H2020 5G Dive Project
Grant No. 859881

D5.2 Final Project Report

Abstract

This deliverable (D5.2) reports the management tasks for the second reporting period of the project. It encompasses the Part B (technical) part of the final periodic report that will be submitted by end of February 2022.

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Disclaimer

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1. Explanation of the work carried out by the beneficiaries and Overview of the progress

1.1. Objectives

The tables below report on the project progress in this reporting period towards the target objectives described in the description of action (DoA).

OBJ. 1 WP1	Design and validate 5G-DIVE technologies for specific applications, including the Industry 4.0 and Autonomous Drone Scouting verticals	
TARGET R&D TOPIC	**PROGRESS TOWARDS TARGET**	**DELIVERABLE**
Analysis of the technical, functional, and business requirements of the vertical industries use cases considered.	This topic has been fully addressed and the results reported in Chapter 3 of the first deliverable D1.1 [1]. This included the specification of the five targeted use cases, namely: *i)* Digital Twinning, *ii)* Augmented Zero Defect (ZDM) Manufacturing, and *iii)* massive Machine-Type Communications (mMTC) for Industry 4.0, and *iv)* Drones Fleet Navigation; and *v)* Intelligent Image Processing for Drones for Autonomous Drone Scouting. This specification detailed each use case's objectives, conditions, actors, execution flow, business, functional and technical requirements.	D1.1
Techno-economic analysis of the benefits of applying 5G to the vertical use cases.	This topic has been fully addressed and the results reported in D1.2 [2]. The work on this topic included: *i)* identification of the different stakeholders and their role in the value chain; *ii)* definition of the business model canvases for both the *System & Service Provider* and application providers of the 5G-DIVE pilots / use cases, showcasing the points of view of the key stakeholders in the eco-system; *iii)* definition of an evaluation methodology to help quantify the benefits of the solution; and *iv)* analysis of the business model impacts on the CapEx and OpEx in each vertical pilot / use case. Ultimately, it highlights the economic and operational feasibility of the 5G-DIVE solution and its applicability into the targeted use cases.	D1.2
Design and validation of the 5G-DIVE platform for the specific vertical use cases based on the results of the field trials.	This topic has been completely addressed by designing the baseline architecture of the 5G-DIVE solution (as shown in D1.3) and the output of field trials carried out in WP3 are summarized in D1.4 [4].	D1.1 D1.3 and D1.4
VERIFICATION	**STATUS**	**DELIVERABLE**

Demonstration of two verticals, namely Industry 4.0 and Autonomous Drone Scouting over the 5G-DIVE platform, having diverse 5G technical and business requirements, by conducting four E2E field trials in Europe and Taiwan.	D1.3 is positioning DEEP platform over a complete end-to-end (E2E) architecture and presenting the refinements over the main supporting strata but also describing the workflows with respect to baseline operations performed over the DEEP platform. The actual demonstrations are being specified jointly with WP2 and WP3, and the end-to-end trials in Europe and Taiwan are executed in WP3. The trial result and validation of requirement of I4.0 and ADS use cases had shown the benefit of 5G DIVE platform in three trials (i.e. 5G network, DEEP platform, fog and Edge computing).	D1.1 D1.3 and D1.4
Report on techno-economic study and validation of business models.	This is the main subject of deliverable D1.2 [2], Also, had has defined the business models Canvas of system and service provider. D1.3 describes the DEEP platform aiming at translating business requirements into technical requirements for the underlying infrastructure and while performing this task	D1.2, D1.3 and D1.4
Present and validate the advantages of verticals in an exploitation-specific workshop with verticals	The workshop hold with 5G-Growth project presented the latest updates for the 5G-DIVE use cases. Also, a workshop on ADS in 5G-DIVE occurred in 2020 and 2021. The workshop, especially in 2021, has demonstrated 5G-DIVE platform and end-to-end system Field trials in disaster relief missions. A Workshop organized in EuCNC 2021 demonstrated the DT use case benefit of utilizing 5G-DIVE platform. Extended report about the exploitation is presented in D4.3.	D1.4 and D4.3

OBJ. 2 WP2	Design and develop the 5G-DIVE Elastic Edge Platform (DEEP)	
TARGET R&D TOPIC	PROGRESS TOWARDS TARGET	DELIVERABLE
Analyze the 5G-CORAL architecture and identify the technical gaps and enhancements required to support 5G-DIVE vertical use cases and field trials.	The analysis of the 5G-CORAL architecture and identification of any gaps have been carried out in the baseline architecture design in WP1 and validated in in the DEEP design framework specification in WP2. This is reported in D1.1 [1] (WP1) and in D2.1 [5] (WP2). No significant gaps have been identified especially as the 5G-DIVE DEEP platform is positioned as an over-the-top middleware compliant for running over any Edge infrastructure (including reference 5G-CORAL). The focus here was on identification the interfaces for interaction between the 5G-CORAL EFS and	D2.1 and D1.1

	OCS, and the DEEP platform strata, namely DASS, BASS, and IESS. An enhancement of the 5G-CORAL infrastructure was also provided by adding an optical tunnel network system (OPTUNS).	
Enhance the connectivity layer of 5G-CORAL with 5G NR and its connectivity with a distributed 5G Core.	The introduction of the 5G system including RAN (with 5G NR access and DU-CU split fronthaul and backhaul transport) and Core has been addressed in Chapter 2 of deliverable D2.1 [5]. The focus was set on characterizing the 5G features that will benefit the targeted use cases as well as on specifying and testing the 5G system components (including UEs, CPEs, gNBs, and Core) for deployment of the 5G-DIVE solution in the targeted use cases. For example, in all use cases, the focus was set on non-standalone deployment in the mid-band (e.g., 3.5 GHz) as deemed sufficient to support the I4.0 and ADS use cases. RAN network equipment from Ericsson (e.g., Ericsson RDS) and ASKEY, core network software (EPC and 5G Core) from Ericsson, III, and ITRI, and UEs from Sierra Wireless, WNC, and Huawei have been prepared and are being tested for end-to-end deployment in the 5G-DIVE vertical pilots.	D2.1, D2.2, D2.3 and D2.4
Develop the 5G-DIVE Elastic Edge Platform (DEEP)	D2.3[7] and D2.4[8] have concluded the work on this objective. These deliverables entail the details on the underlying 5G connectivity options for the 5G-DIVE solution and use cases. In addition, the final specification of the DEEP platform and its components was reported. Details are documented on the final architecture of all the three DEEP components, the DASS, the BASS and the IESS. The deliverable covers the final specification of all the use cases and the final key modules as well as the features that were designed. With the final DEEP and use case design documented, the deliverable addresses the integration of all the use cases with the different components of the DEEP, at a conceptual level. Diagrams are presented describing all the relevant flows of interaction between each use case component and module/feature, and each of the DEEP platform component that has been assigned for integration.	D2.1 and D2.2
VERIFICATION	**STATUS**	**DELIVERABLE**
Analyze and simulate to pre-evaluate medium	Scalability has been a key requirement for the design of the 5G-DIVE solution, and this has been	D2.1 and D2.2

and/or large-scale systems.	covered in the specification of DEEP strata through the DASS, BASS and IESS. In terms of implementation and preliminary evaluation, this has been carried out mostly through experiments in small scale laboratory environments, involving few end user devices. Some medium scale simulation setups have been developed noticeably for the DT and ADS use cases. The evaluation through simulation and/or analytical studies for medium and large scale in both I4.0 and ADS have been reported in D2.3 [7] and D3.3 [11].	
Develop and demonstrate proof-of-concept prototypes (TRL 4/5).	Code implementing the key innovations of the project was presented in D2.4. All use cases make use of this code, specially the BASS implementation and will be showcased in the final demo. In addition, the DT and ADS use case have been demonstrated in different venues. DT and mMTC use cases have been integrated in 5TONIC. ZDM has been integrated in a pilot with Vodafone UK and Amazon Web Services. ADS has been integrated with a local 5G cell.	D2.1 and D2.2

