D1.3

IoT meta-architecture alignment & continuous technology watch

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DISCLAIMER

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List of Acronyms and Abbreviations

IoT	Internet of Things
WP	Work Package
AAA	Authentication Authorization Accounting
AGV	Autonomous Guided Vehicles
AI	Artificial Intelligence
API	Application Programming Interface
ARIMA	Autoregressive Integrated Moving Average
AWS	Amazon Web Services
BDV	Big Data Value
BDVA	Big Data Value Association
BSI	German Federal Office for Information Security
CDR	Call Detail Record
CMOS	Complimentary Metal Oxide Semiconductor
CNN	Convolutional Neural Network
D2D	Device to Device
DDoS	Distributed Denial of Service
DID	Decentralized Identifier
DL	Deep Learning
DLT	Distributed Ledger Technology
DR	demand-response
DSO	Distribution System Operator
DS-TT	Device-Side TSN Translator
DTA	Dynamic Traffic Assignment
EGMOI	Electric Grid Monitoring by Open-Access IoT
ETL	Extract-Transform-Load
EV	Electric Vehicle
FL	Federated Learning
FSL	Few-Shot Learning

GAN	Generative Adversarial Network
GCN	Graph Convolutional Network
GDPR	General Data Protection Regulation
GE	Generic Enablers
GRU	Gated Recurrent Unit
HPC	High-Performance Computing
I/O	Input/Output
IDAC	IoT Devices Access Control
IDI	IoT Device Indexing
IoT	Internet of Things
KNN	K-Nearest Neighbors
LAI	Leaf Area Index
LL	living lab
LSTM	Long Short-Term Memory
MaaS	Mobility as a Service
MAD	Malicious Attack Detector
MCU	MicroController Unit
ML	Machine Learning
MLaaS	Machine Learning as a Service
MLOps	Machine Learning Operations
MQTT	Message Queuing Telemetry Transport
MTD	Moving Target Defense
NIR	Near-Infra Red
NLP	Natural Language Processing
NSA	National Security Agency
NW-TT	Network-Side TSN Translator
OSL	One-Shot Learning
PA	Precision Agriculture
PATE	Private Aggregation of Teacher Ensembles
PMU	Phasor Measurement Unit

PPFL	Privacy-Preserving Federated Learning
PVC	PolyVinyl Chloride
PWM	Pulse Width Modulation
RA	Reference Architecture
RAF	Reference Architecture Framework
RTLS	Real Time Location System
SRIA	Strategic Research and Innovation Agenda
SSI	Self Sovereign Identities
STEP	Strategic Technology Evaluation Program
SVM	Support Vector Machines
TSN	Time Sensitive Network
TSO	Transmission System Operator
UC	Use Case
UE	User Equipment
UV	Ultra Violet
UWS	Ultra WideBand
VC	Verifiable Credential
VIS	Visible Spectrum
VR	Virtual Reality
VWC	Volumetric Water Content
W3C	World Wide Web Consortium
WoT	Web of Things
WP	work package
ZSL	Zero-Shot Learning

Executive Summary

This document constitutes Deliverable "D1.3: IoT meta-architecture alignment and continuous technology watch", which is an output of Work Package (WP) 1, entitled "Next Generation IoT Requirements & Meta-Architecture.

This document focuses on the following outcomes:

- Detailed analysis of the new use cases coming from the Open Call Participants
- Update and a summarize the benchmarking KPIs of all use cases
- An initial assessment on the potential and commercialisation interest of the use cases and verticals to be investigated
- Snapshot of the continuous technology watch both from the use case and the technology perspective
- A summary of the novelties stemming from the technology development work packages allowing a comparison of with the technologies currently in the market
- Provide a summary of the initial Living Lab tests
- Describe the updated and aligned IoT-NGIN meta-architecture

The technological novelties of IoT-NGIN together with the initial assessment on the potential and commercialisation interest of the use cases and verticals will be used as an input to the exploitation task in WP8. On the other hand, the description of the new use cases and the updated benchmarking KPIs will be used as an input by the living labs in WP7.

Further analysis of the initial snapshot of the continuous technology watch will follow through task 1.4 and will be included in D1.4 "Continuous technology watch and alignment" but will also provide further input to the exploitation and business models tasks in WP8.

1 Introduction

The main objective of this deliverable is to finalize the mate-architecture of IoT-NGIN and the specifications of its individual components through the alignment of the previously defined meta-architecture from deliverable D1.2. This alignment is based on a survey of the available technologies in the field of IoT and more specifically the technologies relevant to the four verticals that IoT-NGIN is concerned, Smart Cities, Smart Agriculture, Industry 4.0 and Smart Energy. As a secondary objective of this deliverable, which contributes towards the main objective, is the detailed description of four new use cases coming from the Open Call Participants. These new use cases and their details have been taken into account in order to ensure that the final version of the IoT-NGIN meta-architecture will be compatible with them and vice versa.

Furthermore, an initial evaluation on the potential and commercialisation interest of the14 use cases of IoT-NGIN is included in this deliverable. The purpose of including this initial evaluation is to provide an initial contribution to the exploitation of the project's technologies and the extended business models that will be developed in Work Package 8. In conjuction of the potential and commercialisation interest of the use cases themselves, this deliverable also provides a summary of the technological novelties that IoT-NGIN develops. This will be used as an additional input to the business models and exploitation of the project since these are the technological spearhead of IoT-NGIN.

The deliverable has as its final aim and objective to provide a summary of the benchmarking KPIs for the use cases based on the initial Living Lab tests, outputs that are also considered in the alignement of the meta-architecture. As an additional input to the alignment of the meta-architecture, a snapshot of the continuous technology watch is included in this deliverable highlighting the approach followed. The continuous technology watch was divided into two perspectives, the use case perspective and the technological perspective. In the use case perspective, the technology watch started from the 10 initial use cases and identified the technologies that are currently being used. The technological perspective started from technologies that have the potential to be included in IoT-NGIN and provided an overview about in which use cases those technologies are currently being used. The final contribution from the technology watch will be included in deliverable D1.4 and will take into account the 4 new use cases defined in this deliverable.

1.1 Intended Audience

The document is especially useful to stakeholders invested both in the 14 use cases of the project but also to all the technologies described within the framework of this delvierable. End-users within the four verticals of smart agriculture, smart cities, smart energy and industry 4.0, will can take significant advantage of this document as it provides very useful information both from the technological aspect but also the commercial aspect.

The document could be especially useful to IoT stakeholders interested in adopting the newly aligned IoT-NGIN meta-architecture. IoT and edge hardware manufacturers, IoT solution providers, but also 5G and AI-related stakeholders could get insights on the architectural patterns for their fields of interest. Finally, the report is useful internally, to the members of the development and integration team of the IoT-NGIN consortium, along with the Open Call winners, but also to the whole Consortium for validation and exploitation purposes.

1.2 Relations to other activities

This document's contribution to the project is significant from multiple aspects. The document takes input from Task 1.1, 1.2 and 1.3 from WP1 but also from WPs 2, 3, 4 and 5 since they are the technology developing WPs. On top of that, the document takes information from WP7 on the implementation of the use cases in the Living Labs (LLs) focusing on the further defined benchmarking KPIs. This document takes information from WP1 and the use cases definition to refine the KPIs of the initially specified use cases. It then continues to provide the details of the 4 new use cases coming from the open call participants from WP9. These new use cases will feed into WP7 and the LLs especially since they will be implemented in the 7 LLs of the project.

Moreover, the document provides an initial overview of the use cases potential and commercialization interest, something that will significantly feed into WP8 to define a market position. To add to that, the document includes a summary of the project's technological novelties together with a snapshot on the technology watch from WP1 that will also feed into WP8 to define unique value propositions for the developed technologies and solutions. Based on the outcomes of the technology watch, from which a snapshot is provided in this document, the meta-architecture from Task 1.2 and from Deliverable 1.2 is aligned with the existing technologies to ensure compatibility and technological comprehensiveness.

1.3 Document overview

The present deliverable is divided into seven chapters, as follows.

Chapter 1 introduces the **motivation and objectives** of the deliverable. Moreover, it explains **the inter-relationships of this deliverable with other Work Packages** of the project.

Chapter 2 provides an **update on the use cases & the benchmarking KPIs** presenting a summary of all the KPIs from the initial 10 use cases but also presenting the four new use cases coming from the Open Call Participants.

Chapter 3 describes a **snapshot of the technology watch** looking at it from 2 different perspectives, the use case perspective and the technology perspective. The use case perspective starts with investigating the technologies that are implemented for the 10 initially defined use cases whilst the technology perspective is looking at the various available technologies and see in which vertical or application they are implemented. Additionally, this chapter expands to include an **initial evaluation of the 10 use cases as to their commercialization interest**.

Chapters 4 provides an **overview of the technological novelties of the project**, which will feed into the exploitation task of Work Package 8.

Chapter 5 presents some **initial Living Lab results** and conclusions. It continues with the **alignment of the meta-architecture and the component specifications update** based on the initial snapshot of the technology watch presented in chapter 3.

Chapter 6 concludes with the **main findings and outputs of the report** as well as an initial perspective on the **next steps** towards the continuous technology watch.

2 Update on Use Cases & Benchmarking KPIs

This chapter provides a complete summary of the benchmarking KPIs for the initial 10 use cases and all the details for the 4 new use cases coming from the Open Call Participants.

2.1 Benchmarking KPIs of existing use cases

The KPIs of the existing UCs of the different Living Labs in IoT-NGIN were defined in *D1.1 – Definition, analysis of use cases and GDPR Compliance*. This section provides a summary of the defined KPIs along with any necessary updates that stemmed from the work done in both WP1 and WP7 since the delivery of *D1.1*. The KPIs are listed in Table 1 below.

Table 1: Benchmarking KPIs of the existing use cases of the IoT-NGIN Living Labs.

KPI ID	Name	Description	Metric	Method of measurement	Target
UC1 – Traffic Flow Prediction & Parking prediction					
KPI_UC 1_1	Real-Time Monitoring	Improve efficiency and traffic congestions in twin smart cities	Percentage	Log and analysis	>20%
KPI_UC 1_2	Cross-border data models	Number of proposed cross-border data models	Numeric	Number of data models	>4
KPI_UC 1_3	Data sources analysis	Number of different types of sensors' data (multispectral/visual camera, RFID) to be analyzed	Numeric	Number of different sensors used	>6
UC2 – Crowd Management					
KPI_UC 2_1	Real-Time Monitoring	Improve efficiency and traffic congestions in twin smart cities	Percentage	Analysis and calculation	>20%
KPI_UC 2_2	Cross-border data models	Number of proposed cross-border data models	Numeric	Number of data models	>4
KPI_UC 2_3	Data Sources analysis	Number of different types of sensors' data (multispectral/visual	Numeric	Number of sources analyzed	>6

KPI ID	Name	Description	Metric	Method of measurement	Target
		camera, RFID) to be analyzed			
UC3 – Co-commuting solutions based on social networks					
KPI_UC 3_1	Data Sources analysis	Number of different types of sensors' data (multispectral/visual camera, RFID) to be analyzed	Percentage	Number of sources	>6
KPI_UC 3_2	Cross-border data models	Number of proposed cross-border data models	Numeric	Number of cross-border models	>4
UC4 – Crop diseases prediction. Smart irrigation and precision aerial spraying					
KPI_SA1 _01	Irrigation improveme nt	Reduction in the water needed for irrigation compared to manual irrigation	Difference in quantity of water between the two cases	Log analysis and calculation	20%
KPI_SA1 _02	Aerial spraying improveme nt	Reduction in pesticides used for spraying compared to manual irrigation	Difference in quantity of pesticides between the two cases	Log analysis and calculation	20%
KPI_SA1 _03	Product quality improveme nt	Increase in quantity of fruits harvested compared to manual irrigation and spraying	Difference in quantity of fruits harvested between the two cases	Log analysis and calculation	15%
KPI_SA1 _04	Sensor compatibilit y	Number of sensors tested for connectivity with IoT-NGIN Smart Agriculture app	Number of sensors	Log analysis	>9
UC5 – Sensor aided crop harvesting					
KPI_SA2 _01	Farmer safety	Collisions of AGLVs with human workers	Number of collisions	Log analysis, observation	0

KPI ID	Name	Description	Metric	Method of measurement	Target
KPI_SA2_02	System reaction	System reaction in emergency cases	Reaction time	Log analysis	<1 sec
KPI_SA2_03	Carrier time improvement	Reduction of time needed for carrying crates to the loading point, compared to manual carrying	Average difference of time for the same route	Log analysis, calculation	10%
UC6 – Human-centred safety in a self-aware indoor factory environment					
KPI_IN1_01	Human safety	Collisions of AGVs with humans or human-guided vehicles	Number of collisions	Image analysis, data log analysis	0
KPI_IN1_02	Planning efficiency	Deviation of actual route time to planned time	Average time difference between both times for all routes	Server clock, data log and calculation	<5% of average planned time
KPI_IN1_03	Planning improvement	Reduction of route time between start and end of living lab	Average difference of time for the same route	Server clock, data log and calculation	10%
KPI_IN1_04	AGV occupation	Time the AGV spends carrying goods	Percentage	Data log and calculation	>85% active time (the time when the AGV is intentionally idle will not be counted)
UC7 – Human-centred augmented reality assisted build-to-order assembly					
KPI_IN2_01	Human safety	Collisions of AGVs with humans or human-guided vehicles	Number of collisions	Image analysis, data log analysis	0
KPI_IN2_02	System reaction	System reaction in emergency cases	Seconds	Time	<0.5 sec
UC8 – Digital powertrain and condition monitoring					

KPI ID	Name	Description	Metric	Method of measurement	Target
KPI_IN3_01	Sensor data	Different types of sensors' data to be analyzed	Numeric	Number of successful interfaces	>5
KPI_IN3_02	ML Models	Number of implemented ML models	Numeric	Number of ML models	>/=3
KPI_IN3_03	Digital powertrains	Number of digital twins to be created using an NGIN conformant pipeline	Numeric	Number of digital twins	>3
UC9 – Move from reacting to acting in smart grid monitoring and control					
KPI_UC9_1	Time granularity for monitoring	Time granularity for monitoring	Seconds (s)	Measure the field data amount collected	<1s
KPI_UC9_2	Interaction capability	Information exchange are man	()	Evaluating the deployment of project solution in the whole distribution network	>100.000 measurements/minute
KPI_UC9_3	Event detection time	Event detection time using the digital twin concept	Seconds (s)	Measure the field data amount collected	<50 ms
KPI_UC9_4	Reduce the probability of Smart Grid failure	Reduce the probability of Smart Grid failure due to voltage instability at least	Probability (%)	Evaluation of measured data leveraging data of the network	25% reduction
KPI_UC9_5	Flexibility exploitation	Increase urban Electrical Vehicles charging efficiency	Percentage (%)	Evaluation of measured data leveraging data of the network	20%
KPI_UC9_6	Percentage of lost (missed)		Percentage (%)		<1%

KPI ID	Name	Description	Metric	Method of measurement	Target
	measurements				
UC10 – Driver -friendly dispatchable EV charging					
KPI_UC 10_1	Real-Time Monitoring	Time granularity for monitoring	Second (s)	Measure the data gathering sampling rate	<1 s
KPI_UC 10_2	Big Data Collection	Interaction capability	Measurements/minutes	Measure the field data amount collected	>100.000 measurements/minute
KPI_UC 10_3	Electricity Surplus Management	Reduction of reverse power flows	kWh/day	Measure the energy that flows from the user networks in the substations	About 10 kWh/day
KPI_UC 10_4	EV User Experience #1	Increase EV charging efficiency	Monetary savings	Measure the money saved involving EV users in demand-response (DR) campaigns	money saved: 0.05 €/kWh
KPI_UC 10_5	EV User Experience #2	Increase EV charging efficiency	Renewable energy %	Measure the percentage of renewable energy used to charge the EVs involved in DR campaigns	>50%

2.2OCP Use cases

This subsection provides a detailed description on the new use cases coming from the Open Call Participants and their corresponding KPIs.

2.2.1 UC11 - Smart Health Monitoring

Automation in heavy industrial settings is becoming more and more common. This use case will demonstrate the safety parameters in factories where human workers and automated guided vehicles work together.

2.2.1.1 UC Scenario

2.2.1.1.1 UC Objectives

The UC objectives are:

- Improvement of safety parameters inside factories.
- Demonstrate IoT-NGIN contextual IoT based on human-centric sensing to predict, identify and avoid medical emergencies in humans.
- Federate and interwork IoT for localization, 5G for high-speed wireless and edge computing and distributed AI self-learning to analyze input from multiple sensors, RFID nodes and cameras.

2.2.1.1.2 Actors

The actors involved in this use case are:

1. Factory workers.
2. Factory Managers.

2.2.1.1.3 Background

Human safety in factory is a continuous challenge. Workers having mild chronic conditions increase their risk of accidents. It might also lead to severe or critical conditions at work. This is both an insurance, human resource management and safety risk.

This can be solved by having trained medical professionals screening factory workers on a weekly/monthly basis. However, this is very expensive and as a result screening often happens once a year outside the facility. This increases the chance of a medical event happening. By combining existing care pathways and point of care medical devices with new wireless data transmission technologies, the Internet of Things and the use of Artificial Intelligence combined, can overcome many of such challenges.

For example, a voice-based interface can collect patient symptoms, coupled with a point of care devices like BP monitors, weight machines, blood glucose monitoring systems. This gives a 360º view on the worker's health. AI algorithms can calculate the risk and alert the line manager using an easy-to-use dashboard. All these improvements provide increased safety for workers, and an increase in productivity derived from fewer supply shortages and bigger use of resources.

2.2.1.1.4 Narrative

Our QuasaR™ device is the world's first conversational wearable medical device for chronic disease prevention. The device can collect vitals like blood pressure, heart rate, AFib detection and combines this with voice-based symptoms collection to provide a 360° view on patient's health. QuasaR™ is now a closed IoT platform that is limited to chronic hypertension, cardiac and diabetes prevention.

In this project QuasaR-NGIN we will add Next Generation Internet components to the QuasaR device by embedding IoT software components running on FPGA/soft cores or IoT devices. We will also deploy this new HW/SW functionalities as an open-source platform and test them within the context of the IoT-NGIN pilots (Examples of potential - Trial 1, Trial 2, Trial 5 and Trial 7).

The QuasaR-NGIN will have additional components i.e.:

1. 5G & Edge cloud connectivity to enable real-time communication with healthcare provided in events like stroke and fall events.
2. Cross Blockchains/smart contracts to ensure data can be securely used by multiple healthcare providers/Electronic Health Records.
3. Enhanced privacy layer ensuring that the voice-based data collected is secure and patient specific.
4. Enhanced cybersecurity layer to prevent attacks on ML and voice-based interaction layer.
5. Human centric ambient intelligence that takes age, gender and race into consideration while collecting vital and conversational data.

For the factory we will develop an automatic worker safety protocol, that can use voice technology to collect patient symptoms and point of care medical device to collect patient data. This will then be processed by AI to determine a health risk. The factory will feature edge computing resources that will be used to support a set of virtual AI functions that will process the data.

2.2.1.1.5 Risks/Challenges/Assumptions

Three risks were identified signifying the importance of protecting the human workers as well as the machines both of whom co-work in the factory. These risks are listed below:

1. Risk of not detecting potential collisions.
2. Risk of cameras information not being available while workers are on their jobs.
3. Physical safety risk for workers and machines.

2.2.1.1.6 User Groups

The identified users for UC6 are identified below:

- Factory workers.
- Security responsible person.
- Factory owner.

The specific end-user requirements and needs are:

1. Improve the production line efficiency and decrease the number of collisions between AGV in the factory to zero.
2. Workflow optimization.

3. Reduce accidents in factory environment.
4. Ability to store the system information.

2.2.1.1.7 Features

The features of the "Human-centered safety in a self-aware indoor factory environment" UC have been extracted by means of use cases used for explaining concepts implemented in the project, give rise to the lists of requirements and attempt to provide some scope for test cases that will later be used to validate the IoT-NGIN framework. These use cases are presented in Table 2 below.

Table 2: Smart Health Monitoring UC11 details.

Use Case 11 - Smart Health Monitoring	
Brief Description	Collision prevention to avoid collisions that may harm human workers in the factory
Actors(s)	Human Workers, Server
Priority	Medium
Trigger	AI detects chance of human falling sick
Pre-Conditions	Human submits symptoms and vitals to system

2.2.1.2 UC Target KPIs

The key performance indicators as defined by QuasaR-NGIN, owner for UC11, are shown below in Table 3, alongside the method of measurement and the numerical target.

Table 3: Smart Health Monitoring UC11 KPIs.

