Next Generation Meta Operating System

D5.2 Living Labs and Data Management Plan (DMP). Final version

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List of Acronyms

Abbreviation / acronym	Description
3GPP	3rd Generation Partnership Project
AAA	Authentication, Authorization, and Accounting
aAGV	automated Autonomous Guided Vehicle
ADAS	Advanced Driver Assistance System
AF	Application Function
AGV	Automated Guided Vehicle
AGLV	Automated Guided Land Vehicle
AI	Artificial Intelligence
API	Application Programming Interface
AR	Augmented Reality
ASBS	Automated Sorting and Booking Station
AV	Audiovisual
CDN	Content Delivery Network
CFDRL	Cybersecure Federated Deep Reinforcement Learning
CMDT	Cybersecure Microservices' Digital Twin
Cobot	Collaborative Robot
CPO	Charging Point Operator
CPU	Central Processing Unit
DLT	Distributed Ledger Technology
DMP	Data Management Plan
DoA	Description of Action
DR	Demand Response
DSO	Distribution System Operator
Dx.y	Deliverable number y belonging to WP x
EC	European Commission
EDA	Electrodermal Activity
EV	Electric vehicle
FL	Federated Learning
FML	Federated Machine Learning
GPS	Global Positioning System
GPU	Graphics Processing Unit
HMD	Head Mounted Display
HPC	High Performance Computing
HR	Heart Rate
HTTP	Hypertext Transfer Protocol
HW	Hardware
IaaS	Infrastructure-as-a-Service
IDM	Identity Management
IoT	Internet of Things
K8s	Kubernetes

KPI	Key Performance Indicator
LAN	Local Area Network
LCM	Life-Cycle Manager
LSP	Large Scale Pilot
MAC	Mandatory Access Control
MEC	Multi-access Edge Computing
meta-OS	Meta-Operating System
ML	Machine Learning
mNCC	Meta Network Cluster Controller
MOCA	Monetization and Consensus-based Accountability
MQTT	Message Queuing Telemetry Transport
mRA	meta-Reference Architecture
NEF	Network Exposure Function
NF	Network Function
NFV	Network Function Virtualization
NIC	Network Interface Card
NRF	Network Repository Function
NVR	Network Video Recorder
NWDAF	Network Analytics Function
OAM	Operations, Administration, and Maintenance
OBD	On-Board Diagnostic
OS	Operating System
PaaS	Platform-as-a-Service
PDU	Protocol Data Unit
PLC	Product Life Cycle
PMU	Phasor Measurement Unit
PPEF	PRESS & Policy Enforcement Framework
PWA	Power Quality Analyzer
PRESS	Privacy, data pRotection, Ethics, Security & Societal
QoE	Quality of Experience
RAM	Random Access Memory
RAN	Radio Access Network
RBNR	Racing Bib Number Recognition
RL	Reinforcement Learning
ROS	Robot Operating System
RTT	Round Trip Time
SAM	Segment Anything Model
SaaS	Software-as-a-Service
SC	Smart Media/City
SDK	Software Development Kit
SDN	Software Defined Networking
SEE	Secure Execution Environment
SLA	Service Level Agreement
SLAM	Simultaneous Localization and Mapping

SLO	Service Level Objective
SMX	Smart Meter eXtension
SSD	Solid-State Drive
TEMP	skin temperature
TSN	Time Sensitive Networks
UC	Use Case
UE	User Equipment
VM	Virtual Machine
VNF	Virtual Network Function
VPN	Virtual Private Network
VR	Virtual Reality
WP	Work Package
YAML	Yet Another Markup Language
XR	Extended Reality

Executive Summary

NEMO aims to address the demand of application and resource delivery and management in the highly heterogeneous, diverse and complex landscape of the next generation of IoT and internet in general. Through the proposed meta-Operating System (meta-OS), NEMO enables cybersecure, flexible and efficient automated orchestration of both computing workloads, computing and network resources dispersed in IoT, edge and cloud, possibly across domains and for multiple stakeholders. Hence, NEMO provides unique opportunities for high-tech businesses to thrive across different application verticals.

The NEMO meta-OS capabilities are planned to be piloted in 4 application verticals; Smart Farming, Smart Energy, Smart Industry and Smart Media, through 9 use cases, which expose highly diverse requirements in highly diverse environments and businesses.

Thorough planning is key for successful implementation of the pilot activities, validating and evaluating NEMO outcomes. This report documents the preparation outcomes related to the trial site setup and the allocation of resources, referring to hardware equipment, involved partners, as well as data collection mechanisms. It also defines specific test scenarios for the technical validation of the pilot. Each defined scenario sets a clear scope for NEMO validation, with respect to satisfied requirements and measurable KPIs. It also identifies the NEMO components involved in each scenario and prerequisite setup for the scenario execution. The test procedure is described on a step-by-step basis, involving relevant actors in each scenario. The evaluation of the scenario outcomes will be done based on the defined success or failure states. In addition, user experience validation is planned through means identified for soliciting end-user feedback.

Further assisting the pilot implementation, the exploitation of specific NEMO capabilities in the context of each trial is elaborated and use case specific developments are presented. Based on these, the test scenarios' workflow is technically designed through appropriate diagrams, highlighting the functionality and interactions among NEMO and use case specific components.

The initial results, mainly referring to tangible outcomes of the pilot activities, are provided for each pilot. These mainly include development, installation, configuration and adaptation of hardware or software components involved in the pilot.

Moreover, an update to the project's Data Management Plan (DMP) has been conducted, based on feedback from the Consortium members. The updated DMP relied on more detailed questionnaires collecting feedback about the Ethics, used and generated Datasets and Data Management processes, compared to the initial DMP version, submitted in February 2023.

The well-defined pilot planning presented in this document allows effective preparation, communication among involved stakeholders and replication of the defined scenarios. It also allows continuous monitoring through periodic updates on it, as planned in the forthcoming deliverables of WP5. Updates about the results of the trials are expected by February 2025 and will be summarized in D5.3 "NEMO Living Labs use cases evaluation results. Initial version". Then, final results will be reported in the deliverable D5.4 "NEMO Living Labs use cases evaluation results. Final version", due in August 2025.

1 Introduction

The NEMO project offers unique opportunities for innovation across different application verticals. The power of IoT and edge computing has already unleashed significant benefits into business operations through increased efficiency, cost savings, improved customer experiences, and the ability to accompany/serve users anywhere any time. Combined with Artificial Intelligence (AI), enhanced capabilities are provided to the end users, with the added intelligence supporting adaptability, flexibility and robustness, leading to improved decision making. The ever-increasing emergence of smart applications, often high-demanding, is fertilized by the parallel evolution of a rich toolset of technological offerings, such as Augmented/Virtual/Extended Reality (AR/VR/XR), Machine Learning, Distributed Ledger Technologies, Digital Twins, 5G/6G communications, etc.

The perpetual progression of technologically ambitious and innovation-driven businesses is challenging the underlying infrastructure, as well as the management of the plethora of new and emerging applications. Moreover, significant security and privacy challenges arise as a result of the volume, velocity, diversity and complexity of data, devices, networks and underlying solutions, which also raise a non-trivial interoperability issue.

NEMO aims to address these concerns through the proposed meta-Operating System (meta-OS) which enables cybersecure, flexible and efficient orchestration of both computing workloads, computing and network resources dispersed in IoT, edge and cloud hierarchical levels, which are possibly deployed across multiple domains and brokered or owned by multiple stakeholders. Hence, NEMO contributes to increased resource efficiency, usage and availability, while respecting user, business or privacy requirements, and provides a huge potential for innovative businesses to thrive.

The NEMO meta-OS benefits will be piloted in 4 application verticals; Smart Farming, Smart Energy, Smart Industry and Smart Media, through 9 use cases, which have been analyzed in deliverable D1.1 "Definition and analysis of use cases and GDPR compliance" [1]. As derived from this analysis, the use case cases expose diverse requirements in terms of application performance, both from a computational and network point of view, devices, spanning IoT, edge and cloud, as well as data, referring both to adopted formats and communication protocols for data and metadata, as well as to velocity, volume and variety. In addition, security and privacy requirements are diversified across the use cases. Moreover, the use cases involve different types of actors, anticipating different business models for the exploitation of the meta-OS, including the meta-OS owner/administrator, the application provider and user, as well as the resource provider and user. Overall, the defined use cases offer a multi-modal substrate for the validation of the NEMO capabilities.

1.1 Purpose of the document

The successful piloting of NEMO innovations involves careful planning, effective execution, and strategic evaluation. In the present document we aim to document thorough planning activities which have been conducted for the 4 Living Lab trials of the project. So, for each pilot the preparation activities are reported, following a common structure:

- Trial site description: A short description of the pilot site, expressing business as usual in the said use cases, as well as the expectations introduced through NEMO innovations.
- Technical validation: It aims to outline the scope of the research outcomes aimed to be validated in the context of the use cases and identify specific goals and outcomes expected from the pilot. This is achieved through the definition of specific test scenarios, which are developed such as to relate to fulfilling the defined requirements for the use case in D1.1. Monitoring of the pilot's progress is also addressed through key performance indicators (KPIs) identified for each test scenario. Moreover, specific criteria for evaluating the success or failure of the test scenarios have been established.

- User experience validation: The validation of the user experience relies on soliciting feedback from stakeholders and participants involved in the pilot. This feedback will be useful to iterating and refining the NEMO components or functionality, aiming to address user satisfaction. The user validation can be realized through quantitative metrics, user satisfaction surveys, or other relevant indicators that align with the pilot's objectives.
- Required equipment: The allocation of necessary resources, referring to hardware devices that are necessary to support the pilot is addressed for each of them. Adequate resources are essential for the successful implementation in a real-world setting.
- Data collection: Data collection mechanisms have been defined for each pilot to capture datasets required for the implementation of the pilot. Data management during the pilot is crucial for assessing the performance, effectiveness, and impact of the NEMO outcomes.
- Alignment with NEMO: Identification of NEMO capabilities and their use in the context of the pilot is important in order to ensure that the expected functionality is supported and that relevant components are configured or adapted appropriately. This exercise also fosters open communication and collaboration among team members, including pilot entities and developers/integrators. Moreover, use case specific functionality required for the successful implementation of the pilot is briefly presented.
- Use case diagrams: Specific diagrams for each use case facilitate the pilot implementation, identify interactions among NEMO and use case specific components and constitute a common communication document among pilot owners/users and developers. Sequence diagrams have been largely adopted for designing the workflow and interactions for the execution of each defined scenario.
- Roadmap: A well-thought-out plan helps in efficient execution and ensures that all aspects of the pilot are considered. A pilot plan that includes timelines and aligns with the project's milestones, deliverables and integrated releases is provided for each pilot.
- Initial results: Tangible outcomes of the pilot preparation activities are presented.

Following this structure, NEMO documents the scope of the pilot activities, provides thorough planning of the pilots, which is intended to be used as a reference for the pilot implementation, once integrated releases of the NEMO meta-OS are available.
Moreover, the present document aims to provide an update of the Data Management Plan (DMP), developed in February 2023 and documented in D5.1 [2]. To this end, updated Ethics and Data Management Questionnaires have been developed and used for collecting information about potential updates on the DMP since February 2023. The outcomes of these activities are also reported in the present document.

1.2 Relation to other project work

This document (D5.2) is the second iteration of the four deliverables in the context of Work Package 5 (WP5) and aims to describe the pilot preparation activities and updated DMP of the NEMO project. It is based on the use case analysis presented in D1.1, as well as the NEMO architecture and functional description presented in D1.2 [3]. Moreover, the present document updates the DMP provided in D5.1.

The forthcoming two deliverables are D5.3 "NEMO Living Labs use cases evaluation results. Initial version", due in the first quarter of 2025, and finally D5.4 "NEMO Living Labs use cases evaluation results. Final version", which will be produced in the third quarter of 2025.

1.3 Structure of the document

The rest of the document is organized as follows.

Chapter 2 to chapter 5 present the pilot preparation activities for the Smart Farming, Smart Energy, Smart Industry and Smart City/Media, respectively.
Chapter 6 presents the updated DMP.
Finally, chapter 7 draws conclusions and next steps.

2 Smart Farming Living Lab

In the era of intense environmental pollution and draining of resources worldwide, availability of sufficient and high-quality food supplies is greatly threatened, while over-cultivation combined with excessive use of chemicals as either fertilizers or pesticides even endanger food safety. As a noble alternative, organic farming promotes sustainable and environmentally friendly agricultural practices. Organic farming methods prioritize the use of natural processes and avoid synthetic chemicals, pesticides, and fertilizers. This helps reduce the environmental impact associated with conventional farming, including soil and water pollution. Moreover, organic farming avoids the use of synthetic pesticides and herbicides, which can have negative effects on human health. Choosing organic products can help reduce the risk of exposure to potentially harmful chemicals in food. In addition, organic farming benefits water conservation.

On the other hand, organic farming poses challenges in weed control, as well as pest and disease management**.** Organic farmers often rely on mechanical and cultural methods for weed control, such as hand weeding and cover cropping. These methods may be less efficient than the use of synthetic herbicides in conventional farming, leading to increased competition for resources and lower yields. In addition, organic farmers use natural predators, crop rotation, and resistant crop varieties to manage pests and diseases. While these methods are often effective, they may not provide the same level of control as synthetic pesticides used in conventional farming, leading to potential yield losses.

NEMO aims to research and assist organic farming practices in addressing some of these challenges, targeting higher yields and rationalized use of resources, whether they refer to fertilizers, pesticides, water or energy. The pilot use cases refer to organic olive groves.

Olive oil production is greatly affected by the climate change of the recent years realized intensely in major European olive producing countries, like Spain, Italy and Greece. High temperature and drought negatively affect the yield quantity and quality worldwide for various crop types [4]. In particular, for olive trees the effects of a high-temperature environment are genotype dependent and in general, high temperatures during fruit development affected three important traits: fruit weight, oil concentration and oil quality in a cultivar-dependent manner [5]. The combination of the prolonged drought and absence of rain result in the soil being dried out and the olive trees deprived of any water source and the growers of a substantial crop.

On the other hand, olive fruit fly development is favored by the lack of heat waves and rain. The olive fruit fly (scientific name "Bactrocera oleae" or "Dacus oleae (Gmelin)") is a major concern for olive tree cultivation, causing serious damage in the olive fruit, significantly affecting both quantity and quality of yields [6]. Kaolin clay or spinosad-based bait are often used for olive fruit fly control as an organic treatment and have been used to protect plants from various insect pests, achieving protection against total and harmful fly infestation [7].

In such a direction, precision irrigation and spraying may achieve a good balance between organic olive yield quantity, quality and costs through collaborative intelligent systems. Leveraging on machine learning based innovations, this approach can also be made autonomous, leading to significant cost savings and increased crop performance. In this manner, this Pilot will combine many intelligent components within an olive grove to automate the process of precision bio-spraying suitable for olive fly containment and weed control, while ensuring low energy footprint.

The NEMO capabilities will be validated in the Smart Farming domain, through two use cases, as defined in D1.1 [1]:

- SF_01 Aerial Precision Bio-Spraying, aiming to protect the olive trees from olive fruit fly through aerial spraying conducting by UAV. This use case will combine microclima data collected via Synelixis SynField® [8] IoT nodes and real-time video analysis of olive groves from visual and multi-spectral cameras attached on semi-autonomous drones to identify in real-time where bio-spraying is needed. The bio-spraying decision will be based on ML models, which will optionally run on the end devices (UAV) or edge devices, while increased model performance and increased energy efficiency will be investigated during the training process through Cybersecure Federated Deep Reinforcement Learning (CF-DRL) and flexible deployment of the training jobs across the IoT, edge and cloud resources available.

- SF_02 Terrestrial weed management, aiming to organically control weeds in olive groves through Autonomous Guided Land Vehicles (AGLV). Autonomous robots equipped with cameras & sensors collect data for detecting obstacles and enabling autonomous weed mowing. The use case relies on ML models for the detection of obstacles like trees and humans, as well as for the autonomous movement within the olive grove. The ML services may run on the AGLV or at the edge resources of the Smart Farm or even move to servers of another farm for the sake of energy efficiency or ensuring high Quality of Service.

The next subsections report the pilot preparation activities for the Smart Farming Trial.

2.1 Trial site description

The Smart Farming pilot activities will be conducted in Agia Sofia estate, which is an organic olive farm located on an untouched, east-facing slope over the Myrtoan Sea. Its well-drained soils, morning sun and elevation of around 200m above sea-level, is ideal for olive cultivation and favorable for organic olive cultivation.

Figure 1: The Agia Sofia estate location and cultivation

It hosts 2000 olive trees in a grove of 200ha. The Agia Sofia estate is committed to producing high-quality, organic olive oil using sustainable and environmentally friendly methods.

The farm is planted with the local "Athinoelia" cultivar, which is perfectly suited to the region and although is slightly less productive, it has an exceptional aroma and yields a unique olive oil.

Sparsely planted, carefully pruned, organically manured and watered modestly, the olive trees are naturally disease resistant and yield olives of superior quality. The cultivation is certified as organic by Dio[1].

The state-of-the-art, low-volume oil-mill is designed and tuned with quality in mind:

- controlled temperatures, 19C to 25C throughout the process
- low pressure, vertical malaxers (reduced oxidation)
- 2-phase decanter (preserves polyphenols, aromas)
- direct 2-pass filtering (no final centrifugal separation)

Following its production, the oil is filtered and stored in stainless steel, closed tanks, filled with nitrogen. The tanks reside in a controlled temperature room (12ºC to 20ºC throughout the year).

[1] http://www.dionet.gr/

2.2 Technical validation

The technical validation of the Smart farming trial will be realized through the test scenarios described in the next subsections, referring to both SF_01 and SF_02.

2.2.1 Test scenario SF01_Test_Scenario_1

Table 1: Test Scenario 1 for the bio-spraying use case of the Smart Farming Trial

SF01_Test_Scenario_1	
Scenario ID	SF01_Test_Scenario_1 App owner as application provider App user as resource provider and app user NEMO-offered Federated Learning (FL) services (PaaS) Local training in own resources only (private IaaS, SaaS)
Objective	FL will be used for training image segmentation ML models used in Smart Farming application for olive tree identification by UAV. Local trainings, pertaining to different app users, i.e., Smart Farmers, will be performed in clusters of different administrative domains. Secure communication of ML model parameters between participants and aggregator nodes will be achieved via privacy preserving FL techniques and secure micro-slice creation through mNCC. Trained model will be stored and served by NEMO. Execution of training workloads will be constrained in user-defined clusters. Also, tokens will be calculated for the provision or use of NEMO apps and resources.
Features to be tested	MLOps (FL, model storage, model sharing) Meta-Orchestrator, PPEF, CFDRL (Observability, Workload deployment & migration, limit execution within a cluster set) CMDT (workload discovery) Intent-based API (app and resource selection) LCM (app deployment and LCM visualization) IdM & Access Control (users) MOCA (tokens' calculation) mNCC (secure micro-slice creation)
Requirements addressed[2]	SF_01_FR01, SF_01_FR02, SF_01_FR03, SF_01_FR04, SF_01_FR07, SF_01_FR08, SF_01_FR011, SF_01_FR012, SF_01_FR014, SF_01_NFR01, SF_01_NFR02, SF_01_NFR03
KPIs[2]	KPI_SF_01_1, KPI_SF_01_2
Prerequisites	The NEMO platform should be installed and configured. At least 3 users are registered and signed in with relevant access. One of them (let assume they are called OWNER) is acting as Smart Farming Application Owner (SFAO), who uploads their Smart Farming App in NEMO, available for deployment by third parties and has access as NEMO partner (see NEMO roles in D1.2 [3]). The rest users (let assume they are USER_A and USER_B) should be registered both as NEMO cluster providers, having provided their resources in NEMO, and as consumers, wishing to deploy the Smart Farming app in their resources only through NEMO. Thus, individual clusters in different administrative domains should be available for each of these cluster providers, aimed for simulating the resources (at least 1 edge/cloud server and 1 UAV) of the Smart Farming

[2] Based on naming adopted in D1.1.

	application users. FL training should be supported for at least one ML task in the Smart Farming application. The clusters should be configured appropriately, in order to be integrated into NEMO resources and be able to run local training tasks as FL participants. NEMO should be configured, in order to allow restricting FL training tasks in user-defined resources. The OWNER should be able to initiate an FL training task. Also, 1 user is registered as meta-OS Provider (ADMIN).
Test steps	Resource onboarding 1. USER_A signs in the NEMO dashboard and accesses the resource onboarding functionality. 2. USER_A selects the option to add their resources into NEMO and provides relevant info. 3. USER_A is notified about the result through the dashboard. 4. USER_A is informed about their credits. The same process is followed by USER_B. Workload registration 1. The OWNER signs in NEMO as meta-OS consumer. 2. The OWNER uploads their application into NEMO and is notified about the result. 3. As soon as the upload is successful, it will be available for third parties to deploy and use it. 4. The OWNER enables and configures the plugin that allows FL training to be initiated for an ML task in their application. 5. The OWNER visualizes lifecycle data and credits through the NEMO dashboard. Workload execution 1. USER_A accesses the workload execution functionality in the NEMO dashboard. 2. USER_A selects the Smart Farming app to be executed in their resources only. 3. USER_A enables FL training for the app's ML tasks. The same steps are followed by USER_B. FL training 1. The OWNER sends a request for FL training for their app. 2. The FL training process is executed with the user-defined parameters (rounds, epochs, FL participants, etc.) 3. The training process completes and the aggregate model is stored. 4. USER_A and USER_B are notified about the newly trained model. Model sharing & deployment 1. USER_A sends a request through the NEMO dashboard to deploy the new model on their UAV. 2. USER_A checks that new model is deployed on their devices through the dashboard.

Success state	The training process completes successfully and OWNER, USER_A and USER_B get notified accordingly. The final ML model is stored in NEMO resources. The final ML model gets deployed on the selected UAV.
Failure state	The training process has not completed; and/or The final ML model is not accessible; and/or The final model has not been deployed on the UAV.
Responsible for testing and implementation	ESOFT, SYN
Risks	No risks identified so far.

2.2.2 Test scenario SF01_Test_Scenario_2

Table 2: Test Scenario 2 for the bio-spraying use case of the Smart Farming Trial

Scenario: SF01_Test_Scenario_2	
Scenario ID	SF01_Test_Scenario_2 App owner as application provider. App user as resource provider and app user. Execution in own and NEMO resources, across domains (hybrid IaaS, SaaS).
Objective	The objective is to validate NEMO capabilities in running ML-based applications on UAV, edge or cloud devices, allowing olive tree's detection/recognition and assisting in applying aerial bio-spraying.
Description	This scenario investigates the NEMO benefits in automating aerial bio-spraying in organic olive groves for controlling fruit flies' population. Pest control applied via aerial bio-spraying by UAV will be piloted, relying on ML-based applications for the detection of olive trees on which aerial bait spraying will be applied. Moreover, the decision on the frequency or need for such spraying will be assisted by crop and environmental conditions' awareness, developed via IoT sensor readings. The potential of executing the ML based application on different levels of the continuum will be evaluated with the aim to achieve high application performance and low latency to allow aerial spraying. The application execution will be able to take place either on user's UAV or on NEMO resources (edge or cloud). The scenario also involves the calculation of tokens to be credited or charged, based on the use of NEMO resources.
Features to be tested	Meta-Orchestrator, CFDRL (Observability, Workload deployment & migration) CMDT (workload discovery) PPEF (observability, privacy compliance) Intent-based API (app and resource request) mNCC (micro-slice for sending video/images to CF-DRL (cloud) in case of inference there, inter-domain communication during migration) LCM (app deployment and LCM visualization) SEE (select secure execution of Unikernels (e.g. ML model inference) at robot, drone, edge, cloud) IdM & Access Control (users) MOCA (tokens' calculation)

Requirements addressed	SF_01_FR01, SF_01_FR02, SF_01_FR03, SF_01_FR05, SF_01_FR06, SF_01_FR07, SF_01_FR08, SF_01_FR010, SF_01_FR011, SF_01_FR012, SF_01_FR013, SF_01_FR014
KPIs	KPI_SF_01_1, KPI_SF_01_2
Prerequisites	The NEMO platform should be installed and configured, including at least 1 cluster of at least 1 drone. The ML application for olive tree identification should be able to run either directly on the drone or on an edge or cloud device. Environmental and crop data should be available to guide the prediction of olive fruit fly development and UAV flight decision. Monitoring data about resources and workloads running on them should be available and sufficient to allow evaluating the workload performance and device capabilities, including energy consumption and efficiency. One registered user (let assume they are called OWNER) is acting as Smart Farming Application Owner (SFAO), who has uploaded their Smart Farming App in NEMO, available for deployment by third parties. At least 1 user (let assume they are called USER_A), is registered in NEMO as both a partner (see NEMO roles in D1.2 [3]), having already integrated their resources (at least 1 drone) to NEMO, and as a consumer for executing the aforementioned apps in their resources. The monitoring app (e.g. SynField® [8]) is already running in NEMO resources. USER_A is subscribed to the monitoring app. The ML app is already registered into NEMO and available for deployment by third parties. Also, 1 user is registered as meta-OS Provider (ADMIN).
Test steps	1. USER_A signs in NEMO as meta-OS consumer. 2. USER_A requests to deploy the ML-based Smart Farming application on their drone. 3. Upon success, USER_A signs in the Smart Farming app. 4. USER_A gets informed about favorable conditions for olive fruit fly development and also favorable for the UAV to fly. 5. USER_A initiates a flight round for the drone in their farm. 6. The drone flies over the olive grove, collects images and applies the ML task for detection of olive trees on the fly. At the same time, NEMO collects monitoring data of the devices and workloads involved. 7. When NEMO identifies a risk in the app execution on the drone (e.g. due to its power exceeding a predefined limit), NEMO undertakes reallocation of the workload to some other device (e.g. edge or could). 8. USER_A monitors the application, workload and device performance through the NEMO (LCM) dashboard. 9. The flight of the drone completes and application logs are collected.
Success state	The ML-based SF application is executed with no interruption and has successfully identified olive trees on the fly.
Failure state	The operation of the ML-based SF app experiences interruption that is obvious to the user and the UAV, impacting on the timely delivery of the inference result to support precision spraying on the fly.
Responsible for testing and implementation	ESOFT, SYN
Risks	No risks identified so far.

