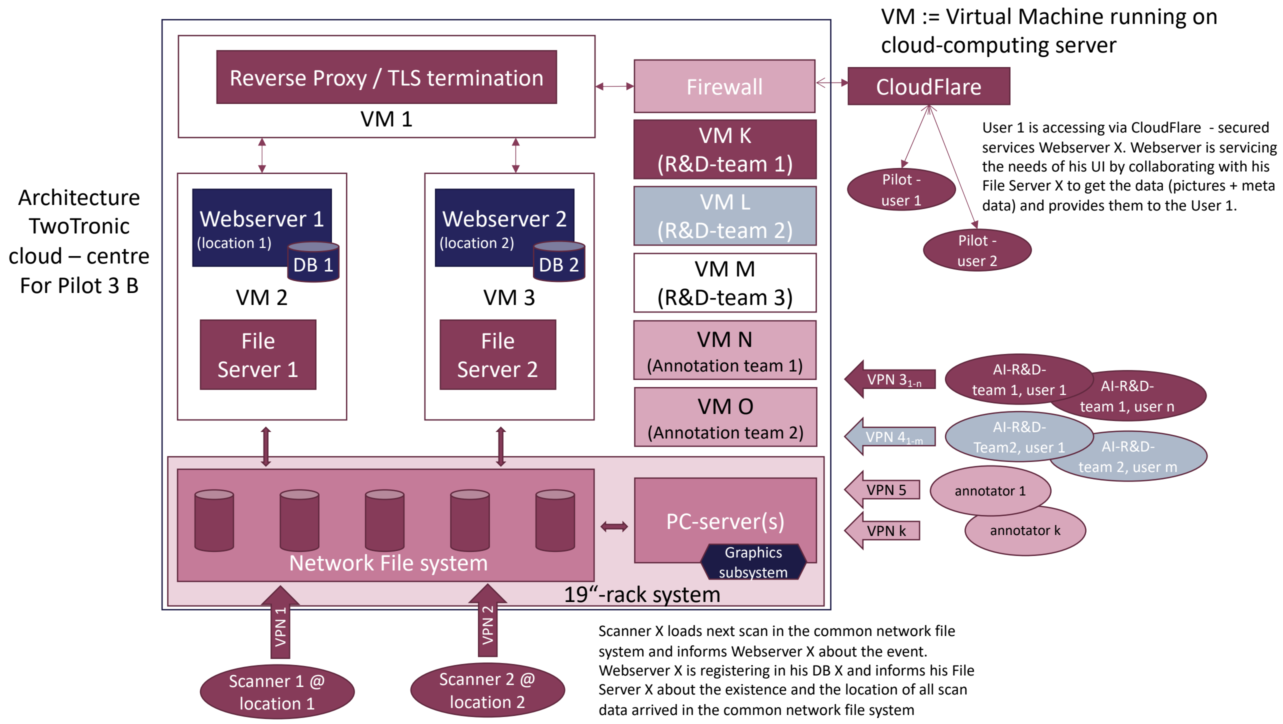

Figure 88. Design and current setup of the remote server in the cloud

Pilot3B_DevAct_ID3 Development of user interface

To cope with the cost- & time-efficient usage of the hundred thousand of pictures and their associated meta data a human-centred, ergonomic user interface is mandatory. So far, either a very simple, host operating system-based viewing mechanism or a PC-based program with additional functionalities was available. To deal with the multilevel, multi-user, multifunctional needs of the information retrieval and usage, a web-based frontend is being developing, also utilizing the advanced ASSIST-IoT architecture with novel visualisation techniques. Easy deployable properties and multi-platform supporting technologies allow the end-users of the targeted markets, like the vehicle inspectors, to use appropriately the information generated by the scanner ecosystem for documentation purposes supported by automatic surface inspection possibilities.

In this context a new user interfacing environment is being defined with rapid prototyping methodologies and dedicated testing possibilities for the end user towards an ultimate user interaction at multiple semantic levels. A first minimal testing environment includes coherent scan overviews (see figure), scanned vehicles overviews (see figure 46 below) and zooming possibilities for detailed optical reviewing on monitors by the users to determine vehicle exterior conditions (see figure 47 below). Additionally, the annotation team must have the possibility to annotate in appropriate ways the found damages even pixel level and let the system save and manage the created ground truth patterns for AI-training but also AI-results verification (see figure). The three following pictures show the development work so far done for the corresponding interaction aspects. The software has been implemented in a containerized version for easy deployment and is focussed to use the most widely used browser, i.e., Chrome. In the future more browsers will be investigated and implemented, particularly with respect to smart devices typically used by the end-users and considering minimal system requirements for smart visualisation techniques.