KPI ID	Name	Description	Metric	Method of Measurement	Target
KPI_UC11_01	Human safety	Human worker falling sick while working	Number of medical emergencies/ workers/ months	Image analysis, data log analysis	0

2.2.1.3 UC Requirements

2.2.1.3.1 Functional Requirements

The functional requirements of the "Human-centered safety in a self-aware indoor factory environment" UC are listed in Table 4, providing a unique identifier, description and foreseen priority level for each requirement.

Table 4: Smart Health Monitoring UC11 - Functional Requirements.

Requirement ID	Description	Priority
REQ_UC11_F01	All potential health emergencies are identified and correctly classified.	Medium
REQ_UC11_F02	The UC application has to use a deep learning algorithm to determine potential medical events and how to avoid them	High
REQ_UC11_F03	The service has to provide weekly information of workers health in the factory	High

2.2.1.3.2 Non-functional Requirements

The non-functional requirements of the "Human-centered safety in a self-aware indoor factory environment" UC are listed in Table 4, providing a unique identifier, description and foreseen priority level for each requirement.

Table 5: Smart Health Monitoring UC11 - Non-Functional Requirements.

Requirement ID	Description	Priority
REQ_UC11_NF01	The application has to guarantee reliability, availability and low latency	Medium
REQ_UC11_NF02	AI functions must predict medical events with a maximum accuracy and reliability	Medium
REQ_UC11_NF03	Edge computing resources shall be robust and horizontally scalable	Low
REQ_UC11_NF04	Personnel self-security must have absolute priority over any other factor	High
REQ_UC11_NF05	No personal data is gathered or processed, so that it is not possible to identify any person on the shop floor	Medium

2.2.2 UC12 - Predictive maintenance

Predictive maintenance is a major Industry 4.0 issue. Being able to anticipate maintenance and breakdowns at best allows to avoid unforeseen and heavy costs linked to the immobilization of machines.

2.2.2.1 UC Scenario

2.2.2.1.1 UC Objectives

The UC objectives include:

- Evaluate machine learning (ML) algorithms running on MCU to detect anomalies and predict failure of a rotating machine.
- Securely interface with the IoT Platform, and, depending on the available communication link (Ethernet or cellular), continuously push data and/or raise alerts on anomaly detection.

2.2.2.1.2 UC actors

The actors involved in this UC are:

1. AI engineers.
2. Embedded software engineers.

2.2.2.1.3 Background

ML models have been successfully deployed multiple times in the past in previous CATIE's projects but never embedded on low power resources such as MCUs. The growth of IoT and IIoT, the generalization of AI use, and the need of more private usage of collected data, drive us and the 6TRON platform to evaluate and integrate ML models on these low-cost targets to process data efficiently and securely on the devices collecting it.

2.2.2.1.4 Narrative

Evaluating ML models and methods to make them run on MCUs will allow to develop the 6TRON platform to answer the needs of the platform's users. Enforcing secure communications, and using 5G connectivity, will enable deployments and ease maintenance of new devices everywhere, from urban buildings to rural, difficult to reach zones.

2.2.2.1.5 Risks/Challenges/Assumptions

Many ML models, particularly deep learning ones, need resources not commonly available on MCUs (MicroController Unit), such as memory and computing power) and are energy hungry. When evaluating algorithms and tools, a focus should be made on the methods to reduce and use the generated models with as low resources as the performance degradation allows. While the use case is mainly centered on anomaly detection, the physical system used is not the main focus of the development. It will be necessary to find how to develop a realistic test bench able to simulate failure repetitively to qualify the AI developments.

2.2.2.1.6 User groups

The identified users for this use case are:

- 6TRON platform's users

2.2.2.1.7 Features

The features of the use-case have been extracted by means of use cases, which are used for clarifying concepts implemented in the project, forming functional and non-functional requirements, and providing some scope for test cases that will be later used to validate the IoT-NGIN framework. These use cases are described in Table 6 and Table 7 below.

Table 6: Predictive maintenance UC12.1 - Anomaly Detection.

Use Case OC12.1: Anomaly detection	
Brief Description	For each ML model trained on the same data from normal operation, check the ability to detect anomalies before failure.
Actors(s)	AI and embedded software engineers.
Priority	Medium
Trigger	-
Pre-Conditions	-

Table 7: Predictive maintenance UC12.2 - "Secure device".

Use Case OC12.2: Secure device	
Brief Description	Securely interface with the IoT platform.
Actors(s)	Embedded software engineers.
Priority	Medium
Trigger	-
Pre-Conditions	-

2.2.2.2 UC Target KPIs

The OC1-CATIE use case will be evaluated against the KPIs and target tabulated in Table 8 below.

Table 8: Predictive maintenance UC12 KPIs.

KPI ID	Name	Description	Metric	Method of Measurement	Target
KPI_UC12_01	ML Models	Number of evaluated ML models	Numeric	Number of ML models	≥3

2.2.2.3 UC Requirements

2.2.2.3.1 Functional Requirements

The functional requirements of the OC1-CATIE UC are listed in Table 9 with a unique identifier, a description, and a level of priority.

Table 9: Predictive Maintenance UC12 - Functional Requirements.

Requirement ID	Description	Priority
REQ_UC12_F01	The test bench should allow for repeatable operation and easy failure generation.	Medium
REQ_UC12_F02	The device should securely interface with the IoT platform.	Medium

2.2.2.3.2 Non-functional requirements

The non-functional requirements of the OC1-CATIE UC are listed in Table 10 with a unique identifier, a description and assigned a level of priority.

Table 10: Predictive Maintenance UC12 - Non-Functional Requirements.

Requirement ID	Description	Priority
REQ_UC12_NF01	The evaluated ML models should allow for execution on selected MCU.	Medium

2.2.3 UC13 - Electric Grid Monitoring by Open-Access IoT

Electric Grid Monitoring by Open-Access IoT (EGMOI) is a unique solution of HW and SW that consist of smart self-powered wireless sensors nodes integrated in a SaaS platform enabling several use cases to optimize maintenance and operation of electric grid assets.

Our core innovation consists of miniaturized autonomous wireless sensor nodes that can harvest ambient energy from magnetic fields and convert it into electricity. Our patented devices use novel lead-free piezoelectric technologies together with low-cost and rapid prototyping techniques such as inkjet printing, laser cutting, and lamination. It can be placed not only encircling conductors, but also in any asset of the grid, such as towers, insulators, or substations.

2.2.3.1 UC Scenario

2.2.3.1.1 UC Objectives

The objective of this use case is to use self-powered smart IoT devices to monitor critical distribution grid assets, such as substation's transformers or electrical lines in order to face the increase of complexity of the electrical grid caused by EV chargers and renewable sources (TRIAL #6). Having a smart monitoring, this use case will help ASM to optimize their "digital twin" of the grid and increase grid resiliency and real-time monitoring of asset conditions.

2.2.3.1.2 UC Actors

The actors involved in the use case include:

1. Electrical users (from Terni – Italy).

2. Distribution System Operator – (DSO) (ASM Terni).
   a) Electrical distribution grid department and Control center technical group.

2.2.3.1.3 Background

This project aims to test the use case in ASM facilities:

- 2 secondary substations
  - 9 sensors (3 per substation).
  - 1 gateway per substation for a total of 2 gateways.
  - The sensors will monitor the power line (3 phases) and the transformer (3 phases) in each cabin.

Type of conductor to be monitored:

- Diameter: about 95 mm^2 of section, in addition there is the insulator, so the total diameter is of about 20 mm.
- Material: the conductor is in copper and the insulator is PVC (PolyVinyl Chloride).
- Current: The current depends on the load power. In general, in medium voltage, it is 10 A, while in low voltage it is 500 A.
  - for the use case test, it will be preferable to test in the low voltage with 500 A.

Communication:

- there is 4G internet coverage in the area, while there is no Ethernet line.
- The IoT devices will communicate to the gateway using a proprietary protocol based on Sub 1- GHz.
- The gateway will use 4G internet to communicate to the cloud.

Figure 1: Transformer and a part of the secondary cabin.

2.2.3.1.4 Narrative

We are in a global context where energy generation has exacerbated the climate change problem. Moreover, **the grid infrastructure needs more capacity and resiliency** to face the expected growth of electricity up to 50% of final consumption by 2050[1], due to electric vehicles (EV) and buildings and industrial processes' electrification. Network monitoring is expected to provide intelligence to network operators (DSO and TSO) to optimize their maintenance and operation applications.

The primary and secondary substations are an essential asset and must withstand the variations in energy peaks generated by the dynamics of electricity consumption behavior. Currently, increasing demand, unpredictability, and management complexity caused by electric cars and electrification require more use of the capacity of electrical grid assets. In the case of substations, power lines, transformers, and breakers mustn't fail. And even if an accident or failure occurs, the control center must identify as soon as possible which asset had a problem, the reason to solve the issue, and guarantee the supply of electricity to the population.

Therefore, the tested IoT devices will monitor the temperature, humidity, and current of the following assets in each cabin:

- powerline (3 phases).
- transformer (3 phases).

The measurement will be taken every 10 minutes and sent to the gateway that will resend the data to the cloud.

Energiot's software will analyze the data received about the use case framework. Will be generated:

- health index on asset condition.
- alarm if an asset fails or exhibits unusual behavior (e.g., a current spike or high temperature).

This information can be accessed on the Energiot platform or the IoT-NGIN platform through an API explicitly created during the trial for this use. The information will be analyzed using the MQTT protocol, and the data format will be JSON with a sampling rate of 1-5s. Data will be stored on ASM servers with a 30GB hard drive and 8GB RAM.

2.2.3.1.5 Risk/Challenges/Assumptions

The Risk/Challenges/Assumptions associated with UC13 are presented below in Table 11.

Table 11: UC13 Risks/Challenges/Assumptions.

Risk Description	Probability	Impact	Mitigation plan
Accuracy of measurement does not fulfil requirements	Low	Medium	Microcontroller's flexibility, with several I/O ports, allows more accurate low-power sensors

[1] IRENA. Global energy transformation. A roadmap to 2050. 2019

Life-time of devices lower than expected (deterioration by ambient conditions)	Low	Low	More durable materials and components can be used.
Magnetic field restrictions due to line out of service periods (energy not harvested)	Low	Medium	Use other type of power source or adapt the dimension of the piezoelectric harvester
Code development takes longer than foreseen	Low	Medium	Recruitment of software engineer, agile methods.
Semiconductor shortage issue limit component stock availability	Medium	Low	Use alternatives for microcontrollers providers and PCB boards.

2.2.3.1.6 User Groups

The main user group is the Distribution System Operator (DSO) from ASM Terni, specifically the Electrical distribution grid department and Control center technical group. Their main needs are:

- Access and manage the IoT devices used to monitor their assets.
- Visualize in real time the parameters of their assets.
- Receive alarm/notifications of failure on the assets.

2.2.3.1.7 Features

Real-time Monitoring:

The system will provide information in real-time. The measurements will be made every minute and the display will aggregate the information every 5 minutes (this will be validated during the project based on the devices' energy capacity).

Dashboard of parameters:

The Grid Analytic will have a dashboard of the use cases mentioned above and a map of the grid. The parameters can also be viewed directly in aggregate, region, per asset or device.

Alerting & Fault location:

An alert system will be created to notify in real-time the occurrence of an electrical failure or accident. The system will send a notification on the application to the people responsible for the area.

Integration SCADA or other applications:

We will create an API of our Grid Analytics to access our system's information and intelligence through the IoT-NGIN platform which could also be used later to integrate direct to a specific SCADA system of ASM.

Network Asset Management:

The application will handle the inventory & the devices management and be able to declare/delete/modify new devices on the core network server directly.

List of minimal services related to the PoC that will be provided:

Sensors' parameters:

- Power cable Temperature
- Magnetic Field
- Current
- Humidity

Networks:

- Star-type communication (device to gateway)
- 4g communication (gateway to cloud)
- *IT Infrastructure*:
- SaaS infrastructure (Cloud)
- Elastic Cloud service to run the algorithms for use cases

Application:

- Basic/Standard features (authentication, …)
- Real-time monitoring
- Dashboard of parameters listed before
- Alerting & Fault location

Use case:

- Real-time monitoring of asset conditions in secondary substation o DSO wants to know the conditions around the monitored asset
- DSO wants to receive alarm/notification of an eventual failure
- DSO want to use real-time data provided by the IoT devices to enhance their digital twin application

2.2.3.2 UC Target KPIs

The key performance indicators as defined by ENERGIOT owner for UC13, are shown below in Table 12, alongside the method of measurement and the numerical target.

Table 12: Electric Grid Monitoring by Open-Access IoT UC13 KPIs.

KPI ID	Name	Description	Metric	Method of Measurement	Target
KPI_UC13_01	Time for notification	User should receive notification of event in real time	Minutes	Measure the difference of time between the detection of anomaly and the receiver of information by the user.	5 minutes

KPI_UC13_02	Asset Alert	Asset (conductor and transformer) has a safe limit for temperature and current. If overcome limit, an alert is sent.	Temperature (ºC) & Current (A)	Measure the values collected by the devices	1% over the target defined by the user in the platform
KPI_UC13_03	Cost of device	Cost of the final version of the device	Euros	Calculation made by Energiot based on provider and internal costs	< 900 €
KPI_UC13_04	Energiot's devices manufactured	Number of devices produced for the trial	# devices	Devices delivered for the test	10

2.2.3.3 UC Requirements

2.2.3.3.1 Functional Requirements

The functional requirements of the Electric Grid Monitoring by Open-Access IoT UC are listed in Table 13 with a unique identifier, a description, and a level of priority.

Table 13: Electric Grid Monitoring by Open-Access IoT UC13 - Functional Requirements.

Requirement ID	Description	Priority
REQ_UC13_F01	Sensors monitoring temperature and current.	Medium
REQ_UC13_F02	Alarm when current and temperature reach a specific threshold defined by the user in the platform.	Medium
REQ_UC11_F03	Data transmission system using gateway/3g (or other solution).	Medium

2.2.3.3.2 Non-Functional Requirements

The non-functional requirements of the Electric Grid Monitoring by Open-Access IoT UC are listed in Table 13 with a unique identifier, a description, and a level of priority.

Table 14: Electric Grid Monitoring by Open-Access IoT UC13 - Functional Requirements.

Requirement ID	Description	Priority
REQ_UC13_NF01	Visualization Dashboard.	Medium
REQ_UC11_NF02	Data storage platform, where the client is the owner, using a mqqt program to receive it and copy the data real time.	Medium

2.2.4 UC14: Development of an Intelligent decision-support System for Smart Viticulture

2.2.4.1 Use Case Scenario

The use case aims at developing a Smart Viticulture platform to monitor, alert and provide technical solutions for improving vine crops. Figure 2 presents the IoT-layered architecture of the use case scenario. SmartVIT platform will offer the necessary solutions to collect data regarding ripening, yield estimation, water resources needed and crop health issues. Also, the platform is aimed at monitoring vineyard diseases and to prevent them.

Another purpose consists in detection of lack of nutrients, drought or, on the contrary, of high volume of rainfall. The goal of the platform does not reside in the provision of large quantity of data, though, but on the generation and versatile delivery of useful and easy-to-be-used information. An important advantage of the platform consists in the professional approach of the phenological parameters considering specific conditions and dimensions (grapes type, location, technical data sets). This method permits the quality and production of grapes to be improved.

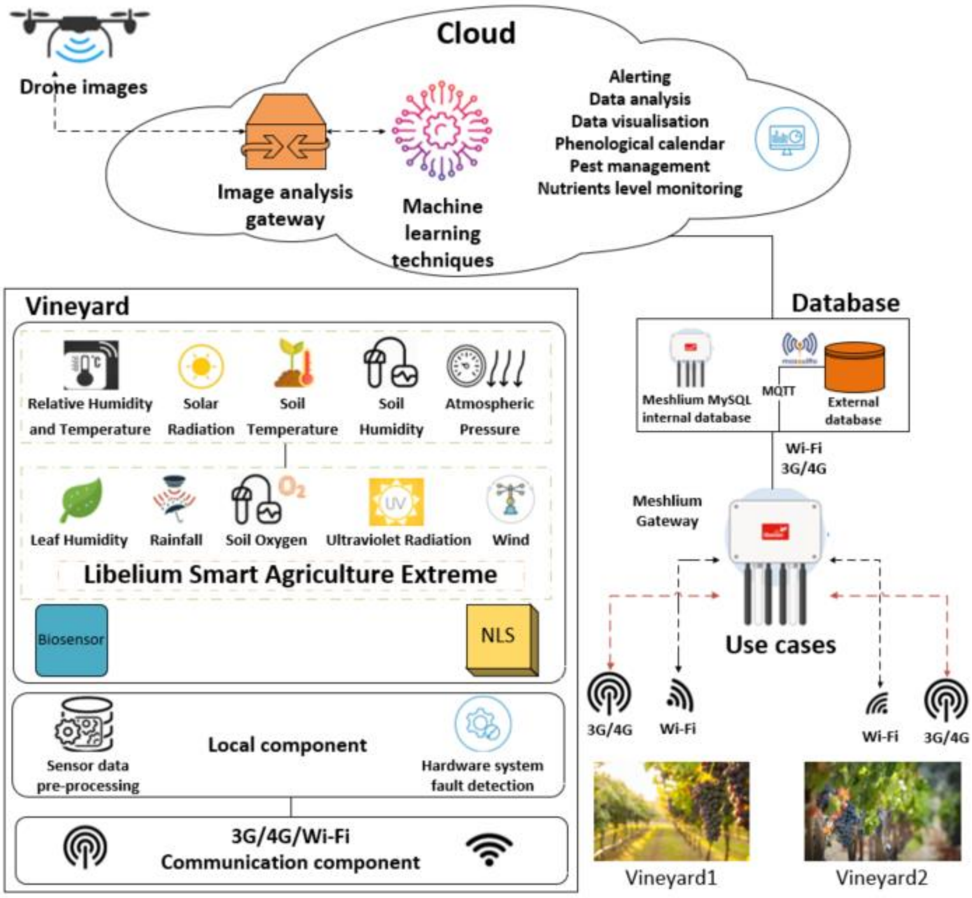

Figure 2: SmartVIT architecture.

SmartVIT architecture comprises four major layers: Vineyard, Network, Cloud and Application. For a better understanding of each layer, the main hardware components and the parameters involved are described.

The **Vineyard** level includes remote sensing and monitoring devices for collecting data on crop stages, crop yield estimation, soil nutrient content and crop disease detection. Among the sensing devices, soil and weather sensors are used. Other remote monitoring methods include drone images. The hardware used employs solutions with various probes for monitoring environmental parameters and detecting vine diseases.

The **Network** layer comprises the network devices (communication modules, gateway) and provides communication over short or long distances between the detection devices and the higher levels of the platform. The communication technologies used in the project are Wi-Fi and 3G/4G. As these are very energy intensive, software routines are implemented at this level to make the transmission more efficient, also avoiding data loss. Sensor data are sent to the Meshlium gateway. The network protocol implemented to send the data to the upper layer (Cloud) is MQTT (Message Queuing Telemetry Transport), a simple protocol designed to limit resource consumption within an IoT platform.

The **Cloud** layer comprises the database involved in storing the time series data that will be used by the Application layer. It also includes the gateway that handles the analysis of images sent by drones. In addition, Machine Learning techniques are used in this layer so that the Application layer can predict the occurrence or presence of a disease.

The **Application** layer is designed to support the platform with a powerful dashboard that supports decision-making, visualization and analysis of data based on maps, notifications and alerts. The platform therefore monitors weather conditions and manages risks associated with plant diseases.

For the use case, the system will gather data regarding crop stages, yield estimation, soil and crop diseases. In what concerns the hardware used, Libelium Smart Agriculture Xtreme station is suitable for the Romanian use case and is equipped with 11 sensor probes [1].