2.2.3 Test scenario SF02_Test_Scenario_1

Table 3: Test Scenario 1 for the weed management use case of the Smart Farming Trial

Scenario: SF02_Test_Scenario_1	
Scenario ID	SF02_Test_Scenario_1 App owner as application provider. AGLV owner as resource provider. App user as app user. Execution in NEMO resources (IaaS, SaaS).
Objective	The objective is to validate the NEMO capabilities in supporting seamless operation of AGLV-based terrestrial weed management, combined with SynField data, while ensuring labor staff safety and safe AGLV movement across the olive grove.
Description	This scenario deals with terrestrial weed management, based on AGLV moving autonomously on the olive grove, and applying weed controls, respecting organic crop development practices. The scenario assumes a Smart Farmer, who desires to make use of a Smart Farming application, available through NEMO by a third party. As the Smart Farmer does not own an AGLV, they may use one of those available in NEMO resources for their area, in order to apply weed control automatically via this AGLV. The Smart Farmer selects the AGLV out of the available NEMO resources and then deploy the app on it via NEMO. The app execution should be flexibly managed in order to allow it to be performed either on the AGLV or in some edge or cloud device provided by NEMO, according to Smart Farmer's preferences or application or resource requirements. For this, ML techniques to lower the ML model size might be needed to allow its execution in IoT, edge or cloud devices, with minimal impact on performance. The scenario also involves the calculation of tokens to be credited or charged, based on the use of NEMO apps and resources.
Features to be tested	Meta-Orchestrator, PPEF, CFDRL (Observability, Workload deployment & migration) mNCC (inter-domain communication during migration) CMDT (workload discovery) Intent-based API (app and resource selection) LCM (app deployment and LCM visualization) IdM & Access Control (users) MOCA (tokens' calculation)
Requirements addressed	SF_02_FR01, SF_02_FR03, SF_02_FR04, SF_02_FR05, SF_02_FR06, SF_02_FR07, SF_02_FR08, SF_02_FR09, SF_02_FR10, SF_02_FR11, SF_02_FR12, SF_02_NFR01, SF_02_NFR02, SF_02_NFR03
KPIs	KPI_SF_02_2
Prerequisites	The NEMO framework should be deployed and functional. One registered user (let assume they are called OWNER) is acting as Smart Farming Application Owner (SFAO), who has uploaded their ML-based Weed Management App in NEMO, available for deployment by third parties. At least 1 user (let assume they are called USER_A) is registered in NEMO as a consumer for executing the aforementioned apps in their resources. At least 1 user (let assume they are called PROVIDER) is registered as a partner, having already integrated their resources (at least 1 AGLV) to NEMO. The monitoring app (e.g. SynField® [8]) is already running in NEMO resources. USER_A is subscribed to the monitoring app. The AGLV must be able to provide its data to edge/cloud device and receive commands. The AGLV App may run an ML-based obstacle avoidance service, based on data collected by the AGLV.

	The Weed Management app is already registered into NEMO and available for deployment by third parties. Also, 1 user is registered as meta-OS Provider (ADMIN).
Test steps	<u>Resource provisioning</u> 1. The PROVIDER logs into NEMO dashboard. 2. The PROVIDER adds their AGLV in NEMO resources. 3. The PROVIDER is notified/informed of tokens and operations' results through the NEMO dashboard. <u>Resource & workload selection</u> 1. USER_A logs into NEMO dashboard. 2. USER_A visualizes the available apps with available devices in their region. 3. USER_A selects the Weed Management app. 4. USER_A visualizes the list of available compatible devices in their region. 5. USER_A selects the AGLV to lease. 6. USER_A requests deployment of the Weed Management app in the AGLV. 7. USER_A is notified/informed of tokens and operations' results through the NEMO dashboard. <u>App execution</u> 1. USER_A signs in the Weed Management app. 2. USER_A configures a new route for the AGLV. 3. The AGLV starts its route. 4. Upon detection of obstacle, the AGLV changes its trajectory. 5. When NEMO identifies a risk in the app execution on the AGLV (e.g. due to its power exceeding a predefined limit), NEMO undertakes reallocation of the workload to some other device (e.g. edge or could). 6. USER_A monitors the application, workload and device performance through the NEMO (LCM) dashboard. 7. The route completes and application logs are collected.
Success state	All obstacles are avoided and AGLV operation stops when the route is covered. The AGLV operation is seamless.
Failure state	The AGLV stops before the route is completed; and/or The AGLV collides with a tree or human; and/or The AGLV operation is interrupted or lags.
Responsible for testing and implementation	ESOFT, SYN
Risks	No risks identified so far.

2.3 User experience validation

The end user for the Smart Farming pilot refers to the application owner, the application user, the resource provider or the metaOS administrator, as presented in the test scenarios. In the Smart Farming trial, farmers will participate as end users of the NEMO metaOS, who in this case will be in the role of the application users. The user experience then will be collected and evaluated through the questionnaires presented in Figure 2 and Figure 3 for Use Case SF_01 Aerial Precision Bio-Spraying and Use Case SF_02 Terrestrial precision Bio-spraying, respectively.

User Feedback										
1	Please rate the usability of the UAV in the field.									
	1	2	3	4	5	6	7	8	9	10
2	Please rate the usefulness of the UAV for bio-spraying.									
	1	2	3	4	5	6	7	8	9	10
3	Please rate the effectiveness of aerial bio-spraying.									
	1	2	3	4	5	6	7	8	9	10
4	Please rate the effectiveness of environmental information for the bio-spraying decision.									
	1	2	3	4	5	6	7	8	9	10
5	Please rate how beneficial the aerial spraying applied in NEMO is for managing olive fruit fly in your opinion.									
	1	2	3	4	5	6	7	8	9	10
6	Please rate how beneficial the aerial bio-spraying applied in NEMO is for increasing olives' yield.									
	1	2	3	4	5	6	7	8	9	10
7	Please rate how important you think Smart Farms' collaboration is for Smart Farming.									
	1	2	3	4	5	6	7	8	9	10
8	Please evaluate the possibility for you to adopt a similar solution like NEMO.									
	1	2	3	4	5	6	7	8	9	10

Figure 2: User feedback questionnaire for the Aerial Precision Bio-Spraying use case

User Feedback										
1	Please rate the usability of the AGLV in the field.									
	1	2	3	4	5	6	7	8	9	10
2	Please rate the usefulness of the AGLV for assisting smart farming processes.									
	1	2	3	4	5	6	7	8	9	10
3	Please rate how easy it has been to work in the field together with the AGLV.									
	1	2	3	4	5	6	7	8	9	10
4	Please rate how beneficial the AGLV is for managing weeds in your opinion.									
	1	2	3	4	5	6	7	8	9	10
5	Please rate how beneficial the AGLV is for relieving human work in your opinion.									
	1	2	3	4	5	6	7	8	9	10
6	Please rate how easy it has been to initiate the AGLV operation.									
	1	2	3	4	5	6	7	8	9	10
7	Please rate how safe you feel working in the field with the AGLV moving around.									
	1	2	3	4	5	6	7	8	9	10
8	Please evaluate the possibility for you to adopt a similar solution like NEMO.									
	1	2	3	4	5	6	7	8	9	10

Figure 3: User feedback questionnaire for the Terrestrial Bio-Spraying use case

2.4 Required equipment

The Smart Farming trial covers computation at IoT, edge and cloud resources, as identified in Table 4.

Table 4: The equipment used in the Smart Farming trial.

Equipment	Description / Specifications	Type	Status
SynField Node	SynField Node able to collect sensor measurements and transmit them to the edge or the cloud, as well as send commands to the actuators (e.g., for irrigation control). It carries a microcontroller.	IoT/field	Available
Agri drone	The agri drone will fly over the grove in order to capture aerial images and perform crop	IoT/far-edge	Available

Equipment	Description / Specifications	Type	Status
	disease detection. It carries a multi-spectral camera, a processing unit, a microcontroller and spraying kit.		
Agri robot	Mobile robot moving autonomously across the grove, avoiding collisions with humans or obstacles and detecting areas to spray. It carries stereo camera and sensors, a processing unit, a microcontroller and a spraying kit.	IoT/far-edge	Available
Edge node	Edge node for running edge analytics for crop disease prediction (based on sensor measurements) and local ML model training.	Edge	Available
Cloud node	Cloud resources to support ML model aggregation/training activities.	Cloud	Available

2.5 Data collection

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

- **Field sensor measurements:** data collected from SynField IoT platform and integrated sensors, including microclimate data (air temperature, air humidity, wind direction, wind speed, rain volume, rain intensity) and soil data (soil moisture). This dataset will be used to calculate where bio-spraying is needed.
- **Drone camera images:** RGB/multi-spectral images collected from UAV's camera during its flight over the olive trees. The images are associated with time information and geospatial/location information provided by GPS.
- **AGLV camera images:** video images collected from AGLV's camera. The images will be used for obstacle avoidance of the AGLV and for the identification of weeds.

2.6 Alignment with NEMO

The added value of NEMO technology in the Smart Farming domain will be demonstrated by highlighting the functionality of NEMO components as in section 2.6.1, activated through business specific logic, as presented in section 2.6.2.

2.6.1 NEMO components in the Smart Farming Trial

The Smart Farming trial will pilot and demonstrate the NEMO features presented in Table 5.

Table 5: NEMO components used in the Smart Farming trial

NEMO functionalities	Foreseen exploitation
AIoT Architecture	Instantiation in the LL
Cybersecure Microservices' Digital Twin (CMDT)	Microservices' discovery and profiling
MLOps via CF-DRL	ML model training Model sharing Model serving
Federated metaNetwork Cluster Controller (mNCC)	Micro-slices creation & management
Micro-services Secure Execution Environment (SEE)	Secure deployment and execution of microservices

PRESS, Safety & Policy enforcement framework	Controlled data sharing/management and definition of strategy for resource management
Cybersecurity & Digital Identity attestation	Advanced access control to devices and microservices
meta-Orchestrator	Flexible allocation of services across IoT, edge, cloud resources
Intent-based migration SDK (R11)	Development / onboarding of smart farming services and applications

2.6.2 Use case specific components

Both use cases of the NEMO Smart Farming trial include use case specific components, which may run IoT, edge or cloud devices, as depicted in the high-level architecture of Figure 4. IoT applications include workloads which run directly on the UAV and the AGLV and enable their autonomous operation, based on data (images/measurements) acquired by those devices' sensors and cameras. Moreover, the IoT layer includes data collection from less capable smart sensing devices, referred as "sensor data" in the figure. Components which appear with dashed line may optionally run in this layer, according to NEMO's decision. The edge layer hosts more demanding functions, such as local training processes for ML models which assist UAV or AGLV functions. Moreover, the dashed-line components may also run at the edge, based on NEMO's workload scheduling and allocation. Last, the cloud resources host aggregation functions for collaborative training, as well as end-user applications.

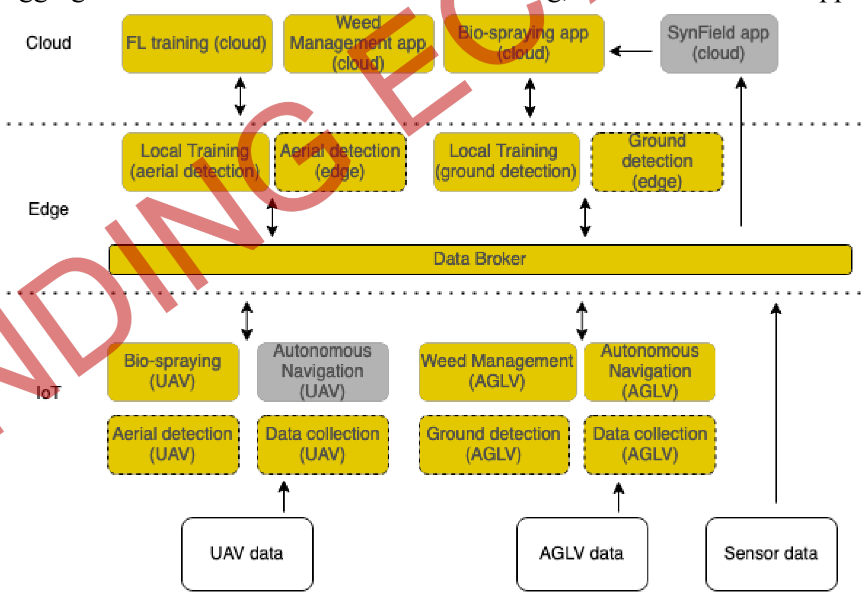


Figure 4: Smart Farming application components across the IoT, edge and cloud resources

The components in yellow boxes refer to use case specific applications developed within NEMO. The components in grey boxes refer to third-party applications, which may be hosted in NEMO resources for supporting the pilot cases. In more detail, use case specific developments include the following.

<u>Data Collection (UAV/AGLV)</u>

This component caters for capturing aerial/ground images at defined frequency, persisting them in UAV/AGLV's storage component and providing them to other applications for further processing. In this trial, images will be provided as input to Aerial/Ground Detection component, which may be executed either locally or some edge device. Images may be optionally persisted in external storage on the UAV/AGLV.

Aerial detection (UAV/edge)

The application which detects olive trees. It is based on ML models which receive aerial images as input and detect potential olive trees in the images. For increased accuracy, the application will probably combine image segmentation and object detection, in order to isolate areas in the image and classify trees accordingly, without requiring manual intervention. Upon detection of an olive tree, the application generates an event that informs about this detection as its output. The component may be executed either on the UAV or in some edge device.

Ground Detection (AGLV/edge)

This application is responsible for the detection of trees, humans or other obstacles which may affect the movement of the AGLV. It receives images captured from the AGLV's stereo camera as input and outputs the detection of an obstacle, based on relevant ML classification models. The component may run either directly on the AGLV or on some edge device.

Bio-spraying (UAV/Cloud)

This component is mainly responsible for controlling the operation of services which synergistically support the spraying operation. The cloud version of the component exposes interfaces to the end user, a per managing of the spraying process, such as configuration options related to the UAV flight, as well as initiating/pausing or stopping a relevant flight. The cloud Bio-spraying App will trigger the execution of the IoT counterpart on the UAV, as well as the Aerial Detection and Autonomous Navigation services, as result of a relevant user request. The IoT version of the application consumes events of olive tree detection and triggers the spraying operation, properly notifying the Autonomous Navigation component, in order to pause the movement once the spraying is about to start and resume the route once it is complete. It also generates control commands for the spraying actuator of the UAV and may provide status updates to the cloud version of the app.

Weed Management (AGLV/cloud)

This application allows weed control across the field through intelligently controlling AGLV's mowing actuators. The cloud counterpart provides end-user interface and allows for setting routes and configuration options related to the movement and weed mowing operation of the AGLV. Also, this component supports management of other applications running on the device, such as its IoT counterpart, as well as the Ground Detection and the Autonomous Navigation. The Weed Management app is aware of the mode of execution of the Ground Detection service (edge/IoT) and ensures that traffic (captured images) would always reach the service. The IoT version consumes events of the Ground Detection service and controls the mowing actuators accordingly. Moreover, it may apply such controls as a result of relevant messages, e.g., from the cloud counterpart, dispatching an end-user request. Also, the IoT version may provide status updates to the cloud counterpart.

Autonomous Navigation (UAV/AGLV)

For both the UAV and the AGLV, this service allows autonomous movement of the device within a set route. For the UAV case, the service delivers flight operation on a defined route, based on third-party software. For the AGLV, the service will allow it to move without any intervention from an external controller, based on simultaneous localization and mapping (SLAM), enhanced with Deep Learning model.

Local Training (edge)

The local training service supports the relevant ML model training at the edge, without disclosing that user's data. This service refers to the Federated Learning (FL) participant software, based on the Flower framework.

FL Training (cloud)

This service delivers the aggregator functionality in the FL system. It is also responsible for persisting the final aggregate model and providing it to FL participants. It may be also provided to third parties, wishing to deploy the model, without participating in the training process.

2.7 Use case diagrams

The following sequence diagram depict the workflows among NEMO and business specific components which will implement the test scenarios defined for the Smart Farming trial, including resource onboarding, workload registration, workload execution, FL training, ML model deployment, resource and workload selection and application execution for both use cases.