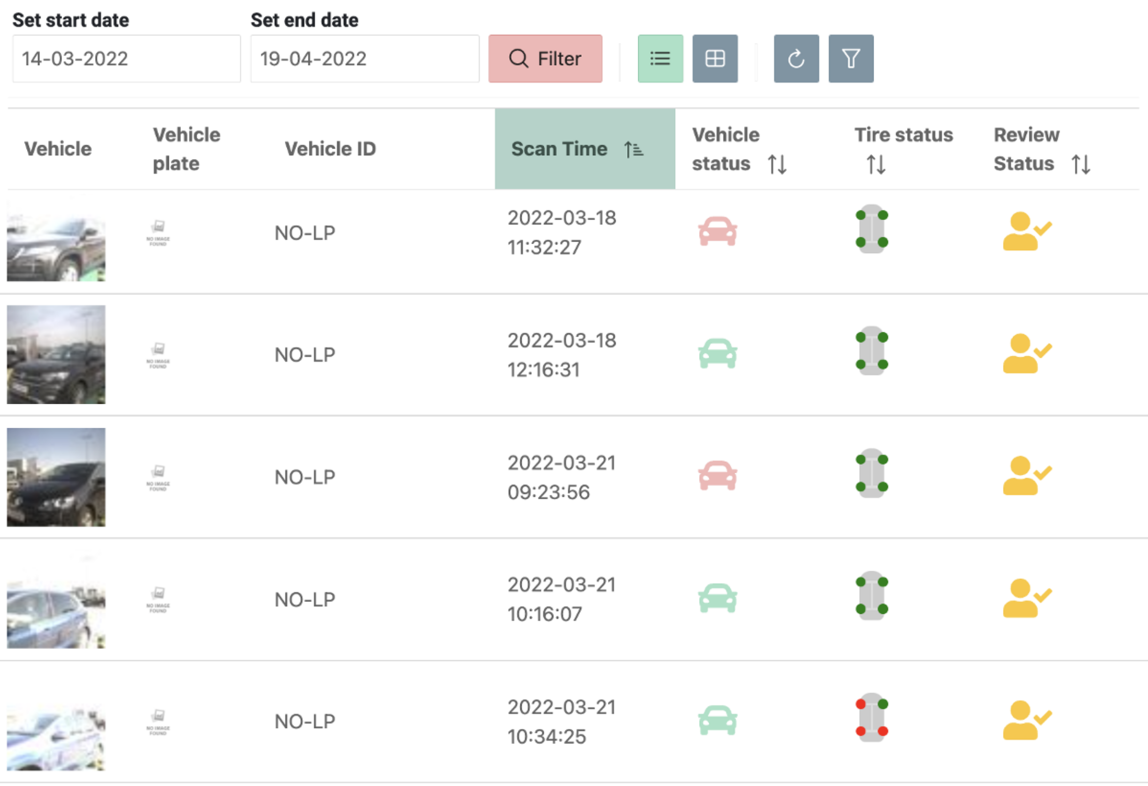

Figure 89. Overview example of scans in a scanner location

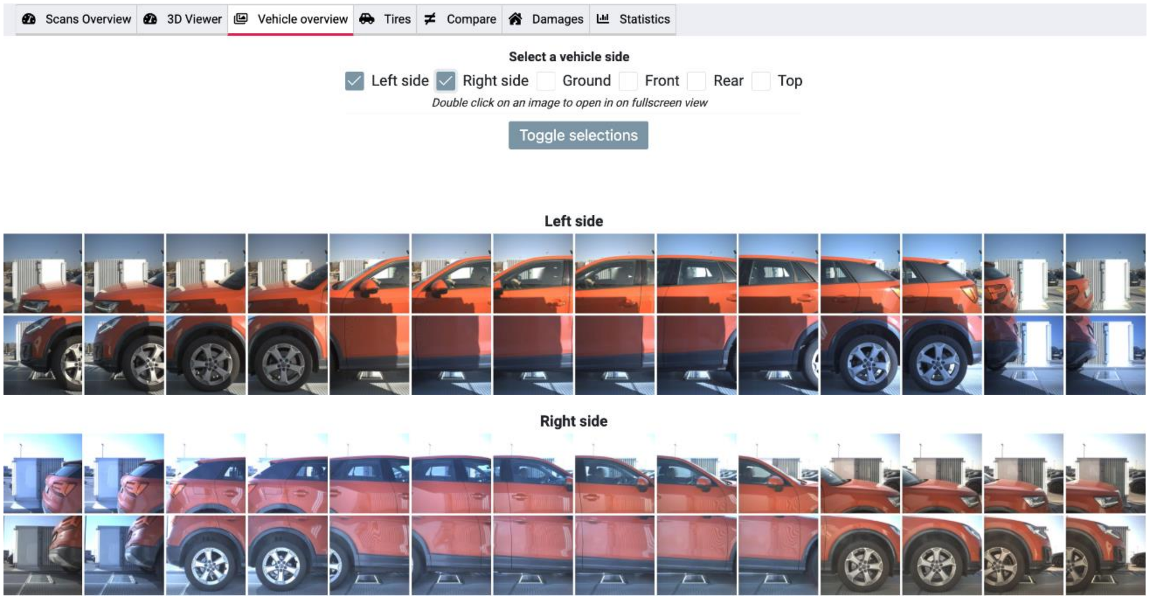

Figure 90. User interface & visualisation of a scanned vehicle

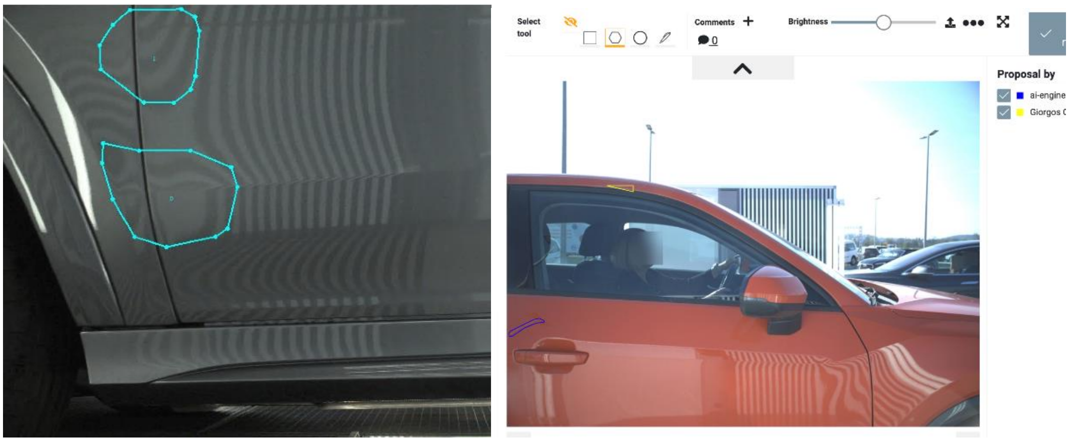

Figure 91. Manual, polygon-based annotation of damages by the annotation team + AI-proposals

5.2.2.3. Integration activities

To increase project R&D efforts efficiency only necessary preparation activities with respect to the underlying application functionalities have been taken place, like architectural-readjustment towards a finer grain-levelling, application programmable interfacing (API) definitions and other preparing work to support a smother collaboration with upcoming ASSIST-IoT enablers.

Pilot3B_IntAct_ID1-Integration of smart Network enablers (T42Ex): Not started yet. Postponed until smart network enablers are developed, and ready for integration.

Pilot3B_IntAct_ID2-Self-* enablers (T51Ex): Not started yet. Postponed until self-* enablers are developed, and ready for integration.

Pilot3B_IntAct_ID3-Federated Learning enablers (T52Ex): Started. Some data sets have been distributed with ASSIST-IoT FL development team in order to start analysing how this integration can be successfully achieved.

Pilot3B_IntAct_ID4-Storage and semantic enablers (T43Ex): Not started yet. Postponed until data management enablers are developed, and ready for integration.

Pilot3B_IntAct_ID5-Security modules (T53Ex): Not started yet. Postponed until cyber-security enablers are developed, and ready for integration.

Pilot3B_IntAct_ID6-DLT incorporation (T54Ex): Not started yet. Postponed until DLT-related enablers are developed, and ready for integration.

Pilot3B_IntAct_ID7-Integration of Application and services enablers (T44Ex): Not started yet. Postponed until application plane enablers are developed, and ready for integration.

5.2.2.4. Validation activities

Pilot2_ValAct_ID1 Definition of scenario and 1st prototype: In progress. Only standard evaluation of impact on end-user processes is taking place based on the installed scanner-ecosystems at dedicated pilot customer organizations

Pilot2_ValAct_ID2: Definition of scenario and 1st trial: Not started yet.

Pilot2_ValAct_ID3: Definition of scenario and 2nd trial: Not started yet.

Pilot3_ValAct_ID4: Open call demonstration and validation: Not started yet.