- **Leaves and flower buds' temperature sensor**
  Freezing events can happen in installations even if the ambient temperature is 0°C or less. Sensor probe for measuring the temperature of leaves and flower buds is designed to predict frost events.
- **Galvanic cell soil Oxygen sensor**
  The sensor probe for measuring oxygen levels in the soil measures gaseous oxygen and consists of a galvanic cell sensor that provides a measure of the percentage of the total number of oxygen molecules in the air. This sensor is specially designed for use in the soil. During ripening, grapes consume large amounts of oxygen, which is obtained by metabolizing glucose, malic acid, tartaric acid or citric acid. Oxygen consumption increases with air temperature, reaching a maximum level at 37°C.
- **Global shortwave radiation sensor**
  The global shortwave radiation sensor measures radiation from the sun, more specifically, the visible, near-ultraviolet and near-infrared radiant energy. Short-wave global radiation is a radiant energy with visible wavelengths (VIS), almost ultra-violet (UV) and almost infrared (NIR). This sensor consists of an acrylic diffuser, a heating system and a signal processing circuit with an anodized aluminum housing.
- **Ultraviolet radiation sensor**
  Ultraviolet radiation (UV) is normally defined as the radiation whose wavelength ranges from 100 to 400 nm. It is subdivided into 3 wavelength ranges: UV-A (315 to 400 nm), UV-B (280 to 315 nm) and UV-C (100-280 nm). Much of the UV-B wavelengths and all UV-C wavelengths from the sun are absorbed by the Earth's atmosphere. The ultraviolet radiation sensor detects UV radiation from 250 to 400 nm (UV-A and UV-B) and is calibrated in units of micromole photon flow per square meter per second.
- **Temperature, humidity and pressure sensors**
  Another probe of Libelium Smart Agriculture Xtreme kit integrates temperature, humidity and pressure sensors. The humidity sensor has an extremely fast response time and very high accuracy. The pressure sensor measures absolute barometric pressure and has high-precision and low-noise resolution characteristics. Optimized for low noise and high resolution, the integrated temperature sensor is primarily used for temperature compensation at pressure and humidity, and can also be used to estimate ambient temperature. The growth of the grape begins at 5°C. Nevertheless, optimal conditions for growing vines are recorded at a temperature of 25-30 degrees C.
- **Soil conductivity, water content and soil temperature probe**
  The conductivity sensor, water content and soil temperature probe is useful in greenhouse applications, where the probe can be easily inserted into different types of substrates in the soil. The sensor determines the volumetric water content (VWC) by measuring the dielectric constant (a) of the environment using frequency field technology. A thermistor is used to measure the temperature, and for electrical conductivity a series of stainless-steel electrode matrices is used.

- **Leaf moisture sensor**
  The leaf moisture sensor measures leaf surface moisture using the dielectric resistance of the sensor. This sensor has a very high resolution and it is useful to detect water or ice on the surface of the leaf.
- **Dendrometers**
  Dendrometers are extremely precise instruments designed for continuous measurement of plant diameter changes (growth dynamics, diurnal diameter changes). This type of sensor does not measure the total diameter of the trunk or fruit, but the micro dimensions in diameter. This is an appropriate tool to assess how well the plant grows, absorbs and evaporates water, its hydrological stress and possible diseases.
- **Brightness sensor**
  Brightness sensor is able to acquire data concerning the environmental light intensity. It resides in a converter which has the role of transforming the light intensity into a digital signal. This device combines a broadband photodiode (visible and infrared) and an infrared photodiode that responds in infrared on a single CMOS an integrated circuit capable of providing an effective 20-bit (16-bit resolution) dynamic range response. Optimal conditions for growing vines are recorded at a light intensity of 25-35.000 lux.
- **Contactless temperature sensor**
  The contactless sensor can be used to determine the temperature of the plant tunic. It measures the electromagnetic radiation emitted by objects having a temperature higher than the absolute zero temperature (the reference based on which one calculates the temperature of the object from a distance).
- **Water content sensor**
  The sensor that determines the amount of water in the soil measures the potential and temperature of water in the soil and porous materials. Its extensive range makes this sensor ideal for measuring water potential in natural or other dry systems. Temperature measurements are used to determine the amount of water in frozen soils.

2.2.4.2 Objectives

The objective of this deliverable is to describe the overall reference architecture of the SmartVIT framework, using the requirements, the best practices and viticulture use scenario. The overall reference architecture will be a Big Data-based architecture for IoT and will include a conceptual model that identifies the main components of the architecture, the complete description of the components identified, the definition of the SmartVIT architecture based on the identified relationships between its components, and the definition of the interfaces between components.

2.2.4.3 Actors

The following actors are involved in the use case:

1. The Smart Farmers, which are in charge of managing crop production
2. The cooperative, which may consist of independent organizations such as agronomists who offer agricultural assistance.
3. Viticulturists

2.2.4.4 Background

Considering the geographical location of the vineyard, production and plant quality conditions differ according to soil type and climatic factors. The aim is to collect as much information as possible from the vineyards, which is why in most vineyards growers prefer to use wireless sensor networks to accurately monitor weather, atmospheric and environmental conditions as well as plant monitoring. This leads to the implementation of precision viticulture [2], which exploits the widest range of available information. Sensors are deployed directly in the soil, embedded in the vine stump or placed among the leaves, depending on the data to be collected.

Soil Humidity sensors

Data collected from soil humidity sensors are used to determine the required irrigation time, interpret soil water flows and detect areas where roots absorb water. In areas where water quality is affected by high salt concentrations, soil humidity sensors provide information on the efficiency of irrigation or rainfall in terms of salinity infiltration potential outside the root zone.

Another important aspect is the choice of sensor location in a vineyard. Ideally, sensors should be placed at several points to obtain an average soil moisture value over a given area. However, due to the cost of implementing the technology required to collect the data, sensors are placed in an area that best reflects the true soil humidity value.

Precision viticulture

Blockchain technology allows transactions to take place without the intervention of an intermediary. Blockchain technology ensures transparency between the parties involved and facilitates the collection of reliable data. This is useful in developing solutions to improve the environmental conditions of vineyards, based on data collected during plant growth [3].

Precision viticulture is characterized by the use of IoT devices, sensors and various modern technologies for data collection, storage and analysis. Existing methods of data management are error-prone and do not provide a high level of security. For example, centralized government units manage environmental data and can manipulate decisions related to this data.

The use of Blockchain technology in viticulture ensures the storage of data collected throughout the entire agricultural process (from seed to sale) and transparency for all parties involved.

Compared to traditional data storage in servers managed by administrators, this technology is not vulnerable to data loss by distributing data to servers over the Internet. The implementation of Blockchain and IoT technologies leads to a secure, comprehensive and often used infrastructure in smart agriculture models.

Agricultural Insurance

Due to climate change in recent years, leading to extreme weather conditions that can endanger crops, more and more farmers are opting for traditional agricultural insurance. Under these insurances, farmers pay the first instalment before the start of the harvest cycle. They receive financial support whenever losses are incurred due to weather conditions affecting agricultural production.

Traditional agricultural insurance and the risk payment system differ according to how the loss is assessed. Evaluation methods are those that involve an expert's estimate of the loss. In this case, several factors can influence the process:

- informing farmers about insurance.
- production history (farmers who have been exposed to crop damage in the past are more likely to buy insurance than those with lower risk factors).
- the possibility of practicing a riskier production method knowing that they are insured (moral hazard).

Because of these factors, a much more objective method of assessment using measurable indices is needed. This involves the use of historical data from a weather station near the production area, accurate and clear data for both the farmer and the insurer, and farming practices that do not influence the eventual payment of compensation.

2.2.4.5 Narrative

The concept entitled precision agriculture refers to specialized agricultural practices and productivity that depend on the location of the crops and plants being grown, the local climate, and the software and hardware resources employed to provide appropriate productivity yields [4].

More than 200,000 people enter the world every day, and by the year 2050, it is predicted that there will be 9.6 billion people on the planet as a whole. Additional food demand will arise from this, which can only be satisfied by increased agricultural productivity. Protecting the agriculture industry is therefore urgently needed. The low crop yield is caused by various factors that can be mitigated by using drone technology in agriculture. Precision agriculture (PA) uses drones to inspect crops and apply pesticides. This concept is about drone structure, multiple sensor development and the use of Artificial Intelligence [5]. Understanding the agricultural system (soil, climate, crop) and using instruments that may assist the farmer's management techniques are the fundamentals of agricultural management [6].

Diagnosing diseases in vineyards with existing technologies requires cost and labor-intensive work for farmers. Therefore, to develop an IoT powered easy-to-use/user-friendly product which helps to detect the early disease stage is a big challenge. The diseases of the vineyard that are considered the most widespread and harmful to the crop are powdery mildew, gray rot and downy mildew. These diseases occur mostly due to weather phenomena, precipitation and high or low temperatures. If these diseases appear, then crop losses can range from a few percent to total loss of production. In Romania, more than 8000 hectares of vineyards are affected annually by these diseases. The loss of vine crops due to the appearance of diseases is the main problem faced by all viticulturists, because their detection is at a medium or advanced stage. Some of the effects that can occur are given by affecting the supply of wine to the HORECA and retail industry, affecting grape development and also negatively impacting the food product.

Farmers used to be able to carefully inspect their croplands by simply strolling across the fields, but as farms become bigger, this work gets increasingly challenging. With precision viticulture, one may assess important structural factors like the Leaf Area Index (LAI) and better understand the vineyard. A standard method of monitoring vegetation is remote sensing, which detects the spectral data directly emitted and reflected from plants [7].

The SmartVIT system brings a new approach to vineyard monitoring to fully exploit data and information sources. With multiple data sources, data fusion techniques can be further applied to extract valuable information. Even though it does not use open-source hardware and low-cost sensors, the calibrated sensing devices and the commercial platform used make it a good candidate for real and reliable deployment.

The use of drones adds mobility to the whole system. Even though 4G and Wi-Fi communication technologies have high energy consumption, they are less limited by constraints such as data transmission rate, available spectrum, duty cycle, LoRa or other low-power technologies.

The SmartVIT system is designed to send alerts and notifications and perform data analysis and information extraction. In addition, the dashboard designed to be easy to use and easy to configure is an advantage over similar systems.

2.2.4.6 Risk/Challenges/Assumptions

Cybersecurity is needed at all levels of the Internet of Things (IoT), primarily at the level of devices that include probes to monitor weather conditions, soil nutrients and grape quality. Secondly, the level of communication between devices is usually through gateways and a secure cloud-based data management application. IoT security services provide a set of security guarantees [8]. Benefits can mainly arise for device manufacturers, service operators, farmers, manufacturers, and are directly related to the following security guarantees:

- uniquely identified and authenticated devices;
- data sent by the device signed and accepted by the software system, so that it cannot be modified to simulate false measurements;
- device firmware not hacked (secure boot), so that it is not possible to control the device or mount a potential DDoS (Distributed Denial of Service) attack from the infrastructure.

The exponential increase in cyberattacks requires improved cybersecurity, as it is one of the most important areas of the Internet of Things (IoT) [9]. Thus, with the help of cybersecurity, the risk of possible cyberattacks on IoT devices is reduced, the rate of which is increasing, according to the 2021 Cyberthreat Defense Report. However, emerging cybersecurity technologies and tools offer opportunities for better management of IoT security.

The envisaged cyber security concept thus becomes a factor in positioning the SmartVIT project results at a commercialization level.

2.2.4.7 User Groups

For the Development of an Intelligent decision support System for Smart Viticulture use case, the identified user groups are:

- Public sector - Government Agro Agencies Administration
- Small and medium vineyards still managed in a traditional manner
- Cooperatives

2.2.4.8 Features

In Smart Viticulture [10], the system is based on monitoring soil nutrients, particulate matter in the air and weather conditions. Managing and analyzing the quality of water, air, soil and grapes leads to improved detection of vine diseases. The sensor network is connected to a Cloud platform via a reconfigurable wireless transmitter and integrates several low-cost sensors that can measure different parameters (Figure 3).

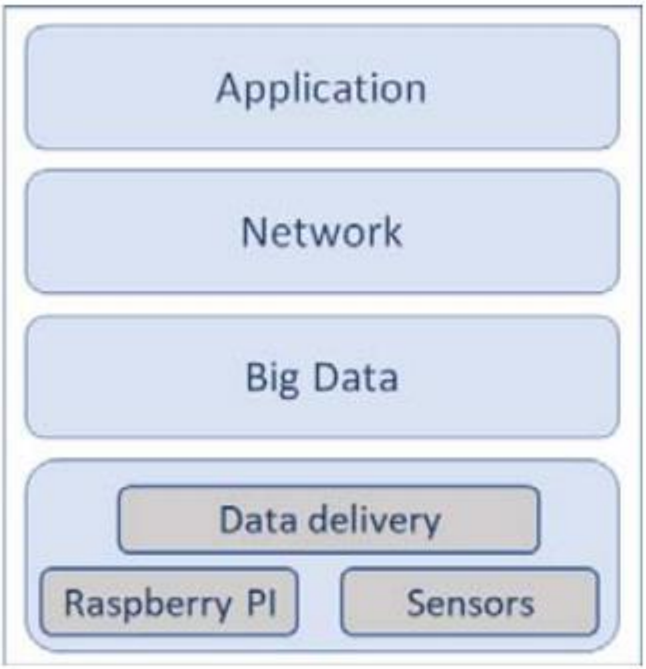

Figure 3: Internet of Things (IoT) architecture.

Data are collected from various sensors, and the existence of these sensors involves the analysis of various parameters, based on current weather conditions, light and radiation levels, soil morphology, presence of fertilizers, growth and development of plants, fruit and other environmental parameters needed to improve crop quality and performance and to avoid possible crop losses.

Data collection is accomplished through sensors [1] required for precision viticulture:

- Leaf and flower bud temperature sensor (Apogee SF-421)
- Soil oxygen level sensor probe (Apogee SO-411 & SO-421)
- Shortwave radiation sensor probe (Apogee SP-510)
- Ultraviolet radiation sensor probe (Apogee SQ-110)
- Temperature, humidity and pressure sensor probe (Bosch BME280)
- Soil conductivity, water content and temperature sensor probe (Decagon GS3)
- Phytos 31 foliar moisture sensor (Decagon Phytos 31)
- Dendrometric sensor probe for Smart Agriculture Xtreme (Ecomatik DC3, DD-S and DF)
- Light sensor probe (AMS TSL2561)
- Non-contact surface temperature sensor probe (Apogee SI-411)
- Soil water potential sensing probe (TEROS 21 Meter)

2.2.4.9 UC Target KPIs

The Development of an Intelligent decision support System for Smart Viticulture use case presents the KPIs in Table 15.

Table 15: Development of an Intelligent decision support System for Smart Viticulture UC14 KPIs.

KPI ID	Name	Description	Metric	Method of Measurement	Target

KPI_UC14_01	Temperature	Temperature	°C	MCP9700A	-40<x<125
KPI_UC14_02	Humidity	Humidity	% RH	808H5V5	0<x<100
KPI_UC14_03	Pressure	Pressure	kPa	MPX4115A	15<x<115
KPI_UC14_04	Leave wetness	Leave wetness	V	LWS	1<x<3.3
KPI_UC14_05	Soil humidity	Soil humidity	cb	Watermark	0<x<200
KPI_UC14_06	Soil temperature	Soil temperature	°C	PT-1000	-50<x<300
KPI_UC14_07	Solar radiation	Solar radiation	nm	PAR (SQ-110)	410<x<655
KPI_UC14_08	UV Radiation	UV Radiation	nm	SU-100	250<x<400
KPI_UC14_09	Wind and speed direction	Wind and speed direction	km/h		0<x<240
KPI_UC14_10	Precipitation	Precipitation	mm of rain	-	-

2.2.4.10 UC Requirements

2.2.4.10.1 Functional Requirements

The functional requirements of the "Development of an Intelligent decision support System for Smart Viticulture" use case, are listed below.

Table 16: Development of an Intelligent decision support System for Smart Viticulture UC14 - Functional Requirements.

Requirement ID	Description	Priority
REQ_UC13_F01	Advanced dashboard supporting decision making, where all useful information will be displayed in real time and composed of map-based analysis, alarms, e.g., for any interruption in vineyard monitoring or energy consumption.	Medium
REQ_UC13_F02	Real-time network monitoring for quality, consumption, vulnerability detection, prevention and remediation.	Medium
REQ_UC13_F03	Traceability report generation	Medium
REQ_UC13_F04	Remote verification and control: analytical view of monitored parameters according to customer needs.	Low
REQ_UC13_F05	Environmental impact assessment.	Medium
REQ_UC11_F06	Professional approach using specific conditions and dimensions (grape type, location, technical data sets).	Low

2.2.4.10.2 Non-functional Requirements

The non-functional requirements of the "Development of an Intelligent decision support System for Smart Viticulture" use case, are listed below.

Table 17: Development of an Intelligent decision support System for Smart Viticulture UC14 – Non-Functional Requirements.

Requirement ID	Description	Priority
REQ_UC13_NF01	Analytical characteristics of sensors: sensitivity, accuracy, precision, selectivity, reproducibility.	Low
REQ_UC13_NF02	Operational characteristics of sensors: stability, lifetime, calibration frequency, maintenance, etc..	Medium
REQ_UC13_NF03	Interfaces between components/sensors.	Low
REQ_UC13_NF04	IoT communication options for multi-protocol development.	Low
REQ_UC13_NF05	Available functionalities, compatibility, data visualization from software point of view.	Medium
REQ_UC11_NF06	Production requirements towards improved end price.	Low

3 Continuous Technology Watch Snapshot

This chapter aims to provide an initial snapshot of the continues technology watch and in order to properly deliver that, it has been divided into three main subsections. Initially, it provides an initial investigation towards the potential and commercialization of the chosen use cases, which will feed into Tasks 8.3 and 8.4 for the business models and the exploitation. It then continues to show the two perspectives adopted, the use case and technology perspective, to continuously monitor the available technologies in the 4 verticals of the project and beyond.

3.1 Use Cases Potential and Commercialization Interest

Since the start of the IoT-NGIN project in October 2020, major external factors and key market trends influencing the IoT market have multiplied and intensified. Factors such as the increasing global competition over access to energy and food was largely unforeseen when planning the project and selecting its use cases (UC).

In hindsight, it can be said that the importance of the project's use cases ranging from smart agriculture + energy solutions, to new industrial competitiveness via e.g., working environment safety and smart management and monitoring of cross-border traffic has become even more topical in today's business environment. Similarly, the trend in growing industry and market expectations for European-originated and developed IoT solutions have become stronger. Thus, the selection of the ten (10) IoT-NGIN use cases increasingly meet industry and market needs for innovative and productive IoT solutions based on European-led development and trials.

It can also be estimated that the successful outcomes of the IoT-NGIN project can directly benefit from the scaling opportunities of European networks employed in the IoT-NGIN project by its industry and research partners.

Besides the externally driven market expectations and demand, the chosen use cases of IoT-NGIN are well-aligned with the technology maturity of IoT solutions as described in the below graph [11].

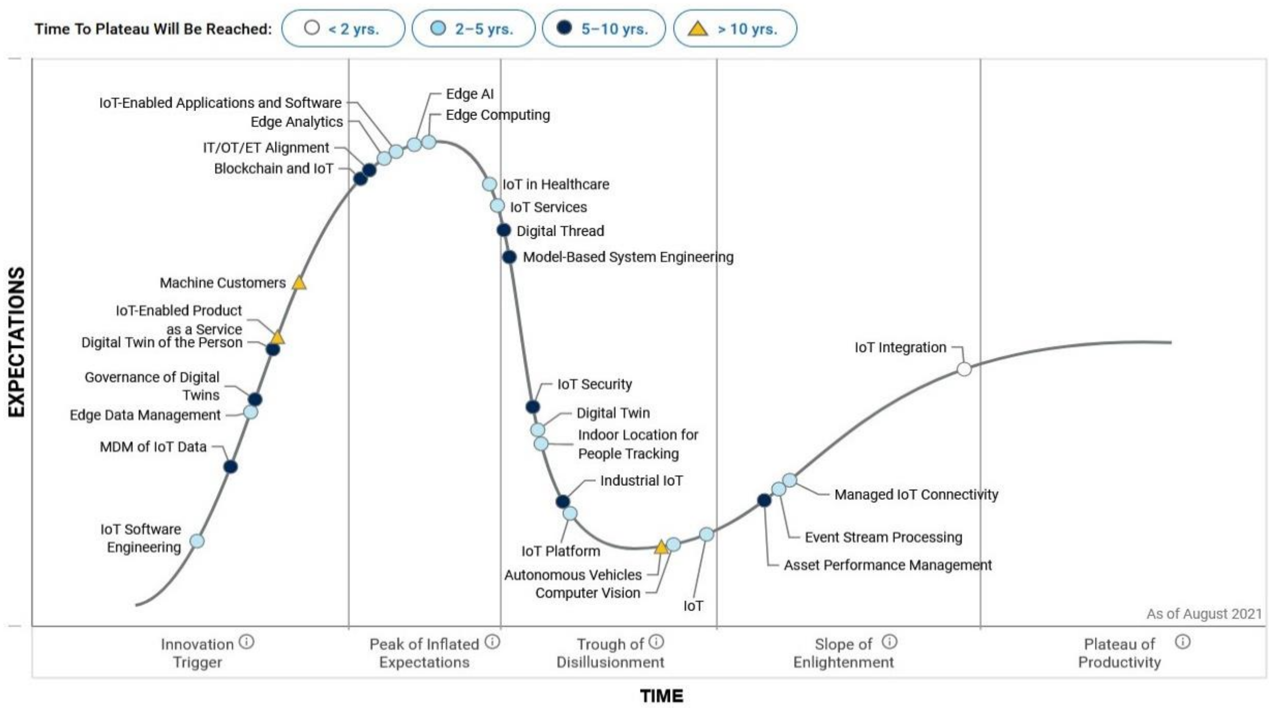

Figure 4: Hype Cycle for the Internet of Things.