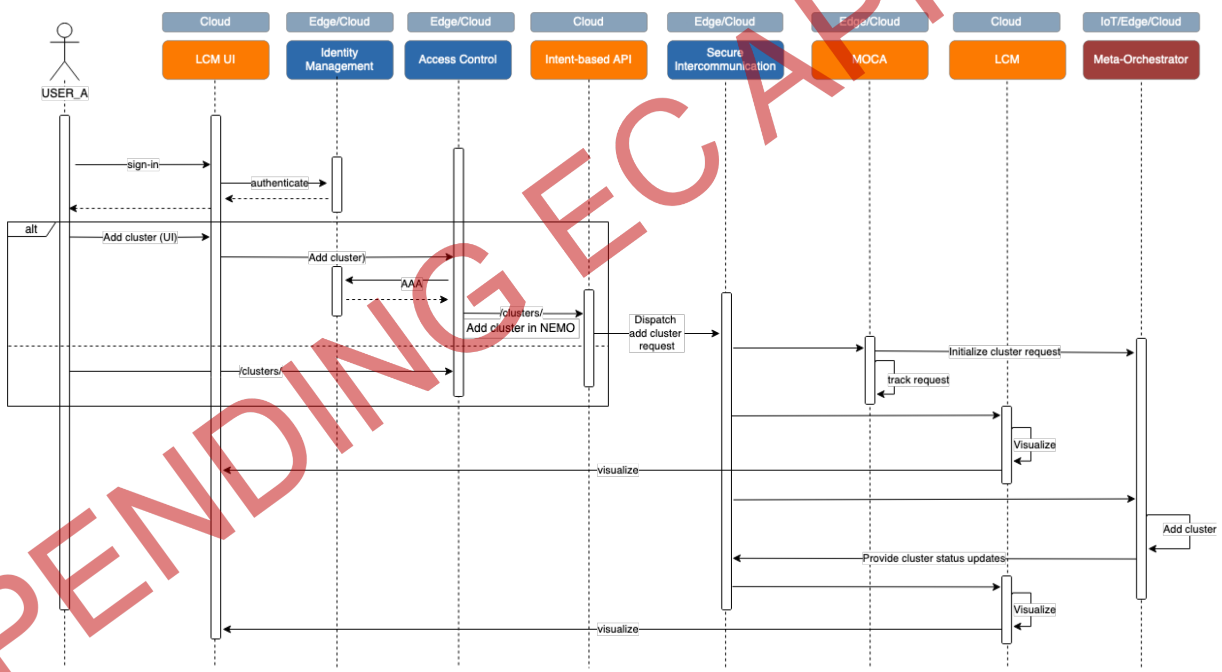


Figure 5: Sequence diagram for resource onboarding in SF01_Test_Scenario_1

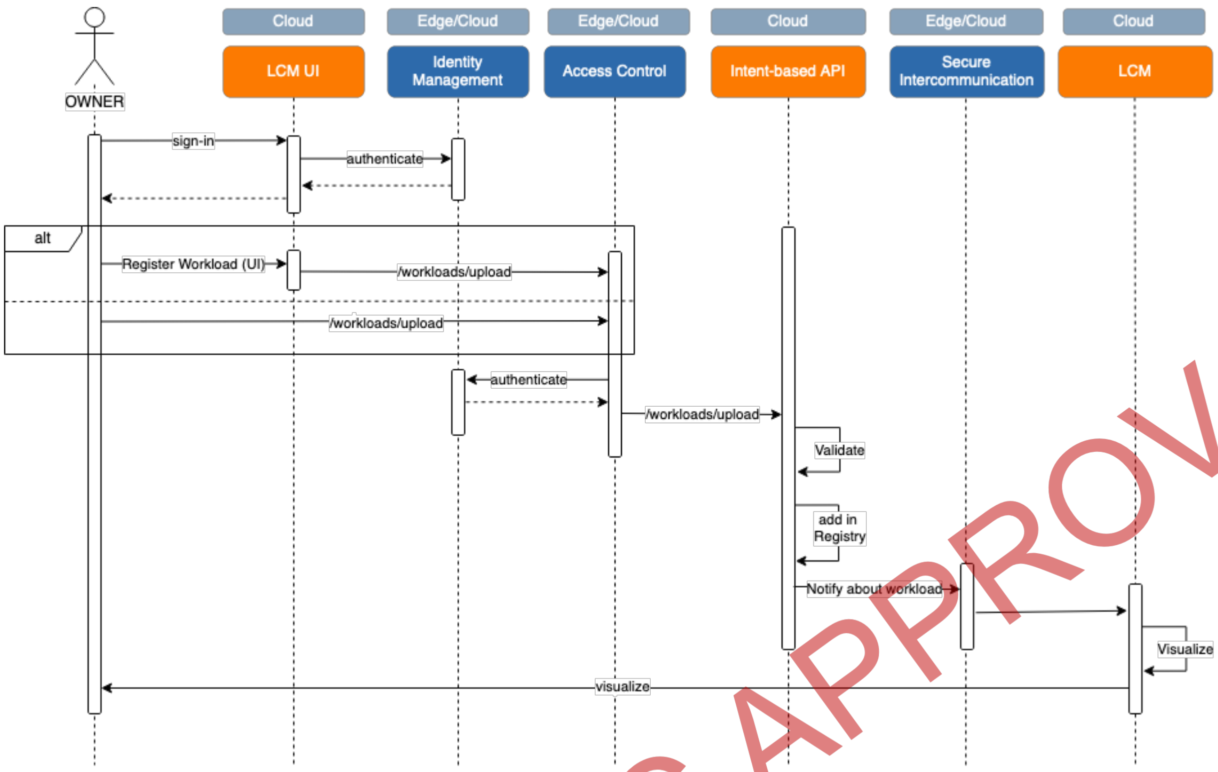


Figure 6: Sequence diagram for workload registration in SF01_Test_Scenario_1

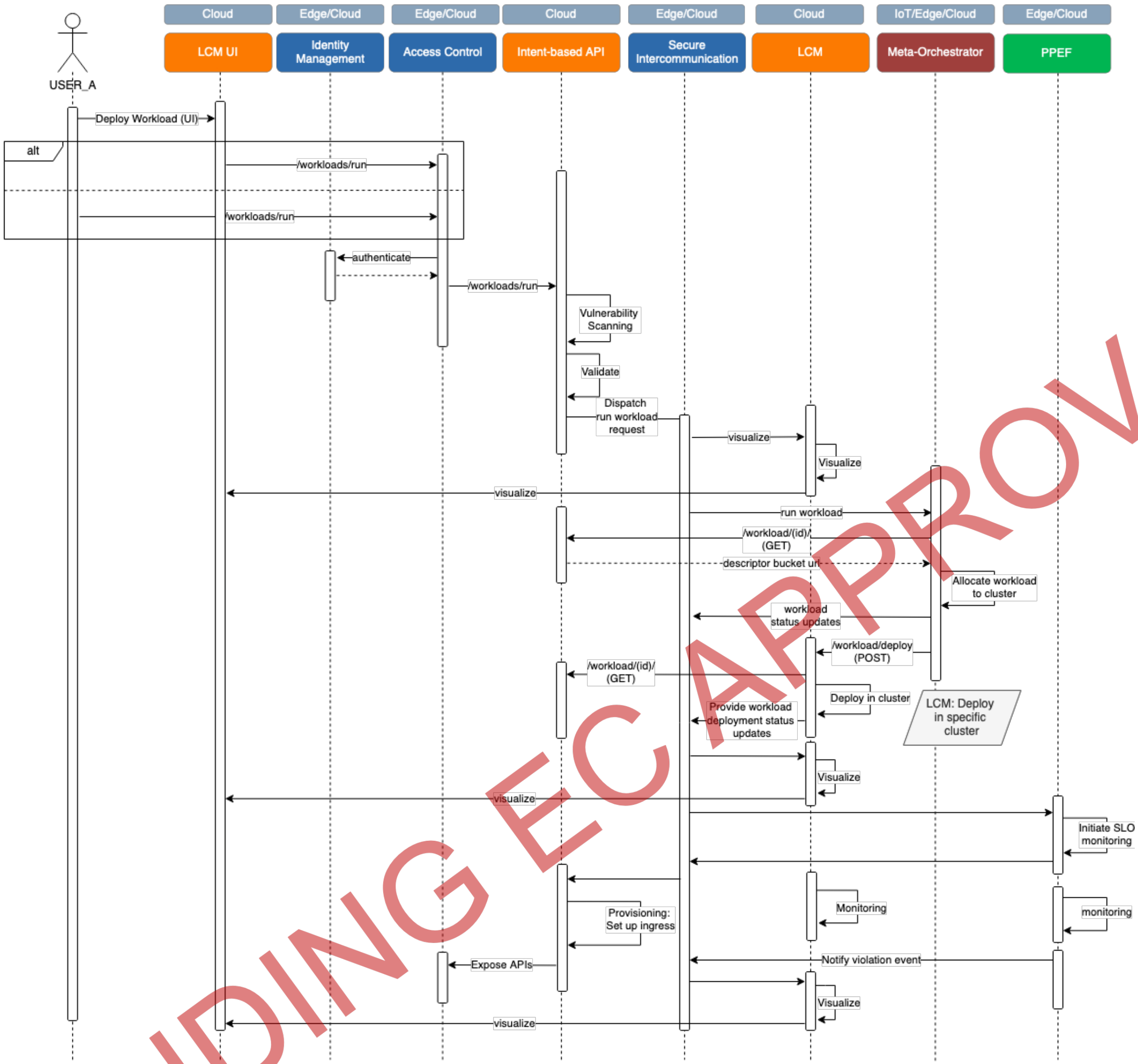


Figure 7: Sequence diagram for workload execution in SF01_Test_Scenario_1

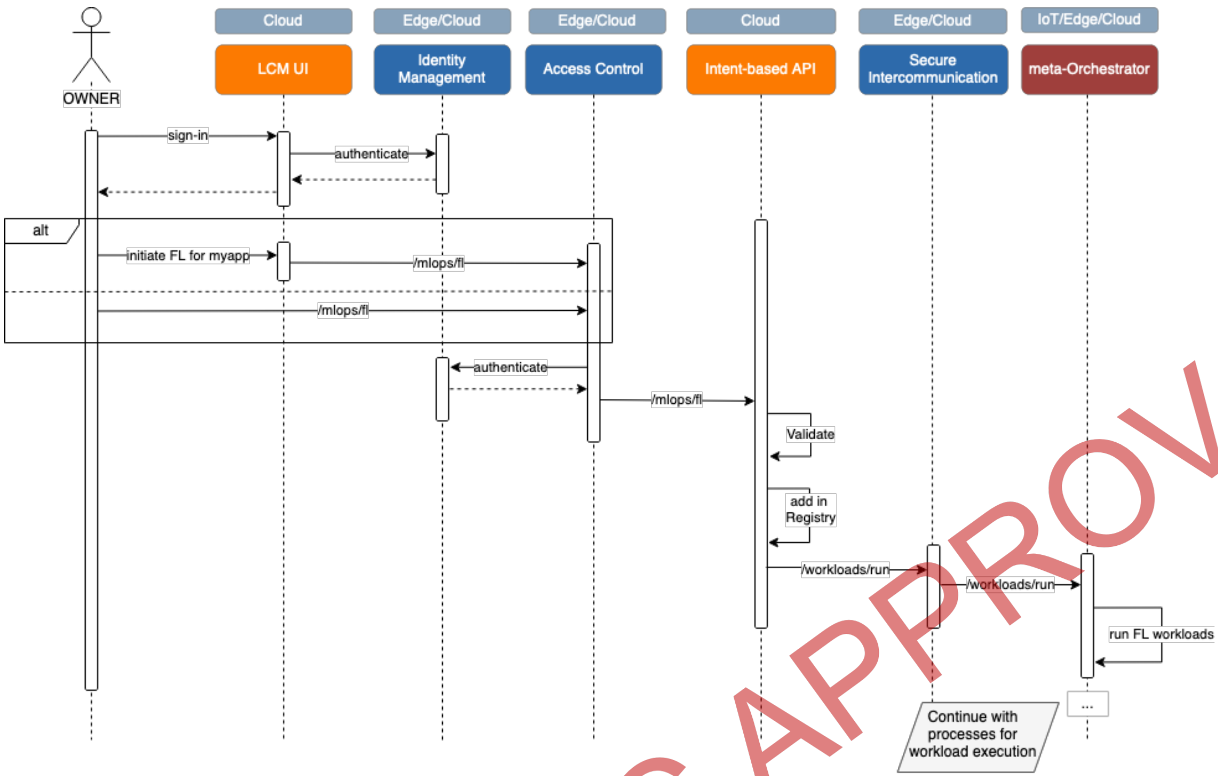


Figure 8: Sequence diagram for FL training in SF01_Test_Scenario_1

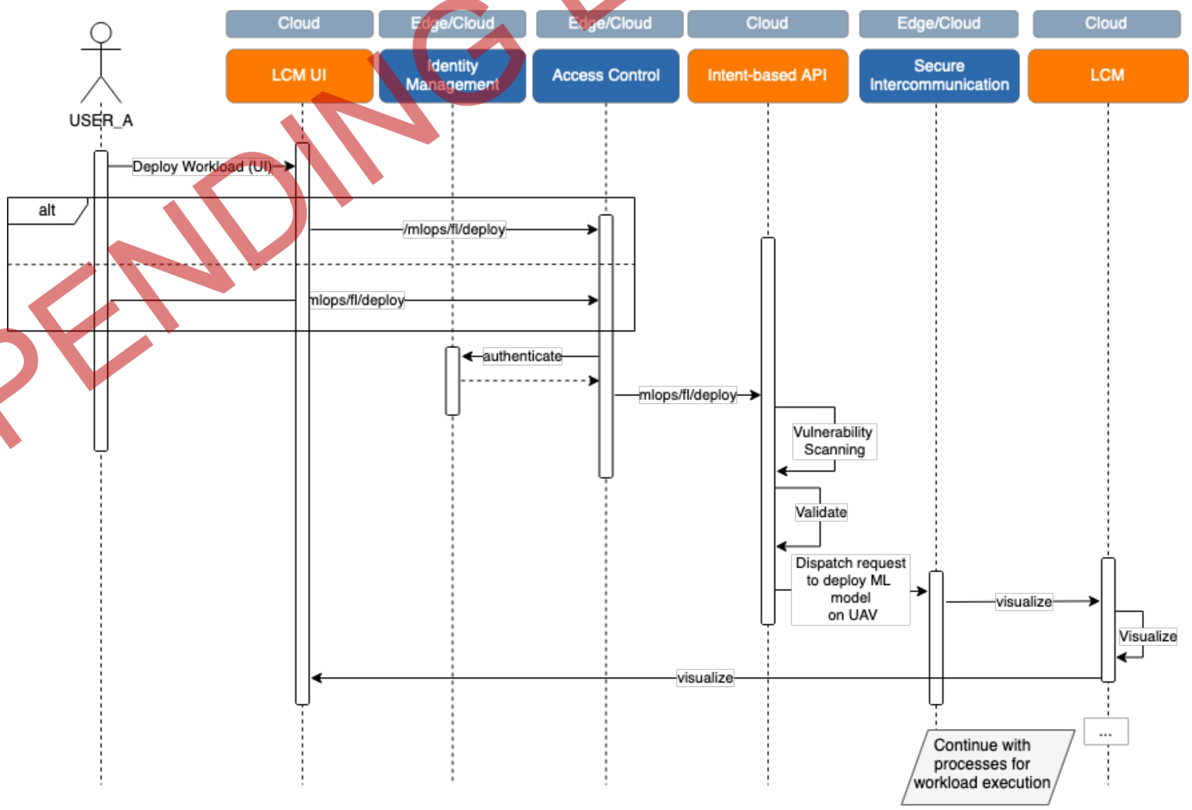


Figure 9: Sequence diagram for ML model deployment in SF01_Test_Scenario_1

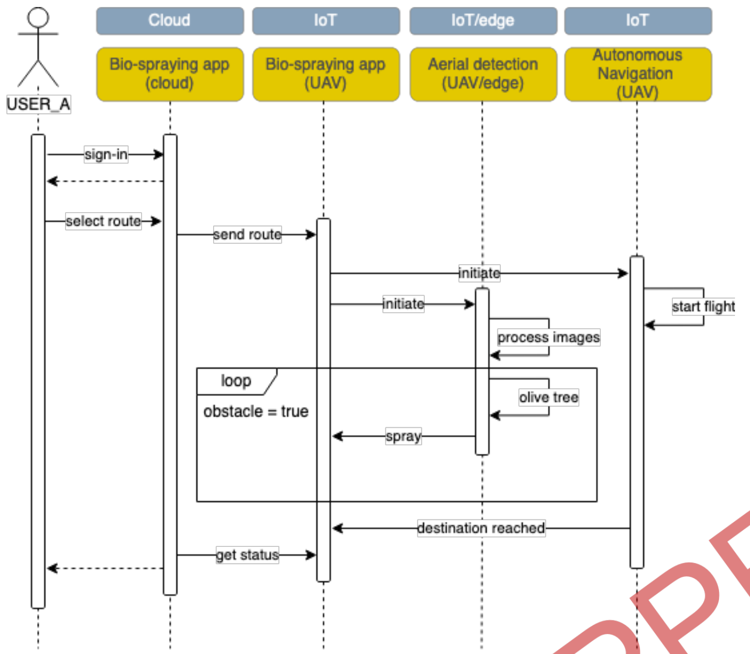


Figure 10: Sequence diagram for application execution in SF01_Test_Scenario_2

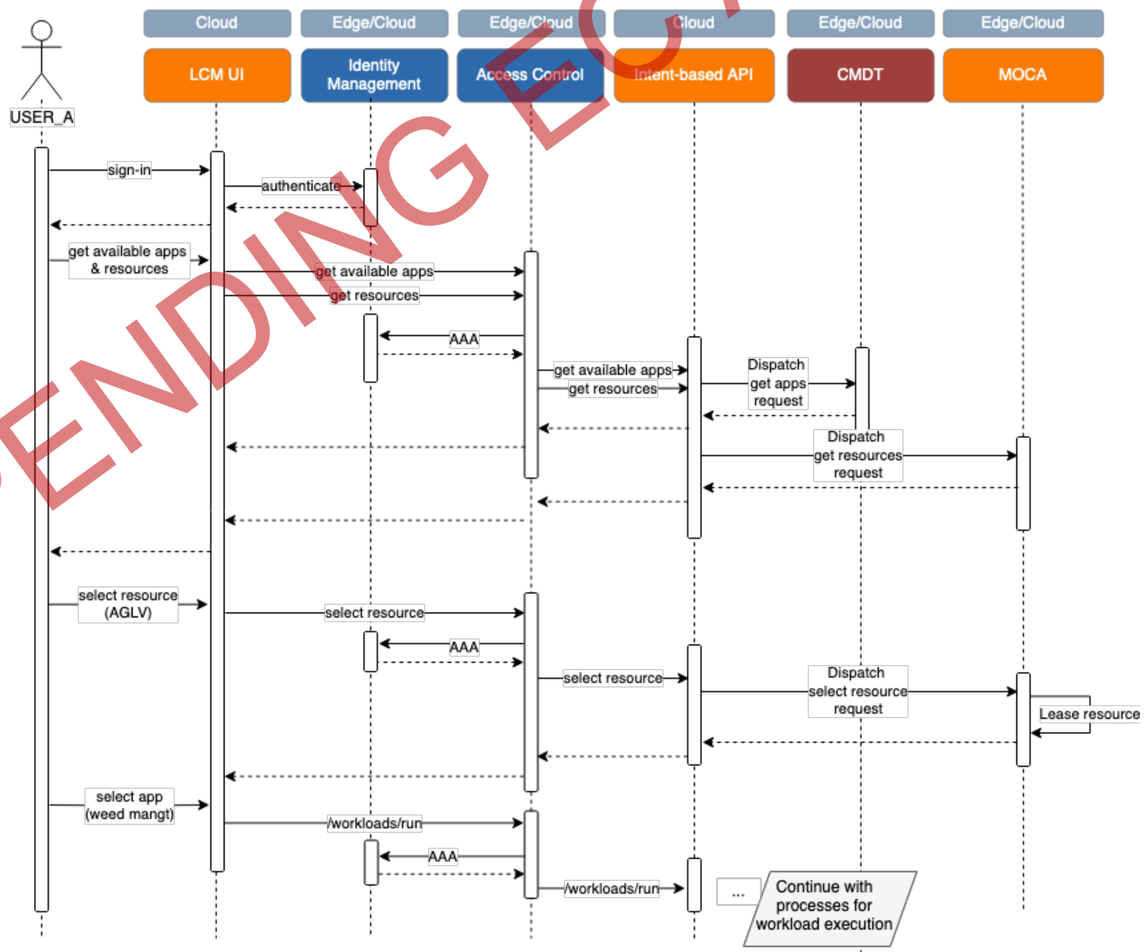


Figure 11: Sequence diagram for resource and workload selection in SF02_Test_Scenario_1

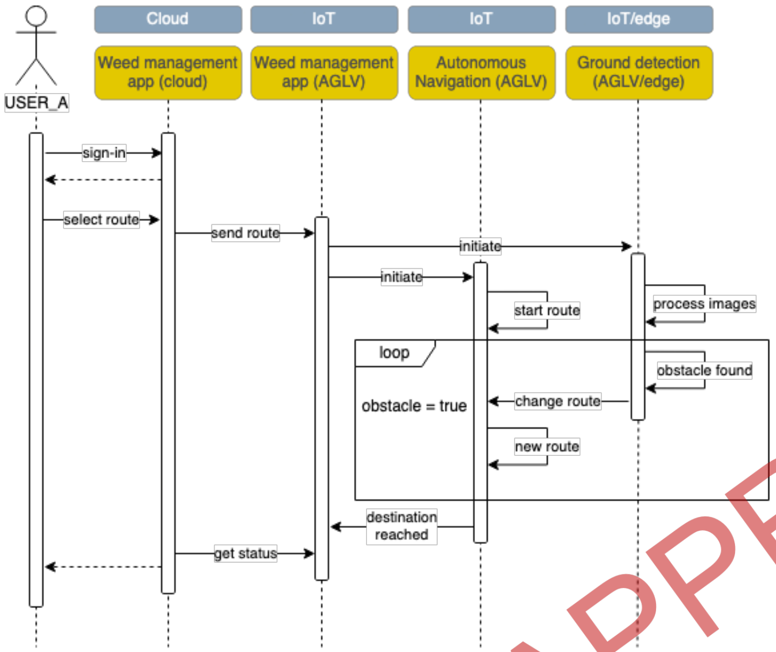


Figure 12: Sequence diagram for application execution in SF02_Test_Scenario_1

2.8 Roadmap

The trial activities follow the schedule depicted in Table 6.

Table 6: Schedule for Smart Farming trial

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

2.9 Initial results

Olive Trees Segmentation from UAV images

Dataset Overview

The primary challenge encountered in our task stems from the scarcity of publicly available datasets. Despite some works focusing on olive tree segmentation, there is a notable absence of dedicated public datasets. Even for the broader task of tree segmentation, the existing datasets are limited and exhibit three key characteristics that render them unsuitable for our specific objectives.

- **Multiple Tree Classes:** Existing datasets often include multiple tree species, none of which correspond to the olive tree [9] [10]. Our goal is not to differentiate between tree species but rather to distinguish the tree from its background.
- **Street Level View:** Many available datasets capture trees from a street-level perspective, resulting in a shape representation that is vastly different from that observed at drone level [10].

Given our emphasis on drone image analysis, we specifically require top-down views of the olive tree crowns (canopies).

- **Diverse Environments:** Several datasets showcase trees in forested or urban environments, which significantly differ from the open field setting of an olive tree plantation. Such environmental disparities can profoundly impact segmentation performance [11].

In addressing these challenges, the project utilized three publicly available datasets obtained from Roboflow[3], all related to olive tree analysis. All datasets feature images with a resolution of 640x640 pixels and are singularly focused on a unified class – "olive trees".

The first dataset [12], the largest among the three, comprises 622 training images, 137 validation images, and 127 test images. On average, each image contains 78.9 boxes, totaling 52,837 instances of olive trees.

The second dataset [13] consists of 155 training images, 50 validation images, and 38 test images. The average number of boxes per image is 82.3, contributing to a total of 14,202 instances of olive trees.

The third dataset [14], focused on segmentation, is comparatively smaller. It includes 67 training images, 19 validation images, and 9 test images, with an average of 8.2 masks per image. In total, this dataset comprises 681 instances of olive trees.

This dataset selection strategy ensures relevance to the objectives, providing diverse and sufficiently challenging data for the development and evaluation of the olive tree segmentation model.

Figure 13: Samples from first dataset

Figure 14: Samples from second dataset

[3] https://universe.roboflow.com/

Figure 15: Samples from third dataset

Approach

The primary challenge in the task is to perform real-time instance segmentation on olive trees running on a drone, necessitating a careful balance between model size, inference time and accuracy. Although state-of-the-art models like the Segment Anything Model (SAM) and YOLOv8x excel in performance, their deployment on edge devices, such as drones, is hindered by computational resource limitations. To address this, lightweight model variations are considered that, while sacrificing some accuracy, deliver commendable results with significantly reduced inference times. MobileSAM [15] introduces the use of TinyViT [16] to replace the heavy image encoder, reducing parameters from 615M to 9.66M and cutting inference time from 456ms to 12ms on a single GPU. Despite this improvement, deployment on resource-constrained edge devices encounters challenges due to the memory and computational overhead associated with self-attention mechanisms. RepViT-SAM [15] takes a step further by replacing the image encoder with RepViT [17], achieving superior performance to MobileSAM with nearly ten times the inference speed. YOLOv8 introduces a nano version with only 3.2M parameters, compared to the 68.2M of the x version, and an inference time of 80.4ms versus 479.1ms on CPU.

Two distinct approaches were explored, employing RepViT-SAM and YOLOv8n. Both approaches propose a pipeline that combines these models in different orders, with each approach tailored to specific considerations: data availability and optimization of inference time on edge devices, such as drones.

RepViT-SAM for Final Segmentations

The initial approach utilizes RepViT-SAM for the final segmentations. RepViT-SAM, being class-agnostic, requires bounding boxes (bboxes) as input for segmentation predictions. Although it delivers impressive zero-shot results without fine-tuning, it demands bounding boxes as input, making it necessary to create a pipeline for real-time segmentation. The suggested pipeline combines YOLOv8n as the olive tree detector with RepViT-SAM for olive tree segmentation. However, since the pre-trained YOLOv8n model does not recognize the class "olive trees" or even "trees," it needs fine-tuning.

The YOLOv8n model was fine-tuned on DATASET1, comprising 622 training images for 100 epochs, with early stopping patience set to 10 epochs and default hyper-parameters. Training concluded after 42 epochs, achieving a mean Average Precision at 50 IoU (mAP50) of 0.93285. Inference involves using the fine-tuned YOLOv8n on the input image to detect bounding boxes, which are then passed to RepViT-SAM for final segmentation. The total inference time for both models on a CPU is 34.5 ms for YOLOv8n and 380 ms for RepViT-SAM, resulting in a total inference time exceeding 400 ms. While this approach simplifies fine-tuning using available data, it relies on two resource-intensive models, impacting inference time and resource requirements.

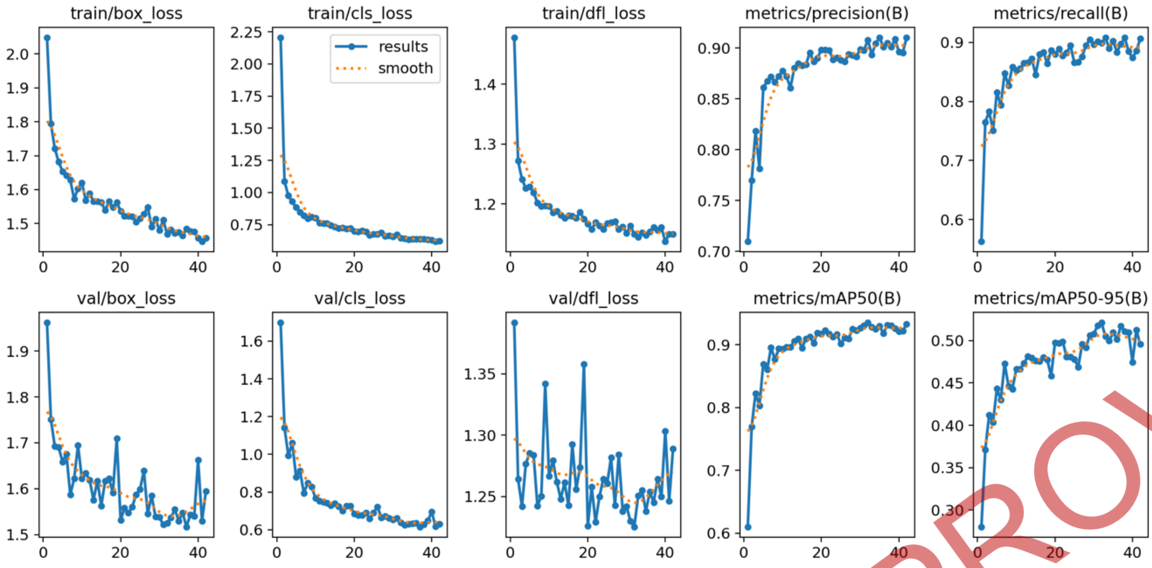


Figure 16: Fine-tuning YOLOv8n for detection

(a) (b) (c)

Figure 17: (a) Initial image; (b) bboxes after YOLOv8n; (c) segmentations after RepViT-SAM

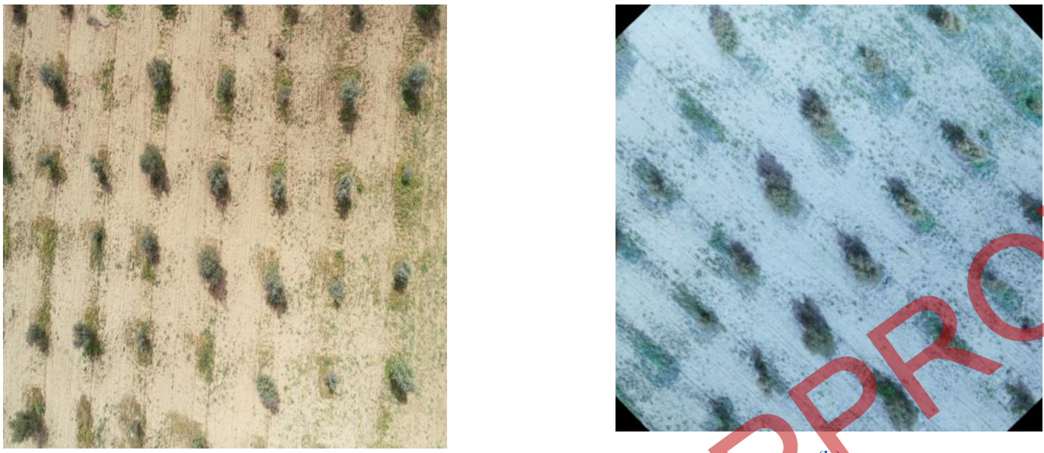
YOLOv8-seg for Final Segmentations

The second approach adopts the YOLOv8-seg model for final segmentations. Although more complex in terms of fine-tuning, this approach streamlines inference by utilizing only the YOLOv8n-seg model for segmentation. Similar to the first approach, YOLOv8n-seg requires fine-tuning since the pre-trained model does not recognize the class "olive trees" or "trees." To overcome the absence of a dedicated segmentation dataset, a custom segmentation dataset is created using DATASET1 and RepViT-SAM.

In this procedure, RepViT-SAM is applied to all images in the detection dataset, utilizing corresponding bounding boxes for segmentation. The resulting segmentation masks, initially in binary form, undergo a transformation into polygons compatible with YOLO. A custom script is employed to execute these transformations and store the outcomes as .txt files for each image. To enhance performance and increase generalization capabilities, we integrate the third dataset into the custom annotated segmentation dataset.

Prior to the merge of the two datasets, a straightforward data augmentation technique is employed, involving horizontal flips, random rotations, and random intensity changes. This augmentation is specifically applied to the third dataset, generating augmented images for each original image. The decision to apply data augmentation solely to one dataset is influenced by the considerable imbalance between the two datasets. To achieve a more balanced outcome while maintaining enough images, we up-sample the smaller dataset to approximately 150 images and retain only 150 images from the larger dataset. The final merged dataset comprises 323 training images, with an average number of masks per image set at 39.7.

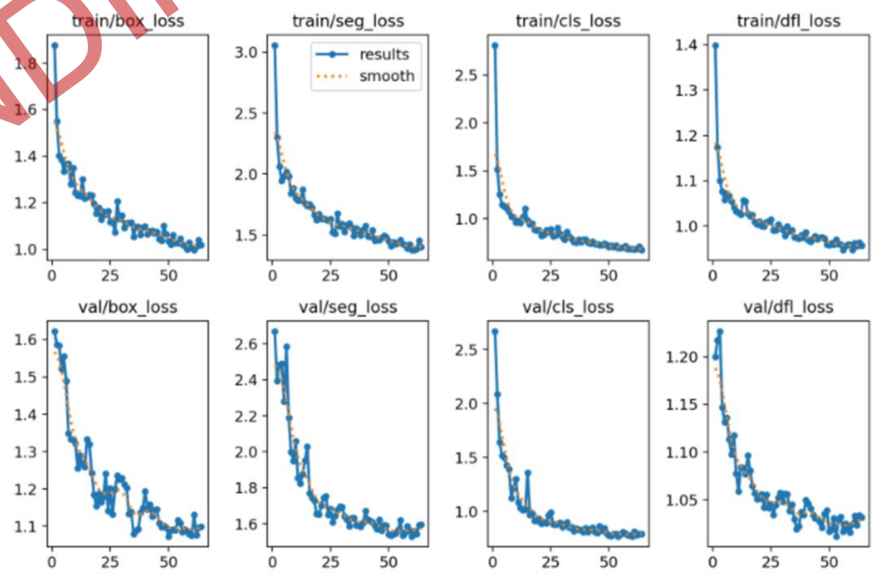
This strategy aims to address the inherent dataset imbalance and enhance the model's ability to generalize across diverse scenarios, contributing to the overall robustness of the segmentation model.



(a) (b)

Figure 18: (a) Initial image; (b) Augmented image

YOLOv8n-seg is fine-tuned on this merged custom dataset, involving 323 training images with on average 39.7 number of masks per image, for 100 epochs with early stopping at 10 epochs and default hyper-parameters. The training stopped after 64 epochs achieving 0.761 mAP50. The fine-tuned YOLOv8n-seg model is used directly for predicting segmentations on input images. The inference time for YOLOv8n-seg is 45 ms. Consequently, during drone-based inference, only the YOLOv8n-seg model is utilized, ensuring faster inference times.



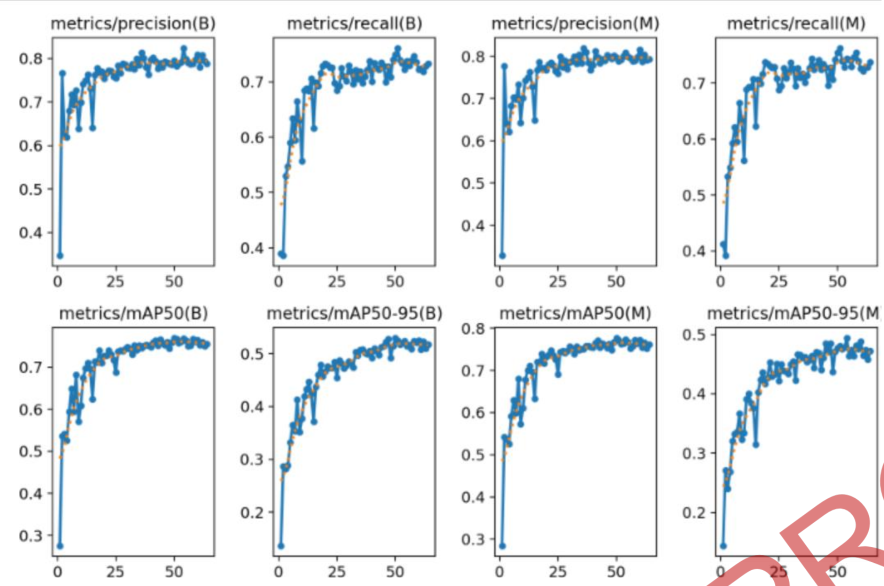


Figure 19: Fine-tuning YOLOv8n-seg for segmentation

(a)

(b)

Figure 20: (a) Initial image; (b) Segmentations after YOLOv8n-seg

3 Smart Energy & Smart Mobility Living Lab

3.1 Trial site description

The Smart Energy Living Lab is located in Terni, central Italy. Managed by ASM Terni, the electric distribution network is currently facing a series of challenges and opportunities, primarily due to the adoption of Renewable energy sources which, while beneficial for reducing carbon emissions and dependence on fossil fuels, have contributed to making the grid more susceptible to imbalances. These imbalances manifest in several ways, including voltage fluctuations (surges and under voltages), current overloads, and power distribution issues (notably, reverse power flow peak phenomena). Such challenges require innovative solutions to ensure the stability and efficiency of the electric grid.

On one hand, electric vehicles are a promising step towards reducing greenhouse gas emissions and transitioning to sustainable modes of transportation. On the other hand, if the charging of these vehicles is not strategically managed, they can exert significant strain on the electric grid. This strain is most evident in the form of increased demand for electricity, which can lead to overloads and the existing imbalances within the grid. However, with proper management and integration into the grid's operations, EVs can play a pivotal role in enhancing grid stability. By leveraging smart charging strategies, EVs can shift their load to times of peak generation, particularly when renewable energy sources are producing excess power. This not only helps in alleviating stress on the grid during high demand periods but also aids in the optimal utilization of renewable energy.