5.2.3. Deviations from original planning

There are no substantial project deviations in the Pilot 3B activities resulting into any new risks for the main project targets. Only the integration activities have been shifted for the near future, adapting themselves to a more mature understanding of the project interdependencies. Additionally, the content of the T4.1 activity as part of the demonstration & validation activities has slightly change creating a light shift in the project plan. In the originally planning it had a more rapid-prototyping character to create a dialog with the users, what was not any more needed, as a physically installed scanner, was able to deliver the wished user feedback about the impact of application process digitalisation. Thus, a more technical-oriented prototype demo with the first integrated enablers has been considered to be more effective and be planned between the months 18th and 23rd.

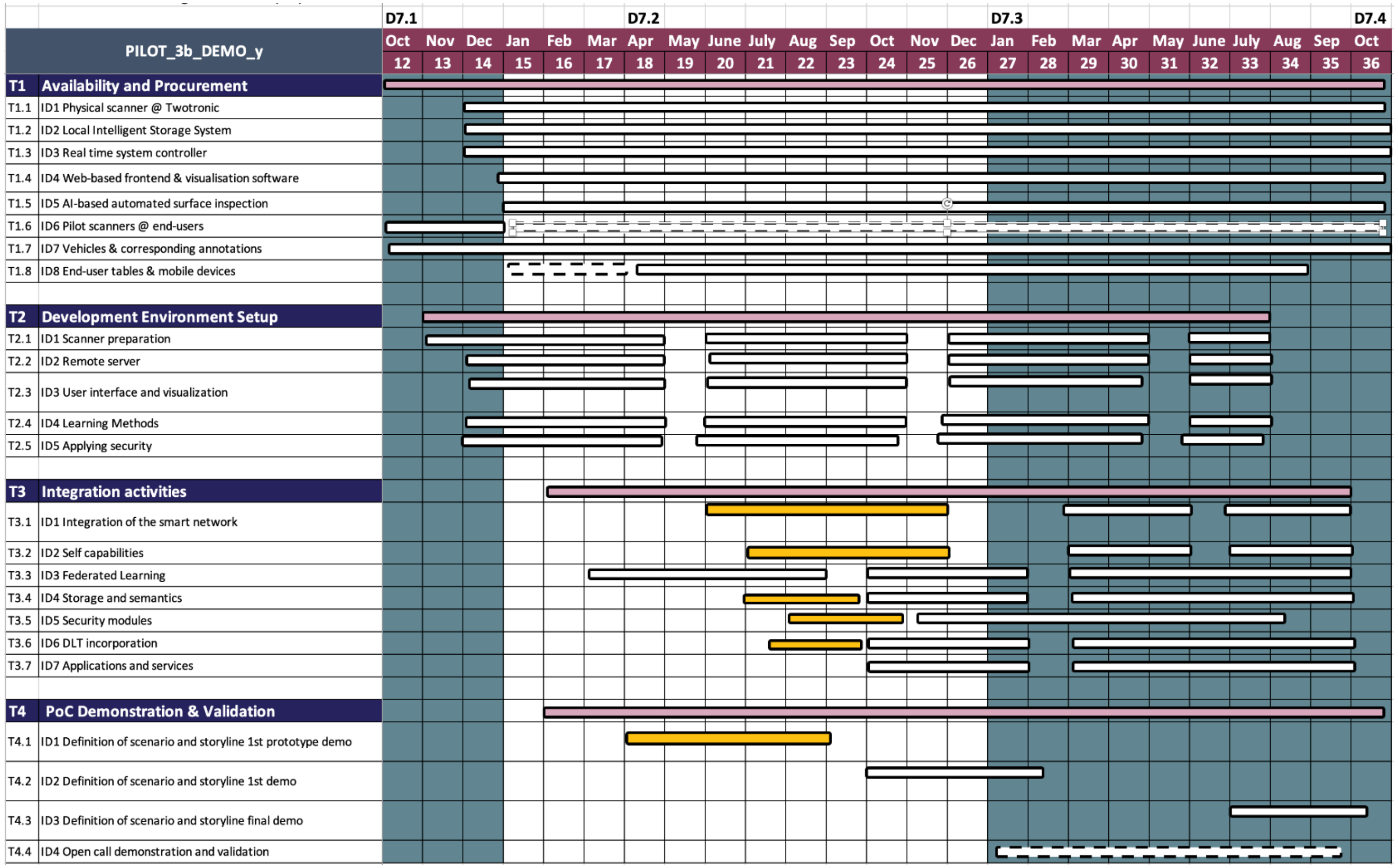

Figure 92. Pilot_3B_Trial Gantt chart.

6. Open Calls (First Round)

6.1. Introduction

The main purpose of the ASSIST-IoT Open Calls (OCs) is to enable third parties to form part of ASSIST-IoT project, devoted to the following goals:

1. Validation and improvement of technical components of the architecture.
2. Take up of ASSIST-IoT by application developers, domain experts and entrepreneurs to create new applications and services.
3. Pushing ASSIST-IoT technology and service visibility on the market.
4. Supporting an innovative, dynamic and industry open ecosystem around ASSIST-IoT results.
5. Gathering new market relevant inputs ASSIST-IoT components and finding industry experts to improve technical capabilities as well as filling possible missing functions, needed adoptions or modifications.