OBJ. 3 WP3	Perform field trials and showcase vertical use cases	
TARGET R&D TOPIC	PROGRESS TOWARDS TARGET	DELIVERABLE
Integrate novel 5G-DIVE DEEP strata developed in WP2 into the 5G-CORAL baseline architecture.	Following the specification of 5G-DIVE DEEP in D2.1 [5] and its initial implementation provided in D2.2 [6], work in WP3 integrated novel algorithm both at edge and fog in the integrated field trial. trial setup for all the vertical use cases. This integration is completed in line with the timelines set for the first field trials planned in Taiwan and Europe in 2021, Also reported in D3.3.	D3.1 ,D3.2, and D3.3
Deploy the 5G-DIVE platform across all trial sites, including software and hardware components for all use cases planned.	In the second reporting period, the focus has been on defining a single platform for all the trial sites for I4.0 and ADS pilots. Afterward, the common DEEP platform is used for all the use cases. Specifically, DASS selected Zenoh for data exchange and more functionalities such as the replica of DT. Also, all use cases connected with the BASS platform which is developed and tested by TELCA for DT, ZDM, mMTC, and ADS use cases. In addition, the consortium managed to deploy one platform in MIRC building/Taiwan for ADS and one platform for I4.0 in 5TONIC/Spain both is live monitored by BASS.	D3.1 ,D3.2, and D3.3

Field trial the 5G-DIVE pilots over the E2E European and Taiwanese testbeds.	The field trials are executed in the second reporting period as the culmination of the work carried out in WP1, WP2 and WP3. In this second period, the complete E2E trial setup is completed including components integration of DASS, BASS, and IESS. Also, long and short validation for the provided solution occurred to measure the reliability, availability, and stability of the services provided in different use case solutions.	D3.1 ,D3.2, and D3.3
VERIFICATION	**STATUS**	**DELIVERABLE**
Demonstration of Industry 4.0 Digital Twin use case.	The full demonstration of this use case is completed in the second reporting period. Multiple video demonstrations on digital twin use cases have been showcased by UC3M covering different aspects of DT such as movement prediction and SLA enforcer.	D3.3
Demonstration of Industry 4.0 Connected Worker Augmented ZDM use case.	The full demonstration of this use case is completed in the second reporting period. Two video demonstration on ZDM use case has been showcased by IDCC throughout the first reporting period. Furthermore, ZDM use case utilized a commercial 5G network integrating an Edge solution. Also, used a new defect model with AWS telemetry in second periodic report.	D3.3
Demonstration of Autonomous Drone Scouting Drone Fleet Navigation use case.	The full demonstration of this use case is completed in the second reporting period. A few video demonstrations on ADS use cases have been showcased in the Workshop that occurred on the NCTU campus beside extensive field trials using 5G-NSA solution, scalable design validation, and stress test in different environmental conditions.	D3.3
Demonstration of Autonomous Drone Scouting Intelligent processing of images use case.	beside the features used in drone fleet navigation. EagleEye and Eagle stiching are used with new scalable design and shows the detection of multiple PiH using 5G-NSA solution.	D3.3

OBJ. 4 WP4	**Dissemination, standardization, and exploitation of 5G-DIVE**	
TARGET R&D TOPIC	**PROGRESS TOWARDS TARGET**	**DELIVERABLE**
Outreach communication to all stakeholders including the general public.	Various communication activities have been undertaken including press releases, videos, workshops, in addition to social media (Website, Twitter, LinkedIn, etc.).	D4.1, D4.2 (a&b) and D4.3
Dissemination to relevant industrial and academic communities.	This included workshops, panels, webinars, publications, standard contributions, and academic courses.	D4.1, D4.2 (a&b) and D4.3

Impact of project innovations through coordinated exploitation activities led by the innovation manager.	The impact of the project innovations and their exploitation has been subject for coordination by the Innovation Manager. This includes various exploitation paths such as standardization, proof-of-concepts, commercial solutions, licensing of technology and software, branding, etc.	D4.1, D4.2 (a&b) and D4.3
Contributions to top-tier scientific journals, conferences, and magazines.	The project set a target of 24 peer-reviewed articles published by the end of the project. By the completion of the project, 30 articles have been published or accepted for publications.	D4.1, D4.2 (a&b) and D4.3
Contributions to standardization bodies.	The project has been active in disseminating to various SDOs noticeably in 3GPP, ETSI MEC and IETF. Some 63 contributions have been submitted including 18 adopted so far and the rest either noted or ongoing.	D4.1, D4.2 (a&b) and D4.3
Generation of IPR.	The project set a target of 3 patent applications to be filed by the end of the project. There have been two patent applications filed in the second reporting period.	D4.1, D4.2 (a&b) and D4.3
Contribution to open-source projects.	The project set a target of 1 major contribution to open-source projects by the end of the project. By the completion of the project, 2 key contributions have been delivered namely on Zenoh and Fog05 by ADLINK partner to the ECLIPSE Foundation project.	D4.1, D4.2 (a&b) and D4.3
VERIFICATION	STATUS	DELIVERABLE
At least 12 publications per year in top-tier scientific journals and conferences.	30 articles have been published or accepted for publications during the project lifetime.	D4.1, D4.2 (a&b) and D4.3
File at least 3 patent applications.	2 patent applications have been filed on this period	D4.1, D4.2 (a&b) and D4.3
At least 15 contributions, of which 5 adopted.	18 contributions have been adopted in various SDOs such as ETSI MEC and IETF.	D4.1, D4.2 (a&b) and D4.3
Organization of at least 2 workshops.	5 workshops have been organized.	D4.1, D4.2 (a&b) and D4.3
At least 2 demonstrations per year, including one at a flagship event such as MWC, EUCNC, COMPUTEX and in vertical-oriented events.	Six demonstrations have been delivered so far including two at the booth and four online. Flagship events have been cancelled due to the COVID-19 pandemic.	D4.1, D4.2 (a&b) and D4.3

1.2. Explanation of the work carried per WP

1.2.1. Work Package 1 – Vertical industry-centric use cases and system design

5G-DIVE aims to enhance the management and automation of business processes by adopting data analysis and Artificial Intelligence running on top of the 5G-CORAL platform, which is for edge and fog computing. This concept materialized in a new building block called 5G-DIVE Elastic Edge Platform (DEEP).

Two vertical pilots: (i) Industry 4.0 and (ii) Autonomous Drone Scout are built and examined to show the technical merits and business value proposition of 5G technologies.

For I4.0, the use case Digital Twin shows the capability of real time control. The other use case proves automatic detect defects in production lines can be benefited by adopting AI/ML algorithms with the help of edge/fog computing.

For Autonomous Drone Scout, the use case of Drone Navigation demonstrates collision avoidance can be achieved by drones' built-in AI/ML algorithms. The other use case presents the detection of victims in a disaster area by leveraging more powerful AI/ML algorithms running on the edge computers.