Demand Response (DR) mechanisms further complement these efforts by facilitating active user participation in grid management. In essence, while the diffusion of EVs and the implementation of DR mechanisms introduce new complexities to the management of the electric grid, they also offer unique opportunities to enhance its resilience and efficiency. Through strategic integration and management, these developments can help in addressing the challenges posed by the increased penetration of renewable energy sources, ensuring a stable, efficient, and sustainable electric distribution network.

The living lab is equipped with advanced monitoring tools such as smart meters, phasor measurement units, and power quality analyzers. These devices collect data on electricity flow and quality, which is essential for maintaining grid stability and efficiency. A SCADA system collects data from the various sensors and facilitates effective data sharing and analysis.

3.2 Technical validation

The technical validation of Smart Grid flexibility UC leverages the combined expertise of technical partners and the operational capabilities of the Distribution System Operator (DSO). This collaborative effort focuses on assessing data transmission capabilities, specifically the granularity and volume of information relayed, and evaluating the resultant improvements in network performance. Key areas of improvement include the early identification of potential grid blackouts and enhanced energy flexibility.

The validation process will be conducted in the living lab utilizing both real-time and historical data to mirror actual operating conditions closely. This approach allows for a comprehensive evaluation of the system's responsiveness and resilience. It is validated in several distinct phases:

- Initiating the process by sharing real-time and historical data among project partners to ensure a comprehensive analysis base.
- Utilizing predictive models to anticipate energy production and demand, thereby enabling more efficient grid management.
- Assessing the network's defenses against potential cyber threats to ensure the integrity and reliability of the energy supply.
- Enhancing the efficiency of grid operations through the application of advanced analytics and machine learning techniques.

- Evaluating the effectiveness of service recovery strategies and other innovations in improving grid stability and energy flexibility.

3.2.1 Test scenario SE01_Test_Scenario_1

Table 7: Test scenario for the grid optimization use case of the Smart Energy trial

Scenario: SE01_Test_Scenario_1	
Scenario ID	SE01_Test_Scenario_1
Objective	Grid Optimization via forecasting energy generation and consumption
Description	In order to enhance the understanding of the electrical network's behavior and provide more effective guidance to the operational staff, it is essential to accurately forecast the power flow that will pass through the main feeder. This predictive insight will not only allow us to optimize the management of our network resources but also enhance the reliability and efficiency of power distribution. By doing so, the aim is to equip the operators with the necessary information to make well-informed decisions, thereby improving the overall performance and stability of the electrical grid.
Features to be tested	AIoT Architecture CMDT Micro-services Secure Execution Environment MLOps via CF-DRL PRESS, Safety & Policy enforcement framework Cybersecurity & Digital Identity attestation meta-Orchestrator
Requirements addressed	SE_01_FR01, SE_01_FR02, SE_01_FR03, SE_01_NFR01
KPIs	KPI_SE_01_3, KPI_SE_01_4
Prerequisites	The NEMO platform should be installed and configured. All the sensors are deployed in the electrical grid and collect the data continuously. The data will be used to train ML models for forecast of production/consumption.
Test steps	• Development of the forecasting model utilizing machine learning techniques. • Training the model with the ASM dataset. • Evaluation and refinement of the model based on analytical results.
Success state	Improved visibility of the grid. The final trained ML models deployed and forecasting the energy production and consumption accurately.
Failure state	The training of ML models is not done. The ML models fail to predict the grid discrepancies.
Responsible for testing and implementation	ASM
Risks	Potential delays due to partner withdrawal have been mitigated so far

3.2.2 Test scenario SE02_Test_Scenario_1

Table 8: Test scenario for the smart mobility use case of the Smart Energy trial

Scenario: SE02_Test_Scenario_1	
Scenario ID	SE02_Test_Scenario_1
Objective	• Improve Renewable Energy Sources (RES) load balancing via EV chargers. • Predict traffic flow/parking prediction via EV chargers and parking positions for Mobility. • Support citizens eco-mobility in a smart city scenario combining crowd sourcing. info and public transportation, weather/noise data, along with historical data and analysis of CCTV/traffic.
Description	Currently the transition to renewable energy and electric mobility is proceeding in parallel, creating new opportunities and new obstacles: by increasing the number of electric vehicles, the amount of electricity that must be supplied increases and, therefore, a necessary strengthening of power lines follows; moreover, this energy will progressively come from intermittent and non-programmable renewable energy plants, resulting in an energy balancing challenge. In this context, a cooperation mechanism between DSO (Distribution System Operator), eMSP (electric Mobility Service Provider) and EV users allows both a power lines improvement limitation and grid balancing service by coordinating EV charging. DSO monitors the electricity grid and, thanks to accurate forecasting systems, will be able to identify how, when and where to charge electric vehicles for grid balancing. eMSP will then be able to offer advantageous charging price at DSO-selected charging stations, attracting more EV users. In particular, ASM and EMOT, supported by ENG and TSG will realize driver-friendly scenarios for smart city mobility and dispatchable charging of EVs based on RES demand-response along with human-centred smart micro-contracts and micro-payments. The use case will utilize basic geography, street-level, public transportation, weather and noise data, along with historical data and analysis of CCTV/traffic cameras to model and train distributed AI models on traffic flow and parking prediction in a greedy layer wise fashion.
Features to be tested	AIoT Architecture Cybersecure Microservices' Digital Twin (CMDT) MLOps via CF-DRL Federated meta Network Cluster Controller (mNCC) Micro-services Secure Execution Environment (SEE) PRESS, Safety & Policy enforcement framework Cybersecurity & Digital Identity attestation meta-Orchestrator Intent-based migration SDK
Requirements addressed	SE_02_FR01, SE_02_FR02, SE_02_FR03, SE_02_FR04, SE_02_FR05, SE_02_FR06, SE_02_FR07, SE_02_FR08, SE_02_FR09, SE_02_FR10, SE_02_FR11, SE_02_FR12, SE_02_FR13, SE_02_NFR01, SE_02_NFR02, SE_02_NFR03, SE_02_NFR04, SE_02_NFR05, SE_02_NFR06, SE_02_NFR07
KPIs	KPI_SE_02_1, KPI_SE_02_2, KPI_SE_02_3, KPI_SE_02_4
Prerequisites	The NEMO platform should be installed and configured. Consumption and production data should be constantly collected. DSO and CPO platforms must implement a Demand/Response (DR) marketplace.
Test steps	• Grid operator and electric mobility operator signs in NEMO as meta-OS consumer.

	• Grid operator sends a request through NEMO API to retrieve the ML-based energy forecasting. • Grid operator initiates a DR campaign to address energy flexibility needs. • Electric mobility operator participates to DR campaign via blockchain-based marketplace and a smart contract is signed. • Energy flexibility is provided by electric vehicles. • Grid operator performs micro-payment for service received.
Success state	Involve EV users in DR campaign for energy flexibility provision.
Failure state	Grid needs not aligned with electric mobility needs.
Responsible for testing and implementation	EMOT, ASM
Risks	Potential delays due to partner withdrawal have been mitigated so far

3.3 Required equipment

The equipment used in both use cases of the Smart Energy trial includes hardware resources, as identified in Table 9.

Table 9: The equipment used in the Smart Energy trial

Equipment	Description / Specifications	Type	Status
Phasor Measurement Unit	Devices able to monitor in real-time the grid status with a 1-s time resolution. The PMUs are located in two primary substations.	IoT/far-edge	Available
Smart Meters	Smart meters collect real-time data about energy consumption and production across Terni pilot electricity grid.	IoT/far-edge	Available
Charging Stations	IoT charging stations equipped with single-board computer for real-time monitoring and remote management, like charging session start&stop and charging station power output modulation.	IoT/far-edge	Available

Equipment	Description / Specifications	Type	Status
OBD Devices for EVs	Electric vehicles equipped with IoT on-board diagnostic device to collect real-time data.	IoT/far-edge	Available
Parking Cameras	Cameras that monitor traffic flow and provide information on parking availability.	IoT/far-edge	Available
SCADA System	To collect the real time data and store the historical data of the sensors.	Cloud	Available
Cloud Node	Cloud resources to support ML model aggregation/training activities.	Cloud	Available

3.4 Data collection

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

- **Smart Meter eXtension (SMX) dataset**: Measurements of voltage, currents, and power derived by ASM energy units, collected through an MQTT protocol via public IP and/or LAN/VPN connections. To ensure secure access to the dataset, credentials will be required.
- **Phaser Measurement Units (PMU) dataset**: Measurements of voltage, currents, and power derived by ASM energy units, collected through HTTP protocol only via LAN/VPN connections, which provide built-in security access features.
- **Power Quality Analyzers (PQA) dataset**: Measurements of voltage, currents, and power derived by ASM energy units, collected through HTTP protocol only via LAN/VPN connections, which provide built-in security access features.
- **Charging station data**: Real-time and historical data collected from the charging stations deployed in the trial site (Terni, Italy). The data will include information about the charging station and each charging session (energy data).
- **Electric vehicle data**: Real-Time and historical data collected from electric vehicles deployed in the trial site (Terni, Italy). The data will include state of charge level to assess potential energy flexibility provision.
- **Parking camera/Sensor data**: Real time and historical data collected from the smart cameras and sensors deployed in the trial site (Terni, Italy).

3.5 Alignment with NEMO

3.5.1 NEMO components in the Smart Energy Trial

The Smart Energy trial will pilot and demonstrate the NEMO features presented in Table 10.

Table 10: NEMO components used in the Smart Energy trial

NEMO functionalities	Foreseen exploitation
AIoT Architecture	Instantiation in the LL
Cybersecure Microservices' Digital Twin (CMDT)	Microservices' discovery and profiling
MLOps via CF-DRL	ML model training Model sharing Model serving
Monetization and Consensus-based Accountability	Decentralized IoT data transfer and monetization services
Micro-services Secure Execution Environment (SEE)	Secure deployment and execution of microservices
PRESS, Safety & Policy enforcement framework	Controlled data sharing/management and definition of strategy for resource management
Cybersecurity & Digital Identity attestation	Advanced access control to devices and microservices
meta-Orchestrator	Flexible allocation of services across IoT, edge, cloud resources

3.5.2 Use case specific components

The Smart Energy trial implementation requires the development of business specific components, as regarding the smart grid optimization and smart mobility cases, on top of the NEMO platform depicted in Figure 21.

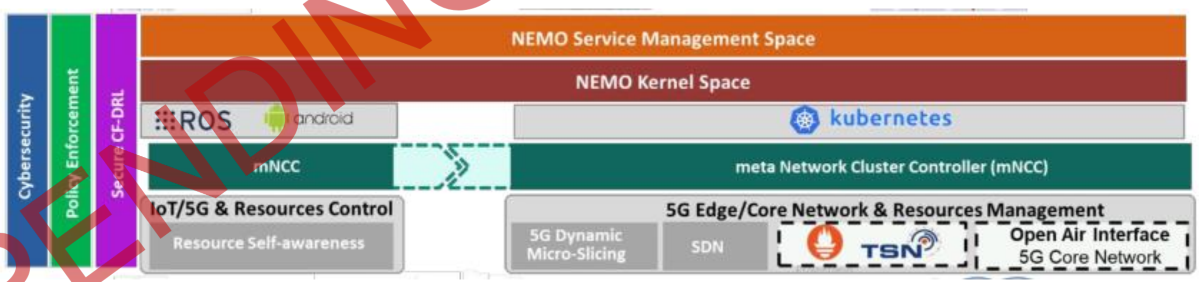


Figure 21: Smart Mobility/City NEMO functionalities

3.6 Use case diagrams

The trial involves implementation of processes among NEMO and business specific components, depicted in the following figures.

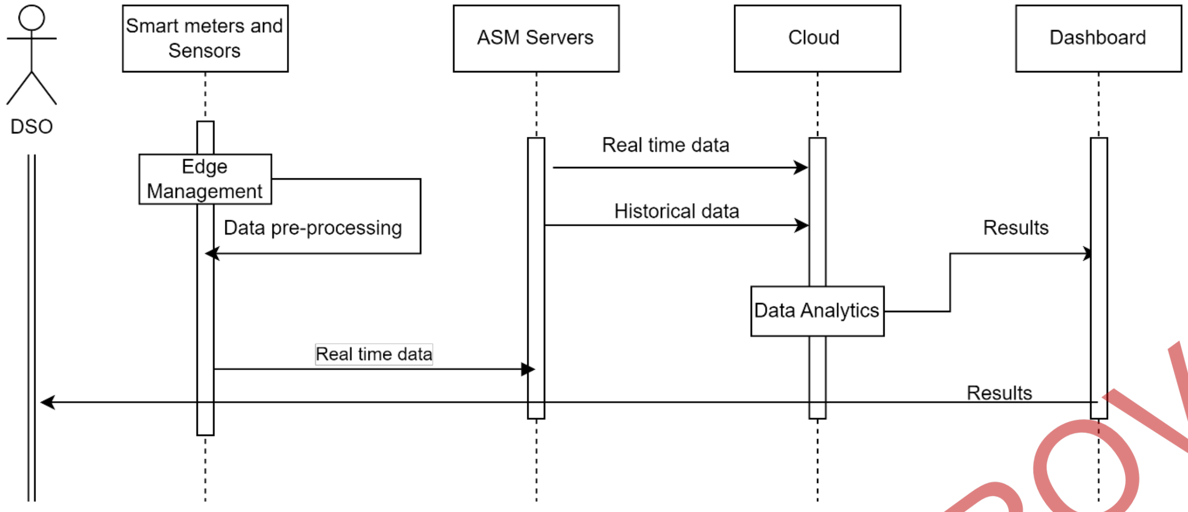


Figure 22: Sequence diagram for Smart Energy case

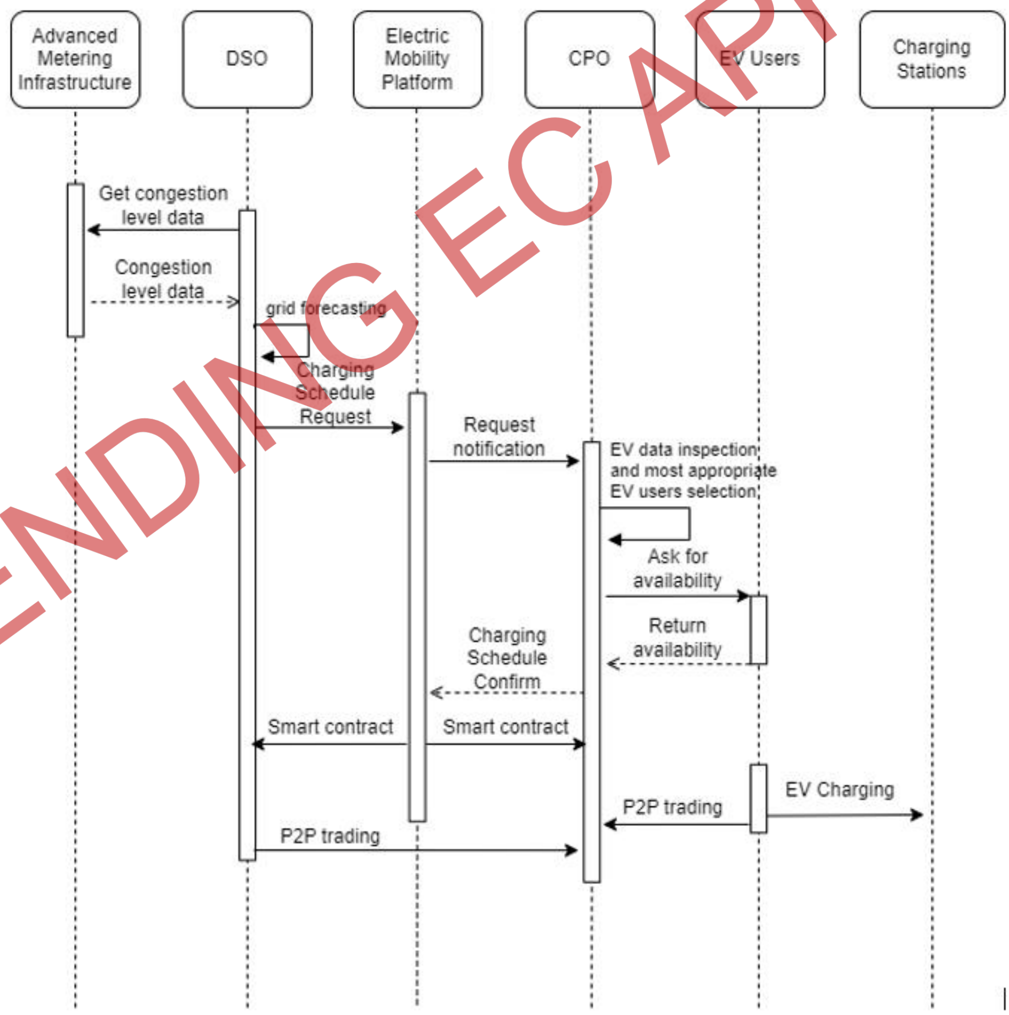


Figure 23: Sequence diagram for the Smart Mobility case

3.7 Roadmap

The trial activities will be executed according to the following schedule:

- Trial set-up and equipment procurement [M9-M18]
- Initial implementation and validation [M18-M24]
- Intermediate implementation and validation [M24-M30]
- Final implementation and validation [M30-M36].

3.8 Initial results

The initial findings are primarily associated with the setup of the trial.

Parking cameras with NVR (Network Video Recorder) are deployed in the Trial site. These cameras process the images into data and monitors the traffic and parking availability. Two Infrared sensors for EV parking slots with information display are deployed. These sensors are being integrated into the SCADA and the data will be stored in the ASM database.

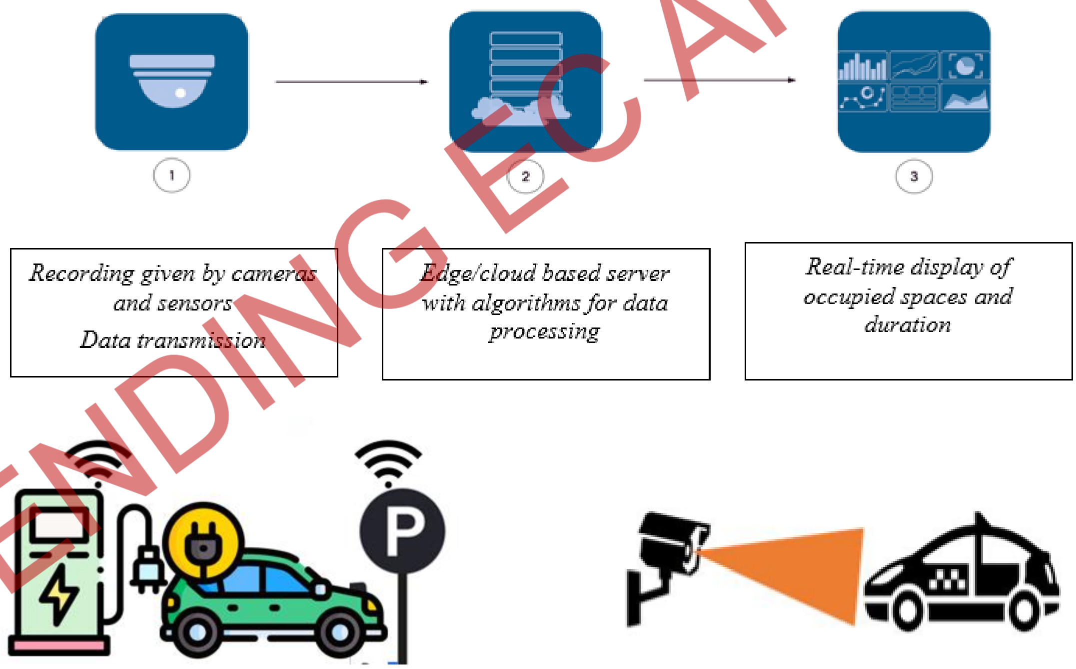


Figure 24: Smart Mobility/City parking sensors

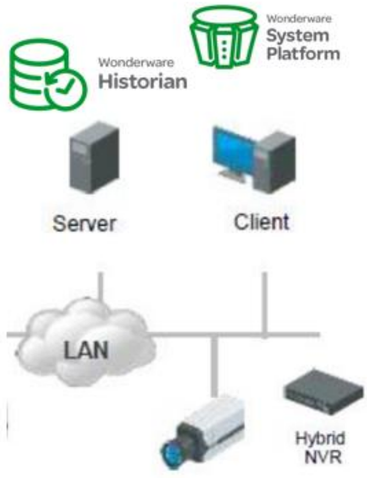


Figure 25: Smart Mobility/City parking sensors

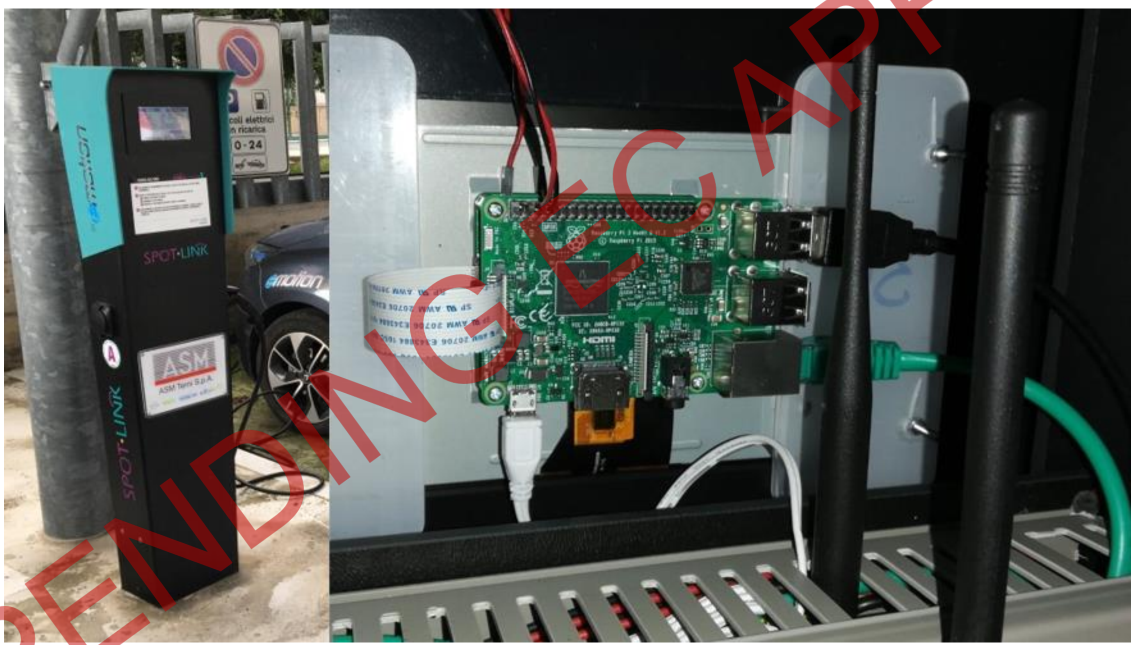


Figure 26: Smart Mobility/City charging station

EV charging monitoring & remote management service developed by EMOT has been deployed for Smart Mobility/City use case operation and it is based on IoT charging stations developed by EMOT, equipped with a single-board computer to enable real-time data collection with one second sample rate in JSON format. EMOT charging stations exchange data through a modem connected to a single-board computer; charging station protocols are OCPP, the application protocol for communication between charging stations and EMOT central management system, and WebSocket, the computer communications protocol, providing full-duplex communication channels over a single TCP connection. These fine-grained data will be used to train a ML model and obtain an accurate prediction for a highly efficient charging session management to balance a grid in a condition of high penetration from distributed renewable energy plants bringing benefits to DSO, CPO and EV user. According with real-time DSO needs, based on data collected from distributed smart meter, charging sessions can be started/stopped remotely and power output can be modulated remotely using EMOT APIs.

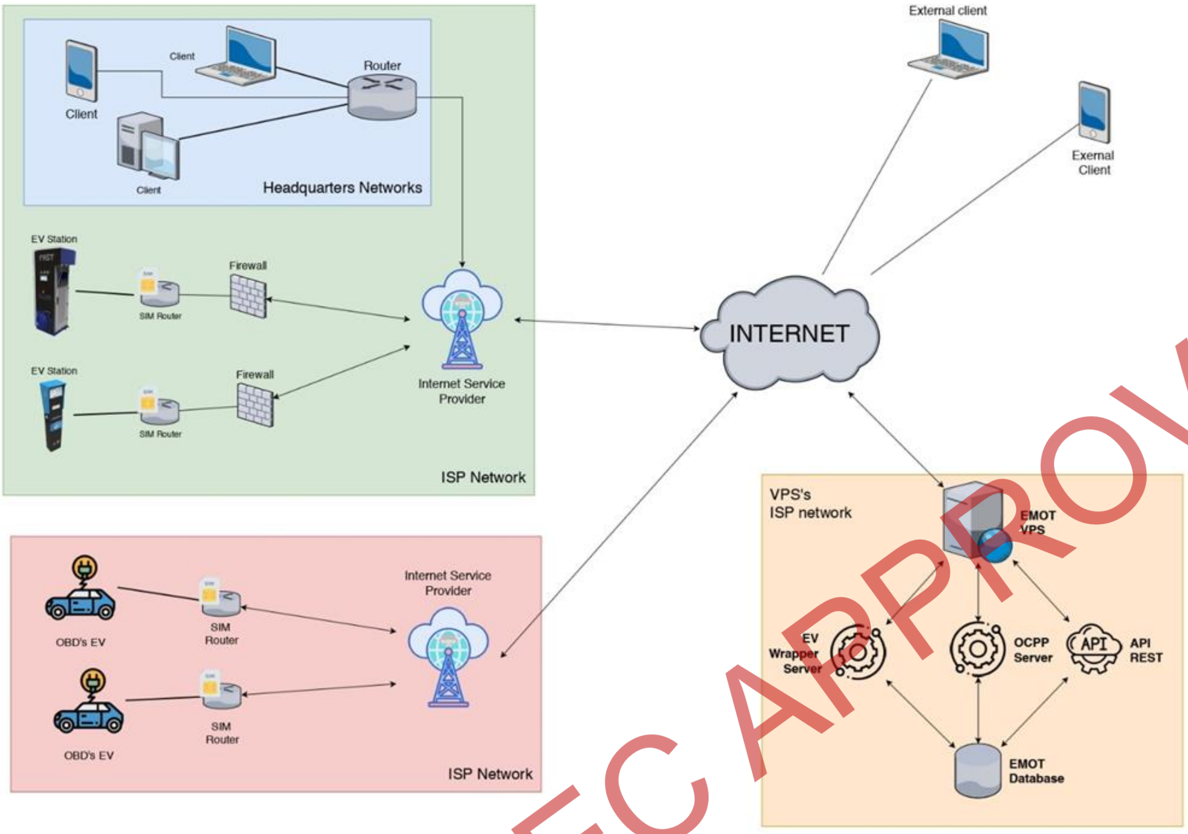


Figure 27: Smart Mobility/City network topology

Regarding EV monitoring, EMOT installed an on-board diagnostic device (OBD) to retrieve data from the EV; OBD is a IoT component that utilize a TCP/IP communication to a TCP/IP server. The network connectivity of the OBD device is via data SIM (UMTS) and the server is a python software; OBD protocol is MQTT, and the sampling rate is 2 seconds. The OBD connects to the diagnostic interface from which it can extract the information from the electric vehicle control unit using the CAN-bus protocol. The output data format of the OBD is an ASCII string; when the data is sent to the server, it is reorganized into a wrapper, thus obtaining a grouping of the data in JSON format.