A maximum of 15 OCs are expected to be funded, 7 OCs in the first open call, and 8 funded in the second open call. In order to implement the planned OCs, ASSIST-IoT Consortium has established all necessary processes for their implementation: call definition, promotion, templates, submission, and evaluation. However, as it can be observed in Figure 93, due to the project timeline, the granted parties of the first open call will not contractually start until M19, May 2022, i.e., just after this deliverable is submitted.

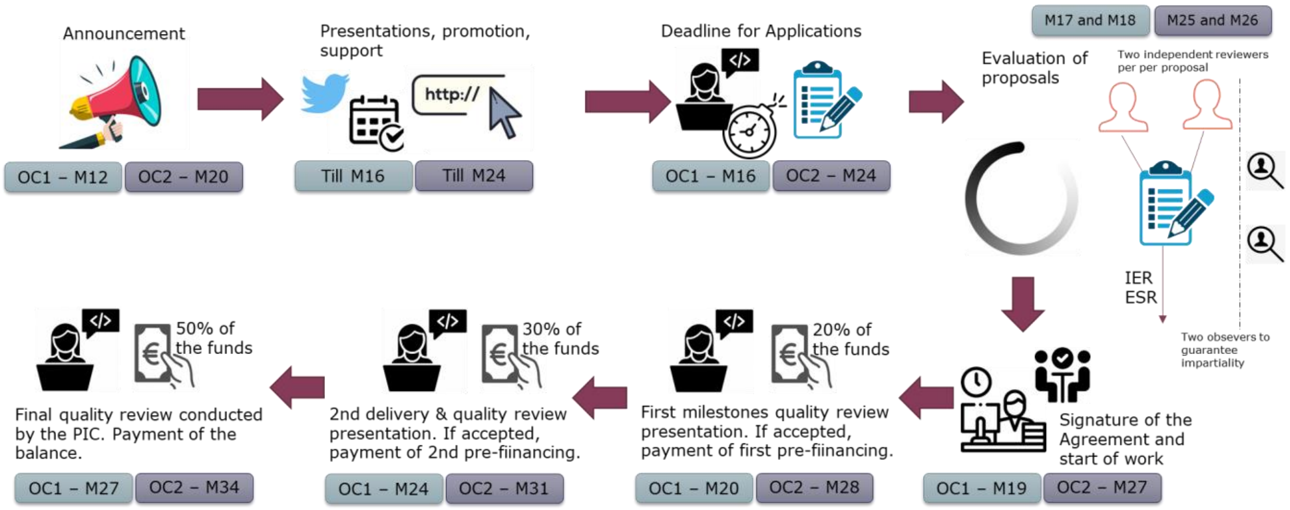

Figure 93. ASSIST-IoT Open Call timeline

This section consequently summarizes the OCs submissions for the ASSIST-IoT project in general, but with special interest in their relationship with WP7 pilot implementation activities in particular. The following quantitative analysis have been extracted from the 37 successfully submitted proposals in the first open call: (i) Open calls received per country, (ii) open calls received per entity type, (iii) open calls received per pilot, (iv) open calls received per pilot challenge. They are briefly summarized next.

6.2. Open calls received per country

The geographical spread of the proposals is shown in Figure 94. From this graph, it is clear that submissions of proposals are concentrated in the countries covered by the ASSIST-IoT project partners, but clearly also new players from new countries are appearing. The fact that northern European countries (Germany, Netherlands, Sweden, Finland, etc.) are less represented is to our opinion related to the fact that in these countries, other funding opportunities exist for running NG-IoT experiments.