In the final period, WP1 focuses on the extraction of business requirements and the refinement of technical and functional requirements for the four vertical industry pilots and the design of the architecture of the 5G-DIVE platform. As can be inferred from the list of activities, WP1 oversees the overall validation of the vertical industry use cases, coordinating the different inputs from the remaining technical WPs and providing an overall assessment of their outcomes in terms of business, functional and technical KPIs. Previously, WP 1 had as main objective the design of the 5G-DIVE solution. WP1 had invested its efforts on three main fronts: *i)* further analysis of the targeted use cases by detailing their technical and non-technical requirements; *ii)* developing the baseline architecture, including functional blocks and reference interfaces as well as its mapping to relevant standardization bodies; and *iii)* elaborating the techno-economic analysis of the 5G-DIVE project, studying the main pillars of the solution that its deployment in the selected use cases.

The aforementioned fronts of research in WP1 are structured into two tasks: *i)* Task 1.1 (Analysis of the vertical industry use cases including their business, functional, and technical requirements and techno-economic analysis of the solutions) in charge of providing a deep analysis of the requirements of each use cases and providing the techno-economic analysis; and *ii)* Task 1.2 (5G-DIVE system design and evaluation for vertical use cases) in charge of defining a complete architectural framework, its relation with relevant SDOs and evaluate how the developed solution serves and benefits the targeted vertical industries and their use cases.

The use cases in the project are divided across Industry 4.0 (I4.0) and Autonomous Drone Scouting (ADS) vertical industries. I4.0 focuses on creating flexible and resource efficient production systems and demonstrating the values of 5G technologies to potentially increase the productivity of factories and quality in manufacturing. I4.0 has been structured in three use cases:

- Digital Twin provides interactive digital replicas of physical assets and processes, through which changes are replicated as they occur in the actual physical system.
- Zero Defect Manufacturing System investigates the capability of 5G and Fog/Edge to support real time analysis of HD/4K video of goods on a production line to detect possible defects.

- Massive Machine-Type Communications focuses on the IoT applications based on massive machine-type communications (e.g., NB-IoT, CAT-M, LoRa, IEEE 802.15.4, etc.), which is a key pillar for digitalized IoT factories (e.g., for process and assets monitoring and predicative maintenance).

ADS targets public safety services (e.g., the firefighter department) for commissioning drone fleets to scout a disaster area. It also aims at showcasing the value of a 5G system integrating an intelligent edge for connecting and navigating a fleet of drones seamlessly. ADS has been structured in two use cases:

- Drones Fleet Navigation enhances the current navigation system by enabling local and remote data processing as well as dynamic changes into the flight trajectory of a drone fleet.
- Intelligent Image Processing for Drones enables two potential applications, namely image processing and pattern recognition for drones. Images from drones are processed in real-time edge applications for emergency detection and response.

The architecture of the project takes the 5G-CORAL as the basis of the underlying Edge Computing Infrastructure. The architecture focuses mainly on the 5G-DIVE Elastic Edge Platform (DEEP), which is composed by three main supporting strata: DASS (Data Analytics Support Stratum), IESS (Intelligence Engine Support Stratum) and BASS (Business Automation Support Stratum). The reported platform details the design of the internal elements of each building block of the DEEP, their internal and external interfaces and their key workflows. The internal architecture of DEEP platform, including its three supporting strata (DASS, IESS, and BASS), is depicted in Figure 1-1, as well as the interfaces between the different components of the DEEP, the VSS/OSS/BSS, and the Edge Computing Infrastructure.

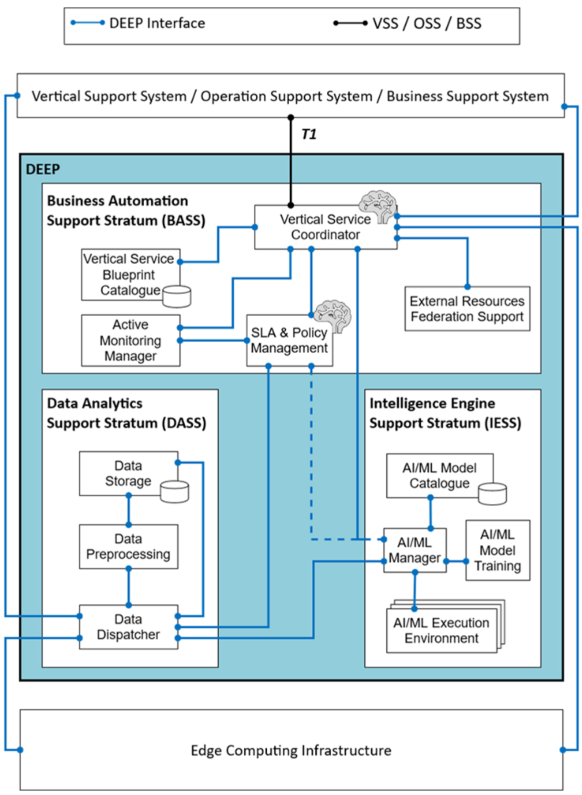

FIGURE 1-1: DEEP INTERNAL ARCHITECTURE

The DASS offers the necessary support for pre-processing, storing, and sharing data generated by a variety of sources: (i) application metrics, namely related to the vertical service operations; and (ii) infrastructure metrics, namely contextual information from both the virtualization infrastructures and VNFs. As such, it implements an internet-scale data-centric protocol that unifies data-sharing between any kind of device including those constrained with respect to the node resources, such as computational resources and power, as well as the network resources. The DASS comprises three main elements, as depicted in Figure 1-2:

1. **Data Dispatcher:** gathers data from the different sources and delivers it to all the subscribed entities, enforcing authorization mechanisms if required, the data dispatcher can send raw data to be pre-processed or directly stored in the data storage element.
2. **Data pre-processing:** transforms raw data into an understandable and common format (e.g., data encoding/decoding, transcoding, querying, filtering, grouping, normalization, anonymization, and compression), the resulting data can be directly stored in the data storage element.
3. **Data storage:** stores gathered data and processed data. The decision of whether to store the data is up to its source which, optionally, also provides its lifespan. The data storage can store raw data coming from the data dispatcher or processed data from the pre-processing element.