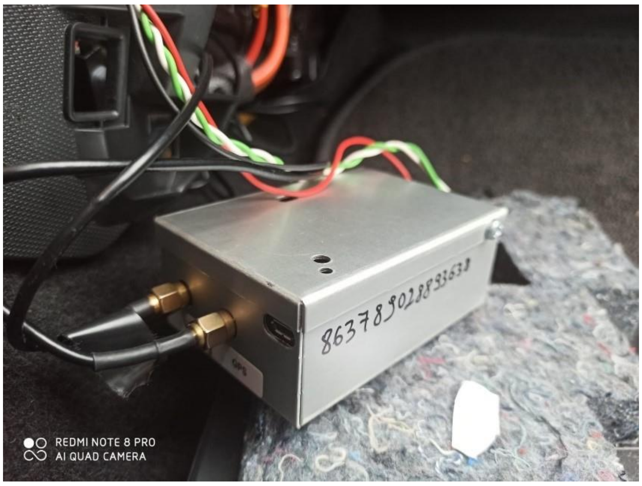


Figure 28: Smart Mobility/City On-Board Diagnostic Device

Data are provided to NEMO technical partners via REST API and via MQTT broker implementation.

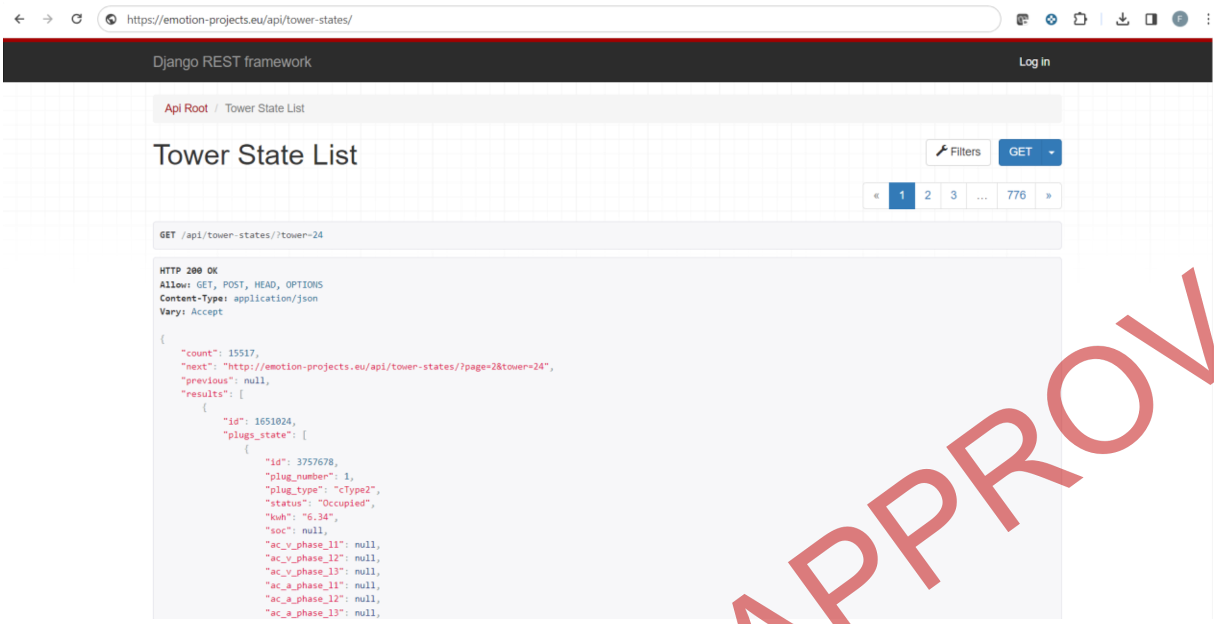


Figure 29: Charging station historical data

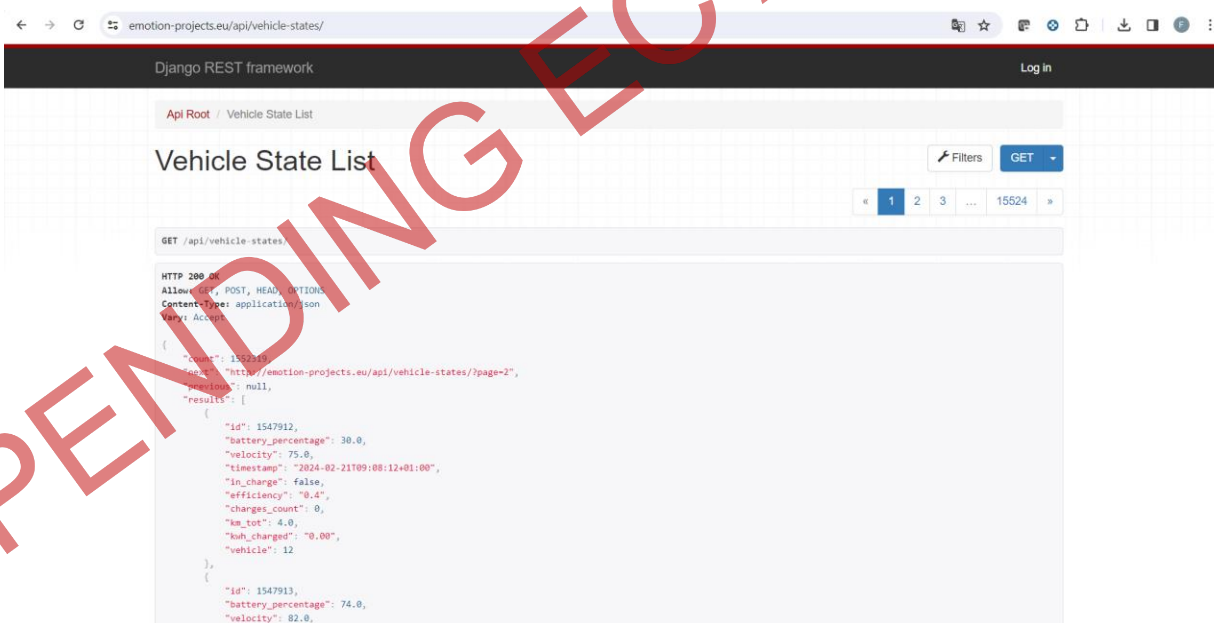


Figure 30: Electric vehicle historical data

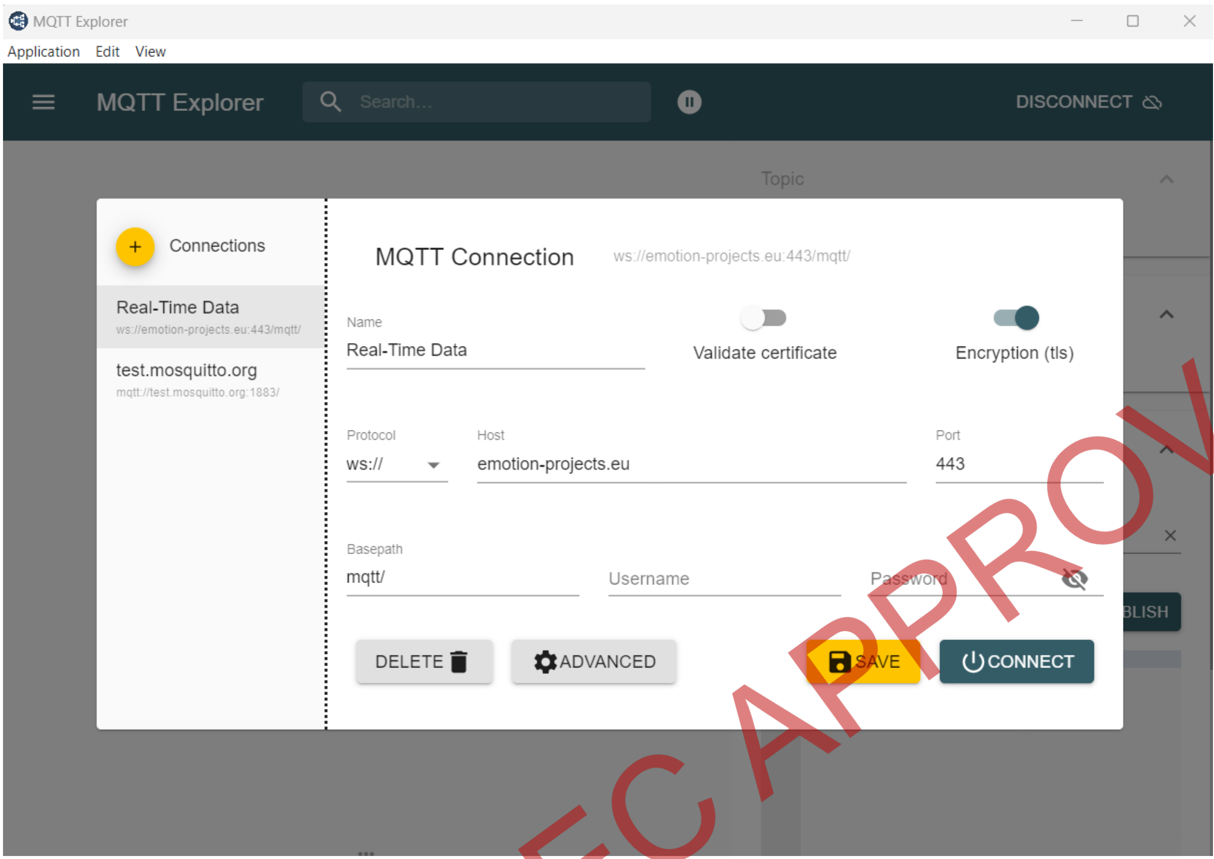


Figure 31: Charging station and electric vehicle MQTT broker

4 Smart Manufacturing & Industry 4.0

4.1 Trial site description

Robotics in general and particularly Cobots have a strong impact within highly automated production facilities. As market demands transformation and demographic change induce new challenges on mass production, CONTI has already undergone feasibility and profitability assessment for the application of flexible Cobots in upcoming assembly facilities. In parallel, CONTI investigated Cobots and AGVs with respect to the strict requirements of electronic production and has gained deep insight into industrial needs and problem settings. The leadplant of CONTI for advanced driver assistance systems (BU ADAS) is located in Ingolstadt. The plant has a high level of automation in manufacturing and logistics as well as high specialization in Cobots and AGVs. Innovative manufacturing processes are set up in Ingolstadt for the first time and upon successful verification are transferred to the other ADAS sites.

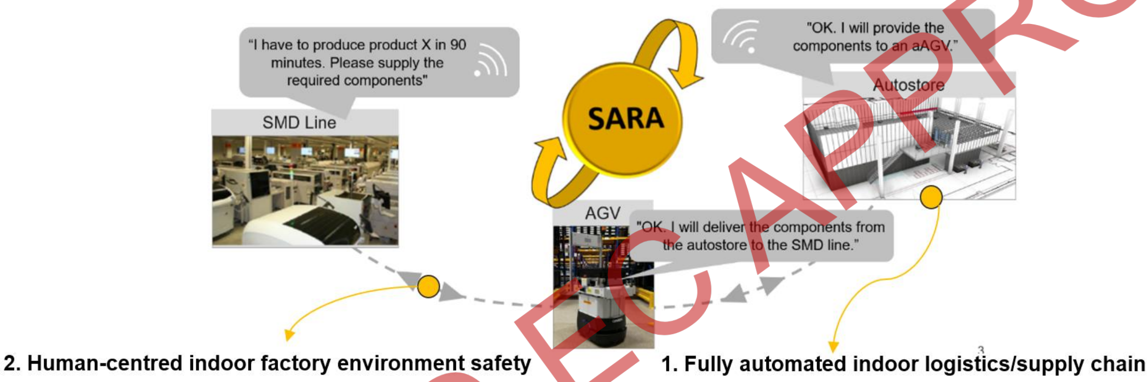


Figure 32: Abstract visualisation of material supply in Continental plant Ingolstadt

CONTI considers two applications to be implemented, relevant to validating NEMO, as follows:

SM_01: Fully automated indoor logistics/supply chain: This Use Case targets ADAS manufacturing. Currently, handling and transport of material (SMD-Components) from the Auto Store to the production sites are performed manually every 30 minutes. By utilizing a 3D-Vision-Camera for Bin Picking Application, an integrated Barcode Scanner and collaboration between different robot systems (one Cobot and several types of AGVs), CONTI aims to fully automate controlled material picking from Auto Store and autonomous transfer to the production line.

SM_02: Human-centered indoor factory environment safety. This Use Case will provide a high precision AGV localization layer merging real time localizations info obtained from cognitive sensors (safety cameras, radar and Lidar). A high speed and ultra-low latency (TSN) private wireless network will support massive data uploads to the edge cloud facilities, where AI functions will detect the position of each body and build a "safety shell" around it to ensure human-centered safety, while federated CF-DRL will enable model transfer learning to the AGVs to enable autonomous avoidance of potential collision between AGVs, or between a worker and an AGV.

4.2 Technical validation

The technical validation of the Trial #4 is done in Continental Ingolstadt in the Smart Technology and Application Room with the involvement of the technical experts and those responsible from the relevant areas such as logistics and production as well as the employees involved from the warehouse, material planning and the operators.

The trial aims to validate the following challenges:

- Improve mass production and safety in factories with high levels of automation, enabling Collaborative Robot (Cobots) systems, Automated Guided Vehicles' (AGVs) and humans' co-work.
- High-speed heterogeneous connectivity using 5G NR, TSN and WiFi and various types of AGVs.
- Analyze input from sensors, 3D cameras and RFID nodes and predict, identify and avoid collisions between humans and AGVs and between different types of AGVs.

4.2.1 Test scenario SM01_Test_Scenario_1

Table 11: Test Scenario for SM01 - Fully automated indoor logistics/supply chain

Scenario: SM01_Test_Scenario_1	
Scenario ID	SM01_Test_Scenario_1 (SM01_TS01)
Objective	• More efficient use of employees and improved ergonomics. • More flexible material removal. • Better just-in-time delivery (no longer clocked in 30 min). • Expansion to include backend production (till date only front end).
Description	The current situation refers to an inefficient operation because the materials are removed from the AutoStore every 30 minutes manually by an operator. For this, employees have to interrupt their other work. The process is not ergonomic and very time consuming. The future situation, generated by the Use Case trial, corresponds to a fully automated indoor logistics with focus on human and environment safety.
Features to be tested	• Correct component recognition in AutoStore. • Correct gripping / removing of the components. • Efficient and effective transfer to AGV. • Required communication between robot and AGV. The above functionalities will be tested within the following components of the NEMO platform: • AIoT Architecture (Cybersecure distributed learning framework, Federated meta-Network Cluster Controller, micro-services, Cybersecurity & Unified/Federated Access Control) • IoT/5G Time Sensitive Networking (TSN). • SEE and SLO meta-Orchestrator.
Requirements addressed	• **SM_01_FR01:** Bin Picking: The platform must ensure secure part recognition and handle position determination (no component destruction). • **SM_01_FR02**: Camera: Must ensure recognition of black parts in black trays. • **SM_01_FR03:** Bin picking: The application should provide a sufficiently short cycle time. • **SM_01_FR04:** Bin Picking: The application must ensure error-free component assignment / QR code read.
KPIs	• **KPI_SM_01_2:** Different types of sensors' data to be analyzed (> 10). • **KPI_SM_01_3:** System reaction in emergency cases (< 0,5 sec). • **KPI_SM_01_4:** ADAS supply chain improvement: accuracy (> 30 %). • **KPI_SM_01_5:** Cost and time reduction (> 20%).
Prerequisites	Facility conditions at the Ingolstadt location due to the historical structural development of the production and logistics areas present challenges and limitations in the implementation of automated material transport. Innovative and intelligent solutions are being sought.

	There is a well-organized process flow in place, which allows the full automation of material supply. The implementation and evaluation of the NEMO solution comprise several development phases and complexity steps.
Test steps	Step-by-step implementation of the trial: 1. Automatic component removal from storage. 2. Automatic component provision to AGV. 3. Extension to backend materials (optional).
Success state	The first three trial steps have successfully been realized. These steps contribute mainly to the first application "Fully automated indoor logistics/supply chain" In general, the project progress can be assessed as positive. So far, the set trial goals have been achieved. The trial is running according to schedule. The success rate will be measured according to the KPIs.
Failure state	Currently, both applications corresponding to the trial work according to the planning.
Responsible for testing and implementation	The core team for testing and implementation are the employees in Smart Technology & Application Room in strong cooperation with technical experts and those responsible from the relevant areas such as logistics and production as well as the employees involved from the warehouse, material planning and the operators.
Risks	• Automatic component recognition 📫✇ Failure. • Automatic picking process 📫✇ Scrap.

4.2.2 Test scenario SM02_Test_Scenario_1

Table 12: Test Scenario for SM02 - Human-centred indoor factory environment safety

Scenario: SM02_Test_Scenario_1	
Scenario ID	SM02_Test_Scenario_1 (SM02_TS01)
Objective	• Improve safety of operators working on the manufacturing processes. • Smart detection of the position of each body and build a human-centered safety environment around it. • More efficient use of employees and improved ergonomics.
Description	This scenario is focused on localizing the AGVs with high precision, by collecting and processing real-time data from smart sensors and devices (safety cameras, radar and Lidar). The private wireless network (TSN) will support great amount of data uploads to the edge cloud facilities, where AI algorithms will detect the position of each body and build a "safety shell" around, thus ensuring the human-centered safety.
Features to be tested	• Identifying the position of AGVs within the manufacturing processes. • Detecting the position of each body and build a safety area around it. • Processing the real-time data in order to avoid collisions between AGVs, or between a worker and an AGV. The above functionalities will be tested within the following components of the NEMO platform: • AIoT Architecture (Cybersecure distributed learning framework, Federated meta-Network Cluster Controller, micro-services, Cybersecurity & Unified/Federated Access Control). • IoT/5G Time Sensitive Networking (TSN). • SEE and SLO meta-Orchestrator.

Requirements addressed	• **SM_02_FR01:** The application should provide information about the localization of AGVs. • **SM_02_FR02:** The application must provide information about the localization of the human worker. • **SM_02_FR03:** The application has the capability of detecting/identifying the human body. • **SM_02_FR04:** The application will send alerts in case of potential collisions between human workers and AGVs.
KPIs	• **KPI_SM_02_1:** Different types of AGV and Cobots to be addressed (> 4). • **KPI_SM_02_3:** Improve human collision avoidance and manufacturing safety (30 %). • **KPI_SM_02_4:** Cost and time reduction (> 20%).
Prerequisites	Facility conditions at the Ingolstadt location due to the historical structural development of the production and logistics areas present challenges and limitations in the implementation of automated material transport. Innovative and intelligent solutions are being sought. There is a well-organized production workflow in place, which involves both human staff and robots. Data are collected via AGVs and Cobots and the devices are connected to the NEMO platform.
Test steps	Step-by-step implementation of the trial: 1. Automatic material transport to production, on the same floor. 2. Automatic material transport to production on another level (floor jump). 3. Extension to backend materials (optional).
Success state	The current focus of the trial is in the second application "Human-centered indoor factory environment safety" addressing the step 2 Automatic material transport to production on another level (floor jump). The Benchmark for a suitable technology was already evaluated with the SERVUS-System.
Failure state	Currently, both applications corresponding to the trial work according to the planning.
Responsible for testing and implementation	The core team for testing and implementation are the employees in Smart Technology & Application Room in strong cooperation with technical experts and those responsible from the relevant areas such as logistics and production as well as the employees involved from the warehouse, material planning and the operators.
Risks	No risks identified so far.

4.3 User experience validation

ASBS (Automated Sorting and Booking Station) is a first of this type of AI based technology in CONTI to ensure fully automated material supply covering the entire demand from AutoStore for ADAS Plant Ingolstadt. Sorting errors are eliminated and handling costs are reduced. A previously ergonomically not suitable manual picking can now be fully automated and seamlessly integrated with AutoStore. It works in sync with SAP & PLC real time. The new technologies contribute to performance excellence through optimization of existing processes and systems. The user experience will be evaluated by questionnaires.

4.4 Required equipment

Table 13: The equipment used in the Smart Manufacturing & Industry 4.0 trial.

Equipment	Description / Specifications	Type	Status
SARA	Standard Automated Replenishment Application	Edge/Cloud	available
AutoStore	Warehouse-System	Edge/Cloud	available
ASBS	Automated Sorting and Booking Station	Edge/Cloud	available
conveyor system	to transport parts	Edge	available
scan gate	to register the parts	Edge	available
Robot (TM / UR)	to sort and put away the parts	Edge	available
box station	for automatic supply of boxes	IoT/Edge	available
NAiSE	Order manager	IoT/Edge	available
aAGVs / Fleetmanagement	To transport material to production line	IoT/Edge	available
Servus	Floor jump material transport	IoT/Edge	In procurement

4.5 Data collection

The Automated Sorting and Booking Station (ASBS) works in sync with SAP & Product Life Cycle (PLC) ensuring real time booking. The process starts with the image recording of material in AutoStore box. A 3D Sensor placed over the box takes pictures of the content inside the box and evaluates them with the help of AI. The sensor uses light field measurement and has been evaluated specifically for this application. Due to the various surfaces of materials (especially transparent and mirroring packaging), it was not possible to identify material with the existing systems at Continental. The camera software transfers all relevant data to the PLC. Part of this data is the position of material, path of robot and size of material. The size of the material is relevant so that the gripper can be set to the correct size.

To generate the AI based bin picking neural networks were trained completely in-house to identify standard SMD reels, FR4 board packages, etc. More than 5000 pictures of various material packaging and forms in-house were trained. Similar-looking material is also very well recognized and contributes to the detection rate of 99.9 %. Due to the fact that this is standard material from the world market, recognition using a classical algorithmic approach is not possible with the high recognition rate. The AI therefore not only recognizes the pick position but also provides the following information: material category, pick position, barcode of the selected material and number of materials in the image.

4.6 Alignment with NEMO

Description of specific Use Case developments

The Automated Sorting and Booking Station (ASBS) is a first of this type of artificial intelligence (AI) supported technology in Continental to ensure fully automated material supply that completely covers the entire demand from AutoStore for ADAS Plant Ingolstadt.

The technology is meanwhile successfully tested at the smart technology application room in Ingolstadt. With a target of at least 3000 picks per day, it offers a substantial improvement over manual picking process. Additionally, it ensures a complete touchless material flow and thereby technical cleanliness.

A unique combination of a Light Field Camera system in combination with image evaluation with neural networks allow for a 100 % fulfilment of the AutoStore demand for ADAS Plant Ingolstadt. One of the challenges in identifying the materials is that unfortunately there are no awareness of what kind of material is in the box placed from the AutoStore. Glossy film packaging and transparent reels brings classic 3D-sensors (Triangulation) to its technical limits. This could not be set to known and shared sensors. After a thorough market analysis, an evaluation of a light field sensor from a startup company named HD Vision was done. This sensor uses the physical conditions of light field refraction and thus also recognizes transparent or reflective surfaces. HD Vision provided a stable and secure solution. Due to the fact that not only reels but also Printed Circuit Board packages and various mechanical components (e.g. lenses, flexcables, etc.) are stored in the AutoStore, standard grabbers and suction systems available on the market were not suitable. A new tool has been developed and purpose - built in house. Also, the project automated the booking in SAP from the warehouse to production.

During image evaluation, the material label is read and transmitted to SAP. The business software developed by the central I4.0 team for sorting incoming goods is extended also for outgoing goods by adapting the middleware.

In the last step, the robot places the reels inside a transfer box. The robot always has two free transfer boxes for placing the materials, if a new box is needed for a new destination, it is provided via one of the two box towers. A total of ten sorting targets are available to the robot. When the robot is done, the transfer box is made available for further transport for the automated Autonomous Guided Vehicle (aAGV) via a conveyor line. The transfer boxes are then automatically transferred to the aAGV which brings it to production.