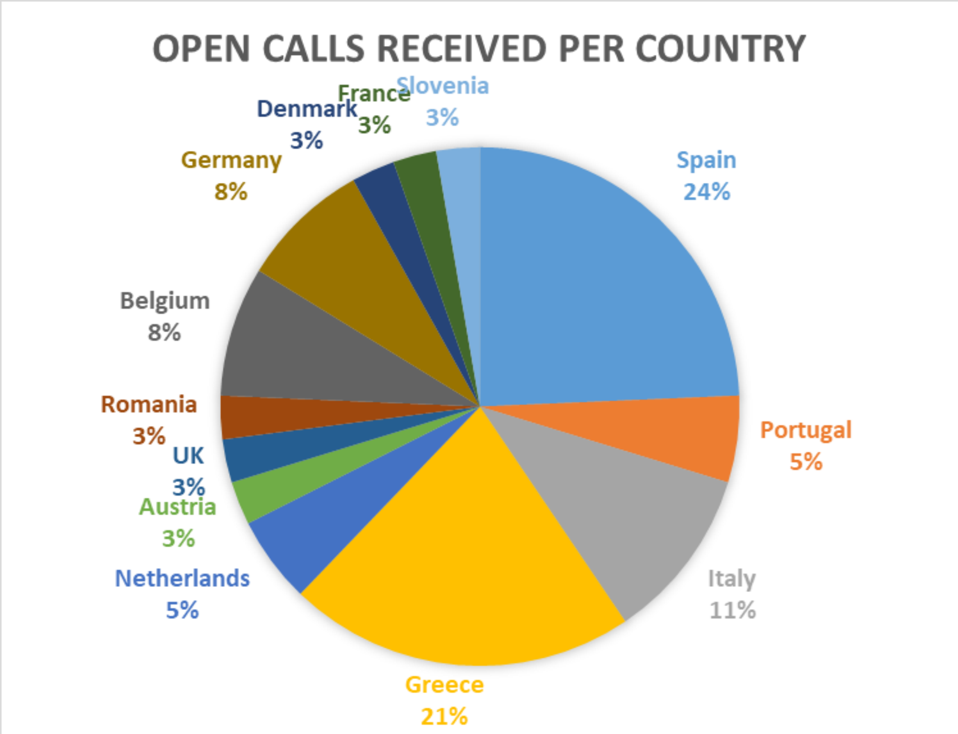

Figure 94. Geographical spreading of proposals submitted to ASSIST-IoT #1 Open Call

6.3. Open calls received per entity type

Figure 95 clearly illustrates that most of the proposers belong to SMEs, with a 76%, with the remaining submissions coming from universities (19%) and Research Institutes (5%). This is clearly a sign that the NG-IoT functionalities to be pushed ASSIST-IoT technology and service are really visible on the European R& D market.

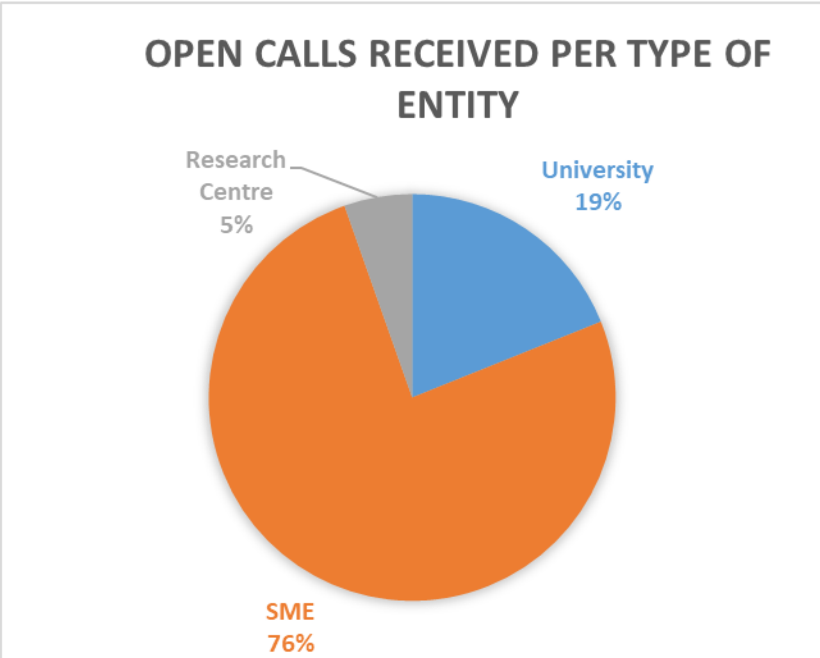

Figure 95. Total number of proposals per category to ASSIST-IoT #1 Open Call

6.4. Open calls received per pilot

From the very beginning of ASSIST-IoT, it was agreed that all four pilots will provide *guaranteed access* to all pertinent infrastructures, to be used in Open Calls. During the call definition, and promotion of the first open call, it was requested to every OC proponent to identify which pilot will be used for validating their technical innovations. To do so, the pilots infrastructure to be deployed will be finally integrated with the OpenAPI management enabler. This enabler, that forms part of T4.4, will be an API Manager that allows enablers to publish their APIs, to monitor the interfaces lifecycles and also make sure that needs of external third parties (including granted open callers), are met. Hence, the OpenAPI manager will provide competencies for ensuring successful API usage in developer environment, but also will help ASSIST-IoT administrators for preserving platform's security and protection. Figure 96 shows the mapping of the received open calls with the ASSIST-IoT pilots. It can be seen that a well balancing among Pilot 1, Pilot 2, and Pilot 3A is obtained. However, only one proposal for Pilot 3B was submitted. This lack of interest on this pilot will be analysed in detail in order to boost the engaging in the second open calls, later from M20.