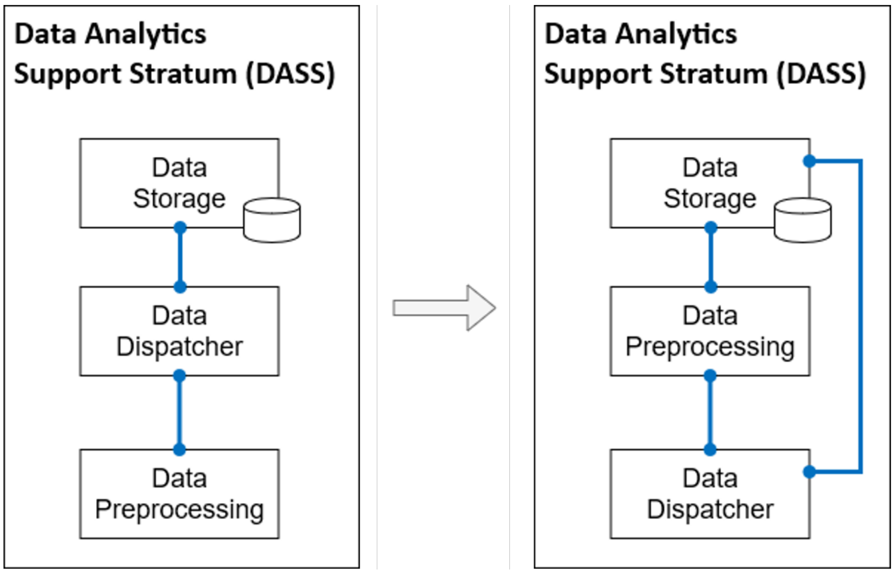

FIGURE 1-2: DASS REFINEMENT FROM ITS ORIGINAL DESIGN

Envisioned as an AI/ML engine, the IESS supports, simplifies and automates the integration of AI/ML features for the vertical services themselves and/or for business automation tasks. It leverages data-driven AI/ML models to support complex decision-making systems, perform classification, forecast demands, predict events, find patterns and anomalies, among others. To do so, the IESS follows an intent-driven approach, offering functions to interact with several AutoML and AutoAI frameworks, integrating a semi-automated selection of the appropriate framework based on context information. The IESS comprises four main elements, as depicted in Figure 1-3:

1. **AI/ML Manager:** coordinates all the requests for AI/ML capabilities, manages the available AI/ML models contained in the IESS catalogue, and packages the trained AI/ML models.

2. **AI/ML Model Catalogue:** consists of a repository of trained and untrained AI/ML models made available by the DEEP platform. These are annotated with metadata describing their features, requirements, and suitable applications.
3. **AI/ML Model Training:** handles the procedures for training an AI/ML model, from the selection of one or more AI/ML algorithms, their hyperparameters and training dataset, up to the cross-validation of their accuracy.
4. **AI/ML Execution Environment:** comprises the runtime environment to train the selected AI/ML model(s).

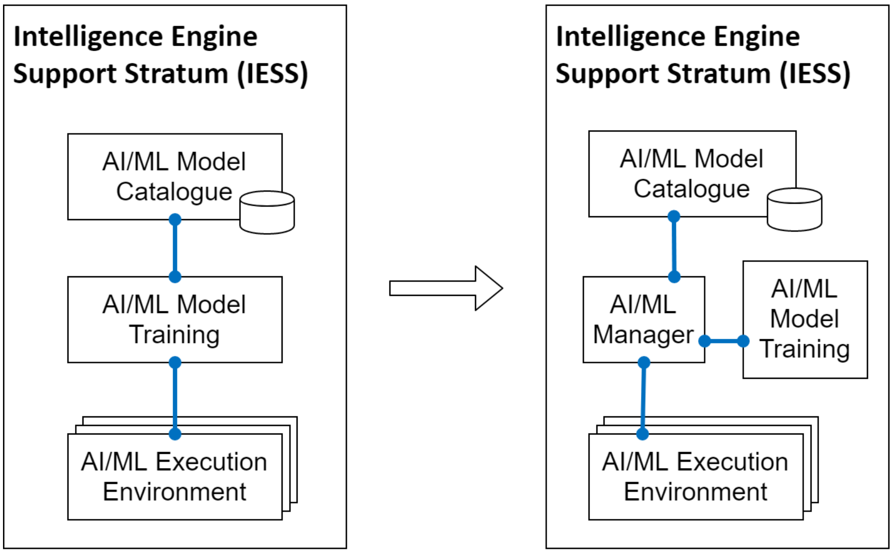

FIGURE 1-3: IESS REFINEMENT FROM ITS ORIGINAL DESIGN

The BASS provides the interface to plug OSS/BSS systems into the DEEP platform and it includes several components for the translation of business requirements into technical requirements. Internally, the BASS is composed of several components, each one with a dedicated task. The Vertical Service Coordinator takes care of deploying vertical services and managing their lifecycle. It directly interacts with the Edge Computing infrastructure and takes control of decisions with the support of the other components. The BASS comprises five main elements, as depicted in Figure 1-4:

- **Vertical Service Coordinator:** handles vertical-oriented requests, translates them into network services, and coordinates their E2E deployment. It can be enhanced with intelligence capabilities.
- **Vertical Service Blueprint Catalogue:** consists of a repository containing vertical service blueprints, providing a vertical service template with service-specific parameters.
- **SLA & Policy Management:** monitors the SLAs and policies for different vertical services and, in case of a violation, triggers corrective actions. It can be enhanced with intelligence and forecasting capabilities so that violations are predicted and dealt with preemptively.
- **Active Monitoring Manager:** manages the deployment of monitoring probes required for performance monitoring, including a catalogue of available probes.
- **External Federation:** handles the deployment of E2E vertical services across different administrative domains.

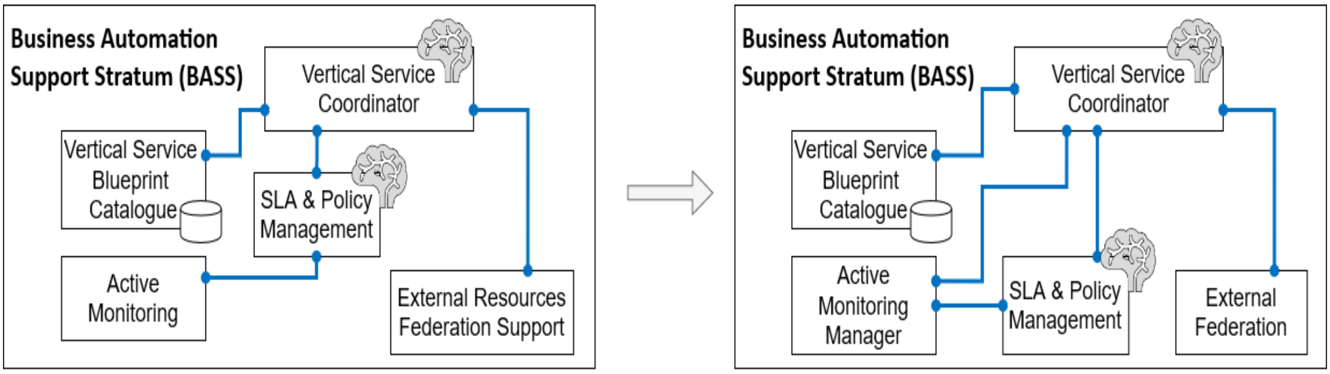

FIGURE 1-4: BASS REFINEMENT FROM ITS ORIGINAL DESIGN

DEEP platform abstracts the underlay heterogeneous networks and servers and provide vertical industries the right size of computing power to fit their need in terms of the given service level agreement. The BASS and its features have been thoroughly tested in two distinct phases. In the first phase, the 5G-DIVE use cases have been integrated in the BASS by leveraging remote vertical premises. In more details, an instance of the BASS was deployed in Spain and secure connectivity was put in place to connect it with distributed resources offered by the verticals. This setup allowed for a preliminary, successful verification of the BASS features while the verticals remained in full control of their resources and could perform debugging and troubleshooting on their services. In the second phase, a trial testbed has been setup at 5TONIC premises for a joint final validation of both the DEEP platform and the use-cases. More information about the executed tests and complete result reports can be found in D3.3 [11].

This is a short summary of the BASS features that have been verified successfully:

- Multi-region orchestration
- Service management
- Active monitoring

At the same time, non-functional requirements such as scalability, availability, and reliability have been verified demonstrating the high quality of the software, its stability, and its good performance.