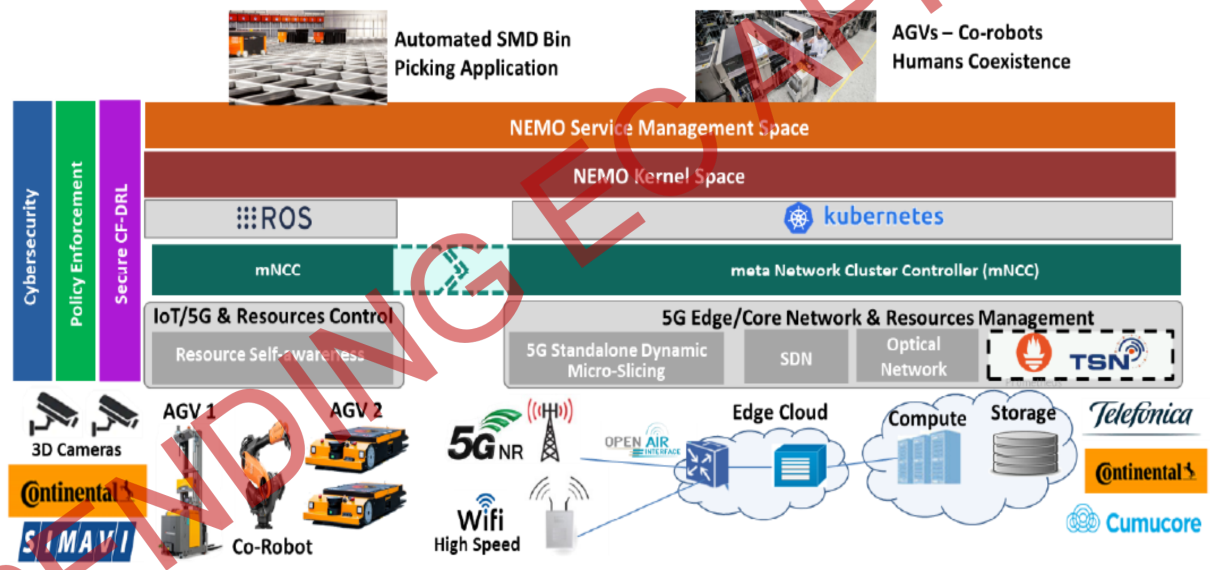
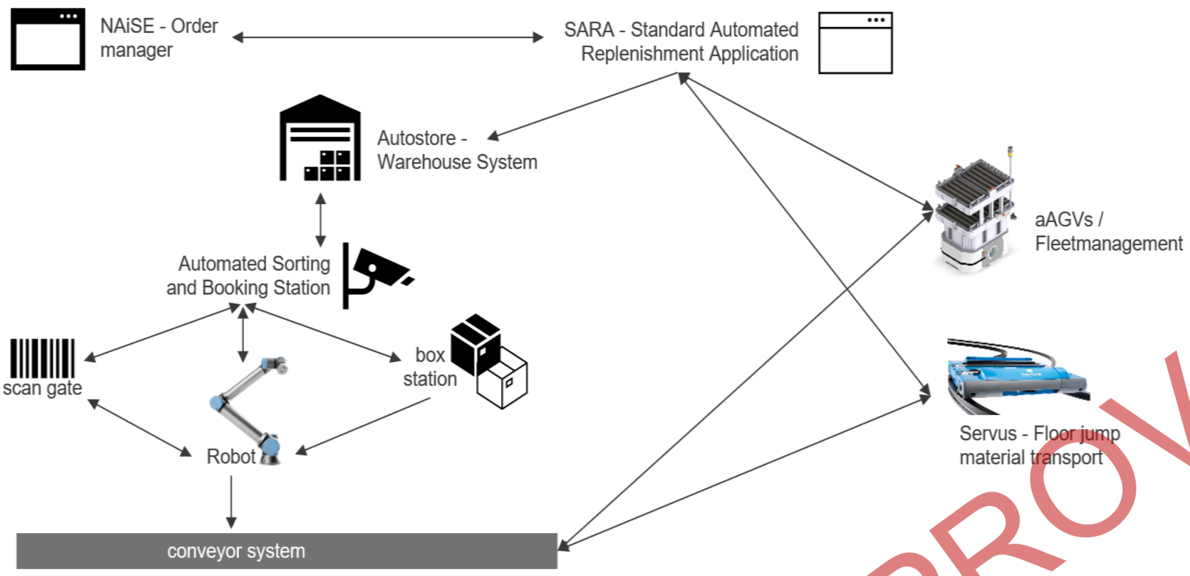


Figure 33: AIoT architecture specific to Smart Manufacturing & Industry 4.0 trial

4.7 Use case diagrams

Specific Use Case sequence diagrams have been drafted to reproduce the flow of processes and operations corresponding to Trial #4. In the following, a graphical diagram of the workflow is presented in order to highlight each element and the links between the elements, as described hereinbefore, in Chapter 4.6.



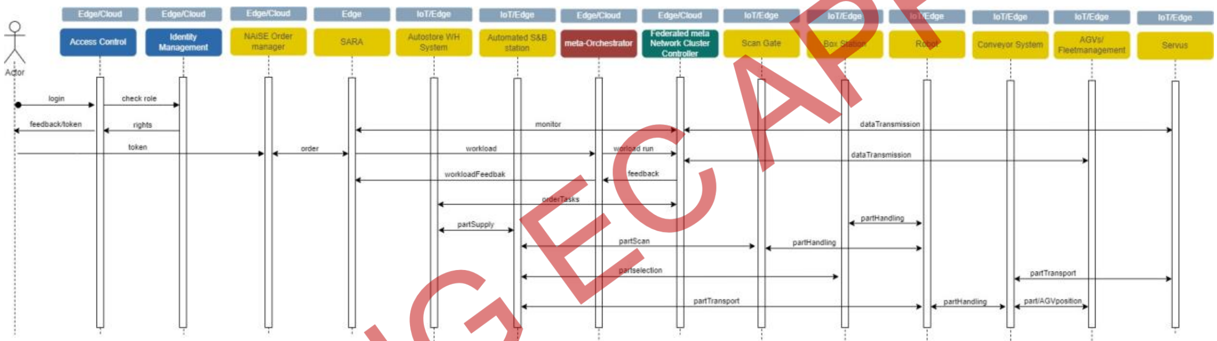


Figure 34: Use Case sequence diagrams for Trial #4

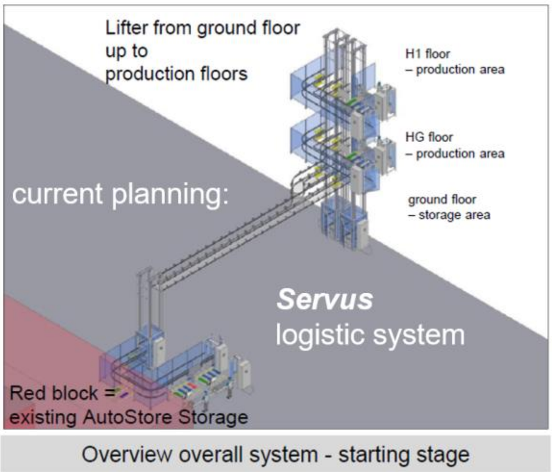
4.8 Roadmap

The focus of the first project year was the "Fully automated indoor logistics/supply chain", as indicated in Figure 35.

Figure 35: Fully automated indoor logistics/supply chain for Trial #4

The concept for a fully automated indoor logistics/supply chain was realized and tested in Smart Technology and Application Room at Continental Ingolstadt. The essential sensors were selected after a detailed benchmarking analysis. The technical feasibility of the concept and the compatibility of the sensors were evaluated.

The current project focus is represented by the second scenario - Human-centered indoor factory environment safety, as shown in Figure 36.



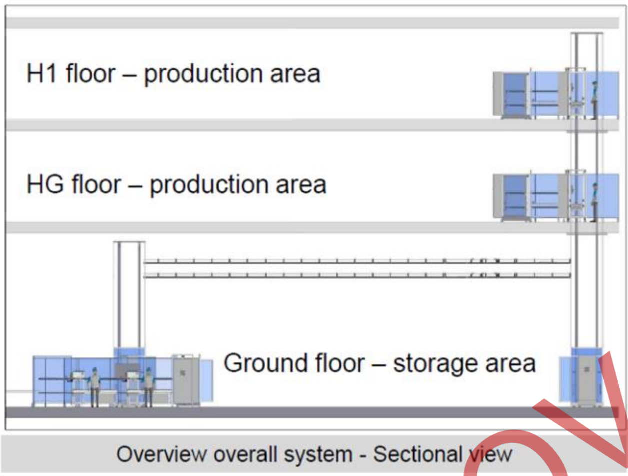


Figure 36: Human-centred indoor factory environment safety, as realized in Trial #4.

A concept of a floor jump for the material transport was generated. This concept will be evaluated, starting with a small number of shuttles and expansion of the fleet over the course of the test period (till end of 2024 /second project year.

4.9 Initial results

Two applications are planned to be demonstrated, validating NEMO. These refer to the fully automated indoor logistics/supply chain and the human-centered indoor factory environment safety. The concept for both applications has been developed. The Automated Sorting and Booking Station (ASBS) scans, sorts and handles all reels, drypacks and PCBs automatically. The robot sorts the reels into boxes with the help of scanning stations, and these reels can then be sent to the warehouse or production. The ASBS consists of conveyor system to transport parts, scan gate to register them, robot to sort and put away the parts, and box station for automatic supply of boxes. The process starts with the image recording of the material in the AutoStore box. The camera software transfers all relevant data to the PLC. The data includes the position of the material, the size of the material and the label information. The size of the material is relevant so that the gripper is set to the correct size. Also, the project automates the booking in SAP from warehouse to production. In the last step, the robot places the reels inside a transfer box. The robot always has two free transfer boxes for placing the materials, if a new box is needed for a new destination, it is provided via one of the two box towers. A total of ten sorting targets are available to the robot. When the robot is done, the transfer box is made available for further transport for the aAGV via a conveyor line. The transfer boxes are then automatically transferred to the aAGV. The orders for the aAGV are created via the NAiSE Order manager. Current activities are focused on the concept implementation of a Servus transport system to realize the floor jump.

Table 14: Challenges emerged and solutions developed

Challenges	Solutions
Arrival of reels in mixed sequence	Auto GR booking
High efforts for individual scanning and transfer	Scanning system alert
Unable to trace urgent orders	Scan gates and sorting robots
High efforts in priority and data handling	Multiple POs and scan list available
High Lead time and probability of failure	Reduced manual touch points

5 Smart Media & XR

5.1 Trial site description

5.1.1 Smart Media/City

This trial tries to enhance the live running sport event spectating experience by enriching the content through AI driven data and content analysis and XR capabilities. During the race, media content is captured by many spectators and selected runners along the running circuit using smartphones/tablets and GoPro cameras, and if existent IP cameras and drones.

Incoming content is automatically processed, annotated and rendered (partially on the device using already trained AI/ML models and partially at the edge), and a selection is directly broadcasted (e.g. via social media) based on location info of the (top) runners and interesting events during the race (e.g. based on contributor annotation).

The audience has the option to improve their contributions and can interact with contributors in case of specific race incidents. The emphasis is on real-time user generated content processing and rendering using FL hosted locally on the IoT nodes (smart phones), in the edge and at the cloud. The AI/Models will be trained to recognize the Racing Bib Numbers on each athlete and street numbers and landmarks of the race in order to first understand the runners in each stream and then enhance the positioning identification of the stream and runners in it.

The race is taking place in a closed and controlled environment of a stadium and also its surroundings. Mobile base stations are deployed to give coverage several km outside of stadium. The commercial network will be used Need to create a dedicated network on top of the commercial network. The resources where the components will be deployed as VM are 2 compute nodes and 1 Control Node. One GPU will be also available as resource for the AI computations.

- We can have the geographical location and identification of places.
- It would be possible to have race situation analysis (to evaluate depending on the final pilot scenario).
- We can have the wired cameras.
- Drones could be possible.

5.1.1.1 Trial Stadium Description

The Smart media Use Case will be hosted in Athens Greece. The OTE building (OTE Academy) in the north side of the city, is a multi-functional complex, that will host the NEMO platform. This site will host the cloud infrastructure where all necessary components of the NEMO platform for the use case implementation will be located. Internet access will be provided by OTE.

Figure 37: OTE Academy Premises

The Smart media Use Case will be hosted in the stadium of Egaleo. This stadium is located in west Athens and will be used to host demonstrations in a more “realistic” environment and suitable to the requirements of Media Use Case.

Figure 38: Egaleo stadium (https://maps.app.goo.gl/NguFsydgTcu7MeJU9)

Figure 39: Egaleo stadium premises

The Smart media Use Case is a demanding use case in terms of network requirements. Although as it is shown below, the stadium is fully covered by OTE's 5G mobile network, during the day of the pilot the coverage will be further enhanced by a mobile station.

Figure 40: Egaleo stadium 5G coverage

5.1.2 Smart Media/XR

The XR use cases will be hosted at the Hellenic Cosmos Cultural Center of the Foundation of the Hellenic World. The Hellenic Cosmos is a multifunctional area where visitors experience Hellenic history and culture, while at the same time it is a venue of cultural creation and expression. In its areas we organize a wide range of activities, open to people of all ages and interests. The XR use cases will enhance two VR experiences available to the public using gestures recognition and biometric data. The experiences that will be enhanced are: a) A VR Head Mounted Display (HMD) experience regarding the visit of an ancient Greek Workshop and b) An interactive real-time VR Dome experience that is presented at the Tholos Dome VR Theatre of the Hellenic Cosmos. The trial consists of several micro-services that are going to be deployed in the continuum (central cloud, edge cloud, IoT devices) via the NEMO platform. The infrastructure in FHW premises (local VMs, servers, IoT/VR devices, etc) consists of the edge/IoT infrastructure and external infrastructures (Central Cloud, HPC servers) will be used for services that demand high computational resources.

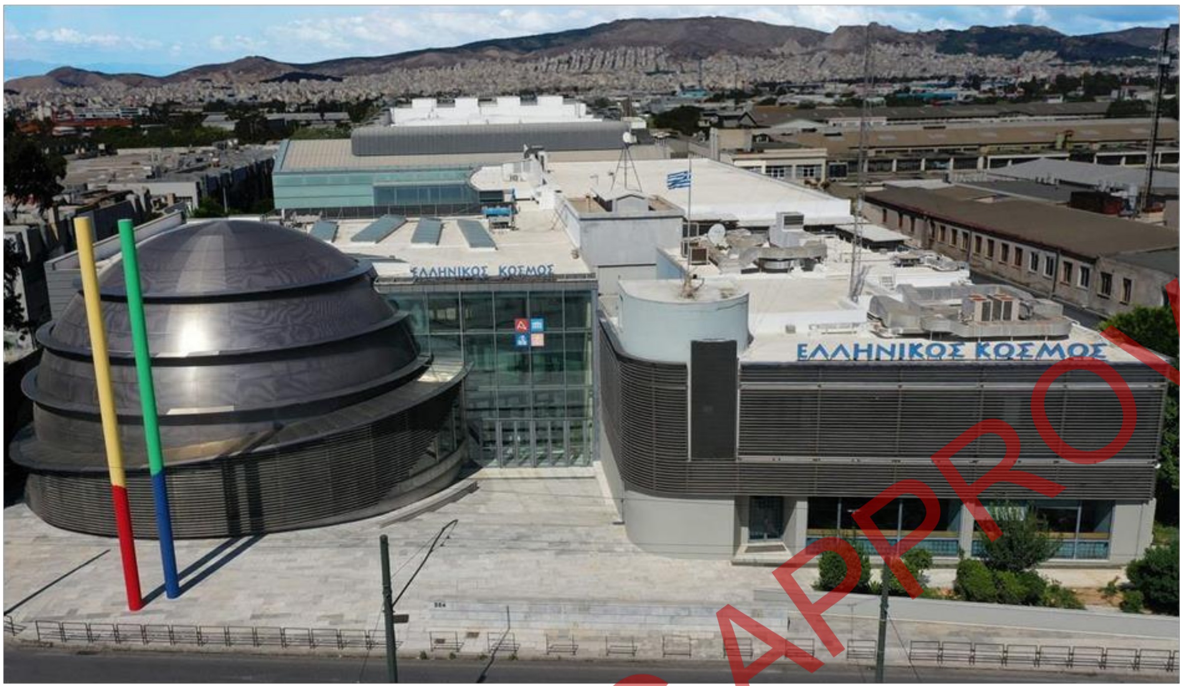


Figure 41: The Hellenic Cosmos Cultural Center. On the left the VR Dome Theatre

5.1.2.1 XR01 - VR Experience about ancient Workshop of sculptor Phidias

The visitors to the premises of FHW Cultural Center will experience a VR application that presents everyday life in the workshop of a famous sculptor Phidias. The users can live the experience of participating in several actions and activities as they are executed in the workshop. The XR application will be based on heterogeneous IoT devices (i.e., Wearables, AR/VR headsets etc.) and is going to collect and analyze anonymized biometric data from the users in order to estimate their emotional and physical status during the VR experience in order to adapt the experience to the user. The specific use case is going to use state-of-the-art machine learning algorithms that are going to be trained and executed in the IoT-to-Edge-to-Cloud continuum.

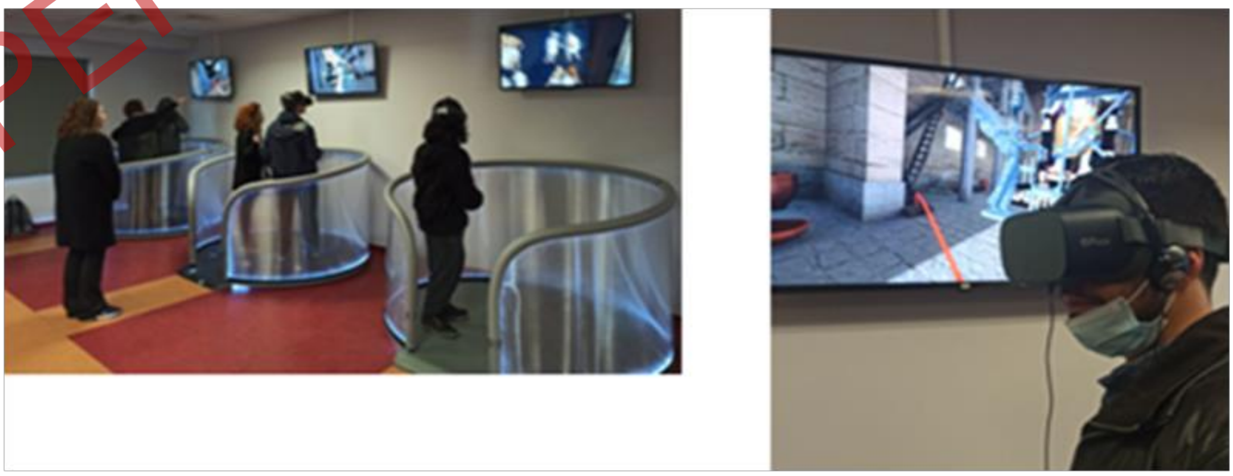


Figure 42: Visitor VR Pods for the HMD Experience “Visit the Workshop of Phidias”

5.1.2.2 XR02 - Enhance AV experience in the Tholos Dome VR Theatre

This scenario is going to further enhance the user's audiovisual (AV) experience in the Tholos Dome VR Theatre by providing the appropriate software and tools to enhance the spectator's experience using additional interconnection to IoT devices and in addition to audiovisual effects. This scenario will analyze the physical position of the presenter and it will perform gesture recognition based on state-of-the-art machine learning algorithms. The system trains and executes ML models in the IoT-to-Edge-to-Cloud continuum and it will trigger events in real time that are going to be consumed by subscribed IoT devices such as smart displays and the actual application that is executed at real-time for triggering actions in the virtual world.

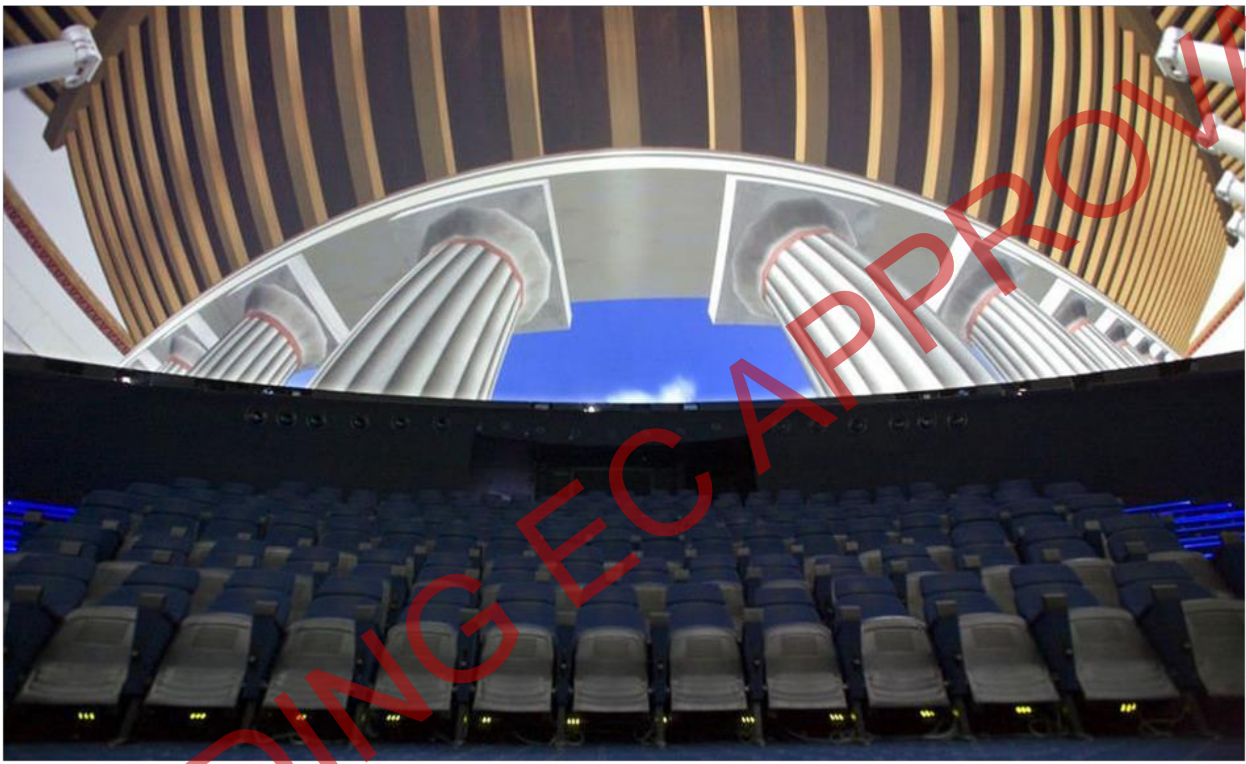


Figure 43: Inside the VR Dome Theatre

5.2 Technical validation

Below follows a description about the three scenarios they will take place as part of this trial. SC stands for Smart Media/City (has one scenario) and XR for Smart Media XR use cases (has two scenarios).

The Smart Media/City scenario will validate the usage of NEMO during live events with focus on mass user interaction using a device APP, an AI/ML component that will recognize the position of runner from their numbers and enhanced oversight of the race using the APP. Its primary focus is on handling video streams, do automatic or manual annotation and authoring to produce new streams for consumption. Furthermore, the GPS location to identify the position of each runner or event depicted in the video will also we calculated.

The XR scenarios will validate the usage of NEMO with VR productions and how they can be enhanced using AI/ML components and opened up for interaction with IoT devices. Primarily the AI/ML components that do gesture recognition on Tholos presenter and emotion detection on the users of AR/VR applications, will be validated as part of the NEMO ecosystem and their ability to be used in real-time VR facilities as the ones provided to the public by the Foundation of the Hellenic World.

5.2.1 Test scenario SC01_Test_Scenario_1

Table 15: Test Scenario for the Smart media/City use case

Scenario: SC01_Test_Scenario_1	
Scenario ID	SC01_Test_Scenario_1
Objective	Enhance the live sport event spectating experience by enriching the content through AI driven data and content analysis via NEMO components and manual production control. Nemo will provide the base components to facilitate communication, network access, migration etc.
Description	During the race, media content is captured by many spectators and selected runners along the running circuit using smartphones/tablets and GoPro cameras, and if available IP cameras and drones. Incoming content is automatically processed, annotated, and rendered (partially on the device using already trained AI/ML models and partially at the edge), and a selection is directly broadcast (e.g. via social media) based on location info of the (top) runners and interesting events during the race (e.g. based on contributor annotation). The audience has the option to improve their contributions and can interact with contributors in case of specific race incidents. The emphasis is on real-time user generated content processing and rendering using FL hosted locally on the IoT nodes (smart phones), in the edge and at the cloud. The AI/Models will be trained to recognize the Racing Bib Numbers on each athlete and street numbers and landmarks of the race in order to first understand the runners in each stream and then enhance the positioning identification of the stream and runners in it. NOVO's mobile app aims to engage runners/spectators/users, facilitating both enhanced content experience and feeding captured events combined (pictures, videos and/or annotations, time and location data).
Features to be tested	meta-Orchestrator, Intent-based SDK (manual authoring), Identity Management & Access Control (users), Intent-based Migration-Controller, CF-DRL (for AI), MOCA (for monetization services), CMDT (for Delivery manager optimization training
Requirements addressed	SC_01_FR01-22, SC_01_NFR01-06
KPIs	KPI_SC_01_1-7
Prerequisites	The NEMO platform should be accessible and running. More than 10 users should be available for using the App and the Trial infrastructure. More than 5 video feeds as sources available at any time. Sources can be Cameras located at the event, Drones, Runner cams and user content provided through the App. A 4-5G network coverage should exist at all places in order to provide high bandwidth and multipath connectivity. Stadium and location for run. User with Phones and App installed. Media Managers for receiving streams and distribution of processed streams available through NEMO components. Production Control system for stream authoring as NEMO plugin service. An AI component as a NEMO resource for automatic annotation and authoring. Network Probe for Media adaptation on network quality.
Test steps	NEMO is deployed and operational. This includes: • Media Production Engine, which includes virtualized video editing tool, virtualized video coding, virtualized video mixer, virtualized video compressor.

	• Cognitive services, which includes data processing, virtualized video annotation tool, AI engine, QoE optimizer, data fusion with external data. • Emission selector, which includes AI engine, Virtualized Media Delivery Manager for delivery. • GoPro cameras on runners, smartphone cameras of spectators, (optional) professional and drones IP cameras are connected to platform and send real time data. • The platform users (professionals) are registered to the platform. Users open App and register as meta-OS consumer. Additional cameras and Runner Cams get ready and broadcast as met-OS providers. Production control commences and AI component start analyzing video feed at the same time NEMO collects monitoring data and workloads. When power of AI reaches a predefined limit, NEMO undertakes reallocation to other devices. Users interact with the APP, choose what their desired viewing experience (general overview, specific runner, action event etc.), but also contribute uploading video and actions as they happen live.
Success state	The users have access to enriched content that includes: • GPS location of the cameras and runners. • AI driven BiB and street image detection for running events. • A program signal created by a professional technical director. • General overview of the event situation (classification, groups, time advantage, etc.). • Runners' numbers recognition for race positioning tracking.
Failure state	AI component fails to identify runner BiB numbers. Production control is not optimal and does not provide qualitative stream. App fails to stream or view specific events. GPS signal is not enhanced.
Responsible for testing and implementation	UPM, NOVO, OTE, TID
Risks	• High computing resources. • High network latency. • High video latency (both for technical director and video delivery). • Synchronization of events with media content. • Right access to content with privacy preservation. • Quality of Experience (QoE) optimization.