The selected fields for IoT-NGIN use cases address the increasing need and demand in the following IoT-enabled market areas:

- smart traffic management in the urban environment,
- electronic vehicle infrastructure,
- energy consumption management,
- enhanced agricultural productivity,
- smart, safe working environment development

European-originated solutions in the above areas, when properly managed and disseminated, can represent significant business opportunities in Europe and globally. This calls for well-managed co-ordination and information exchange between the project's work packages to ensure successful planning for the exploitation and business modelling.

The following chapter 3.2 includes internal assessments on the perceived commercial interest of the IoT-NGIN use cases as seen by the project's use case teams. The internal assessments account for the technology and business maturity of the solutions and the complexities related to their technology and commercial development for wider future usage.

In general, the IoT-NGIN internal assessments range between medium to high on the commercial interest based on participants' previous industry and their market experiences in various IoT-related pilots and projects. The assessments highlight the need for continuous business case development for the individual use cases as well as grouping the existing use cases to clear sectoral offerings.

From the commercial potential perspective, the IoT-NGIN use cases require further efforts to achieve and build for scaling opportunities, which will be taken in the coming stages of the project:

- work on relevant innovation partnerships to **scale** the IoT-NGIN use cases.

- aligning the IoT-NGIN use case **business development** to other existing initiatives in the sectors **for sustainability purposes** and entering regional, national and local networks for joint opportunity identification.
- preparing pathways to construct **a combined and secure offering** of IoT technology-enabled solutions (clusters) fit for the target sectors/markets.
- linking the IoT-NGIN project's outcome to European IoT platform and data spaces development for **interoperability for maximum impact** and channel creation.

Furthermore, the IoT-NGIN project will utilize relevant methodologies such as STEP (Strategic Technology Evaluation Program) and Business Case Development Canvas to further plan and measure the commercial potential of the project's use cases.

The key features provided by the IoT-NGIN use cases will be assessed by external industry/sector experts (on a pro bono-basis) to gather and verify insights on specific demand topics.

This is highly needed for scaling opportunity identification as the general IoT market is expected to grow significantly, but will continue to be divided into vertical-specific and cross-vertical markets, where sector characteristics differ and set the parameters for wider adoption.

The potential economic value of the IoT-NGIN use cases reflect the overall IoT market trends, where most of the value potential is concentrated in use case clusters. Most of these use case clusters are seen in B2B applications.

As most of the demand growth will be in IoT-enabled services for various industries, the European-developed solutions will, according to many experts, have high growth potential in B2B services by 2030. This is reflected in the below picture [12].

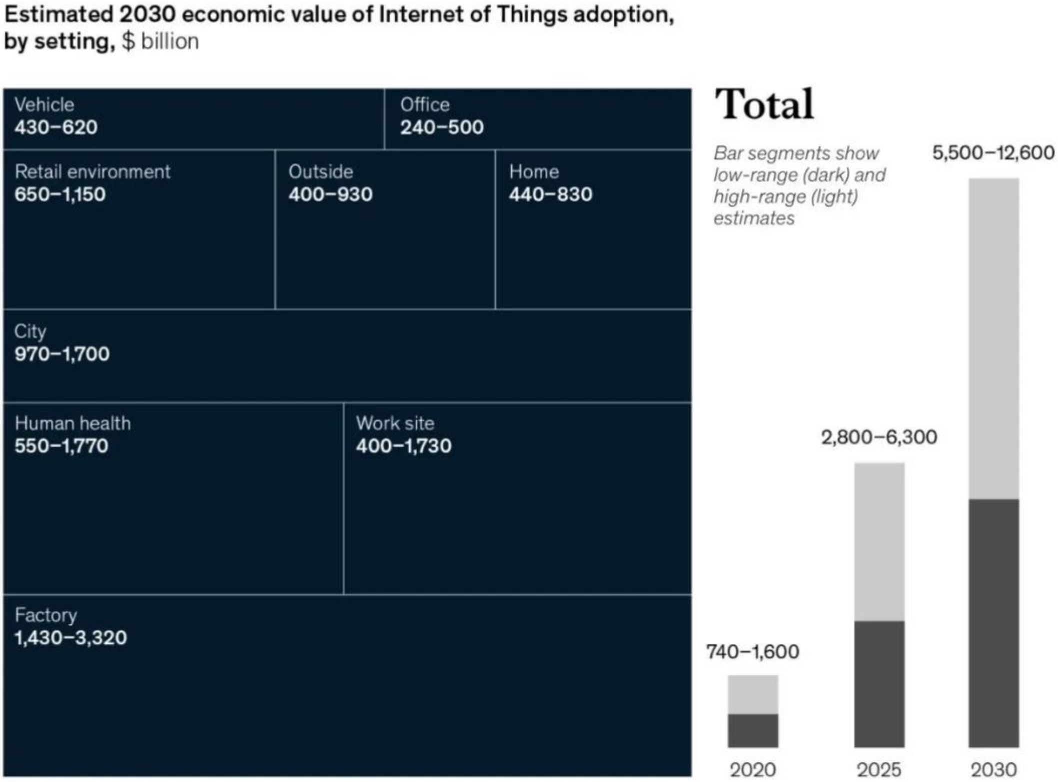

Figure 5: Estimated 2030 economic value of IoT adoption.

McKinsey (2022) estimates that even if the IoT technology solutions market is coming of age, the most future action is still required in the implementation and deployment of the solutions based on the maturity of the customer organizations in the above growth areas. This requires for continuous awareness creation, use case dissemination and showcasing the benefits.

Similarly, the Boston Consulting Group estimates that the digital or digitalized incumbents in the traditional industries will be able to deliver the innovation and revenue growth models of the digital hyper-scalers by 2030. This above descriptions of the IoT market developments, bode well for the European industry sectors, where the global leaders tend to remain in Europe such as in manufacturing, be driven by strong local characteristics for market adoption such as in smart cities and where sector-specifics favor closely controlled and secure European-developed services such as in agriculture.

Focus on the above actions and trends in the second half of the IoT-NGIN project will allow to develop and target the project's use cases for the best fit for the market to realize their commercial potential.

3.2Use Case Perspective

In this subsection, the use case perspective is presented, focusing more on the commercialization interest of the use case and the available IoT technologies used for that specific use case. The next subsection, focuses on the technology perspective, looking into IoT relevant technologies and where they are actually used and implemented.

3.2.1 Traffic Flow Prediction & Parking prediction

3.2.1.1 Traffic Flow Prediction

Table 18: Technology watch analysis for traffic flow prediction use-case.

Commercialization interest	Medium
Sectorial needs	• Adaptability to work seamlessly in new environments with minimal adaption • Adaptability to changes in datasets distribution • Preservation of private data
Technologies implemented by other	• Cameras equipped with AI • Traffic sensors • Simulation models • Statistical models • ML/AL • Hybrid models
Technological maturity	Semi-mature
Pros	• Better management of traffic within the city • Planning of new traffic infrastructures • Less traffic jams

	• Optimization of routes for fleets, delivery, etc
Cons	• High investment from cities, both in terms of CAPEX and OPEX • Potential privacy preservation issues (compliance with GDPR, concerns from citizens) • Solutions may require a high level of customization for each city • Many cities may not have enough datasets to develop / customize such solutions • Compliance with new AI Act

Table 19: Overview of existing solutions for traffic flow prediction. Based on [13], [14].

Solution	Description	Type
Statistical techniques (e.g., Kalman filters, ARIMA) to forecast time series data	Analysis of data collected by connected vehicles or IoT devices.	Academic or scientific publications
Regression models that consider spatial and temporal dependencies and events	Analysis of historical data including events.	Academic or scientific publications
Methods based on Machine Learning (e.g., SVM, KNN)	Extraction of mobility patterns and development of forecasting models	Academic or scientific publications
Methods based on Deep Learning (e.g., CNN, LSTM, GRU, GCN, hybrid models)	High potential in scenarios with high-dimensional and heterogeneous datasets.	Academic or scientific publications
Navigation applications (e.g., Google Maps, Waze, Here, TomTom, ArcGIS)	Selection of optimal routes considering estimated time of arrival and possibility of congestion.	Commercial product
Route optimization (e.g., Routific, Badger, Fixlastmile)	Short-term planning and optimization of routes for delivery or sales businesses.	Commercial product
Downtown.AI	SaaS platform that exploits real-world Big Data and ML to create forecasts and generate dynamic maps.	Commercial product
Yunex Traffic	Traffic dynamics simulation and modelling, dynamic traffic assignment (DTA).	Commercial product

3.2.1.2 Parking prediction

Table 20: Technology watch analysis for parking prediction use-case.

Commercialization interest	Medium
Sectorial needs	• Affordable installation and maintenance • Scalability for several areas in the city
Technologies implemented by other	• IoT parking sensors • Cameras equipped with AI
Technological maturity	Semi-mature
Pros	• Less traffic jams • Citizens are able to find parking spots faster
Cons	• High investment from cities, both in terms of CAPEX and OPEX • Potential privacy preservation issues (compliance with GDPR, concerns from citizens) • Solutions may require a high level of customization for each city • Many cities may not have enough datasets to develop / customize such solutions • Compliance with new AI Act

Table 21: Overview of existing solutions for parking prediction.

Solution	Description	Type
Statistical methods	Behaviors are modelled using probabilistic distributions	Academic or scientific publications
Methods based on ML / DL	Learning spatial and temporal patterns from historical data collected by meters or sensors. External variables can be considered like calendar or weather conditions.	Academic or scientific publications
Methods that consider multi-source data	Car parking availability is forecasted through the analysis of heterogeneous information (e.g., car parking data, traffic status, pedestrian information).	Academic or scientific publications
eParkomat	Parking statistics and availability prediction based	Commercial product

	on data provided by mobile network operators.	
EasyPark	Data-driven application based on multiple sources	Commercial product
Bosch community-based parking	Solution based on information provided by connected vehicles.	Commercial product
BMW and INRIX dynamic parking prediction	Parking prediction based on data from vehicle fleets	Commercial product/research project

3.2.2 Crowd Management

Table 22: Technology watch analysis for crowd management use-case.

Commercialization interest	Medium-high
Sectorial needs	• Preservation of private date • Compliance with GDPR and AI act regulations • Operation with different types of cameras
Technologies implemented by other	• Cameras equipped with AI
Technological maturity	Semi-mature
Pros	• Capacity to prevent bottlenecks • Informed decision-making • Better experience for passengers and citizens
Cons	• Ethical concerns: rise of AI surveillance. Compliance with AI Act • Difficulties for the generalization of the solution between several cities • Lack of appropriate datasets

Table 23: Overview of existing solutions for crowd management.

Solution	Description	Type
Prediction for crowd management based on risk rating [15]	Monitoring of crowd density using images and video, crowd density grading for risk alerts and decision making	Academic or scientific publications
Prediction of crowd dynamics (density and	Based on neural networks, the system is able to predict	Academic or scientific publications

flows) from individual location data [16]	crowd behavior based on data from the previous hour	
Usage of aggregated call records and mobile networks data [17]	Extraction of crowd's behaviors from aggregated and anonymized mobile users.	Academic or scientific publications
Agent-based simulations [18]	Incorporation of real-world observations into agent-based models.	Academic or scientific publications
Crowdscan [2]	Crowd density counting, analytics, prediction and management based on dedicated low-energy radio sensors.	Commercial product
Oasys MassMotion [3]	Simulator of human movement to understand impact on spaces	Commercial product

3.2.3 Co-commuting solutions based on social networks

Table 24: Technology watch analysis for co-commuting solutions based on social networks use-case.

Commercialization interest	Medium-high
Sectorial needs	• Interoperability with multiple independent data providers, high scalability, replicability to different cities and environments, seamless application of analytics and AI, optimization of routes.
Technologies implemented by other	• Solutions based on mobility data, IoT sensors and cameras
Technological maturity	Semi-mature
Pros	• Cost-effective public transport, higher comfort for citizens, promote healthier and greener transports, disincentivize the usage of private vehicles, shorter commute times, reduce cities road congestion.
Cons	• Preservation of private data, i.e., personal information or interactions should not be exposed.

[2] https://www.crowdscan.be/

[3] https://www.oasys-software.com/products/mass-motion/

	• Impact of unreliable or malicious data sources.

Table 25: Overview of existing solutions for co-commuting solutions based on social networks.

Solution	Description	Type
Research about the potential of cellular network data to improve co-commuting solutions	Comparison of the usage of data from Call Detail Records (CDRs) to extract commuting patterns against census information	Academic or scientific publications
Smart tickets	Tracking passengers with Be-in/Be-out support. Wireless beacons including IoT devices can send information to cloud backend platforms. [4]	Commercial product
Data analytics to analyze mobility information	Extract insights and patterns from the aggregation of individual journeys to make long term improvements and adapt services. [5]	Commercial product
Multimodal Mobility as a Service (Maas) solutions / Public transit applications	Mobility solutions that allow monitoring transit information from citizens and to connect local agencies so that commuters can get real-time mobility information. [6] [7] [8]	Commercial product
Intelligent roadside edge processing devices	IoT devices that can be installed in streetlights or similar fixtures to process real-time data to be consumed by smart co-commuting solutions. [9]	Commercial product

[4] https://www.youtube.com/watch?v=hbMw_P40J6o
[5] https://www.snowflake.com/news/transport-for-greater-manchester-chooses-snowflake-to-underpin-its-data-analytics-strategy/
[6] https://moovit.com/
[7] https://axonvibe.com/what-we-do
[8] https://meep.app/
[9] https://www.intel.com/content/www/us/en/transportation/urban-mobility.html

3.2.4 Crop diseases prediction. Smart irrigation and precision aerial spraying

Table 26: Technology watch analysis for crop diseases prediction, smart irrigation and precision aerial spraying use-case.

Commercialization interest	Medium-high
Sectorial needs	• Large areas to cover • Low-cost • Automated disease identification and intelligent precision spraying
Technologies implemented by other	• High Density sensor networks • Satellite imaging • On-the-go sensors • Drones • Robotic arms and vehicles
Technological maturity	Semi-mature
Pros	• KET for automated farming • 1st step towards automated decision-making systems in agriculture • decrease operational costs of farms • improved yields • ensure crop quality
Cons	• Significant initial capital investment at the moment making it non-attractive for small farmers • Common practices must be overcome to enforce the use of technologies in farming

Table 27: Overview of existing solutions for crop diseases prediction, smart irrigation and precision aerial spraying.

Solution	Description	Type
Priva-Maximise[10]	It allows environmental control, gas concentration monitoring, automated irrigation and fertilization as well as predictive environmental control but mostly in greenhouses.	Commercial product

[10] https://www.hortispares.com/machines/priva-maximizer/

Xively[11]	This has now been merged with google cloud IoT and has numerous widgets implemented within	Commercial product
Amazon IoT[12]	AWS IoT Core enables you to connect devices to AWS Services and other devices, secure data and interactions, process and act upon device data, enables applications to interact with devices even when they are offline and that allows you to produce low-cost Alexa built-in devices.	Commercial product
IBM IoT[13]	By combining IoT data with IBM Cloud technologies, business can extract valuable insights to improve virtually every aspect of their operations and enable innovative, new business models.	Commercial product

3.2.5 Sensor aided crop harvesting

Table 28: Technology watch analysis for sensor aided crop harvesting use-case.

Commercialization interest	High
Sectorial needs	• On-node processing • AI-based sensors • AI-based robots • most commonly focuses on computer vision
Technologies implemented by other	• AI-based computer vision • Drones with cameras • Autonomous robots with cameras • Satellite imaging • Phone cameras

[11] http://xively.com
[12] https://aws.amazon.com/iot/how-it-works
[13] http://www.ibm.com/internet-of-things/

Technological maturity	Beginning
Pros	• Human-less operation • Ensures crop quality • Maximizes optimization
Cons	• Significantly high initial cost • Technical difficulties for soft crops

Table 29: Overview of existing solutions for sensor aided crop harvesting.

Solution	Description	Type
Priva-Connext[14]	The system automatically anticipates conditions and events that affect the cultivation, inside and outside your greenhouse. Natural resources such as energy and water are used as efficiently as possible. This enables you to achieve sustainable growth at maximum return. Priva Connext controls, among other things, windows, energy screens, lighting, heating systems, air humidification, air treatment, boilers, CHPs, buffer tanks, disinfection equipment, and fertilizer dosing systems.	Commercial product
Directed Machines[15]	These are autonomous vehicles that can use AI to perform unattended crop harvesting in multiple terrains.	Commercial product

[14] https://www.priva.com/horticulture/solutions/priva-connext

[15] https://directedmachines.com/

3.2.6 Human-centered safety in a self-aware indoor factory environment

Table 30: Technology watch analysis for human-centered safety in a self-aware indoor factory environment use-case.

Commercialization interest	Medium-high
Sectorial needs	• Support the human activities and shorten the execution time of different tasks • Support human repetitive task • Lower the cost for maintenance and asset modeling • Predictive maintenance to avoid fault in the equipment
Technologies implemented by other	• AI and AR for avoid collision in factory environment. Forecast collision. Help on find products on a map • Different virtualization technologies to make prediction on the health status of the powertrain
Technological maturity	Mature
Pros	• Lower the number of incidents in the factory • Assist humans • Lower the cost of activities • Lower the cost, Possibility to anticipate fault in the equipment
Cons	• Needs of optimization and orchestration software to coordinate both workers and machines • Problem on data set retrieval

Table 31: Overview of existing solutions for human-centered safety in a self-aware indoor factory environment.

Solution	Description	Type
Mixed reality system	Furthermore, augmented and mixed reality techniques can be used for user-centric visualization and interaction for HRC	Academic
Deep learning	AI or deep learning-based techniques can be used for human motion recognition for predictive and safe human-robot collaboration	Academic
Digital twin	digital twin can be effectively used to control safe human-robot collaborative assembly operations and support remote human-robot collaboration	Academic
Tactile internet	Tactile internet will benefit virtual reality (VR) by enabling 'shared haptic virtual environments'. High-fidelity interaction requires haptic feedback,	Academic

	which allows the user to perceive objects in VR not only through audio-visual means but also through touch.	
Cobots[16]	The KUKA KMR iiwa proves that mobile robots can also be fully HRC-capable and move freely and safely in the work environment of the human.	Commercial product

3.2.7 Human-centered augmented reality assisted build-to-order assembly

The use case "Human-centered augmented reality assisted build-to-order assembly" is part of the Smart industry Living Lab activities and is carried out in ABB laboratories in Helsinki, Finland.

For this UC the infrastructure is constituted by the ABB Helsinki Factory, with smart tools and cameras, and with the mechanical and electronic CAD models of the different assembly phases, also using from EPLAN Smart Wiring software. The involved stakeholders are ABB and assembly technicians.

The goal of this use case is to create and test a product that increases the safety level of factories with self-driving vehicles used for the assembly, and to improve the efficiency of the service in particular in the assembly of electrical cabinets.

This technology, considering the rapid development of assembly components and the spread of faster and more efficient working techniques, has high commercial interest and a high potential for the near future. Technological development in this sector requires the use of certain technologies such as the presence of communication according to the 5G protocol, ultra-broadband, high connection speed and the presence of autonomous guided vehicles (AGVs) already integrated and configured in the system, equipped with video cameras and other sensors, which allow real-time control and extremely precise management.

This technology is still in its early stages of maturity, but gradually several benefits can be achieved, such as this technology enabling self-driving vehicles to be driven with real-time control of their position, performing certain functions on the edge and with a high focus on the safety of personnel in the factory, in particular activities are related to assisting build-to-order assembly of electrical cabinets. On the other hand, the deployment of this technology requires that high-precision and high-tech instrumentation must already be in place.

In the IoT-NGIN project, this use case makes it possible to produce technology development and increase the TRL of IoT/5G FeD2D, optimize 5G resource allocation, secure edge cloud IoT micro-services execution framework, ambient intelligence monitoring and control and test the augmented reality IoT service. Finally, this use case enables the development and export of a product that increases the reliability of self-driving devices used in the assembly of electrical substations.

[16] https://www.kuka.com/en-de/products/mobility/mobile-robots/kmr-iiwa

3.2.8 Digital powertrain and condition monitoring

Table 32: Overview of existing solutions for digital powertrain and condition monitoring.

Solution	Description	Type
Digital twin for asset monitoring	This solution is created to manage and analyze a software artefact the real object property.	Commercial
Fault prediction based on big data	The solution is based on big data analysis in conjunction with ML to predict the behavior of the powertrain and also try to anticipate possible faults	Academic
Siemens digital power train[17]	Digital Powertrain solution provides advanced capabilities in managing multi-domain solutions and allows operators to design, simulate, and test engine and powertrain solutions to improve powertrain performance.	Commercial

3.2.9 Move from reacting to acting in smart grid monitoring and control

The use case "Move from reacting to acting in smart grid monitoring and control" is part of the Smart Energy Living Lab and activities are carried out in Terni, central Italy.