The BASS architecture, design, and development have proved to satisfy the requirements of the vertical use cases, by providing significative advantages like simplified and abstracted service definition, lifecycle management, and monitoring out-of-the-box.

Regarding the techno-economic analysis of the solution, a business model canvas for the role of the *System & Service Provider* was proposed in D2.2 [6]. It showcased the value proposition of the 5G-DIVE project and its DEEP platform. Two additional business model canvas from the application provider perspective were also included in this deliverable; one for the Industry 4.0 and another for the Autonomous Drones Scout.

The DASS functional and non-functional features have been validated for most of the use cases of the project during the field trials. The use cases have adopted it to perform data storage as well as data dispatching. More information about the executed tests and complete result reports can be found in D3.3 [3]. More specifically, the following IESS features have been verified successfully:

- Data Dispatcher
- Data Storage

The data dispatcher and data storage features were validated during the first trial integration for the I4.0 use cases. The Digital Twin (DT) in the *Replay* feature exploits the functionalities made available by the DASS. The Remote Operator, with the help of the DT application and a remote-control mechanism (e.g., joystick , web interface), remotely controls the physical robotic arm. Consequently, the robot arm in real time updates the DT to keep a tight synchronization between the physical and digital worlds. Simultaneously, the *Replay* feature continuously collects in real time the DT states from the corresponding application using the DASS Data Dispatcher, storing them in the DASS Data Storage. In a specific moment of the remote operation (e.g., due to robot misbehavior), the Remote Operator can request for a replay of a past sequence of movements through the Web Interface GUI by specifying the desired time interval. The *Replay* module queries the DASS Data Storage about the DT states associated to requested time interval. Once the past sequence data is obtained, the *Replay* module starts to playback the data in a loop fashion. The Remote Operator is informed that the action replay is ready via the Web Interface GUI and in that moment, he can add a new virtual replica in the Digital Twin application in order to visualize the replay data.

Additionally, in the ZDM use case, the service flows for telemetry data collection starts when the factory starts working. The camera starts streaming the video towards the Edge node and the factory starts been streamed, with the cubes being placed on the running conveyor belt. The telemetry agent in the EFS uses the Zenoh protocol to communicate with the Zenoh router located at the edge node. Next, the Zenoh router located at the edge node, synchronizes with the Zenoh router located at a Cloud Services Provider. This synchronization is followed by a link establishment between the routers that uses the Zenoh protocol to correctly direct the telemetry data into a Zenoh data storage unit, located in the cloud.

In the massive Multiple-Type Communication (mMTC) use case, the DASS functionalities are used through the DEEP platform. For example, the mMTC use case consumes the IESS catalog and the BASS active monitoring functions, which in turn uses the DASS data dispatching and storage functionalities.

In the Intelligent Image Processing for Drones (IIPFD) use case for Autonomous Drone Scouting (ADS) trial. DASS was integrated as a data transmission protocol for streaming data from the drone to the edge. In the Drone Collision Avoidance System (DCAS) use case for ADS, the DASS provided data dispatcher, and storage solutions at the fog (aerial drone), as well as on the edge.

The IESS features have been constantly tested during the development and they have been finally verified during the trials at IMDEA premises. Testing and verification have always been performed with the involvement of the use cases in order to collect meaningful feedback. More information about the executed tests and complete result reports can be found in D3.3 [11]. More specifically, the following IESS features have been verified successfully:

- Automated model training
- Storage and retrieval of artifacts from the catalogue
- Packaging and deployment of inference applications

Furthermore, the verticals have greatly appreciated the feature offered by the IESS for exposing the model predictions as a service. The trained model is packaged in a RESTful application, deployed close to the consumers of the predictions that can request the latter through a well-defined HTTP interface. This feature solves a common problem in the machine learning field, that is making the model predictions usable in production-like environments. Finally, the IESS catalogue have proven support successfully all the aforementioned operations, as well as providing a shared storage for reusable pre-trained models and software artifacts.

The mapping of the 5G-DIVE solution to each use case of the project served a second purpose as well. It allowed the identification of the different stakeholders participating in the business model of each use case, and the understanding on how the market could address the business demand coming from the targeted of vertical industries. This was also a central part of the WP1 work. In this analysis, we identified that stakeholders could assume more than one role from the value chain, leading to a new role referred to as *System & Service provider*. This new stakeholder comprises roles and capabilities of the Service Provider and Network Operator, which presents as business model canvas.

Furthermore, the business model had been developed as canvases for each vertical pilot, highlighting the value proposition of the 5G-DIVE project and, namely, its DEEP platform. The business model canvases were the basis for the techno-economic analysis and business model validation which resulted in a preliminary and quantitative economic evaluation of the 5G-DIVE pilots. Moreover, they aided the understanding of the business aspects by analyzing how the business model impacts on the CapEx and OpEx of each particular use case. The objectives of the survey can be summarized in the following three points:

- The business model canvas for the role of the System & Service Provider, showcasing the value proposition of the 5G-DIVE project and its DEEP platform. These also included the Industry 4.0 and Autonomous Drones Scouting pilots business model canvas elaborated from the vertical perspective.
- The methodology for the techno-economic analysis, which is based on the specific characteristics of each use case and three pillars (such as 5G, cloud & edge, and artificial intelligence).
- CapEx and OpEx evaluations for each of the 5G-DIVE pilots to demonstrate the economic viability of the project.

To finalize this summary of the work performed in WP1. There are four deliverables reporting the main outcomes of this work:

- D1.1 - 5G-DIVE architecture and detailed analysis of vertical use cases [1]: this deliverable focuses on the providing a deep analysis of each use case and provides the baseline design of the 5G-DIVE solution and its DEEP platform.
- D1.2 - 5G-DIVE Techno-economic Analysis [2]: this deliverable provides the techno-economic analysis of the platform tailored to each use cases, aiming to provide an insight on the economic and operational feasibility of the 5G-DIVE solution and the main conclusions in terms of market opportunities, cost recovery and pricing.
- D1.3 - 5G-DIVE Final Architecture [3]: this deliverable focuses on the complete version of the 5G-DIVE architecture, detailing the architectural components and functions defining the DEEP platform and its integration with the 5G-CORAL architecture.

- D1.4 - Conclusions on vertical oriented 5G field trials and future outlook [4]: this deliverable concludes the work in the project and provides the final conclusions on how the 5G-DIVE platform can provide benefit to the vertical use cases studied. This deliverable also includes information on possible way forward towards future exploitation of the platform innovations.

The key objective of WP1 was to validate the use of 5G on each of the use cases. This validation is provided in D1.4 [4] and supported technically by D3.3 [11].

1.2.2. Work package 2 – 5G-DIVE Elastic Edge Platform design towards field trials

Work Package 2 focused on the specification of the 5G-DIVE solution with all its components, including the 5G connectivity and edge computing infrastructures, and the DEEP platform that provides the project's innovations on top. This specification was done in accordance with the targeted use cases and their requirements, and the baseline architecture specified in WP1. In time, the solution specification also accompanied WP2, with implementation activity for each use case, paving the way for the integration, demonstration, and end-to-end trials in WP3.

WP2 ended on June 2021, so close to the first review. Most of the technical work performed in WP2 was already presented in the First Periodic Report. Herein we focus on the implementation side of WP2, which has been the focus of the second year of the project.

The framework of the 5G-DIVE solution consists of three logical layers, namely the 1) network layer, 2) computing layer, and 3) intelligence layer.