5.2.2 Test scenario XR01_Test_Scenario_1

Table 16: Test scenario 1 for the ancient workshop use cases

Scenario: XR01_Test_Scenario_1	
Scenario ID	XR01_Test_Scenario_1
Objective	VR Experience about ancient workshop of sculptor Phidias. Enhance experience with biometric data.
Description	The VR application presents everyday life in the workshop of a famous sculptor Phidias. The users are able to live the experience of participating in several actions and activities as they are executed in the workshop. The XR application will be based

	on heterogeneous IoT devices (i.e., Wearables, AR/VR headsets etc.) and is going to collect and analyze anonymous biometric data from the users in order to estimate their emotional and physical status during the VR experience in order to adapt the experience to the user. The specific use case is going to use state-of-the-art machine learning algorithms that are going to be trained and executed in the IoT-to-Edge-to-Cloud continuum.
Features to be tested	Meta-Orchestrator (Workload deployment) PPEF (data [image, videos] privacy compliance) Intent-based API mNCC (micro-slice for sending video/images) SEE (select secure execution (e.g. ML model inference) at edge, cloud) LCM
Requirements addressed	XR_01.FR01, XR_01.FR02, XR_01.FR03, XR_01.FR04, XR_01.FR05, XR_01.FR06, XR_01.FR07 XR_01_NFR01, XR_01_NFR01, XR_01_NFR03, XR_01.FR04
KPIs	KPI_XR_01.1, KPI_XR_01.2, KPI_XR_01.3, KPI_XR_01.4, KPI_XR_01.5, KPI_XR_01.6
Prerequisites	The NEMO platform should be installed and configured, including at least 1 cluster of at least 1 wearable device providing biometric measures, 1 AR/VR headset, 3 edge/cloud devices. The ML application for emotional detection should run on edge devices. Monitoring data about resources and workload running on them should be available and sufficient to allow evaluating the workload performance and device capabilities, including energy consumption and efficiency. At least 1 user is registered as NEMO consumer and has access to workload LCM information, as well as at least 1 user registered as meta-OS Provider.
Test steps	• The Smart XR application owner signs in NEMO as meta-OS consumer. • The application owner uploads the workload descriptor on the NEMO platform. • The application owner deploys the application over the continuum via the NEMO API. • The application owner imitates test scenario 1. • The application owner monitors the workload execution and confirms that data from the wearables are sent, analyzed, and consumed properly (LCM) • The application owner retrains the ML model (this process requires the ML micro-service to be migrate to HPC infrastructure). • The application owner terminates the execution and collects the logs.
Success state	• Application running in AR/VR headset consumes successfully events by ML emotional detection service. • Application running in AR/VR headset stops on detection of user's emotional event. • Successfully training of the ML models in central/edge HPC nodes.
Failure state	AI-ML application fails to deploy or to detect emotions, VR app and IoT devices do not receive status changes or do not adapt correctly.
Responsible for testing and implementation	MAG, FHW
Risks	No risks identified so far.

5.2.3 Test scenario XR02_Test_Scenario_1

Table 17: Test scenario 1 for the use case in Tholos Dome VR Theatre

Scenario: XR02_Test_Scenario_1	
Scenario ID	XR02_Test_Scenario_1
Objective	Enhance AV experience in the Tholos Dome VR Theatre. Analyze gesture of museum-educator presenter. Gesture based recognition by using ML in IoT-to-Edge-to-Cloud continuum.
Description	This scenario is going to further enhance the user's audio-visual (AV) experience in the Tholos Dome VR Theatre by providing the appropriate software and tools to support additional interconnection to IoT devices (i.e. cameras, external stimuli systems, etc) and in addition to audio-visual effects. This scenario will analyze the physical position of the presenter and it will perform gesture recognition based on state-of-the-art machine learning algorithms. The system trains and executes ML models in the IoT-to-Edge-to-Cloud continuum and it will trigger events in real time that are going to be consumed by subscribed IoT devices such as smart displays as well as the actual application that is executed at real-time for triggering actions in the virtual world.
Features to be tested	Meta-Orchestrator (Workload deployment) PPEF (data [image, videos] privacy compliance) Intent-based API mNCC (micro-slice for sending video/images) SEE (select secure execution (e.g. ML model inference) at edge, cloud) LCM
Requirements addressed	XR_02.FR01, XR_02.FR02, XR_02.FR03, XR_02.FR06, XR_02.FR07, XR_02.FR08, XR_02.FR09 XR_02_NFR01, XR_02_NFR02, XR_02_NFR04, XR_02_NFR04, XR_02_NFR05
KPIs	KPI_XR_02.1, KPI_XR_02.2, KPI_XR_02.3, KPI_XR_02.4, KPI_XR_02.5
Prerequisites	The NEMO platform should be installed and configured, including at least 1 cluster of at least 1 digital camera, 1 smart display, Tholos gateway, 3 edge/cloud devices. The ML applications for gesture recognition should run on edge devices. Monitoring data about resources and workload running on them should be available and sufficient to allow evaluating the workload performance and device capabilities, including energy consumption and efficiency. At least 1 user is registered as NEMO consumer and has access to workload LCM information, as well as at least 1 user registered as meta-OS Provider.
Test steps	• The Smart XR application owner signs in NEMO as meta-OS consumer. • The application owner uploads the workload descriptor on the NEMO platform. • The application owner deploys the application over the continuum via the NEMO API. • The application owner initiates test scenario 2. • The application owner monitors the workload execution and confirms that data from the camera and wearables are sent, analyzed, and consumed properly (LCM). • The application owner terminates the execution and collects the logs.
Success state	• VR Dome application consumes successfully events by ML gesture recognition service.

	• VR Dome application reacts properly to the presenter signals. • Subscribed IoT devices such a smart TV show info.
Failure state	AI-ML app fails to deploy or to detect gestures, VR application and/or external IoT devices do not receive status changes or do not adapt correctly.
Responsible for testing and implementation	MAG, FHW
Risks	No risks identified so far.

5.3 User experience validation

5.3.1 Smart Media/City

The user experience validation will be based on feedback from the group of NOVO's app end users that will participate in the trial. Users' feedback will be collected through questionnaires aiming to validate and improve the overall spectator/user experience in terms of usability, clarity of interface, overall user experience and satisfaction. Additional feedback will be evaluated considering factors like weather conditions, obstacles and other constraints that could affect the functionality, accuracy, and efficiency of the NOVO app.

5.3.2 Smart Media/XR

The user experience validation will be based on feedback from volunteers that will participate in the application scenarios from different role types (i.e. system administrator, application owner, presenter, etc.). Users' feedback will be collected by specific questionnaires that are going to filled out after the end of each use case scenario.

5.4 Required equipment

OTE partner will provide the cloud infrastructure for hosting the NEMO platform components and functions for the proper implementation of the use case. More specifically, 2 compute nodes and 1 Control Node with more than 160 vCPUs, 500GB HDD and about 200 GB RAM, as shown in table below. One GPU will be also available as resource for the AI computations.

5.4.1 Smart Media/City equipment

Table 18: Required equipment for the Smart Media/City use case

Equipment	Description / Specifications	Type	Status
Android Phone	App for Users	Race Stream App, Race Spectator App	Defined Wireframe, in implementation phase
Media Gateway	For video content adaptation to video over IP	Video2Video-over-IP component that could be hardware or software depending on the source's characteristics.	Defined

Equipment	Description / Specifications	Type	Status
Media Delivery Manager	For content delivery and streaming	IP based streaming network with RTMP servers following a typical CDN architecture.	Defined Architecture in implementation phase
Stream Transcoder, Smart Stream Selector, Stream Monitor, Production Code	Media Production Engine	VM Docker	Defined Architecture in implementation phase
Production Control	Will be hosted in Spain TID	OBS/Voc2Mix, FFmpeg	Defined Architecture in implementation phase
Video Quality Probe, Network Probe	Cognitive Services	VM Docker	Defined Architecture in implementation phase
AI Engine	AI/ML annotation	GPU, VM TensorFlow/PyTorch	Defined Architecture and in implementation phase
IP Cameras, GoPro Runner Cams, IP Drone cams	For additional capture	HW	TBD

Table 19: Hardware requirements for business specific components of the Smart Media/City use case

Component	Deployment Area	vCPU	RAM (GB)	HDD (GB)	OS	SW Dependencies	Deployment	Comments
Race Stream App	TBD	-	-	-	Android	TBD	Local App	NOVO
Media Gateway Manager	TBD	8	8	50	Ubuntu	TBD	Cloud	OTE
Stream Transcoder (feeder)	Edge	m*8	m*8	m*15	Ubuntu	Docker, FFmpeg	Cloud	At least one Stream Transcoder per race stream (m=6)
Stream Transcoder (PGM)	Edge	12	8	25	Ubuntu	Docker, FFmpeg	Cloud	
Smart Stream Selector	Edge	4	4	15	Ubuntu	TBD	Cloud	
Production Core	Edge	8	8	15	Ubuntu	OBS/Voc2Mix, FFmpeg	Cloud/Edge	

Component	Deployment Area	vCPU	RAM (GB)	HDD (GB)	OS	SW Dependencies	Deployment	Comments
Production Control	TBD	8	8	30	Ubuntu	OBS/Voc2 Mix, FFmpeg	Cloud/Edge	Deployed on TID infrastructure
Media Delivery Manager	TBD	16	16	50	Ubuntu	TBD	Cloud/Edge	OTE
Race Spectator App	TBD	-	-	-	Android	TBD	LocalApp	NOVO
Information Bus	TBD	2	2	10	-	TBD	Cloud	Apache Kafka/RabbitMQ. NEMO infrastructure
Video Quality Probe	Edge	(m+o)*8	(m+o)*8	(m+o)*10	Ubuntu	Docker, FFmpeg	Cloud/Edge	They will be deployed on several parts of the architecture (m=6 + o=2)
Network Probe	Edge/Local	4	8	100	Ubuntu	Kubernetes	Cloud/Local	Need to have Intel NIC (Network Interface Card)
AI Engine	Edge	1 GPU	16	20	Ubuntu	TensorFlow/PyTorch	Cloud/Edge	Bib detection; landmark recognition
VPN	-	4	4	10	TBD	TBD	Cloud/Edge	TID

5.4.2 Smart Media/XR equipment

VR Dome rendering and Compute cluster, VR head mounted displays and controllers, as well as smart TVs and minor Arduino and Raspberry HW is to be provided by the FHW. All other resources come from OTE and MAG.

Table 20: Required equipment in the Smart Media/XR use cases

Equipment	Description / Specifications	Type	Status
Smartwatch	Smartwatch device will collect biometric data from AR/VR users	IoT/FHW premises	Available

Equipment	Description / Specifications	Type	Status
Camera	Camera will capture video from presenter to feed ML gesture recognition application.	IoT/FHW premises	Available
AR/VR headset	AR/VR headset application will consume users' emotional status and will react to it accordingly.	IoT/FHW premises	Available
Tholos Dome	Tholos Dome applications will react to it accordingly to the presenter gestures.	IoT/FHW premises	Available
Edge node	Edge node for running edge analytics for emotional and gesture recognition and local ML model training.	Edge/FHW premises	Available
Cloud node	Cloud resources to support ML model training activities.	HPC Cloud	Available

Table 21: Specific HW requirements per component for the Smart Media/XR use cases

Component	vCPU (vCores)	RAM (GB)	HDD (GB)	OS	SW dependencies	Comments
message broker	2	2 GB	10 GB	Ubuntu – centOS	Docker, Kubernetes	RabbitMQ (Edge)
event server	2	1 GB	10 GB	Ubuntu – centOS	Docker, Kubernetes	HTTP Rest (Edge)
ML model #1	4 - 8	8 – 16 GB	10+ GB	Ubuntu - centOS	Docker, Kubernetes, Tensorflow, opencv	Gesture recognition (Edge - Cloud)
ML model #2	2 – 4	4 – 8 GB	5+ GB	Ubuntu – centOS	Docker, Kubernetes, Tensorflow, scipy	Physiological emotion recognition (Edge – Cloud)
DB	2	4 GB	20+ GB	Ubuntu - centOS	Docker, Kubernetes	Postgress, Timeseries to store collected Data (Edge)
Camera gateway	2	4 GB	16 GB	Linux	Docker, Kubernetes, Python	Will run on IoT device or edge server, mounted on IoT device, Jetson (IoT - edge)
Wearable gateway	2 – 4	1 GB	8 GB	Linux	Docker, Kubernetes	Will run on a raspberry close to the IoT device (IoT – edge)
HPC	1-2 GPUs	20GB	1TB	Linux	Kubernetes	The SmartXR use case will need access in an external HPC cluster for the training of the ML models that are going to be used.

5.5 Data collection

5.5.1.1 Smart Media/City

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

Video Media content during the race: RGB video feeds From App users, camera and droned and runner cams.

GPS Data: As non-media source from the app and the AI-ML component recognition.

Network QoS status: obtained through network provider and Network QoS probes.

Runner bib identification: Racing Bib Number Recognition (RBNR) dataset [18], TGCRBNW dataset [19].

5.5.2 XR01 Use Case

Emotion recognition multimodal dataset with smartwatch data. This dataset will combine data originating from smartwatches such as **heart rate**, **skin temperature**, **acceleration** etc. These instances will be measured concurrently and labelled based on location and type of application. The collected data will be anonymous and are going to be used both for training the ML model and for interference. Regarding the ML application relative open-source datasets are evaluated such as the Nurse Stress Prediction Wearable Sensors dataset is designed for stress detection and includes various features such as orientation data, Electrodermal Activity (EDA), Heart Rate (HR), skin temperature (TEMP), an identifier (id) with 18 categorical options, and datetime stamps.

5.5.3 XR02 Use Case

Hand gesture recognition dataset. This dataset will recognize hand gestures from camera AV footage and add relevant labels. The collected **images** will be anonymity and the ML model will be trained to recognize specific gestures from the presenter in Tholos. Currently, the ML model analyzes video input (30 frames per sample) and has been trained to successfully recognize specific gestures and trigger the appropriate actions (i.e. Volume up/down, Lights on/ off, emergency stop application, Virtual effects, etc.).

5.6 Alignment with NEMO

Table 22: NEMO technologies used in the Smart Media/City/XR trial

NEMO functionalities	Foreseen exploitation
AIoT Architecture	Modular and secure use of the AIoT meta-architecture for the underlying implementation.
On-device federated MLOps and TL via CF-DRL	Used to analyze video inputs and recognize actions and persons, gestures and analyze user biodata, based on AI processing.
Federated and Network Adapters	Used for bandwidth and data connection resource transmission.
SEE and meta-Orchestrator	Flexible allocation and secure deployment of services.
Plugins' Life-Cycle Manager and MOCA	Launching, lifecycle management and accounting of apps.
Intent-based migration SDK	Easy deployment and migration for services.

NEMO functionalities	Foreseen exploitation
Policy Enforcement and Cybersecurity Vertical	Implement policy and press enforcement on new posts.
Support 3rd Parties via Open Calls	Open Call for usage of infrastructure based on NEMO meta-OS.

5.6.1 Smart Media/City Specific Developments

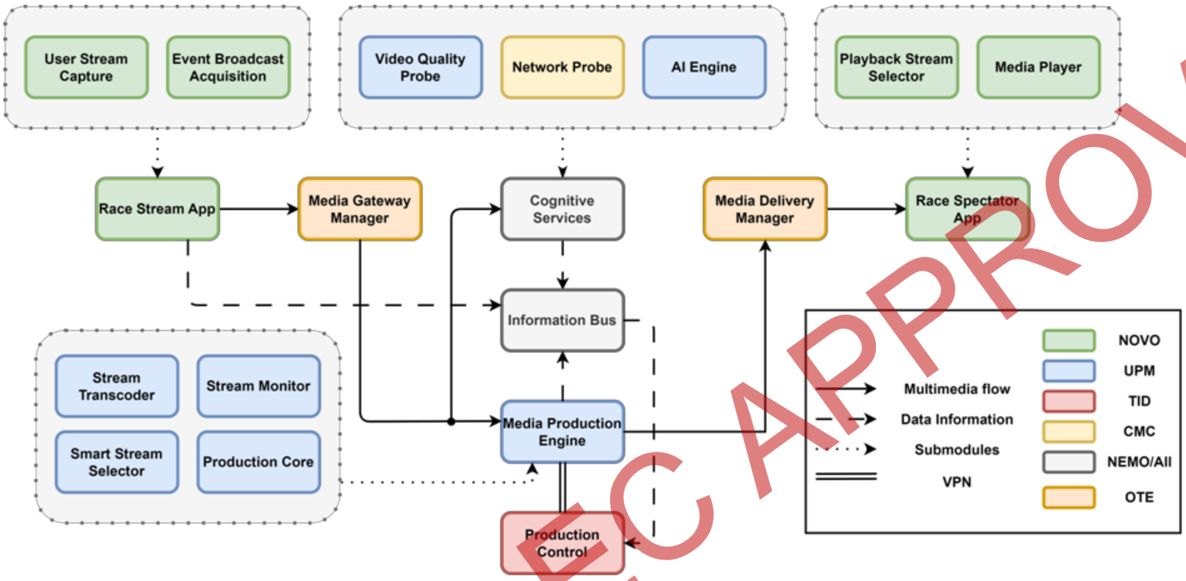


Figure 44: Infrastructure Topology with components and responsible partner implementation

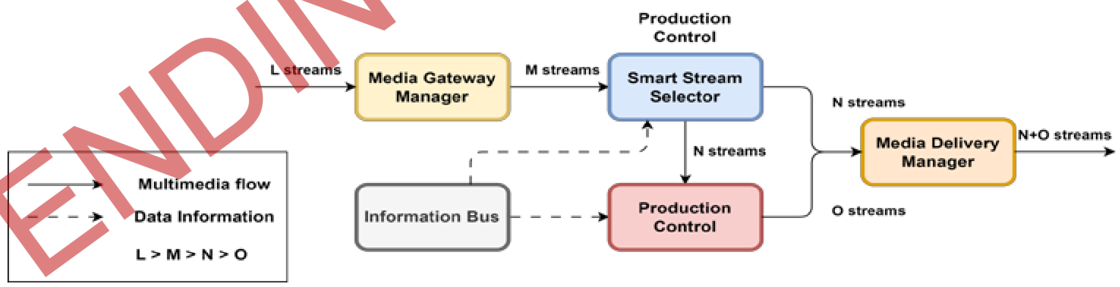


Figure 45: Workflow topology showing the path of the multimedia flow. The variables L,M,N,O are defined in the KPIs

5.6.1.1 Component Description

Media Production Engine

Stream Transcoder

The Stream Transcoder is responsible for compression/decompression and encoding/decoding of the audio/video content. It is based on open-source encoding techniques and aims at using the latest video standards such as H.264/H.265. Depending on the coding parameters it requires high computational power and is an ambitious software-only approach. Typically, hardware en-/decoders are used today to fulfil this task. So, a virtual software-only approach will boost flexibility and agility in the scenario.

As the software basis for the vCompression Engine FFmpeg[4] is chosen. FFmpeg is a very popular multimedia framework which allows for encoding, decoding, transcoding, multiplexing, de-multiplexing, streaming, filtering and playing of almost all media contents. FFmpeg includes libavcodec, an audio/video codec library used by many commercial and free software products, libavformat (Lavf), an audio/video container mux and demux library, and the core FFmpeg command line program for transcoding multimedia files. FFmpeg is published under the GNU Lesser General Public License 2.1+ or GNU General Public License 2+.

Smart Stream Selector

The Smart Stream Selector is a module in charge of determining, from a set of multiple video streams, which are the most suitable for this use case. This module will analyze the parameters of the streams, the image quality, and image metrics such as sharpness, brightness and contrast. Based on a set of predefined rules and conditions, from the analysis obtained, the Smart Stream Selector will determine whether or not an audiovisual content is suitable to feed the Production Control module and the different AI modules contemplated in the use case (such as the bib number detection and recognition).

The objectives of this module are to reduce considerably the number of streamings in the use case platform in an automated way and to maintain those that guarantee a sufficient quality for the correct functioning of the AI modules and an acceptable Quality of Experience for the end users.

Production Core - Production Control

The Production Core is a media-specific function, which acts as a video signal switcher, based on the open-source tools Voctomix[5] and GStreamer[6]. Concretely, the Production Core functions is composed by voctocore, the processing part of the Voctomix solution. This processing core has a python-based code that allows to switch between different input streamings, and to compose a new video streaming, by composing the input together with a background. The running voctocore stays listening for input signals, as well as control commands.

This production core is controlled remotely by the **Production Control** function, based on the vocto GUI part of voctomix.

Stream Monitor

The Stream Monitor module is a stream analyzer that provides relevant information about the multimedia content. It is based on the open-source tool FFmpeg and it provides parameters like the bitrate, fps, resource usage in the transcoder, etc.

Video Quality Probe

The Video Quality Probe network function aims to measure the QoE based on the media content that the platform is presenting at different points of service workflow, including to the final user. This python-based function uses different open-source tools and libraries for its running process: Keras[7], sklearn[8] and FFmpeg.

This function approach collects basic information of the video sequence that is directly provided by FFmpeg without the need of any additional computation. This model can predict the measurement of MOS in real-time. The model receives as input a set of descriptors that are gathered during the data acquisition of the video sequence. Then, the data is normalized and projected in a sub-space where the points are better separated in terms of MOS variable. Finally, a regressor is employed in order to obtain the expected value of the MOS as well as its corresponding confidence interval.

[4] https://ffmpeg.org/
[5] https://github.com/voc/voctomix
[6] https://gstreamer.freedesktop.org/
[7] https://keras.io/
[8] https://scikit-learn.org/stable/

Media Gateway Manager

The Media Gateway Manager module will adapt the input multimedia sources to be transported over IP flows. The need of this module will be clarified depending on the actual hardware devices existing for video capture once the pilot is in deployment phase. The use of IP compatible video sources will make this module unnecessary and the streaming will be directly injected into the Media Process Engine.

Media Delivery Manager

The Media Delivery Manager module encloses the delivery network, which is an emission cloud based on a typical Content Delivery Network (CDN) architecture. The streaming of multimedia content in current telecom operators is based on IP protocol, either in the form of multicast or as unicast traffic.

Multicast mode is typically used for IPTV content distribution, where multiple channels are delivered within the network providing the ability to the subscribers to join those channels according to their preferences. In CDN services, contents are commonly served from distinct caches spread across the network. Thus two main systems can be considered as part of a typical CDN architecture: the network infrastructure where caches and end-users are attached to, providing the necessary connectivity among them; and the CDN itself constituting a kind of overlay network where different type of nodes (e.g., origin servers and delivery endpoints) communicate among them to host the contents, and communicate with the end-users or subscribers to deliver the content to the interested third parties. In a live scenario like the one considered in this use case, the application of caches is not recommended, so the proposed approach includes the substitution of those caches by RTMP servers, maintaining the rest of the architecture. Figure 46 illustrates the network architecture.

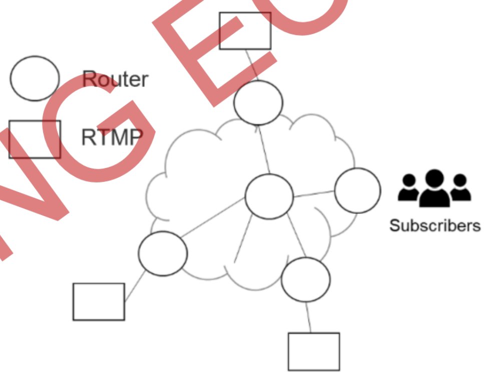


Figure 46: Schematic Media Delivery Manager network architecture

As mentioned, the communication is performed leveraging on IP protocol, so a routed scenario can be considered end-to-end. In this situation is crucial to determine which is the appropriate server (or delivery endpoint) to serve a customer request when requiring content. However, nowadays, the system does not know the status of the underlying network infrastructure. This problem is tackled through NEMO platform, allowing to decide the more convenient server to deliver the traffic for an end-user request considering both application and network information at once. The expectation is to improve the quality of experience (QoE) of the user, for instance avoiding passing through congested links, as well as to provide a more efficient delivery from the perspective of combined resource usage of both application and transport network.

Network Probe

According to 3rd Generation Partnership Project (3GPP) standards, data flow characteristics are delineated by profiles, encapsulated within Protocol Data Unit (PDU) sessions. Each PDU session is associated with a singular Network Slice, and within a PDU session, multiple data flows can coexist.

Additionally, a user equipment (UE) may support multiple PDU sessions and have access to several Network Slices simultaneously, with a maximum limit of eight active slices concurrently.

Facilitating the activation of data flows within Network Slices from external sources is an accessible API interface. This API can be leveraged by external network probes, offering a straightforward means to manage Quality of Service (QoS) and differentiate service levels among data flows. QoS settings, which exert influence over Radio Access Network (RAN), Transport, and Core elements, play a crucial role in ensuring guaranteed connectivity Service Level Agreements (SLAs) for individual services.

In specific scenarios, such as industrial or media use cases, where external applications control or request additional data flow creation for UEs, a Dataflow Application Function (AF) is employed. The security of the Dataflow AF API is fortified with token-based authentication mechanisms. Prior to accessing the services, the requesting service must authenticate itself via the /Login function, providing username and password credentials. Upon successful authentication, the API user receives a session token (of JSON Web Token type), which must be utilized for subsequent API interactions.

The Dataflow AF component utilizes the PCF N5 endpoint for establishing application sessions and data flows for subscribers. The N5 interface specifications are detailed in the TS29.514 specification. Furthermore, the Dataflow AF extends its functionality by implementing a north-bound API, enabling external applications to request data flows for subscribers. An exemplar use case entails a network probe orchestrating data flows for 5G-enabled cameras.

Moreover, to ensure secure access to the DataFlow API, the Dataflow AF integrates with an external OpenID Connect authentication service. Following authentication, an access token is furnished for subsequent API communications, fortifying the integrity and security of data flow operations.

AI Engine

The module associated with the AI Engine is a framework designed to make use of deep learning techniques, particularly YOLOv8, for object detection within frames. The main objective of this architecture is to accurately identify and extract the bib numbers associated with runners in video scenes.

The AI Engine module employs YOLOv8, a state-of-the-art object detection model recognized for its speed and accuracy, to detect the presence of runners within frames. YOLOv8 excels in real-time scenarios, making it a good choice for quickly identifying objects of interest, such as corridors, in varying conditions.

Once the runners are detected, the architecture moves to the next stage, where a custom trained YOLOv8 neural network is used to locate and isolate the bibs associated with each identified runner. With the bibs located, its analysis is further narrowed down by deploying YOLOv8 again, this time focusing exclusively on the regions containing the detected bibs. In doing so, the architecture extracts the numeric digits printed on the bibs, thus obtaining the unique identifiers of each runner.

Figure 47: RBNR (Racing Bib Number Recognition)

One of the main advantages of the architecture lies in its ability to reduce errors by selectively focusing on objects of interest, such as runners and bibs, while filtering out irrelevant elements from the frames, such as advertisements.

This module will include, in future iterations, tracking of runners with respect to race situation, and runners' locations based on data fusion from image analysis and GPS data.

SVHN (Street View House Numbers)

5.6.2 XR Use Cases Specific Developments

The two scenarios of the Smart XR use cases consists of some common services that are going to facilitate the main functionalities of the use case like data gathering, storage, training of ML models and interoperability with external devices and systems. Furthermore, the modular and distributed architecture of the use case different services can be included in order to provide the specific functionalities that are required per use case. Figure 48 presents the architecture of the Smart XR use case that facilitates both scenarios.