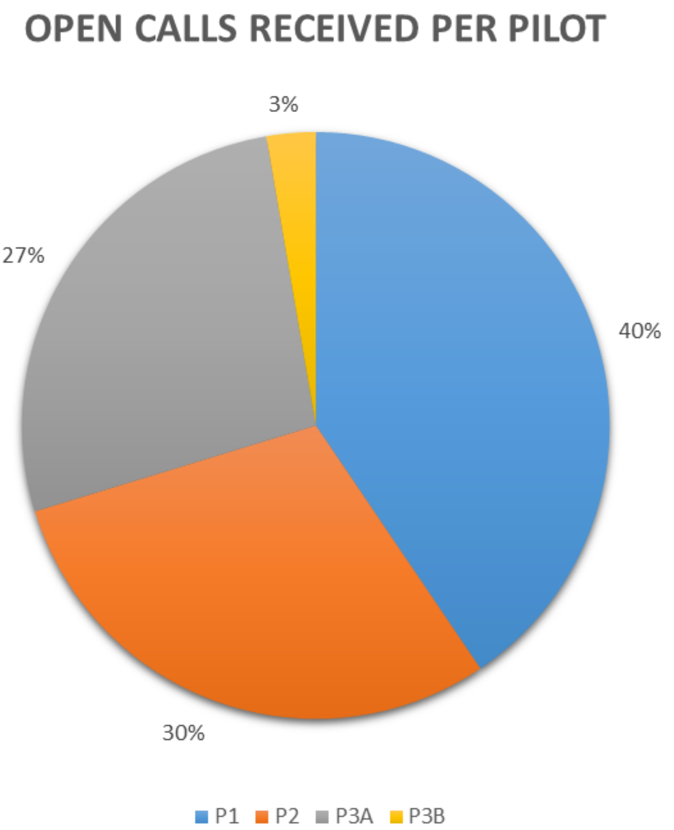

Figure 96. Total number of proposals per target Pilot to ASSIST-IoT #1 Open Call (P1: Port Automation pilot, P2: Smart safety of workers pilot, P3A: Vehicle in-service emission diagnostics, P3B: Vehicle exterior condition inspection and documentation

6.5. Open calls received per pilot challenge

Open Call proposals were also requested to specify which one specific challenge out of a list of possible challenges formulated by each pilot were going to be addressed. In particular, the following table, lists the specific challenges raised by the pilots for this first open call:

Table 1. Open challenges that have been defined for Open Call applicants

Pilot	Challenge ID	Challenge name
P1	P1C1	Low-cost accurate GPS development
P1	P1C2	Data semantic translator
P1	P1C3	Annotation tool

P1	P1C4	Stack collision prevention
P1	P1C5	Path optimising
P1	P1C6	People and vehicle detection
P2	P2C1	MR support for OSH training
P2	P2C2	Vision-based hazard monitoring
P2	P2C3	2D/3D localization map user interface
P2	P2C4	Personal cooling system
P3	P3C1	Integration of vibration sensors
P3	P3C2	Internal and external air quality monitoring.
P3	P3C3	Eco-driving and automotive navigation system as a service
P3	P3C4	3D Image registration
P3	P3C5	Reflections- and shadows-noise removal on the scanned images of the vehicles
P3	P3C6	Image acquisition and processing from user-wear edge nodes

The following figure illustrates the percentage of submissions per pilot challenge for first Open Call. It can be noticed that most of all Pilot 1 and Pilot 2 challenges are at least addressed by one proposal. However, as a consequence of the previous analysis of lack of proposals for pilot 3B, only two Pilot 3 challenges have been proposed in this first open call. As mentioned in the previous section, the lack of interest on this pilot maybe due to the least engaging challenges and will be analysed in detail in order to bring in innovators in the automotive sector for the second open calls, starting from M20.