1) The focus in the network layer has been on an end-to-end 5G network, in both non-standalone and standalone modes. WP2 analyzed different configurations of the 5G system in terms of suitability to meet the requirements of the use cases defined in WP1, but also in terms of availability of the connectivity elements such as UEs, RAN, and Core, as well as the operational spectrum frequencies available in the vertical pilots both in Europe and in Taiwan. After the analysis of these aspects, the final SA and NSA solutions for the underlying connectivity for the I4.0 and ADS use cases, respectively, were reported in D2.3 [7].
2) The focus on the computing layer has been put on the reference 5G-CORAL Edge and Fog infrastructure. This infrastructure has been the subject of enhancement in WP2 by adding OPTUNS (Optical Tunnel Network System) yielding ultralow latency for all computing and processing applications of interest. In addition, WP2 set focus on all interfaces necessary to support the 5G-DIVE DEEP platform over the 5G-CORAL EFS (Edge and Fog System) and under the control of the 5G-CORAL OCS (Orchestration and Control System). A particular attention was given to the far edge capabilities on constrained devices especially in view of the opportunity for standardization impact in the ETSI MEC 0036 study on "MEC in resource constrained terminals, fixed or mobile". WP2 has also performed studies on cloud based platforms to support the heavy training tasks required for the project, investigating available commercial solutions from Amazon, Microsoft and others, and concluded that an AWS-based data lake could not only support these tasks, but also in complement and support the 5G-CORAL distributed edge fabric. This is of particular interest and show case of the ZDM use case.
3) The focus in the intelligence layer has been on the specification of the DEEP platform with its three supporting strata (namely DASS, BASS, and IESS), as well as the intelligent applications

and functions that exploit the DEEP to provide a value to the targeted use cases. WP2 has led the design and development of the three platforms, providing alignment between use case needs and the requirements of the DEEP. With this alignment, the three components of the DEEP have been successfully developed and delivered to WP3 for integration with the use cases. Next, the final status of the implementation that was delivered to WP3 for integration is described. Details on the implemented components of the DEEP can be found in D2.3 [7].

In the following, we present the final status of the implementation of the different WP2 modules.

DASS

The DASS is a data analytics platform suitable for distributed and heterogeneous edge and fog environment. Its final status implementation is depicted in Figure 1-5.

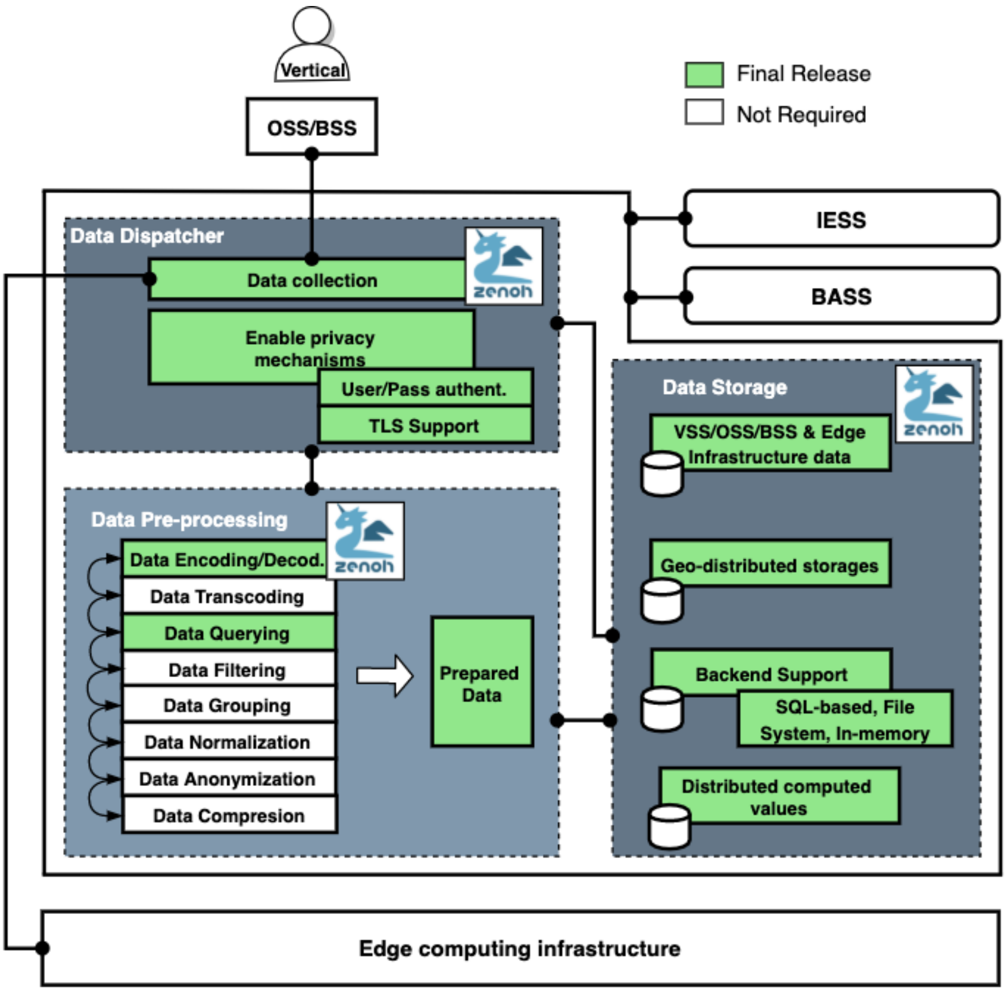

FIGURE 1-5: DASS FINAL DESIGN & IMPLEMENTATION STATUS

Some of the components of the DASS have been planned to be implemented in the initial specifications and use case assessment but after developing this activity, none of the use cases had a need for some of the DASS components. Hence, not all components are marked as completed in the Figure.

BASS

The BASS is an evolution of control systems where an operator oversees the business processes' administration. The final status of the implementation of the BASS is depicted in Figure 1-6