Using part of ASM Terni's infrastructure, i.e., a portion of the medium-voltage grid, two phasor measurement units (PMUs) and around fifty real-time smart meters, active monitoring of the distribution network is to be realized. This will allow real-time knowledge of electrical parameters to be obtained and digital twins to be used to identify when the power quality is no longer adequate and then intervene to bring it back to correct values.

That is, you want to develop and export a product capable of accurately monitoring and optimizing the status of the electricity network in real time by exploiting the flexible sources in the area.

Although aimed at a niche market sector with a small number of stakeholders, this technology has a fairly high commercial interest and significant potential, as it plays a key role in the transition to smart grids in the electricity distribution network. This technological development requires existing tools and platforms, such as the presence of a SCADA system and data exchange methods through a data broker and a database for storing data. In addition, it is necessary, to optimize the grid, so that certain energy flexibility technologies are at an appropriate level of technological development, for example, demand response, peak shaving, storage systems management... For the sector to develop, it is also necessary

17 https://www.plm.automation.siemens.com/global/en/industries/heavy-equipment/digital-powertrain.html

to use low-resolution and inexpensive sensors and to have numerous sensors scattered throughout the territory.

Technological maturity in the market is still in an early stage but would provide several benefits such as better management of energy flows to maximize self-consumption of renewable energy, minimize reverse power flow, so for example allow electric vehicles to be powered according to specific criteria or the adoption of demand response mechanisms. On the other hand, a large number of sensors and a fast and effective central management system are required, user participation and consent are necessary.

Within the IoT-NGIN Project this use case allows for the production of technological development in the smart grid sector, enhancing TRL of involved technologies, mainly of DLT-based meta-level Digital Twin, Secure edge-cloud IoT micro-services execution framework, Ambient Intelligence monitoring and control and Dynamic machine self-learning framework. Furthermore, the opportunities that would open up for the project are to develop and export a product capable of accurate monitoring and optimizing electricity grid status using the flexibility tools available in the grid.

3.2.10 Driver-friendly dispatchable EV charging

The use case "Driver-friendly dispatch-able EV charging" is located within the Smart Energy Living Lab, in Terni, central Italy. In the near future it is expected that electricity grids will be overloaded by the demand for electric vehicles, so coordination between the electricity distribution network and charging stations will be necessary.

The objective of this UC is to develop an EV charging mechanism, which allows vehicles to be powered with renewable energy, to power the e-Mobility with clean energy and help DSO to keep the grid stable in a condition of high penetration of distributed renewable energy plants.

The use case will be carried out in the infrastructure made available by ASM, the Distribution System Operator of Terni and EMOT, an electric vehicle Manager. A portion of the low-voltage grid, equipped with load and photovoltaic generation nodes, two transformers connecting it to the medium-voltage grid, six electric vehicles and three charging stations will be used.

The market interest in this sector is very high because it involves both the mobility sector and the electricity distribution grid, two sectors undergoing a profound transformation.

Progress in this area requires the presence of certain technologies that are already present and can be integrated into the infrastructure, namely a SCADA system and a data broker for the real-time exchange of information regarding power flows, the needs of the electricity distribution network and those of electric vehicle owners; in addition, a DLT platform is needed for smart contracts and micropayments. In addition, a large number of sensors distributed throughout the territory are needed, with low costs and short resolution time. Finally, there needs to be a centralized or decentralized system for control and information management.

Technological development in this area will make it possible to manage the electricity distribution network more effectively and sustainably, powering electric vehicles according to criteria aimed at increasing self-consumption of renewable energy and reducing electricity costs for vehicle owners.

On the other hand, setting up such a technology requires a large number of sensors, connected to a central information management system that is effective and fast. Furthermore, the participation of users and their consent is necessary.

Within the IoT-NGIN project, this use case allows the technologies involved to be tested and the TRL to be increased, by the Grant Agreement. Specifically, it increases the TRL of DLT-based meta-level Digital Twin, Dynamic machine self-learning framework and testing Augmented reality IoT services. This means that the IoT-NGIN Project has the opportunity to create and test an innovative product that optimizes the integration of electric vehicles into the distribution network, providing some ancillary services to the grid and realizing economic and technical benefits to users, such as those offered by augmented reality.

3.3Technological Perspective

3.3.1 Machine Learning Operations (MLOps)

Machine Learning Operations (MLOps) is a new paradigm that has emerged during the last years to describe the needed procedures and tools to automate and operationalize the complete life cycle of products based on Machine Learning (ML) models. According to [19], "*Machine learning operations (MLOps) is the practice of creating new machine learning (ML) and deep learning (DL) models and running them through a repeatable, automated workflow that deploys them to production*." Nevertheless, due to the novelty of this concept, there is not yet a formal and standard definition that is widely accepted by the community. In this sense, [20] has provided an exhaustive analysis of the literature to extract a detailed overview of the challenges, principles, components, architectures and technologies commonly used as part of MLOps practices. An end-to-end MLOps architecture is proposed as showed in Figure 6.

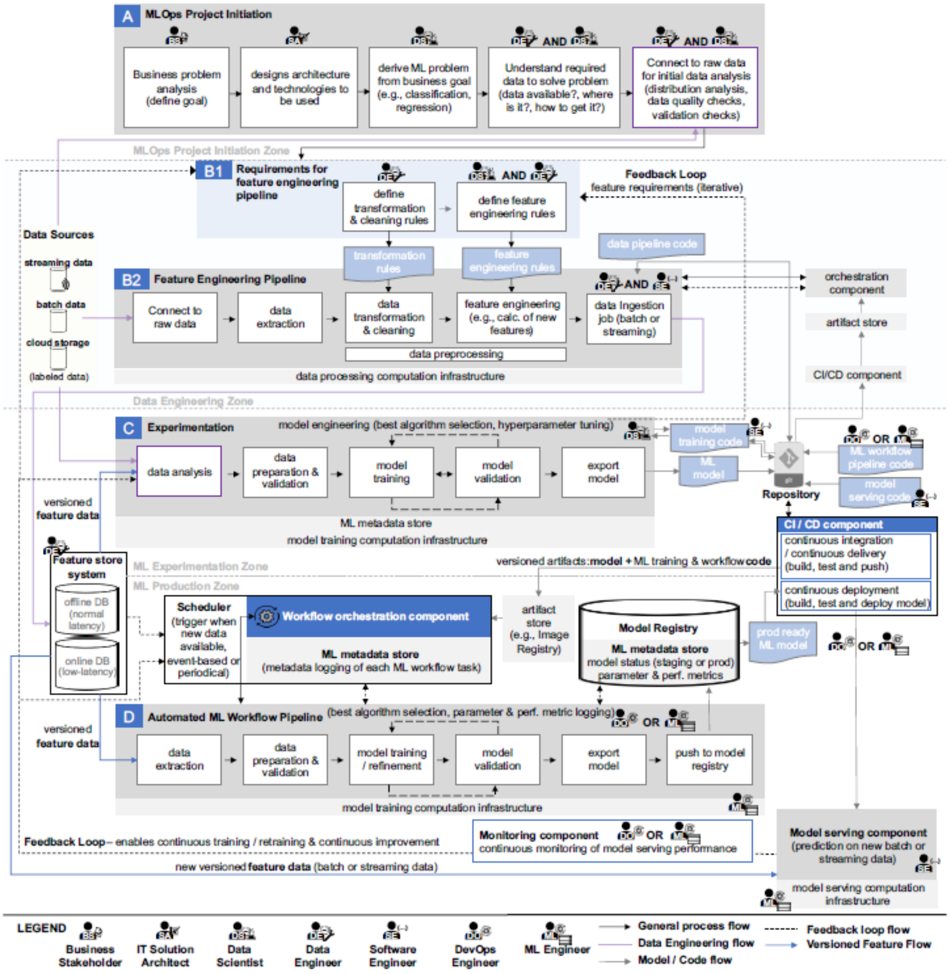

Figure 6: End-to-end MLOps architecture proposed by [20].

Following this trend and to support the growing relevance of ML as a key technology to support digital transformation processes in multiple verticals, during the last years, most cloud providers have added to their offerings holistic MLOps solutions, e.g., Vertex AI in Google Cloud [18], SageMaker for MLOps in Amazon Web Services (AWS) [19] or MLOps in Azure Machine Learning [20]. Specialized providers have also surged as can be seen with examples like Run:AI [21], Databricks [22] or Neptune [23]. Some of them are certified by Nvidia as part of the DGX-Ready Software program [24], complementing the proprietary AI Enterprise Software Suite [25].

In the open-source landscape, multiple MLOps components are becoming more popular and relevant. A summary of the current situation is presented in Table 33 below.

[18] https://cloud.google.com/vertex-ai?hl=es

[19] https://aws.amazon.com/es/sagemaker/mlops/

[20] https://docs.microsoft.com/azure/machine-learning/concept-model-management-and-deployment

[21] https://www.run.ai/

[22] https://databricks.com/

[23] https://neptune.ai/

[24] https://www.nvidia.com/en-us/data-center/dgx-pod/

[25] https://www.nvidia.com/en-us/data-center/products/ai-enterprise/

Table 33: MLOps open-source tools.

Technology	Repository	Technical component category	# of watches	# of stars	# of forks
DVC	https://github.com/iterative/dvc	Feature Store System	135	10k	953
lakeFS	https://github.com/treeverse/lakeFS	Feature Store System	34	2.7k	240
Git LFS	https://github.com/git-lfs/git-lfs	Feature Store System	458	10.4k	2k
Apache Airflow	https://github.com/apache/airflow	Workflow Orchestration	744	26.6k	10.9k
Kubeflow	https://github.com/kubeflow/kubeflow	Workflow Orchestration, Model Training Infrastructure	370	11.6k	2k
Luigi	https://github.com/spotify/luigi	Workflow Orchestration	490	15.8k	2.3k
MLFlow	https://github.com/mlflow/mlflow	Workflow Orchestration, Model Registry, Metadata Store	274	12.2k	2.8k
KServe	https://github.com/kserve/kserve	Model Serving	46	1.6k	628
Tensorflow Serving	https://github.com/tensorflow/serving	Model Serving	240	5.6k	2.1k
Seldon Core	https://github.com/SeldonIO/seldon-core	Model Serving	75	3.3k	681

3.3.2 Zero-shot / Few-Shot Learning

One of the main constraints that currently characterize the development of new products and services based on Machine Learning and Deep Learning technologies is the need to have large and high-quality datasets, which in some cases must be even labelled or annotated if supervised methods are going to be used. This is especially the case for new use-cases where the level of digitalization is not high as it happens in manufacturing or agriculture scenarios. Computer vision or Natural Language Processing (NLP) problems must face commonly this issue.

Zero-shot learning (ZSL) enables an AI system to predict the category to which an object belongs without having observed samples of this class during the training phase [21]. It exploits auxiliary information (e.g., attributes, attached texts) that is combined with data from observed categories. ZSL can be implemented using well-known frameworks like Hugging Face transformers [26] [27].

As an alternative, Few-Shot Learning (FSL) proposes ML systems that are able to learn with just a reduced number of annotated samples. Robotics systems that learn to replicate human actions or behaviors can be seen as a relevant example of FSL [22]. One-Shot Learning (OSL) is a particular case of FSL in which the system learns to discriminate a category from just one sample. Different approaches allow implementing FSL based on prior knowledge about the learning process [23] [24] [25] [26] or data structures and variability [27]. Libraries are also available to facilitate the usage of this novel paradigm [28] [29].

ZSL, FSL and OSL are subfields of meta-learning systems, which "learn to learn" from previous experiences and knowledge in order to improve the performance and efficiency of the overall training process.

3.3.3 Real time monitoring of distribution grids

The activities carried out within the Smart Energy Living Lab aim to development and test the Real time monitoring of distribution network technology service. This technology allows to monitor the network in real time, visualizing critical points, facilitating the work of technicians and consequently allowing better management of the network and a better service for users.

The technology is not yet fully mature and requires the development of some lateral technologies in order to increase its reliability, e.g., it is necessary for data transmission to be faster and more reliable, and it is also necessary to use appropriate tools for the simulation of the electricity network in real time.

This technology is used for electrical distribution networks, to monitor trends in electrical parameters in real time. Within the IoT-NGIN project, this technology was studied in the distribution network of ASM Terni.

Real time monitoring technology enables knowledge of the network parameters, identifying the most critical sections, but requires a large number of sensors, which increases costs and management and maintenance activities.

For IoT-NGIN, this technology allows to develop and export a product capable of accurately monitoring electricity networks, increasing the TRL of certain technologies such as DLT-based meta-level Digital Twin, Secure edge-cloud IoT micro-services execution framework, Ambient Intelligence monitoring and control.

3.3.4 Real time monitoring of charging stations and electric mobility

Real-time monitoring of charging stations and electrical mobility allows electric vehicles to be effectively integrated into the electrical distribution system, enabling certain ancillary

[26] https://huggingface.co/
[27] https://huggingface.co/models?pipeline_tag=zero-shot-classification
[28] https://tristandeleu.github.io/pytorch-meta/
[29] https://github.com/yaoyao-liu/meta-transfer-learning

services to be provided to the electrical distribution grid and providing economic benefits to vehicle owners, as well as promoting the consumption of renewable energy and reducing environmental impact.

The electric recharging sector is at a good level of maturity and commercial deployment is increasing, but the implementation of demand response strategies applied to electric vehicles is not yet mature.

The proposed technology is used to monitor power trends in charging stations and choose how to direct power flows taking into account the needs of electric vehicle owners and the distribution system operator.

This technology allows real time knowledge of power flows and to direct them according to specific needs, e.g., to recharge in the shortest possible time, to increase local renewable energy consumption, to provide grid voltage support services, and more. However, some complexities arise due to the need for widespread sensors, both for the charging stations and inside the vehicles, as well as communication technologies between the vehicles and the charging stations.

For IoT-NGIN Project, this technology constitutes an opportunity for the development and testing of a service related to electric mobility, which currently has a high commercial interest, allowing to increase the TRL of the technologies involved, such as DLT-based meta-level Digital Twin, Ambient Intelligence monitoring and control.

4 Novelties of IoT-NGIN Technologies

This chapter aims to provide the novelties of the technologies developed within IoT-NGIN compared to the current state-of-the-art in the field of Next Generation Internet.

4.1 Enhancing IoT Underlying Technology

We are developing several enhancements to 5G technologies to better cope with IoT-challenging environments and make them move toward commercial maturity and large-scale deployment. We have structured our contributions around four major topics: coverage extension, support of time-critical applications, enhanced exposure of 5G resources, and security. In the following, we briefly describe each of them and present their innovative features concerning existing strategies.

4.1.1 Coverage extension

We propose a simple, effective methodology for coverage extension by establishing device-to-device (D2D) communications between nodes outside the 5G cell coverage area and relays (devices connected to the cellular access point). We focus our work on smartphones and have, as a design principle, to reject solutions that would require modifications on either the device itself or the operating system. The originality of our approach is that candidate relays exchange several metrics with out-of-coverage nodes so that these later select the most suitable relay for some target performance. And, most importantly, without any intervention from the user.

A relay acts as a wireless access point in the most traditional strategy, which is available in commercial devices. It provides an autonomous portable unit (hotspot) to connect to surrounding devices. In the approach we adopted, the relay acts as a service and can be used directly (enabled by the user) or indirectly (enabled by the device). Based on this, a device can establish a D2D link for use as a transport channel between a device connected to a cellular network to one or more devices lacking coverage without the relay's mobile data being tethered.

Furthermore, because our approach leads to a proximity service, we can implement algorithms to meet the requirements of different scenarios that hotspot solutions cannot satisfy. This results in the ability of a device to passively and continuously search for a relevant value in its physical proximity. In the extension of cellular network coverage, the use of D2D during detection and accumulation of metrics during neighbor discovery allows a device to characterize the links from each potential relay to the base station and select the relay that best suits its requirements.

The solution we propose is fully functional for the Android operating system and is available to the community as an outcome of the IoT-NGIN project.

4.1.2 Support of time-critical applications

Several IoT applications, particularly those related to Industry 4.0, require deterministic temporal guarantees. Owners of these use cases are becoming more and more interested in using private LTE and 5G networks to increase their flexibility in configuring devices and communications without the need for cabling and its maintenance. We are addressing this challenge by adapting existing Time Sensitive Network (TSN) solutions (originally designed for wired networks) to wireless industrial scenarios. Industrial IoT and machine process control are today based on wired automation, where data from devices and sensors are collected on edge servers and in a database. In a basic configuration, devices and sensors are connected to an edge server via private 5G networks. However, it is necessary to maintain the current transport and protocols used in wired connections to add new devices to the process and support their mobility over 5G networks. Therefore, existing industrial protocols must be used in both wired and wireless connections.

The work has focused on architectures and prototype implementations of this functionality, which has already been defined in 3GPP standards for 5G networks. These ongoing investigations have focused on both the theoretical use of the functionality and the potential deployment of the functionality in a live LTE or 5G network at trial sites.

We have been developing multiple prototypes to showcase our contributions. The goal of the first TSN prototype is to synchronize wireless devices with the fixed reference master clock to support deterministic communication between wireless and fixed devices in the industry. Initial test results on the synchronization of the prototype on synchronization show a synchronization accuracy of 30-80s. However, this accuracy is not sufficient. The specifications for TSN communications (standard IEEE 802.1AS) state that synchronization accuracies should be better than 900 ns. For this reason, we have developed two new functional units for the time synchronization towards fixed devices (Device-Side TSN Translator (DS-TT)) and towards a fixed network deployed in a factory (Network-Side Translator (NW-TT)). DS-TT is deployed in the User Equipment (UE). The prototype is standardized following specifications in 3GPP Rel-16, specification 23.501, clause 5.27. The prototype is relevant for smart industries and smart agriculture.

4.1.3 Enhanced exposure of 5G resources

A variety of APIs is already integrated into 5G products and services on the market [28]. A key challenge associated with these APIs is that they can be hard to understand for developers unfamiliar with 5G infrastructures and the mobile network domain. We propose a generic 5G resource management API to overcome this difficulty. This API will provide a more generic interface and simplify the usage of 5G resources. The specification of the IoT-NGIN 5G resource management API is an ambitious undertaking. It specifies new simplified resource management APIs for 5G. It can reduce the time and cost of implementing new services and applications using 5G communications by reducing the need for the involvement of 5G experts.

The API focuses on three different groups of capabilities that we identified as central: (i) 5G connectivity and device Management, (ii) network slice management, and (iii) microservice lifecycle management. In a nutshell, the architecture of the IoT-NGIN resource management API is structured in three layers. The top layer serves for customers to run applications on devices in the field as well as on a virtualized infrastructure in the 5G network. These applications interface via the unified and simplified IoT-NGIN 5G resource management API with the network infrastructure. In the middle layer, different modules (5G Connectivity and Device Management, Network Slice Management, and Microservice Lifecycle Management) ensure the translation from the generic operations to the standardized and vendor-specific APIs, which is achieved by utilizing adapters. Finally, the bottom layer graphically depicts the 5G core and edge cloud infrastructure that the IoT-NGIN 5G resource management API can interface with.

The results of the work on the IoT-NGIN 5G resource management API will be published as OpenAPI specifications in GitLab. An open-source implementation of the IoT-NGIN 5G resource management API is under development and will be made publicly available on the project open-source repository in GitLab.

4.1.4 Security

Cloud and edge infrastructures are typically container-based, traditionally relying on OS-level virtualization, where applications are grouped into logical namespaces, generating multiple isolated instances in user space. Those instances can be used as building blocks to deploy, maintain and scale cloud applications and edge infrastructure. Therefore, the entire infrastructure must be hardened against attacks to secure them. The National Security Agency (NSA) and the German Federal Office for Information Security (BSI) publish excellent guidelines for hardening IT infrastructure.

However, there is a lack of isolation between the host operating system and the containerized application. Indeed, a security vulnerability in the container runtime directly exposes the host kernel to attacks or the other containers, which are managed by the runtime.

An alternative to this approach is virtual machines. This approach creates a stronger isolation between the Kernel and the application by emulating a whole PC. This is reasonably fast, due to hardware acceleration but the problem of requiring an additional kernel in the VM still induces a lot of overhead.

The Unikernel approach promises to combine the advantages of both approach: Increased isolation with minimal overhead. This approach promises to be an excellent fit for todays and future edge-clouds, where security as well as performance are vital.

IoT-NGIN sees machine learning as a core topic for next-generation IoT, thus we focus our efforts in developing unikernels for edge-clouds towards this field and are developing a flexible framework which enables developers to easily develop secure and performant unikernels for machine learning and AI in edge clouds.