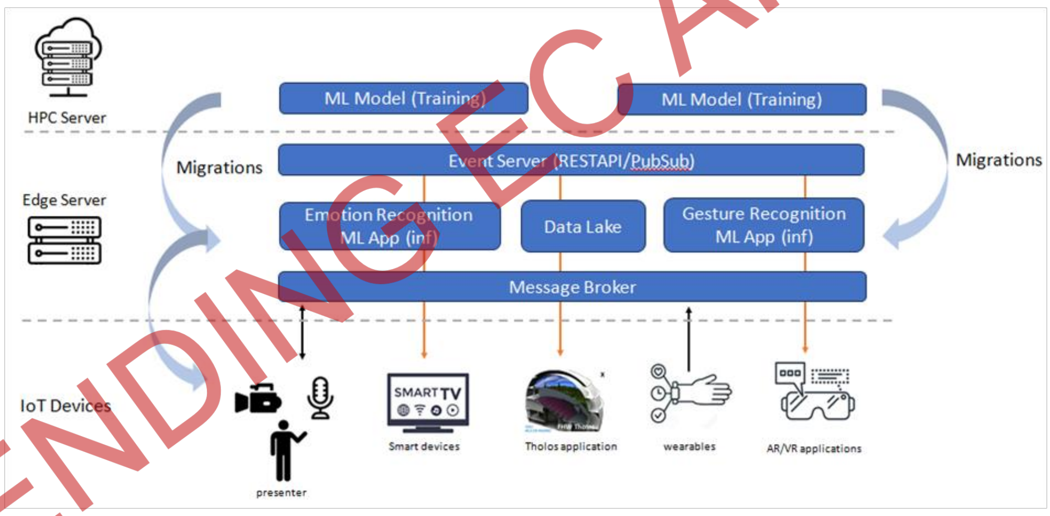


Figure 48: Smart XR use case scenarios

In the context of the Smart XR Use case several micro-services/applications will be developed to provide UC's functionalities and they will be deployed on the continuum taking advantage the features that NEMO platform offers. The basic technical specifications per micro-service/application are listed as follows.

Emotion Recognition MLApp: Input data from Smart Watch (Samsung Galaxy 5) containing biometrics (HBR, Accelerometry, skin temperature, etc.), ML Model: Random Forest Regressor, Dataset: CASE emotion recognition, Technologies: Python/Docker/Kubernetes

Gesture recognition MLApp: Input data from video camera mounted on a minicomputer, Video streaming from presenter in Tholos, ML Model: Custom CNN Model Dataset: Gesture Recognition, Technologies: Python/Docker/Kubernetes

Wearable application: Smart Watch (Samsung Galaxy 5) application based on Tizen OS or Android

Event Server: Input: Events from ML Applications (HTTP REST API), Technologies: Docker/Kubernetes, Python Flask 2.3.3/ Nginx 1.24.0

Message broker: Input: Data from IoT devices (wearables, cameras etc.), Technologies: RabbitMQ-Apache Kafka/Docker/Kubernetes

Data Lake: Input: Data from IoT devices, Technologies: InfluxDB 2.7.1/Postgres 16.0.0, Docker/Kubernetes.

5.7 Use case diagrams

Here we depict the storyboard of involved Actors and a general overview of the components describing the workflow. The sequence diagram that follows describes the interaction of the components in more detail.

5.7.1 Smart Media/City

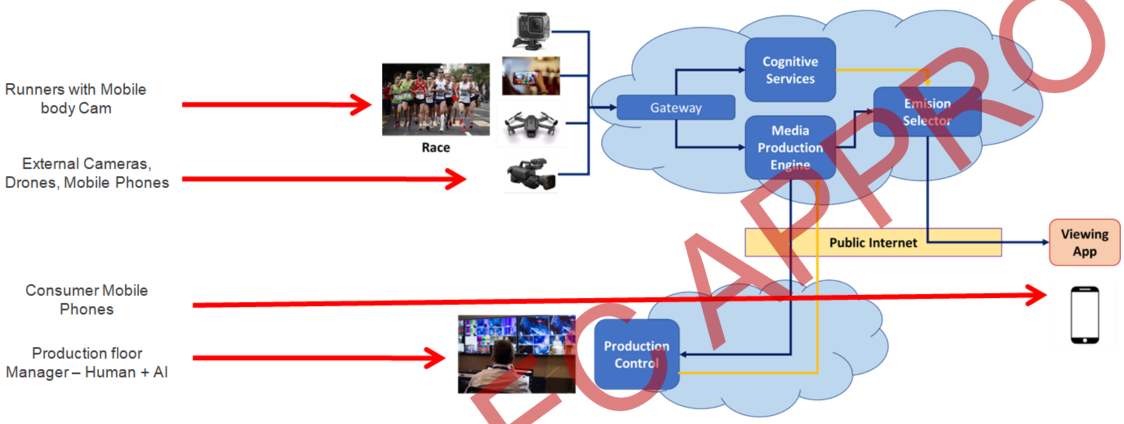


Figure 49: Storyboard and Actors general overview

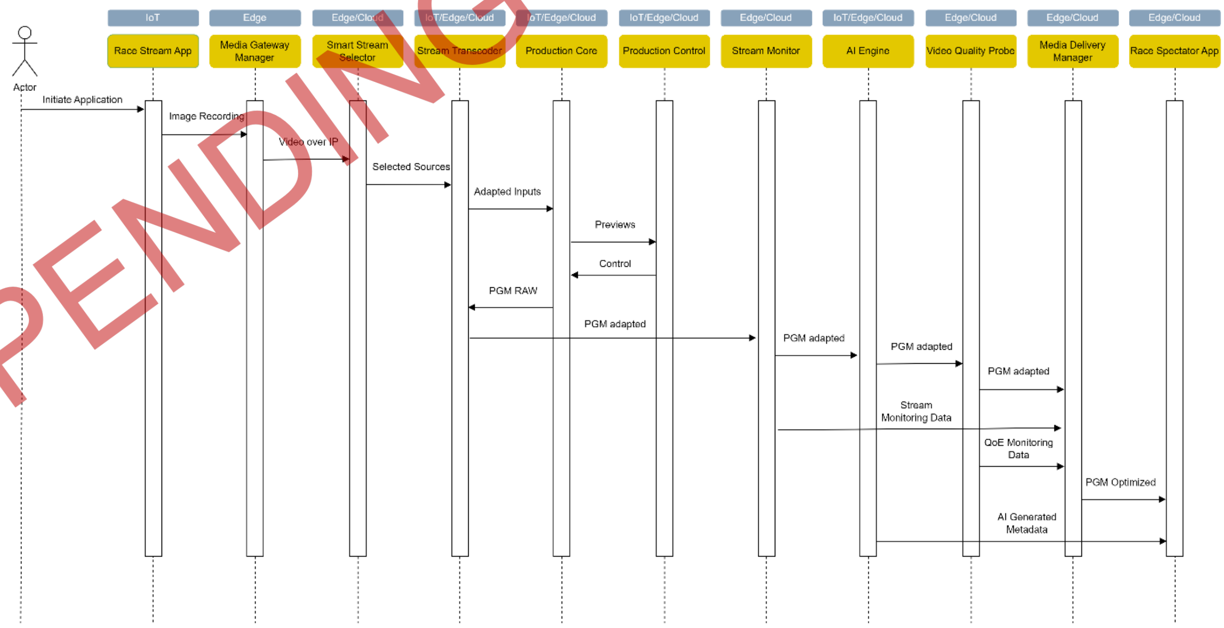


Figure 50: Sequence diagram of Smart Media/City use case

5.7.2 Smart Media/XR

Here we show the involved actors and a high level overview of the components followed by a sequence diagram for both XR use cases.

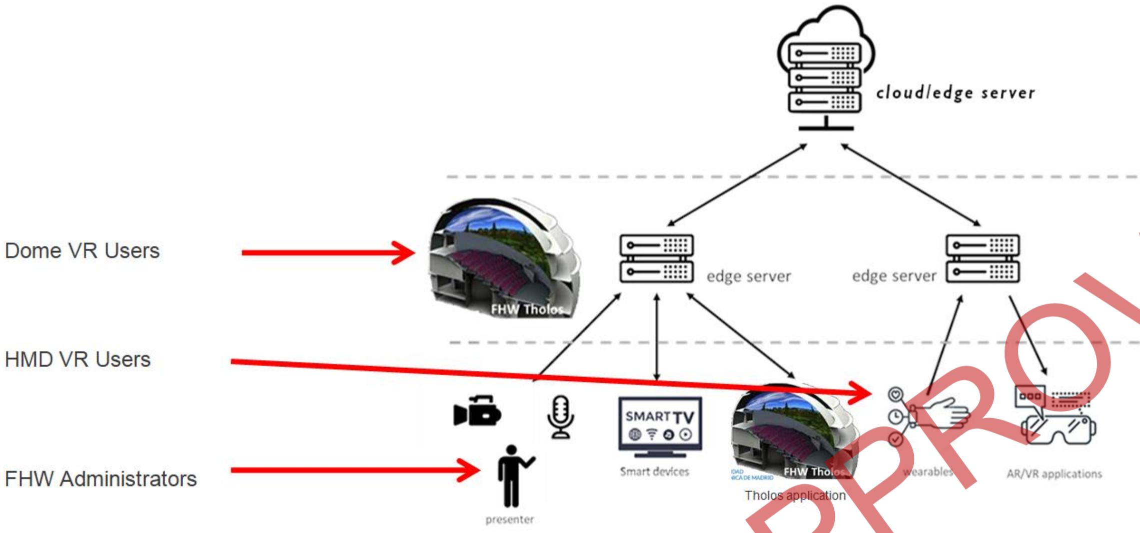


Figure 51: General storyboard and Actors general overview

The sequence diagrams of the two scenarios of the Smart XR use case are shown in the following figures.

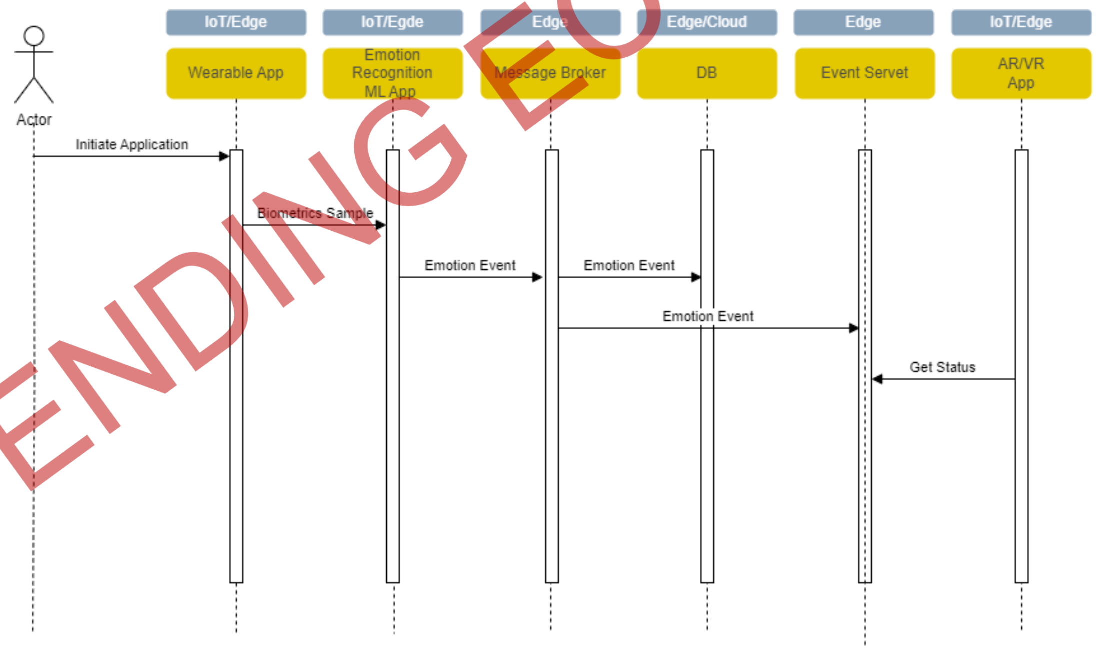


Figure 52: Sequence diagram of Smart XR scenario 1

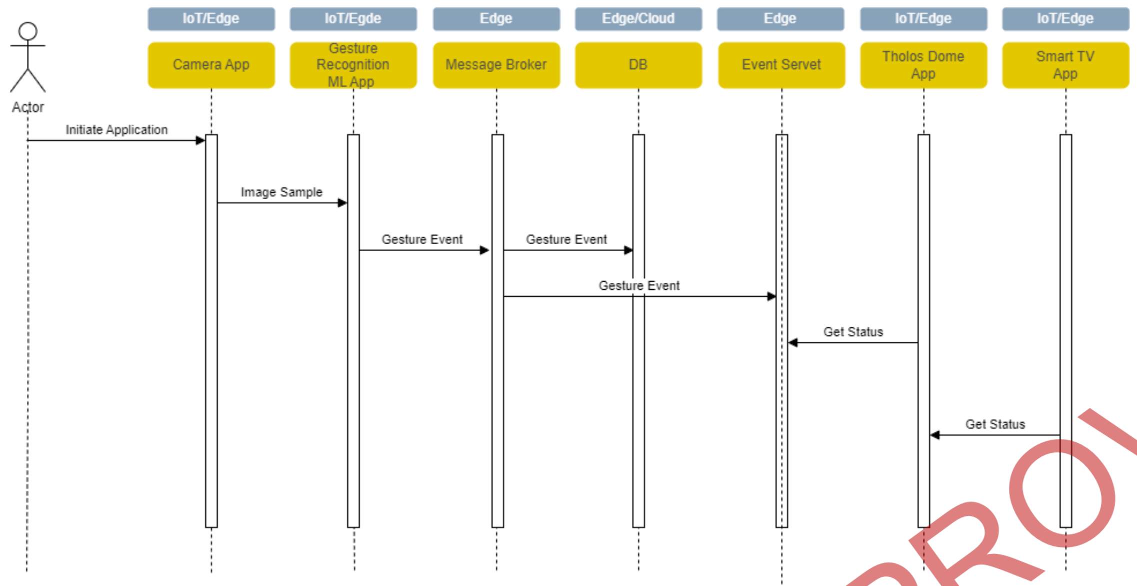


Figure 53: Sequence diagram of Smart XR scenario 2

5.8 Roadmap

The validation plan of the trials consists of these phases.

Initial Phase until M18

The trial scenario, architecture, sequence diagrams and components were defined. Based on the results the HW requirements were described and are presented in this deliverable D5.2.

Proof of Concept implementations M19-20

The most important components of each trial are developed as proof of concept in each partners lab. To be showcased on upcoming review and general assembly. Specifically, the AI/ML and production and Network components are to be evaluated in a sandbox environment before integration into NEMO.

Development and iteration cycle M21-30

Heavy development and integration will follow after M20, with a waterfall scrum project plan that will be defined for each partner. The plan will take into account the maturity of NEMO main OS components and will adapt. Components are to be evaluated in a sandbox environment before integration into NEMO.

Final Use case Trials on site M30-35

Trials will commence on the specific sites during the period of M30-35 depending on the maturity of NEMO components. The Smart City/Media use case will do dry runs two and one month before the final trial event on the local grounds to test the systems in live conditions. As the use case will take place at an external site regular consent of the authorities in the municipality will have to be done after M20 (first POC) and a call for volunteers to be done three months before the trial (M26-29).

The XR use cases will also perform dry runs of the system and the adapted VR experiences several months before the final trial date. This trial will take place in a much more controlled environment under the auspices of the FHW VR Department and FHW Staff which are experienced in Trial run and

Experimental setups. The group will do a user call one month before the final trial date but as the FHW has a very large user base this process will be not a risk factor.

Advanced integration of 3rd parties from Open Call, M36

The results of the trials in M30 are being developed into a deliverable report. Any issues with the system will be addressed and if needed small scale trial to verify that the issues are fixed will be undertaken.

As the 3rd party components will be ready and integrated into NEMO, the above small-scale trials can also validate the added functionality of those components.

5.9 Initial results

As the NEMO components are still under an implementation phase the components and all development of the partners have to be done in Lab in sandboxes.

5.9.1 Smart Media/City initial results

AI Engine

Runner identification module will be placed on the AI engine. We aim to identify bib numbers to enrich the streaming experience, providing additional information to the different streams. This module will be created using Python language, deploying a pretrained model on a sandboxed environment to the real experience. We will fine tune this model based on the experience validated through the first real experiments. AI engine module will be based on YOLOv8, for object detection, tracking and segmentation. This framework is provided in different sizes, so further research is needed to determine the sized used for implementation:

- Nano: 3.2M params
- Small: 11.2M params
- Medium: 25.9M params
- Large: 43.7M params
- Extreme: 68.2M params

Network Probe

The Network Analytics Function (NWDAF) plays a pivotal role in the 5G Core network, collecting data from various network functions and performing advanced analytics to offer valuable insights to consumer network functions. This article provides an in-depth exploration of NWDAF functionality as outlined in the 3rd Generation Partnership Project (3GPP) specifications.

NWDAF serves as a crucial component in operator-managed network analytics, facilitating data collection from Network Functions (NFs) and Application Functions (AFs) within the 5G Core. This document delves into the detailed implementation of NWDAF's Application Programming Interface (API) and its core functionalities as specified by 3GPP standards.

NWDAF encompasses a range of functionalities, including:

- Data collection from NFs, AFs, and Operations, Administration, and Maintenance (OAM) entities.

- NWDAF service registration and metadata exposure to NFs/AFs.

- Provisioning of analytics information to NFs and AFs.

The specifics of NWDAF functionality are elaborated in TS 23.288 and TS 29.520 standards.

NWDAF analytics can be securely exposed by the Network Exposure Function (NEF) to external parties, in accordance with TS 23.288 standards. NF consumers can subscribe to various events, such as service experience information, UE mobility information, communication information, and exceptions information.

NWDAF may collect data from external parties via NEF for analytics generation purposes. In cases where the Application Function (AF) from third-party providers is untrusted, NEF handles and forwards requests and notifications between NWDAF and AF. However, Cumucore implements its proprietary Application Function (CNC), registered to the Network Repository Function (NRF), and NEF is not yet implemented. Therefore, NWDAF utilizes CNC to access network statistics stored in the database.

NWDAF offers three primary services:

1. Event Subscription Service: Enables NFs to subscribe/unsubscribe for different analytic information.
2. Event Notification Service: Provides analytic notifications to NFs based on subscription ID.
3. Analytic Info Service: Allows any NF to request and retrieve specific analytic information.

The app

The NOVO app will be developed for the Android OS, targeting a wide range of devices running Android.

1. Technology Stack: For the frontend development, React Native will be used. React Native is a popular framework for building cross-platform mobile applications using JavaScript and React. It allows for faster development and better performance compared to traditional native app development.
2. Backend Development: For the backend infrastructure, Laravel will be used. Laravel is a PHP framework that provides a robust set of tools for building web applications. It is known for its simplicity, elegance, and ease of use. Laravel will be used to develop the APIs and manage the database for the NOVO app.
3. UI/UX Design: The UX/UI design of the NOVO app will follow modern user-friendly guidelines to ensure that users can easily navigate through the available functions and contribute to the event. The design will be intuitive and visually appealing, with a focus on simplicity and ease of use.

Hereby, we provide NOVO's mobile app wireframe, outlining its key screens and functionalities.

The home screen, illustrated in Figure 54, features fundamental action buttons:

1. Watch live streaming.
2. Capture.
3. Upload from disk.

Figure 54: NOVO app Home Screen design

Figure 55: NOVO app Navigation Menu design

The Navigation menu, illustrated in Figure 55, encompasses basic user actions.

The Streaming interface, illustrated in Figure 56, allows users to select the streaming location/camera.

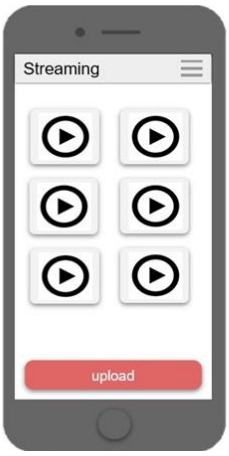


Figure 56: NOVO app Streaming interface

Figure 57: NOVO app Capture interface

The Capture interface, illustrated in Figure 57, guides users through the process of capturing content:

1. Choose location (automatically detect through GPS).
2. Take picture from camera.
3. Insert comment/annotate.
4. Upload.

Lastly, the Contributions interface, illustrated in Figure 58, showcases the uploaded content of each user.

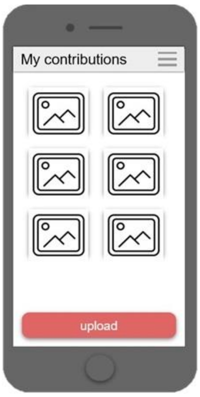


Figure 58: NOVO app Contributions interface

5.9.2 Smart Media/XR initial results

Gesture Recognition ML App

The training process utilized a specialized dataset from Kaggle for gesture recognition, accessible at Kaggle Gesture Recognition Dataset. This dataset was meticulously curated to include sequences of images depicting a variety of hand gestures. Specifically, the dataset categorized these gestures into five classes, each representing a unique command for a media control application: Thumbs Up (to increase volume), Thumbs Down (to decrease volume), Left Swipe (to jump backward 10 seconds), Right Swipe (to jump forward 10 seconds), and Stop (to pause the movie). The data was thoughtfully divided into training, validation, and test sets. This division was crucial to evaluate the model's performance under different conditions.

The outcomes of the training process were notable. The model achieved a high training accuracy of 90%, suggesting robust learning from the training dataset. Equally impressive was the test accuracy, which stood at 85%. This is indicative of the model's ability to generalize well to new, unseen data. Such performance metrics are promising, especially in the context of gesture recognition, which demands high accuracy for a seamless user experience.

Emotion Recognition ML App

The training process will be based on the CASE emotion recognition dataset which contains measurements from several physiological sensors acquired while the participants watched the videos and annotated their emotional response.

At this point, the research efforts are focus on the evaluation of this dataset in VR field.

Wearable application

The appropriate hardware has been chosen and procured (Samsung Galaxy 5). The application is under development.

Message Broker

The message broker application is based on the RabbitMQ.

Data Lake

The components that compose the data lake is defined and the initial deployments have been started.

Event server

The first version of the event server is ready.

Deployment and Integration with NEMO platform

Currently, we develop the consisting components of the SmartXR use case according to the cloud native paradigm and prepare the first version to be deployed by the NEMO platform.

VR Apps to be enhanced are selected and ported to the UNITY 3D game engine for interfacing with NEMO components. The switch from a proprietary engine to a commercial was mandatory to open up the experiences to any integrations needed. The Tholos VR system will be executed on a Unity Render Worker PC capable of 6 outputs and the HMD experience will be deployed to Occulus Quest 2 headsets.

6 Data Management Plan Updates

Effective data management is essential for the integrity, efficiency, and impact of research and innovation efforts across various disciplines within NEMO. It not only ensures the quality and reliability of research outcomes but also facilitates collaboration, compliance, and long-term value creation from research data. In order to collect updated feedback on data collection and management within NEMO, a detailed Ethics and Data Management questionnaire was sent out to the project partners. Table 23 presents a brief overview of the updates on the Data Management Plan (DMP), as reported from the NEMO trials until M18.

Table 23: Updates on the Data Management Plan

Dataset	Purpose	Scope	Open
Aerial olive tree image dataset	This dataset contains aerial images of olive groves, including images of trees (aerial leaf images) and control images (random images taken over an olive grove, but do not contain olive trees). It will be used for image classification to assist aerial precision spraying for the Smart Farming LL trials.	WP5/T5.2	Yes
Weeds image dataset	Images acquired from camera on AGLV to assist terrestrial bio-spraying for the Smart Farming use cases	WP5/T5.2	No
Field sensor measurements	This dataset will be used for analysing plant, soil and environmental conditions, assisting bio-spraying decision	WP5/T5.2	No
Smart Meter eXtension (SMX) data	The purpose is to measure the electric parameters of DSO assets.	WP5/T5.3	No
Charging station & electric vehicle data	Smart Energy & Smart Mobility Validation	WP5/T5.3	Yes
Production RAW material	Smart Industry cases' validation	WP5/T5.4	No
Video feeds	Smart City cases' validation	WP5/T5.5	No
Race dorsal	Image identification	WP5/T5.5	No
Gesture recognition and Stress level detection	The data analysis is part of the Smart XR use case	WP5/T5.5	No

7 Conclusions

This deliverable included a summary of the progress made in the NEMO trials, related to the preparation of the pilot activities. Thorough planning is documented for each trial, aimed to guide the pilot implementation, monitoring and assessment processes, as well as NEMO adaptations based on retrieved feedback both at technical and user experience level.

The report documents the preparation outcomes related to the trial site setup and the allocation or procurement of hardware equipment, as well as data collection mechanisms. It also defines specific test scenarios for the technical validation of the pilot. Each defined scenario sets a clear scope of NEMO validation, satisfied requirements and measurable KPIs. It also identifies the NEMO components involved in each scenario and prerequisite setup for the scenario execution. Then, the test procedure is described on a step-by-step basis, including involved stakeholder types. The outcome of the scenario will be possible to be evaluated through the defined success or failure states. Moreover, required human resources will be allocated based on identified responsible Consortium members. In addition, the user experience validation is planned through means identified for soliciting end-user feedback.

Further assisting the pilot implementation, the usage of the NEMO technologies and exploitation of specific NEMO capabilities in the context of each trial is further elaborated. Furthermore, additional developments, from a use case specific perspective, are presented. Then, the test scenarios' workflow is technically designed through appropriate diagrams, highlighting the functionality and interactions among NEMO and use case specific components.

The initial results, mainly referring to tangible outcomes of the pilot activities, are provided for each pilot. These include mainly development, installation, configuration and adaptation of hardware or software components involved in the pilot.

Moreover, an update to the project's DMP has been conducted, based on feedback from the Consortium members. The updated DMP relied on more detailed questionnaires collecting feedback about the Ethics, used and generated Datasets and Data Management processes, compared to the initial DMP version, submitted in February 2023.

The well-defined pilot planning presented in this document allows effective preparation, communication among involved stakeholders and replication of the defined scenarios. It also allows continuous monitoring through periodic updates on it, as planned in the forthcoming deliverables of WP5. Updates about the results of the trials are expected by February 2025 and will be summarized in D5.3 "NEMO Living Labs use cases evaluation results. Initial version". Then, final results will be reported in the deliverable D5.4 "NEMO Living Labs use cases evaluation results. Final version", due in August 2025.

8 References

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