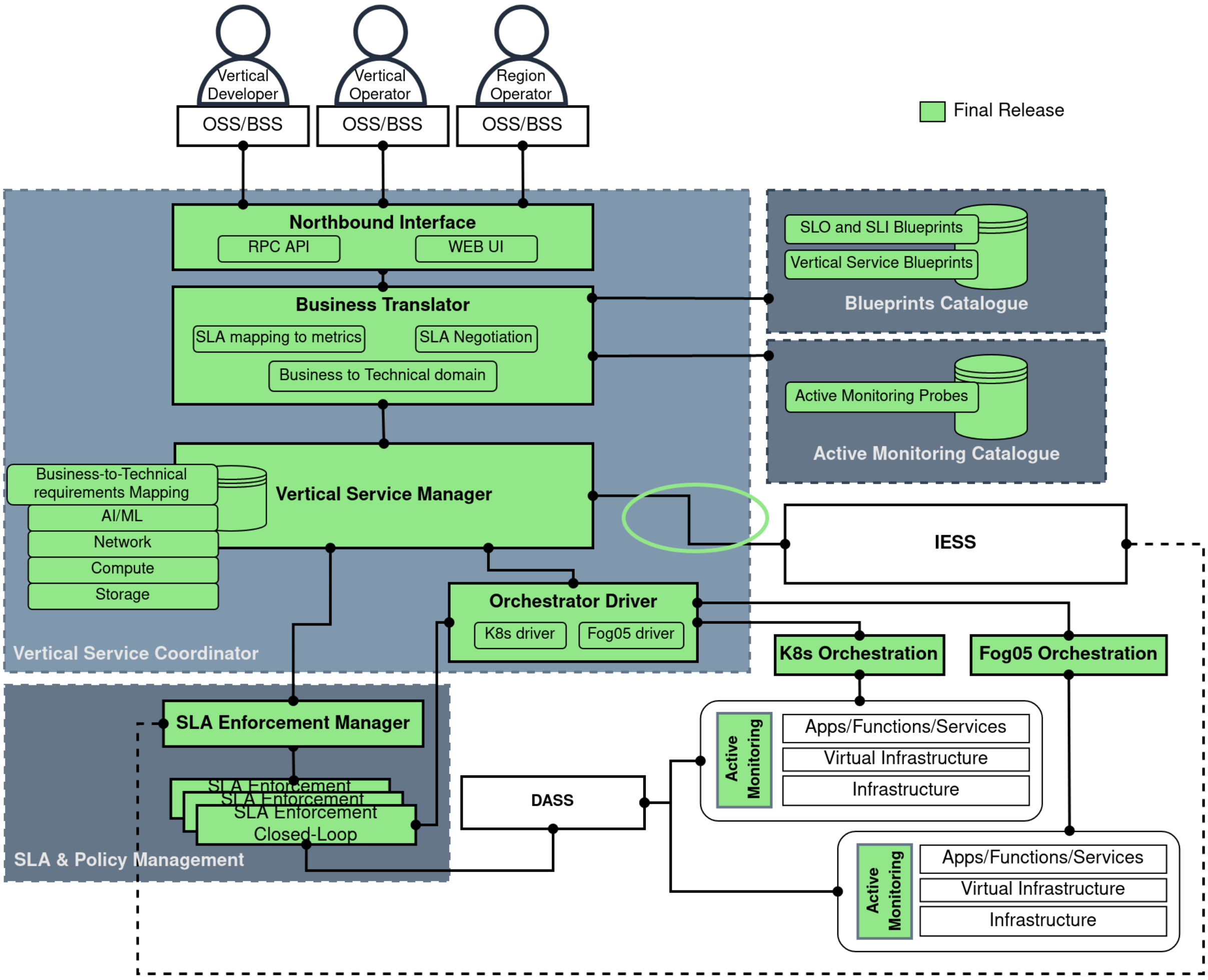

FIGURE 1-6 BASS FINAL DESIGN & IMPLEMENTATION STATUS

All components of the BASS have been successfully implemented.

IESS

The IESS is an Artificial Intelligence Platform which uses data driven algorithms to make predictions, classifications, and decisions. The final status implementation of the BASS is depicted in Figure 1-7

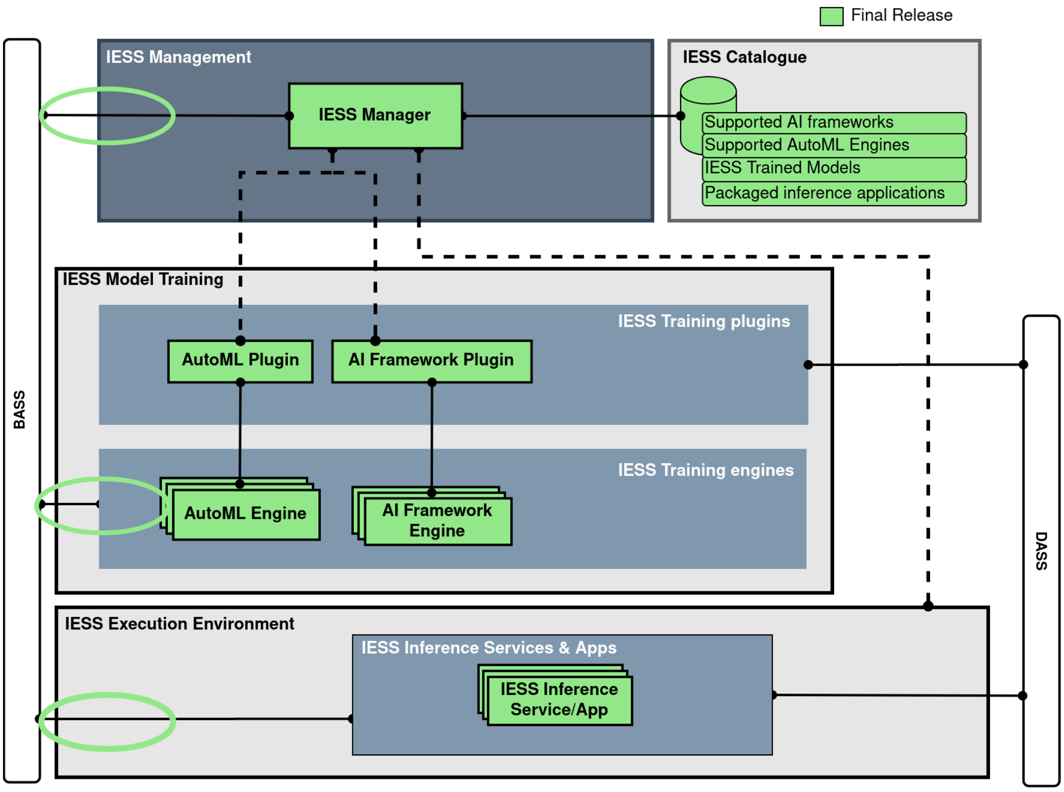

FIGURE 1-7 IESS FINAL DESIGN & IMPLEMENTATION STATUS

All components of the IESS have been successfully implemented.

From the results of the different validation campaigns reported in D2.3 and D3.3, we believe all the objectives of WP2 have been achieved and the different components have been validated.

Besides the presented results, WP2 has also provided other inputs to the project. WP2 has provided an alignment between the 5G-DIVE architecture and relevant current technological standard bodies. A list of currently available datasets for usage in the project was surveyed, and opportunities for dataset dissemination were also identified. In terms of EU TW collaboration, WP2 led paper entitled "Empowering Industry 4.0 and Autonomous Drone Scouting Use Cases Through 5G-DIVE Solution". This paper was submitted and has been accepted for publication to the venue "2021 EuCNC & 6G Summit – VAP".

All the above-mentioned activities have been carried out in close collaboration with WP3, to make sure the work developed in WP2 feeds smoothly into the work developed in WP3.

1.2.3. Work package 3 – 5G-DIVE validation through vertical field trials

ITRI is leading the WP3, covering the demonstration and trials of the 5G-DIVE project. The main objective of WP3 is to integrate and deploy the 5G-DIVE platform on top of Europe and Taiwan E2E testbeds (including the vertical sites). Also, it aims and, to demonstrate two pilots (i.e., I4.0 and ADS) across five use cases through field trials. The uses cases are (defined in D1.1) Digital Twin (DT), Zero Defect Manufacturing (ZDM) and Massive Machine-Type-of-Communication (mMTC) use cases for Industry 4.0 (I4.0) trial, and Drone Collision Avoidance System (DCAS) and Intelligent Image Processing for Drones (IIPFD) use cases for Autonomous Drone Scouting (ADS) trial. The demonstrations are held in Taiwan and European trial sites. Specifically, the I4.0 pilot is demonstrated in 5TONIC facilities, on which the Digital Twin, and mMTC use cases aim at showcasing, respectively, the 5G low latency capability for remote operation, intelligent algorithms in Fog devices for pattern recognition, and support for wireless connectivity (e.g., cellular IoT, wireless sensor networks) for a massive number of small low-powered low-cost sensor nodes. In turn, the ADS pilot is demonstrated in Taiwan trial site, on which the Fleet Navigation use case aims at showcasing the Drone-to-Drone direct link and Drone fleet relay operating in parallel and the Intelligent Processing of Images in the Drones use case at showcasing the processing of images in a multi-tier scenario.