4.2 Enhancing IoT Intelligence

4.2.1 MLaaS

The IoT-NGIN Machine Learning as a Services (MLaaS) is the ML operations (MLOps) platform that offers to data scientists / engineers, ML engineers and other users the services they required to "store data, visualize data, perform ETL (extract, transform, load) on data, train ML/DL models, allow transfer learning and leverage pre-trained models" (D3.1). The concept of MLOps is introduced as "*the practice of creating new machine learning (ML) and deep learning (DL) models and running them through a repeatable, automated workflow that deploys them to production*." MLaaS encompasses some of the MLops procedures and tools described in that section and complements them with additional ones that are not covered by individual open-source implementations listed therein.

As such, IoT-NGIN MLaaS aims to provide a holistic platform for MLOps that combines some of the MLOps open-source implementations with additional services. MLaaS integrates Kubeflow and KServe (some of the MLOps implementations listed in section 3.3). From Kubeflow, MLaaS leverages the MLOps workflow orchestration (i.e., pipelines) and its capability to support model training for supported ML frameworks (e.g., Tensorflow). Kserve offers model inference (i.e., model serving) also for supported ML frameworks, and can be used for model transfer.
IoT-NGIN goes beyond those integrated opensource MLOps, by adding additional services, including:

- ML model storage by integrating MinIO, Rook and Ceph
- Data storage: PostgreS, InfluxDB
- Data acquisition: MQTT, Kafka, Camel-k (for data / service interoperability)
- IAM/AAI: Keycloak
- CI/CD installation based on Argo-CD

In summary, IoT-NGIN MLaaS offers a wider range of MLOps services than those offered by individual opensource MLOps solutions, by combining the Kubeflow / KServe support for ML workflow orchestration, model training and model serving with additional services for data storage, data acquisition and model storage, with additional support for secure access.
Furthermore, IoT-NGIN MLaaS offers a number of additional features as service not present in open-source MLOps frameworks, namely:

- Online model training
- Model translation
- Zero-knowledge model verification based on BlockChain

IoT-NGIN MLaaS offers an online model training service for the dynamic training of ML/DL models with datasets streamed from IoT devices through MQTT / Kafka / HTTP REST data acquisition. As soon as the data is continuously received, the model is trained. This feature is also integrated with model-storage and model-serving for inference / prediction. Inference uses the near real-time trained model version for accurate predictions. This feature supports online training of ML/DL models with several AI frameworks, including Sklearn, Vowpal Wabbit, Tensorflow / Keras, Pytorch. This feature accommodates the IoT need to use near real-time data updates from IoT devices and their environment for serving better accuracy AI models.
MLaaS offers a Model Translation service, integrated with model sharing. This service can translate ML/DL models from one AI framework (e.g., Keras) to another (e.g., PyTorch) by using the intermediate model framework ONNX. Translated models can be stored in the model storage for reuse and sharing. This feature accommodates the IoT need to offer variants of trained models which can be compatible with the high variety of firmware in IoT devices and gateways.
MLaaS offers a Zero-Knowledge model verification service, integrated with model sharing. This service uses Blockchain technology to create a smart contract that embeds model metadata, including the model architecture (e.g., layers, weights) and data access functions. The contract is registered within the IoT-NGIN Ethereum registry. The Zero-Knowledge model verification service offers an API to retrieve the contract by id, retrieve the model hash and verify the model integrity. This feature accommodates the IoT need of verifying the integrity of the AI models whose predictions and control decisions could driving the behavior of critical-mission systems.

4.2.2 Privacy-Preserving Federated Learning

Privacy-Preserving Federated Learning (PPFL) refers to collaborative ML model training, in which locally trained ML models are aggregated in a 'server' node (FL server) and shared to the 'clients' (FL clients), without disclosing data to each other, while enforcing privacy preservation during model exchange. In an IoT/edge/fog/cloud environment, model training may significantly benefit from 'experiences' gained by the participating nodes, without disclosing any data among them.

The Privacy-Preserving Federated Learning (PPFL) Framework of IoT-NGIN provides easy access to ML developers to diverse federated learning (FL) approaches, according to their application needs. Specifically, PPFL integrates and enhances the following FL frameworks:

- NVIDIA FLARE (NVIDIA Federated Learning Application Runtime Environment) [29]. The project contributions include the framework evaluation towards object detection and against several privacy-preserving schemes on real nodes under assessment of the privacy preservation and performance levels tradeoff. Adaptations for experimenting with TensorFlow2 (TF2) on NVIDIA FLARE have been performed, enabling proper visualization for TF2 and streaming TensorBoard events from the FL clients to the FL server.
- FLOWER [30]. As the framework currently does not officially provide privacy preservation, the IoT-NGIN novelties include the integration of the PATE (Private Aggregation of Teacher Ensembles) state-of-the-art technique with Flower, providing in this way an easy to develop, scalable, ML framework-agnostic FL framework with privacy guarantees.
- Tensorflow Federated [31]. The state-of-the-art FL framework of Tensorflow has been used to evaluate the performance of object detection models against the privacy preservation levels through various techniques.

IoT-NGIN will support PPFL as a service, enabling deployment of training tasks per preferred FL framework to preferred locations (nodes). Our effort is focused on defining common specifications for FL framework description/configuration which could allow easy extension of the solution with additional FL frameworks.

4.3 Enhancing IoT Tactile & Contextual Sensing/Actuating

4.3.1 IoT Device Discovery and Indexing

The IoT Device Discovery and Indexing modules are two versatile and fast to deploy software components for recognition, positioning and indexing of different types of objects. The versatility of these modules' relays in that fact that they can be adjusted to include different recognition methods.

The Discovery module is the module containing the different recognition methods. At the present, we have included four recognition methods, three of them are visual and one non-visual. Moreover, three of them present different degrees of improvement beyond the state of the art that have been achieved during this project. The focus of these improvements is the reduction of latency in the detections, but there are also improvements in the accuracy and the robustness of the methods. The main novelties are summarized in the next paragraphs but more details can be found in D4.2 and D4.3.

- Computer Vision. This method detects and tracks objects from video images using convolutional neural networks. It combines existing neural networks for object detection (Scaled-YOLO_v4) and tracking (Siamot), and as a result there is an overperforming the Siamot tracker. The neural networks enclosed in this method have been also improved for detecting specific objects and to reduce the detection time to the values required in Ambient Intelligence and Tactile IoT applications.
- Visual Light Positioning. This method has developed rapidly in the recent years. It requires the installation of a specific device consisting in a camera and a single-boar computer on the object that needs to be detected and positioned. At the same time, several LED lamps need to be installed on the area in which an object might move. Then, the camera on the device can record the light from the lamps and calculate the position of the objects from these references. The novelty proposed in IoT-NGIN modifies both hardware and software of the VLP method to improve the detection and positioning time.
- Ultra-Wide Band Positioning. The positioning of objects through this method is based on the multilateration of different UWB signals received by the objects. The novelty presented in the project are new signal processing algorithms that improve the positioning in Non-Line-Of-Sight situations and noisy scenarios. It also includes improvements on the hardware for a better setup and robustness in industrial environments.

On the other hand, the objects recognized in the IoT Discovery module are registered in the IoT Indexing Module. The information included in each register is the type of object, the ID of the object, a timestamp, the status and any over additional information that might be required by the applications. The IoT Device indexing module is an instantiation of two existing software components, which are the Fiware Context Broker and the Fiware IoT Agent. The main novelty of the IoT Indexing module is that can also support for historical data services and that can be implemented on a Helm chart.

Finally, the last novelty is that the IoT Device Indexing module can register the position of different object using different recognition methods allowing new type of applications. An example of this capability is an application that can detect potential collisions of humans and Autonomous Guide Vehicles (AGVs) working together in a factory. The humans can be easily recognized and positioned with cameras using the Computer Vision method at the same time the AGVs position and trajectory can be known with the UWB positioning method. With all of this information put together in the IoT Device Indexing module, it is straightforward to run an application that can detect potential collisions and take actions before them might occur.

4.3.2 IoT Device Access Control

Access control is of utmost importance in large IoT systems, with multiple services to be protected, a variety of users and different levels of access. The need for a highly efficient and transparent mechanism that allows multiple methods of authorization and authentication as per use case, is mandatory. The IoT Devices Access Control (IDAC) module of IoT-NGIN has been implemented to handle the access to the resources of the IoT-NGIN framework. Detailed analysis of the component can be found in D4.3 “Enhancing IoT Tactile & Contextual Sensing/Actuating” [32].

The IDAC module is implemented as a flexible Ingress Gateway enforcing chained access control methods, following different access control mechanisms which are implemented as plugins. Within the scope of IoT-NGIN, the following custom plugins have been developed:

- Proximity plugin: Through this plugin, access to the protected resources is granted only for requesters which are close enough to the device to satisfy the pre-defined proximity criterion according to the application needs. In IoT-NGIN, the enhanced control mechanisms of this plugin have been integrated with the Digital Twin functionality, provided by the Device Indexing component, thus securing access to the Digital Twin of devices registered in the Device Indexing component. The proximity plugin is an essential part of next-generation internet in the context of ambient intelligence in IoT systems.
- OpenID Connect Authentication plugin: It allows securing applications and services, based OpenID Connect [33] (an extension to Oauth 2.0). Although open-source plugins are available for basic authentication and Oauth authentication services implemented by Kong [34], there is no open-source plugin for Open ID Connect services offered by a third-party provider. This plugin allows to integrate state-of-the-art solutions for the provision of Authentication Authorization Accounting (AAA) services, such as Keycloak [35].
- SSI plugin: It adds protection based on the Privacy Preserving Self Sovereign Identities (SSI) component of IoT-NGIN, presented in D5.3 "Enhancing IoT Data Privacy & Trust" [36]. The plugin facilitates the use of SSI for intercepting communications between clients and resource servers and applying authentication and authorization using user-provided tokens.

Therefore, the IDAC module facilitates the enforcement of diverse access control mechanisms, possibly in a chained manner, without the need of direct involvement of the clients or the devices per se. Through its flexible design, it is very easy to extend it with additional access control mechanisms, integrating additional plugins.

4.3.3 IoT Device Augmented Reality actuation

Several AR applications have been deployed in the use cases of the IoT-NGIN project. These applications together with different frameworks, devices, Github codes and scientific publications will be included in a repository of AR tools for interaction with IoT.

The main novelty is that we have created a set of APIs that will allow the different AR tools to interact with the IoT Device Indexing module. This interaction will give access to the AR tools to the information of the position and status of the objects registered in the IoT Device Indexing module. This connection makes possible new AR applications, i.e., it makes possible to an user wearing AR lens to interact with object that are not visible from his/her point of view but which position is known because it is registered in the IoT Device Indexing module.

4.4 Enhancing IoT Cybersecurity & Data Privacy

Cybersecurity threats challenge the normal operation of IoT systems which suffer from both device or network vulnerabilities, as well as by emerging risks arising through the extensive use of AI. IoT-NGIN innovates in IoT cybersecurity by proposing a cyber-threat modelling approach, mostly inspired and aligned to ENISA's threat modelling methodology for AI, and additionally providing a set of cybersecurity tools implementing this approach.

First, IoT-NGIN provides the **Generative Adversarial Network (GAN) based IoT attack dataset generator** component, which generates high-value synthetic datasets of attacks, using a small portion of real data and preserving the utility and fidelity of real datasets. The GAN Generator of IoT-NGIN is able to create close-to-real synthetic datasets for both tabular data and images, proving useful for training attack detection models targeting both network level and data poisoning attacks.

Moreover, the IoT-NGIN toolset includes the **Malicious Attack Detector (MAD),** able to identify attacks in on-device Federated Learning, based on ML anomaly detection models. MAD incorporates ML models for both network attacks and data/model poisoning attacks and is pertinent to identify such attacks in IoT systems deploying Federated Learning for distributed training of ML models.

The **IoT vulnerabilities crawler** of IoT-NGIN identifies common vulnerabilities in distributed IoT systems. It features a distributed cloud-native architecture leveraging service-oriented plugins, which ensure scalability and extensibility with additional vulnerabilities' sets with minimal effort. The crawler is useful to performing vulnerability assessment of IoT systems, as well as to providing useful feedback for improving their security, as well as to further analyzing cyber-threats or attacks related to the identified vulnerabilities in the IoT systems under investigation.

Last, but not least, the **Moving Target Defense (MTD) network of Honeypots** of IoT-NGIN allows exploration of attackers' behavior, exploiting IoT systems' vulnerabilities. Honeypots are widely used in network security. A honeypot is a decoy computer system that appears attractive to an attacker and can be used to collect information on threat behavior and vectors. MTD dynamically changes the attack surface to continuously increase complexity and confuse the attacker, thus preventing the system vulnerabilities from being exploited. The MTD network of Honeypots of IoT-NGIN can be used to mimic vulnerabilities identified by the IoT vulnerabilities crawler. Then, it can provide useful feedback to the vulnerability and threat modelling, as well as threat detection processes. IoT-NGIN integrates various honeypot solutions and can be easily extended to include more, thanks to its flexible design.

4.4.1 Detection & Mitigation of Cyber Attacks in on-device Federated ML

Much of the cybersecurity and privacy work in WP5 focuses on the IoT-device Triplet shown in the center of Figure 7. The Triplet consists of a real-world entity (in this case, an IoT device), the Digital Twin that exposes the devices capabilities on the net, and the Semantic Twin that semantically describes the other two. When the real-world entity is something other than an IoT device (e.g., a shopping mall or a person), the Triplet can also be called an Entity Triplet, but in IoT-NGIN the focus is mostly on Triplets with IoT devices.

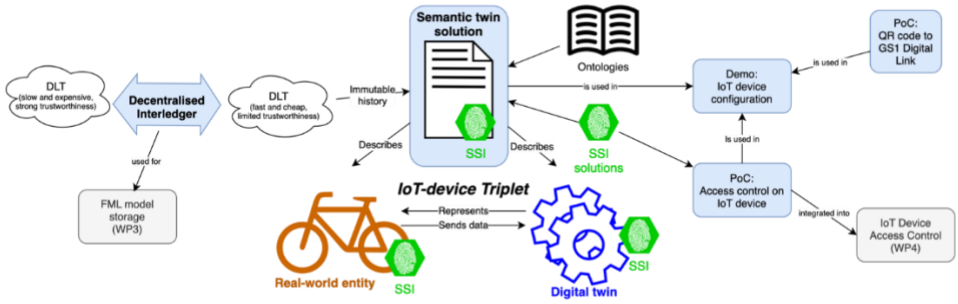

Figure 7: The IoT-device Triplet -related technologies developed in WP5.

To support the Iot-device Triplet, WP5 is developing multiple technologies as shown in blue in the figure. First, the Semantic Twin is a novel concept of providing a structured semantic description of the Triplet. The core element is describing the capabilities of the IoT device and Digital Twin and where they can be accessed, but this information can be complemented with many other types of information, e.g., the licensing of the services and where access could be purchased, information about the validity of the services through, e.g. 3rd-party certification, etc. To make this semantic information as machine-readable and interoperable as possible, the information is organized based on ontologies, particularly SAREF ontologies that are aimed for IoT use cases.

Another technology being developed is a decentralized interledger that allows us to link distributed ledgers (DLTs) and blockchains with atomic transactions. There are multiple interledger solutions, but most only focus on financial transactions or have limitations on the types of DLTs/blockchains they support. IoT-NGIN is focusing a bridging-type interledger, which supports a very wide range of ledgers and is agnostic of the transaction type, so it can be used with any type of application. Specifically, the work builds on an existing centralized bridging solution, which provides suitable functionality and interfaces, but suffers from the limitations of a centralized solution, namely higher trust requirement on the party running the bridge and lower resiliency. IoT-NGIN is, therefore, developing a decentralized version of the technology, which allows us to overcome the limitations by utilizing the same decentralization approach as the DLTs and blockchains rely on. With the interledger, the Semantic Twins can now rely on multiple ledgers to provide immutability in a cost-effective manner.

To improve the privacy of the people, our work utilizes Decentralized Identifiers (DIDs), an identifier technology that follow the Self-Sovereign Identity (SSI) principles of the identity owner being able to generate and use as many anonymous identifiers they need to protect their privacy, e.g., to prevent correlation attacks resulting from the same identifier being used in multiple contexts. We also utilize another SSI-technology, Verifiable Credentials (VCs), to carry information about the trustworthiness of different parties and to implement decentralized access control solutions. The use of DIDs and VCs has been previously explored mostly in the context of people and organization, but we are here focusing particularly on their use for things, IoT devices and the related twins, to bring the privacy and trust benefits also to this application area.

The make the use of Semantic and Digital Twins convenient, we are also exploring using digitally signed QR codes and GS1 Digital Links as a convenient and secure way to locate the Twins related to a particular IoT device. These types of new usability-oriented solutions are required to enable wide-scale usage of Twin-based solutions.

5 IoT Meta-Architecture

Chapter 5 is divided into 2 subsections, the initial living lab results and the alignment of the meta-architecture and component specifications. The alignment of the meta-architecture is done based on the technology watch snapshot, the new use cases and the initial living lab results.

5.1 Initial Living Labs Results

At the time of writing of this deliverable, the definition of the validation processes, KPIs and requirements of all Living Labs has already been done. Moreover, work on all of the Living Lab Use Cases has already been started, albeit at different levels. All of this information was included in deliverable *D7.2 – Trial site set-up, initial results and DMP update*. The deliverable included, among other things, the required equipment, trial site set-up information, alignment with the IoT-NGIN technologies as well as the initial results.

Table 34 below summarizes the initial results of the different use cases as included in D7.2. As the different use cases are at different stages of execution, their initial results may vary from equipment procurement, to infrastructure setup to running initial simulated tests. These initial results are used in this deliverable as feedback to IoT-NGIN meta-architecture to align it better to the needs of the Living Labs.

Table 34: Summary of initial results of the existing IoT-NGIN use cases.

Initial Result Type	Initial Result Description
UC1 – Traffic Flow Prediction & Parking prediction	
Equipment Procurement	The Smart Junction Project[30] has already installed several types of equipment in Jätkäsaari area: - 17 radars, which already provide data - 17 cameras, which are being calibrated - 7 signal controllers, which are being calibrated - 1 LIDAR, which is being calibrated
UC2 – Crowd Management	
Equipment Procurement	- The traffic cameras provided by Conveqs for UC1 can also be used for measuring crowd movements when coupled with appropriate machine vision service
Infrastructure Setup and Data Collection	- Hypercell and City of Helsinki provide crowd activity data based on Bluetooth beacon measurements. Some of the data streams are publicly available and access to more specific data streams can be acquired from the providers.

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

Initial Result Type	Initial Result Description
UC3 – Co-commuting solutions based on social networks	
Given that UC3 will build on top of UC1 and UC2 and requires some results from these use cases, work has not yet started on this use case and there are currently no initial results available. Results on this use case will be included in future deliverable of WP7.	
UC4 – Crop diseases prediction. Smart irrigation and precision aerial spraying	
Equipment Procurement	After performing a market analysis based on the relevant requirements of UC4, the following equipment have been procured: - UAV: DJI MATRICE PRO - Camera: Parrot Sequoia+ camera as the multispectral camera of the UAV (resolution of 11cm/px at 120m) - Processing Unit: NVIDIA Jetson Nano 4GB
Simulated and Laboratory Tests	- The IoT Device Indexing (IDI) component of IoT-NGIN has been deployed on an edge server on SYN premises. - Testing of IDI has been done by registering a new service, representing the UAV under consideration. - Communication has been tested by sending batches of the captured images and the crop disease prediction values from UAV to IDI. The IDI can then be queried to provide data associated with the UAV.
UC5 – Sensor aided crop harvesting	
Equipment Procurement	An approach similar to UC4 has been followed for the drone selection, considering relevant IoT-NGIN requirements of UC5: - AGLV: Wild Thumper 6-Wheel platform - Microcontroller: Arduino Mega2560. A Pulse Width Modulation (PWM) controller used for controlling the velocity of the AGLV motors - Ultrasonic sensor: HC-SR04 - Processing unit: NVIDIA Jetson Nano 2GB - Camera: Zed 2i stereo-camera (to be mounted on AGLV)
UC6 – Human-centred safety in a self-aware indoor factory environment	
Equipment Procurement	For this UC, two types of devices have been procured: - UWB Anchors: static elements that make up the UWB infrastructure and the location area - UWB tag: the mobile element to be located At the hardware level, both devices contain the same elements: - Communication module: The DWM1001 Development Board, which includes the UWB transceiver DW1001C and a Nordic Semiconductor nRF52832 - Processing unit: An Espressif ESP32 development board

Initial Result Type	Initial Result Description
	- A Li-ion rechargeable battery
Simulated and Laboratory Tests	- The UWB-based Real Time Location System (RTLS) developed by I2CAT has been tested in an industrial bay located in the city of Barcelona. - A UWB network has been deployed by means of 4 anchors that form a trapezoid altogether, thus creating a location area of 283.28 m2. The height of the anchors was established at 2 meters using portable poles. - The results of this test prove the high accuracy of the developed localization system. The average position generated by the system is very close to the real position of the UWB tag. In fact, the average error is always below 30 cm (ranging from 6 to 28 cm).
UC7 – Human-centred augmented reality assisted build-to-order assembly	
Simulated and Laboratory Tests	- An initial digital model has been developed for one of the drive cabinet models. Model importing to AR has been tested with Unity[31] and Vuforia Studio[32]. The import was successful with both IDEs.
UC8 – Digital powertrain and condition monitoring	
Infrastructure Setup and Data Collection	- A raspberry PI gateway device has been prepared, which can process and then forward data to IoT-NGIN components, avoiding possible integration problems down the line. - Firmware modifications have been done to the IoT panels of the drive units so that data can be gathered flexibly and utilized by IoT-NGIN components. - An initial twin document has been prepared describing data endpoints of a powertrain ensemble using the W3C WoT model.
UC9 – Move from reacting to acting in smart grid monitoring and control	
Infrastructure Setup and Data Collection	- The infrastructure has been defined and all sensors are placed in the Living Lab and transmit data in real time. - A database with historical data is also in place. - A new SCADA system was implemented, which collects the data produced by the different sensors and allows a more effective sharing of real-time and historical data with partners.
UC10 – Driver -friendly dispatchable EV charging	

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

Initial Result Type	Initial Result Description
Equipment Procurement	The following equipment has been procured: - A dedicated server for DSO operation - A dedicated server for e-Mobility operation - Smart meters - PMUs - Electric vehicles - OBDs and charging stations.
Infrastructure Setup and Data Collection	- Living Lab data was started to be collected from field devices and processed for Machine Learning training.