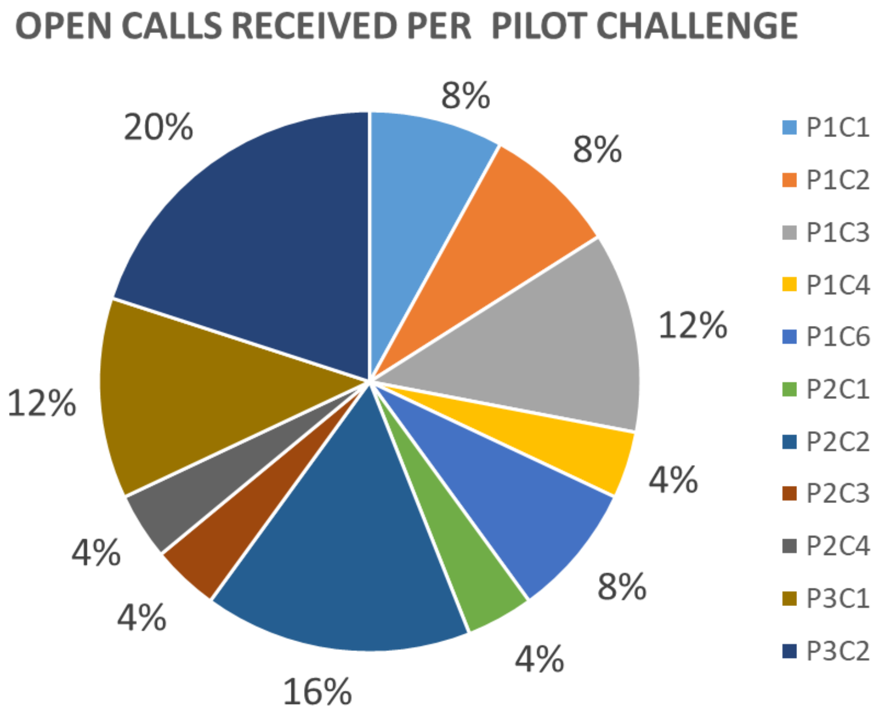

Figure 97. Total number of proposals per target Pilot challenge of ASSIST-IoT #1 Open Call

7. Conclusions / Future Work

ASSIST-IoT WP7 is in charge of deploying an integrated version of all the enablers being developed in WP4 and WP5 in project's pilots. This document has reported all the implementation activities related to the deployment of the trials for the four ASSIST-IoT pilots (Port automation, Smart safety of workers, Vehicle in-service emission diagnostics, and Vehicle exterior condition inspection and documentation) in the period M12-M18 and provides relevant insights about the operational framework of the different real testbeds of the project.

It should be highlighted that in order to clearly differentiate the scope of WP3, WP4/WP5, WP7 activities, a different terminology has been agreed from this deliverable and the following D7.x ones: "while WP3 uses "Business scenarios" and "use cases", WP7 activities will talk about "trials" (and "sub-trials" if needed).

In summary, as a conclusion of D7.2 Pilot Scenario Implementation deliverable, it can be stated that the Pilots are overall in a promising condition – some more advanced than others, but all well within the targets defined in the planning done in the predecessor document D7.1. As a first in a series of three Pilot evolution reporting documents, the deliverable has been consequently focused on the procurement and initial development activities of the pilots, while the integration, and validation activities are still on their infancy in most of the cases.

Regarding pilot specific outcomes:

- Pilot 1 trials #1 and #2 are in good shape with initial successful integration with current MFT systems already performed. Pilot 1 Trial #3 is experiencing procurement delays. However, they should not be longer than two-three months with respect to the original plan, so that no significant deviations are expected.
- Pilot 2 partners have been mainly focusing on generating comprehensive architectural diagrams of all trials in order to identify the mandatory HW components, as well as the required ASSIST-IoT enablers that should be integrated in the pilot. Consequently, in contrast with the other ASSIST-IoT pilots, very few development activities have already started. Nevertheless, the Pilot 2 Trial #3 has steadily advanced on the generation of MR-based safety navigation routes relying on already available BIM models.
- Pilot 3A has successfully completed the procurement of relevant measurement hardware, sensor, and software tools, including temporary replacements for not yet available ASSIST-IoT.
- In Pilot 3B the already available TwoTronics scanner has been prepared for enabling the access to ASSIST-IoT partners to validate the developed enablers, including the development of a human-friendly UI.

In another vein, this report has also performed an analysis of the submissions for the 1st Open Call round of the project, and their relationship with WP7 pilot implementation activities. It has been identified a well balancing among Pilot 1, Pilot 2, and Pilot 3A proponents. However, Pilot 3B has received a lack of interest, which it is expected to be analysed with the coordination team in order to boost its engagement for the 2nd open calls round.

Therefore, in summary, considering that the ASSIST-IoT Project team is in parallel successfully ensuring a timely development and delivery of ASSIST-IoT hardware and enablers, the likelihood of reaching the initially defined ASSIST-IoT Pilot targets is very high.

As a future work, it is expected that the first trials on pilot sites will be carried out during the following 9 months, and consequently reported in D7.3. Furthermore, the on-boarding of granted open callers will also lead to the validation of not yet devised novel functionalities of ASSIST-IoT pilots, which will also be reported in D7.3.

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