5.2Update & Alignment

Deliverable D1.2 [37] defined the IoT-NGIN meta-architecture as a generic "*research-informed framework for designing and implementing IoT solutions in different usage scenarios*", essentially allowing for the design and definition of effective IoT architectures. Indeed, the IoT-NGIN architecture was completely aligned with the meta-architecture, acting as a first example of employment. However, the appropriateness of a meta-architecture cannot be assessed by means of a single application; in the following paragraphs, the IoT-NGIN meta-architecture is compared to five existing, highly acknowledged reference IoT architectures. Interestingly, the IoT-NGIN meta-architecture offers a superset of the considerations of the reference architectures under comparison, being able to accurately model them, also catering for further modalities and technology considerations at all times.

5.2.1 Mapping to Solution Architectures

5.2.1.1 IoT-A Reference Architecture

IoT-A, EC's flagship FP7 project with respect to establishing an architecture for the Internet of Things, has created an "Architectural Reference Model" (IoT ARM) as the common ground for the Internet of Things [38]. IoT ARM's functional model defines functional groups which cover a set of similar functional requirements and indicates interactions among them. A similar approach has been adopted in IoT-NGIN Meta-architecture, whose 'Elements' View' defines functional groups which aggregate the functionality of the related components and, implicitly, provide an indication related to the objective of the group. In Figure 8, an association of the IoT-NGIN Meta-Architecture to IoT-ARM functional model is proposed. As shown in this proposal, the *Things* group of IoT-NGIN provides a different abstraction level, collecting functionality related to the devices, so that it covers part of the functionality from three functional groups of IoT ARM functional model (*Device*, *Virtual Entity*, *IoT Service*). For the rest IoT-ARM groups, one-to-one mappings can be considered in both approaches.

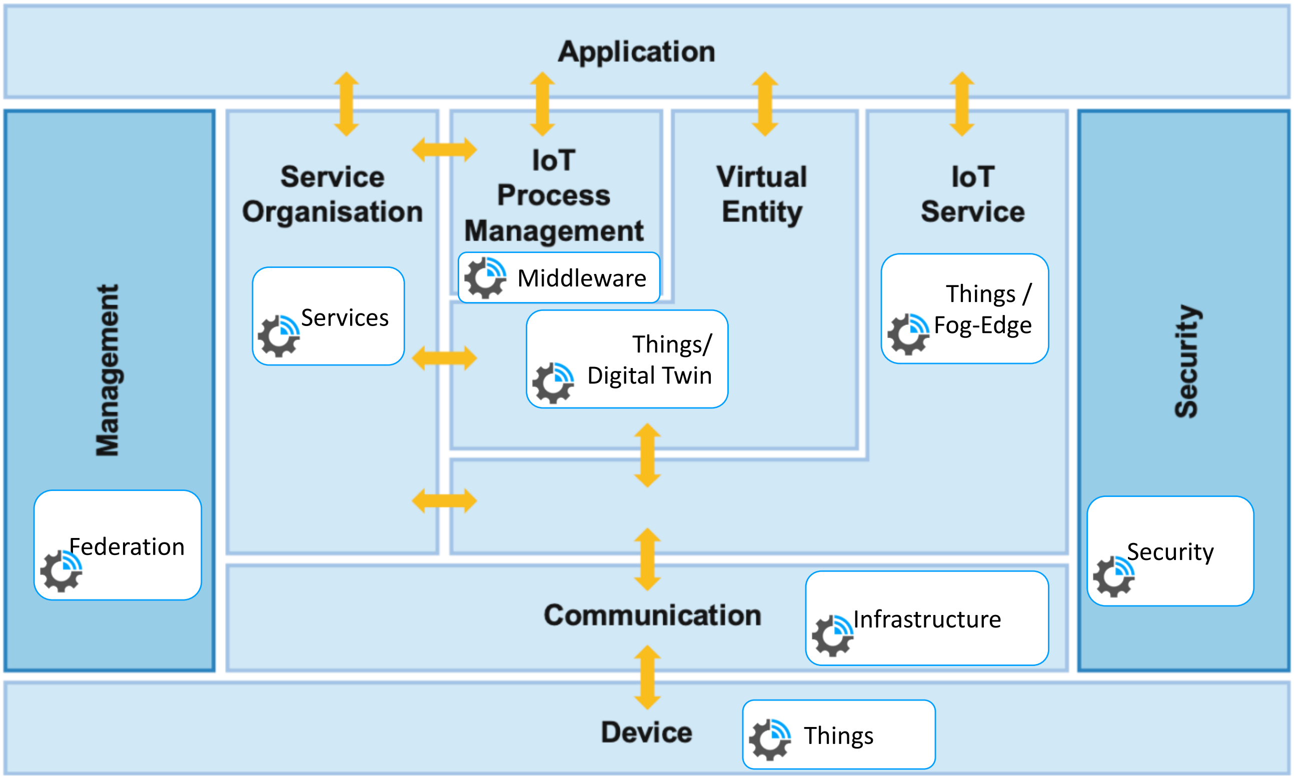

Figure 8: Mapping to IoT-A Reference Architecture Functional Model.

5.2.1.2 AIOTI High-Level Architecture

The AIOTI High-Level Architecture [39] has been based on a layered approach, including the Application Layer, the IoT Layer and the Network Layer. These three layers describe interactions within AIOTI's domain model, which is derived from IoT-A Domain Model [38]. Specifically, the *Application layer* contains the communications and interface methods used in process- to-process communication. The *IoT layer* groups IoT specific functions, such as data storage and sharing, and exposes those to the application layer via interfaces commonly referred to as Application Programming Interfaces (APIs). The IoT layer makes use of the Network layer's services. Last, in the *Network Layer*, data plane services, provide short- and long-range connectivity and data forwarding between entities, and control plane services such as location, device triggering, QoS or determinism.

The mapping of the IoT-NGIN meta-architecture to AIOTI HLA is depicted in Figure 9. In AIOTI's *Application Layer*, the applications for different domains, as considered in IoT-NGIN meta-architecture, can be found. The rest part of IoT-NGIN meta-architecture maps to AIOTI's both IoT and Network Layer. Specifically, The IoT Layer incorporates services considered under the *Things*, *Analytics*, *Automation*, *Workloads*, *Federation* and part of the *infrastructure* functional group. The elements of the *infrastructure* group mapped into the *IoT Layer* include services related to management of a variety of infrastructure elements including (usually virtualised) compute, storage, and network as well as other existing systems and infrastructures, in the context of an edge-oriented next generation IoT platform. The elements of the *infrastructure* group mapped into the *Network Layer* include services which support the fog/edge processing, as well as the ones which address the networking requirements implicitly imposed by the Fog-Edge functional group (essentially 5G with slicing support).

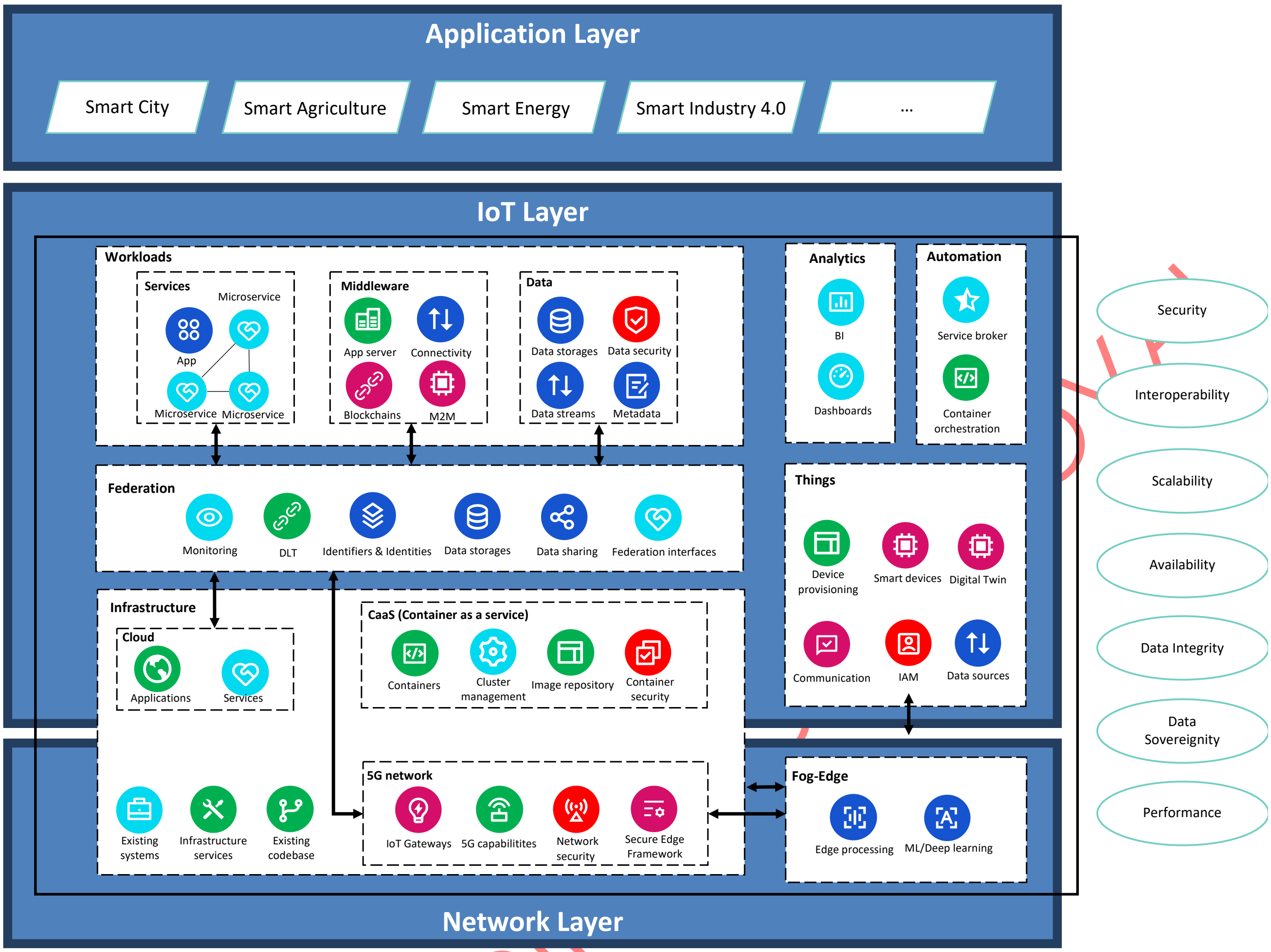

Figure 9: Mapping to AIOTI HLA.

Moreover, AIOTI has defined a *Microservices-based functional architecture for IoT Virtualization* [39]. As this architecture provides the functional split of services into layers (and sublayers) and is proposed as an indicative architectural structure the generic microservices that could be found in an IoT Layer, the IoT-NGIN Meta-Architecture suggests an alternative functional view, which, however, supports similar functionality for the IoT Layer. The mapping of functionality in these two approaches in depicted in Figure 10, which confirms that similar functionality is provided in an alternative architectural organization, which in IoT-NGIN results in greater emphasis on the integration of the IoT, edge and cloud continuum.

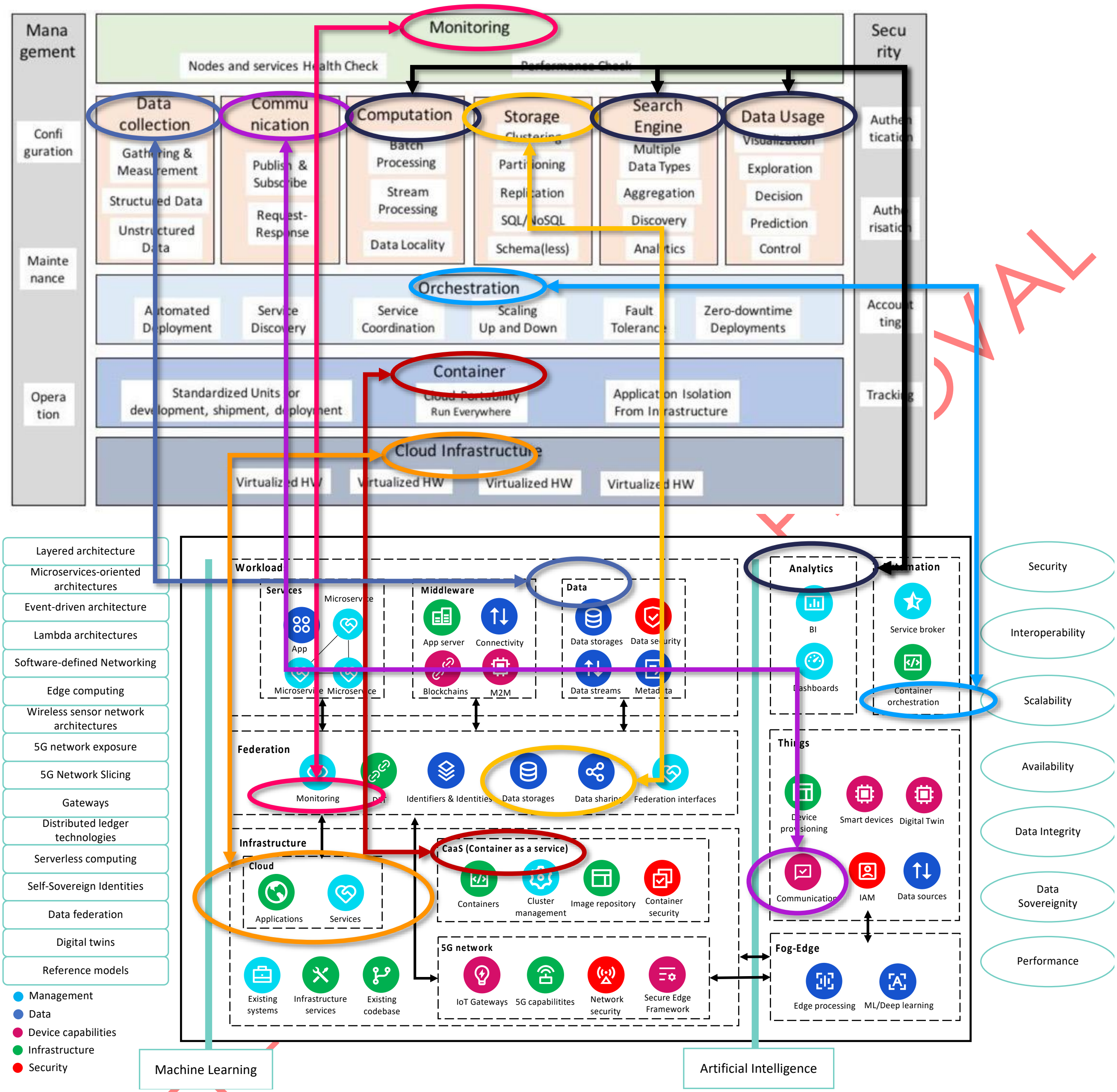

Figure 10: Mapping to AIOTI microservices functional view.

5.2.1.1 W3C Web of things

Web of Things (WoT) describes a set of standards by the World Wide Web Consortium (W3C) for the interoperability of different Internet of things (IoT) platforms and application domains. It is a subset of IoT and is built around software standards such as REST, HTTP, and URIs to allow devices to interact with one another. The pure existence of WoT is to set systematic paths for the information to transfer between points and ensure compatibility with source and destination. It seeks to define web technology standards at the app/service layer above the sensors, actuators and communications technologies that form the IoT. W3C is well positioned to support semantic interoperability of apps and services at a global scale.

The Web of Things (WoT) builds on top of the concept of Web Things – usually simply called Things – that can be used by so-called Consumers **Invalid source specified.**. WoT introduces a simple interaction abstraction based on properties, events, and actions, through which any IoT network interface can be described. *WoT Thing Description* (TD), i.e., an IoT device's metadata, It provides information on which data and functions are provided, which protocol is used, how data is encoded and structured, and security mechanism is used to control access, and further machine-readable and human-readable metadata. A TD is expressed in JSON-LD and can be provided by an IoT device itself or hosted externally in a repository such as a TD Directory. *WoT Binding Templates* refer to metadata providing mapping of specific protocol to WoT's interaction properties-action-event abstraction. The (optional) *WoT Scripting API* enables implementing device logic by reusable scripts executed in a runtime system for IoT applications, while standardized APIs enable portability for application modules. The Web of Things defines Interaction *Affordances* as metadata of a Thing that shows and describes the possible choices to Consumers, thereby suggesting how Consumers may interact with the Thing **Invalid source specified.**.

Figure 11 depicts the abstract architecture of W3C WoT, which indicates how flexibly the *Thing* concept may represent operations at IoT device, edge and cloud level.

Next, Figure 12 suggests a potential mapping of IoT-NGIN meta-architecture to the Thing Architecture. Specifically, *Behavior* corresponds to application layer services, while *interaction affordances* and *data schemas* are included in IoT-NGIN's *Data* and *Things* elements. Security configurations can be covered by the *Security* vertical component, as well as the *Things* group, and especially IAM in it. Last, but not least, *Protocol Bindings* can be provided by the *Middleware* group of IoT-NGIN.

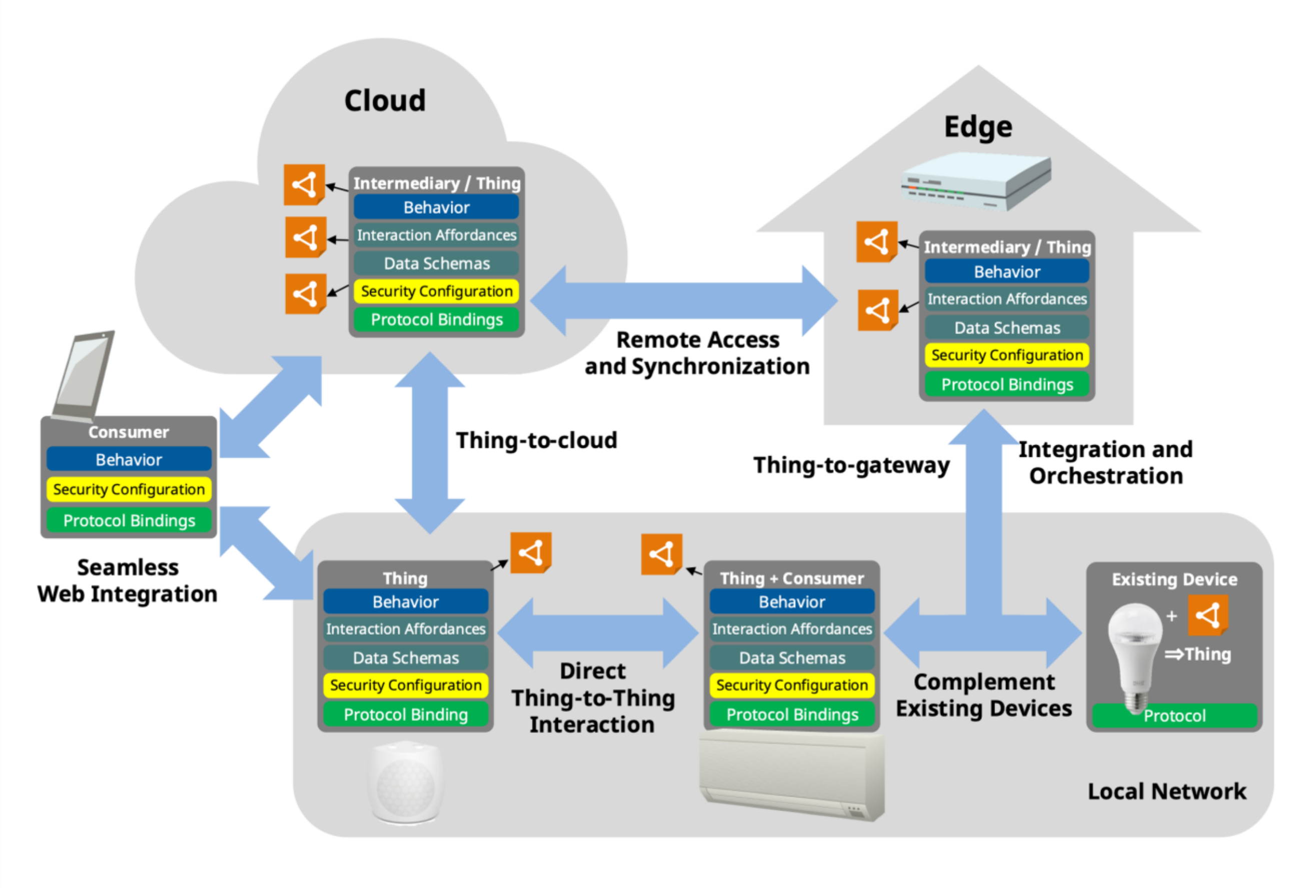

Figure 11: Abstract Architecture of W3C WoT [40].

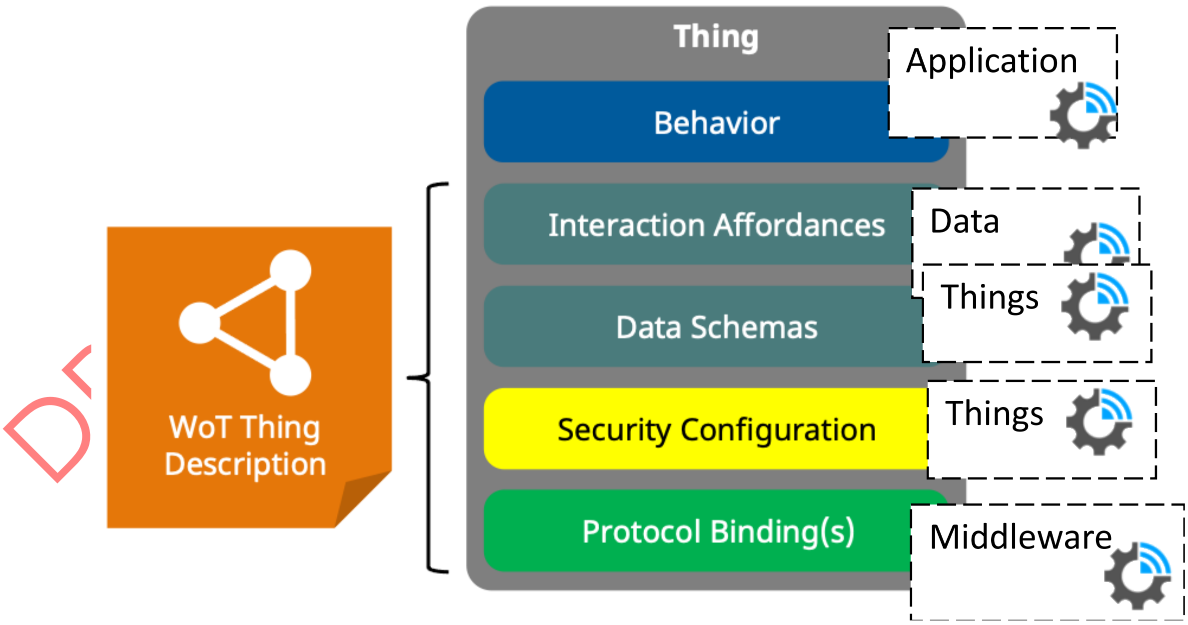

Figure 12: Mapping IoT-NGIN Meta-architecture elements to the architectural aspects of a *Thing*.

5.2.1.2 FIWARE Open-Source Reference Architecture

FIWARE [40] has been the cornerstone of the Future Internet PPP program, a joint action by the European Industry and the European Commission. Today, FIWARE Community's mission is to "build an open sustainable ecosystem around public, royalty-free and implementation-driven software platform standards that ease the development of new Smart Applications in multiple sectors". FIWARE achieves this through open-source tools, delivering generic or domain specific functionality, identified as Generic Enablers (GE) or Domain Specific Enablers respectively, which can be assembled together to derive flexible platforms which accelerate the development of smart solutions.

In the FIWARE Reference Architecture (RA), GEs are grouped based on their functionality into the following groups [41]:

- *Core Context Management*, which enables to perform updates and bring access to context and is provided by FIWARE Context Broker
- *Interface with IoT, robots and third-party systems* for gathering valuable context information or trigger actuations in response to context updates.
- *Context processing, analysis and visualization* for implementing the "smart behavior" expected in any application
- *Context data/API management, publication and monetization*, which provides secure access to components in the architecture.
- *Deployment tools*, using standard containerization techniques.

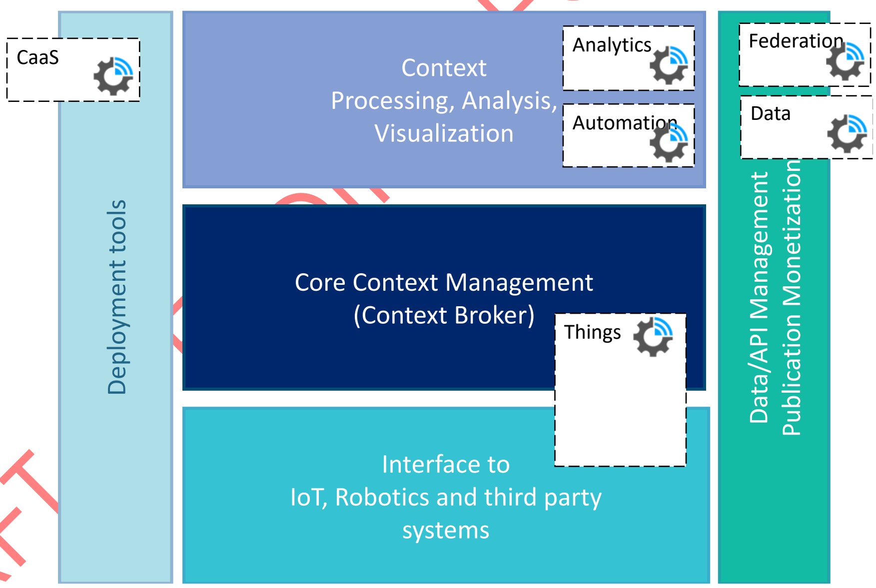

Figure 13: Mapping IoT-NGIN meta-architecture functional groups to FIWARE Reference Architecture.

Although focused on the concept of GEs, the FIWARE Reference Architecture is highly modular and a standard approach for building smart systems. In the context of next-generation IoT, a potential mapping of IoT-NGIN meta-architecture to FIWARE RA is depicted in Figure 13.As shown, the functionality of the *Core Context Management* and the *Interface to IoT, Robotics and third-party systems* can be provided through IoT-NGIN's *Things* functional group. In addition, the *Context processing, analysis and visualisation* operations are well supported by the *Analytics* and *Automation* groups of IoT-NGIN. *Context data/API management, publication and monetization* functionality is delivered though the *Federation* and *Data* groups of IoT-NGIN. Last, but not least, FIWARE's *Deployment tools* provide similar functionality to the *Container-as-a-Service* group of IoT-NGIN.

5.2.1.3 BDVA Reference Model

The Big Data Value (BDV) Reference Model [42] is a reference framework defined by the European Big Data Value Association (BDVA) in their Strategic Research and Innovation Agenda (SRIA) that describes logical components of a generic big data system. The BDV Reference Model is composed of orthogonal components:

- Horizontal components address the data processing value chain, from data acquisition to data visualization.
- Vertical components address cross-cutting aspects, which refer to technologies or modalities which are necessary or facilitate data operations.

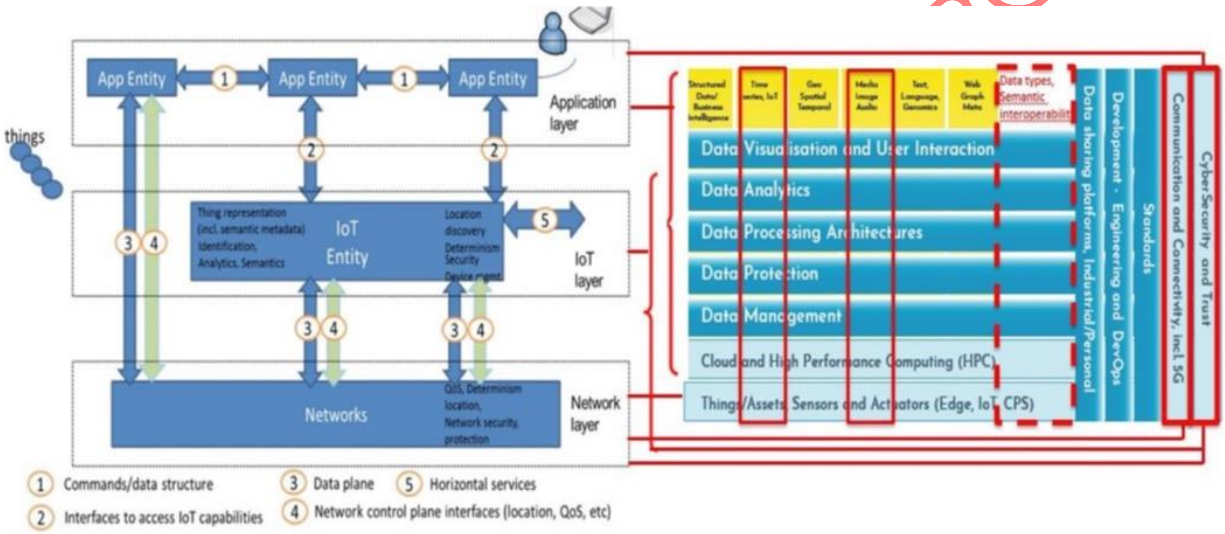

Figure 14: BDV Reference Model mapping to the AIOTI HLA.

A mapping between AIOTI HLA and the BDV Reference Model is provided in Figure 14 by AIOTI [39]. Inspired from that, the IoT-NGIN meta-architecture can be mapped to the BDV Reference model, as proposed in Figure 15. According to that, the functionality envisaged for the lower BDV component (Thing/Assets, Sensors and Actuators (Edge, IoT, CPS) relates to the functionality of the IoT-NGIN *Things* group, while *Cloud and High-Performance Computing (HPC)* is covered by the *Cloud* group of IoT-NGIN. The *Data* group of IoT-NGIN covers parts of the functionality of the *Data Management* and *Data Protection* components of BDV Reference Model, while the *Federation* group complements *Data Management* services, as well. The *Data Processing Architectures* envisage similar functionality to the IoT-NGIN *Services* and *Middleware* groups. In addition, the *Analytics* group of IoT-NGIN supports operations which fall under both the *Data Analytics* and *Data Visualization and User Interaction* grouped of the BDV Reference Model. Moreover, *Development, Engineering and DevOps* of BDV can be related to the *CaaS* and *Automation* groups of IoT-NGIN. Last, the *communication and Connectivity* component can be mapped to the *5G Network* of IoT-NGIN.

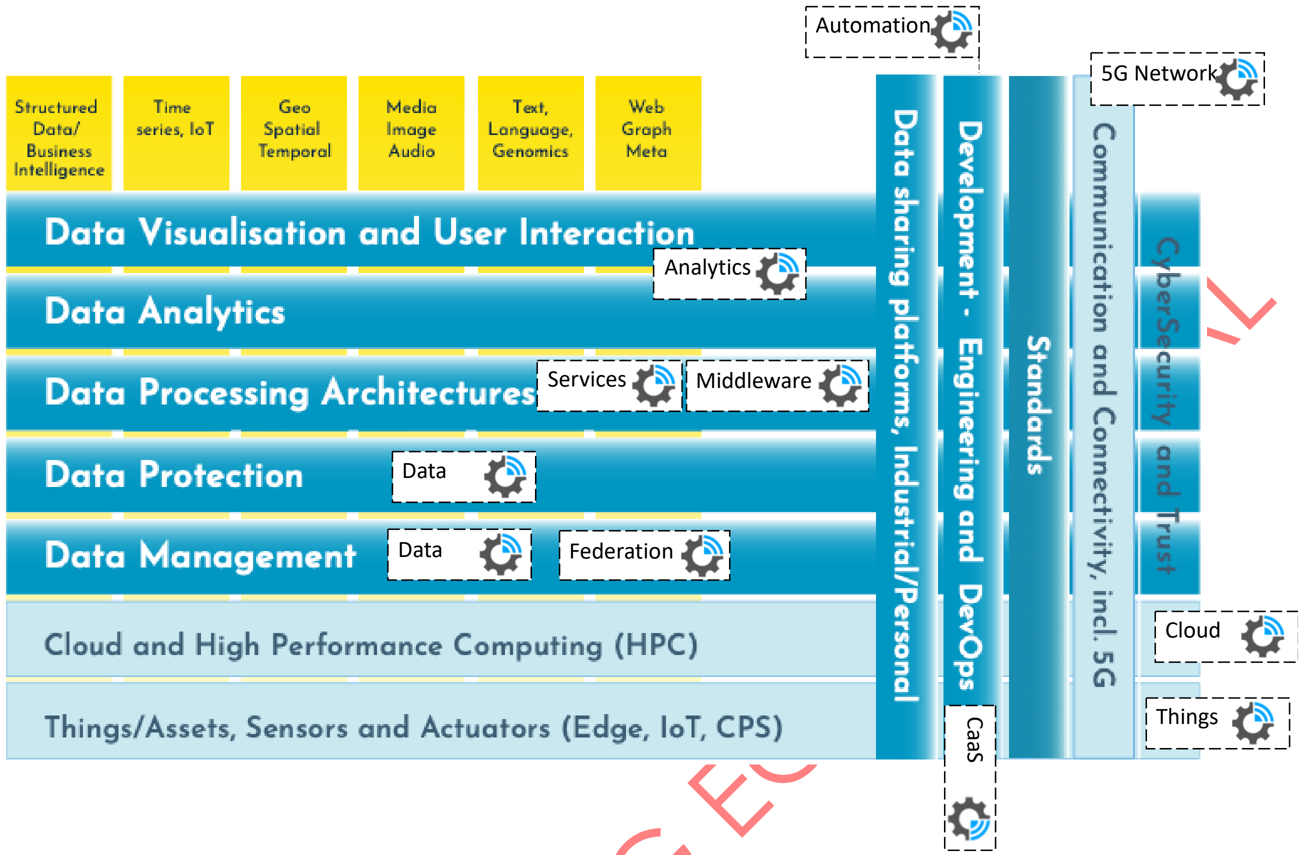

Figure 15: IoT-NGIN meta-architecture mapping to BDV Reference Model.

5.2.1.4 OpenDEI Reference Architecture

The OPEN DEI project has defined a Reference Architecture Framework (RAF) [43], focusing on providing interoperability by design, realized by reusable building blocks, and describing the cross-domain digital transformation. OPEN DEI RAF has been developed around the main concept of Data Spaces in which data is shared (published and accessed) across *field-level (IoT)*, *edge-level* and *cloud-level* data spaces. Moreover, RAF envisages the interaction of these -horizontal- fields with vertical layers for *trust and security*, *data sharing* and *data trading*.

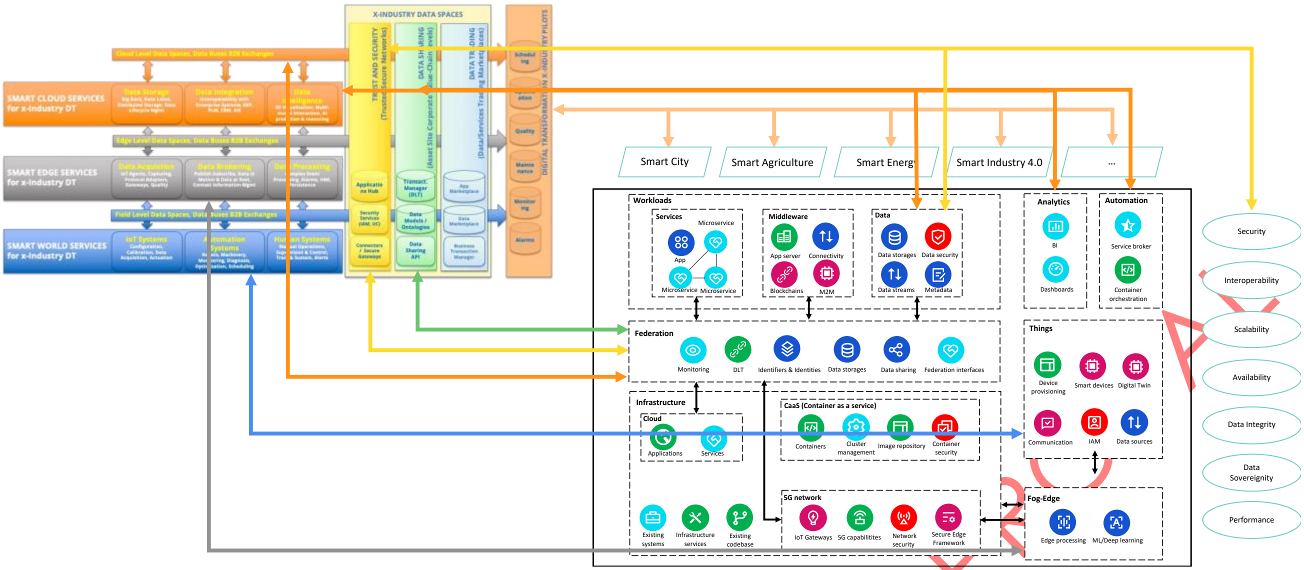

Figure 16: Mapping to OPEN DEI Reference Architecture Framework.

The IoT-NGIN meta-architecture, which has been built mainly around next-generation IoT, can be mapped to the OpenDEI RAF through the mapping proposal presented in Figure 16. Specifically, the *Things* group of IoT-NGIN can be mapped to the *Smart World Services* RAF block, while the *Fog-Edge* group directly connects to the RAF *Smart Edge Services*. The functionalities envisaged under the *Analytics*, *Automation* and part of *Data* groups of IoT-NGIN converge to the ones described in RAF *Smart Cloud Services* layer. RAF *X-Industry Data Spaces* layer refers to functionality supported by IoT-NGIN's *Federation and Data groups*. RAF *X-Industry Data Buses* shares part of the functionality described by IoT-NGIN's *Federation* group. Last, but not least common functionality for the application layer is foreseen in IoT-NGIN application verticals (Smart City, Smart Agriculture, Smart Energy, Smart Industry, etc.) and RAF *Digital Transformation X-Industry Pilots*.

6 Conclusions

This deliverable report reponds to all tasks of Work Package (WP) 1, entitled "Next Generation IoT Requirements & Meta-Architecture. The report describes the following outcomes from WP1:

- Detailed analysis of the new use cases coming from the Open Call Participants of the 1st call. These 4 new use cases have been described in the same manner as the initial 10 have and KPIs for each one have been identified and documented. All of the above mentioned use cases will be implemented and tested in the existing Living Labs of IoT-NGIN. Additionally to the KPIs of the new use cases, a summary table of the updated benchmarking KPIs of the initial 10 use cases is also provided.
- An initial assessment on the potential and commercialisation interest of the use cases and verticals to be investigated. Furthermore, it provides a summary of the novelties stemming from the technology development work packages. This summary of the novelties of IoT-NGIN technologies, together with the snapshot of the continuous technology watch both from the use case and the technology perspective allows an initial comparison and positioning of the IoT-NGIN technologies in the global IoT market. These outcomes presented in this deliverable will be used as an input to work package and more specifically to tasks 8.2 and 8.3 focusing on the creation of the business models and the exploitation and sustainability plans.
- Finally, the deliverable provides a summary of the initial Living Lab tests and together with the snapshot of the continuous technology watch, the IoT-NGIN meta-architecture has been updated and aligned with the current state-of-the-art.

A more in-debth analysis of the technologies identified by the continuous technology watch and a more direct comparison with the IoT-NGIN technologies. The final results and outcomes of work package 1 will be included in the final deliverable D1.4 "Continuous technology watch and alignment", which will include the results of a technological survey assessment to understand the sectoral needs and opportunities for IoT-NGIN, with an initial focus on the involved vertical industry segments (i.e. smart cities, smart energy, smart agriculture and industry 4.0). An analysis will then follow, which will seek to understand well how IoT-NGIN project outcomes compare and contrasts to other next generation IoT technological solutions being developed within the market.

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