Furthermore, WP3 has achieved integration of all use cases into a single platform of DEEP. In particular, TELCA completed a common BASS platform for I4.0 and ADS pilots as shown in Figure 1-8. For the sake of the trials, hosted both at 5TONIC and remotely connected vertical premises, we created a scenario with four distinct regions managed and orchestrated by a single deployment of the DEEP platform. A graphical representation of the setup is presented in this figure, with each region in a different color. The DEEP platform deployment, the Digital Twin UC Region Edge, the Digital Twin UC Region Fog, the ZDM UC Region, and the mMTC UC Region are deployed co-located with the resources provided by 5TONIC. The ZDM UC Region and the ADS UC Region, are remotely located in London and Taiwan respectively, and orchestrated remotely by the same DEEP instance through a VPN connection.

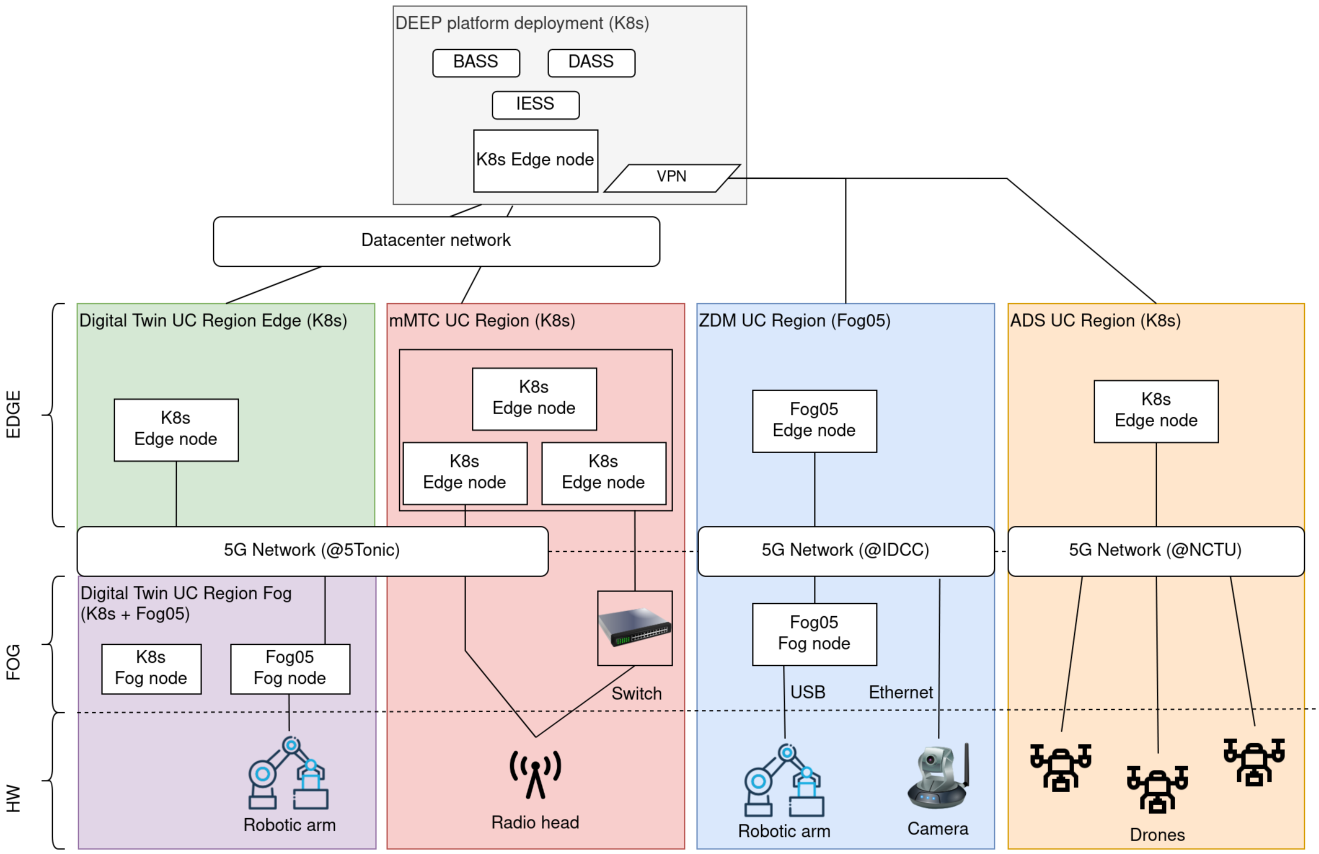

FIGURE 1-8 TRIAL SETUP AT 5TONIC PREMISES

In addition, the scalability of all use case has been tested following the four stages (see Table 1.1), the stages are defined as follow:

- Stage P0: Test different modules separately.
- Stage P1: Emulated end-to-end performance testing and bottleneck analysis.

- Stage P2: End-to-end performance testing and bottleneck analysis.
- Stage P3: End-to-end Load/scalability testing and scalability analysis.

TABLE 1.1: USE CASE STATUS

	Stage P0	Stage P1	Stage P2	Stage P3
I4.0-UC1 (Digital Twin)	✓	✓	✓	✓
I4.0-UC2 (ZDM)	✓	✓	✓	✓
I4.0-UC3 (mMTC)	✓	✓	✓	✓
ADS-UC1 (DCAS)	✓	✓	✓	✓
ADS-UC2 (EagleEYE)	✓	✓	✓	✓

✓ Completed

Finally, deliverable D3.3 has been completed. It includes the final validation results of different 5G-DIVE use cases. In addition, long and short-term validation including scalability analysis and system reliability have been executed and reported. The experimental results are evaluated considering the 5G-DIVE platform, 5G connectivity, and edge and fog computing. This is covered into two tasks: *i)* Task 3.1 (Industry 4.0 Field trial and experimentation), and *ii)* Task 3.2 (Autonomous Drone Scout Field trial and experimentation). The Following subsections provide a brief description of the work performed on each task of this WP.

1.2.3.1. Task 3.1 - Industry 4.0 Field trial and experimentation

This task focuses on building the 5G E2E network and the 5G-DIVE platform specifically tailored for the I4.0 pilot, to validate the 5G technologies (pre-commercial) and the innovations introduced by WP2, and to enable experimentation in the vertical premises. As part of the final output, two main goals are aimed. The first goal is that all components are integrated and ready to be deployed in the field trials. This has already been achieved in 5TONIC as shown in Figure 1-9. In this Figure, the plan of the 5TONIC trial site. The 5TONIC DPC, in the upper part of the image, hosts the edge side of the use cases located at 5TONIC premises. The 5TONIC Industrial Experiments area, 92 sqm big, was dedicated to host the fog side and hardware devices of the use cases. Here, the devices are connected to the Ericsson 5GC, with the UPF server placed in 5TONIC, through the Ericsson Radio Dot indoor antenna, which guarantees coverage for half of the room. The UPF is connected to both the Ericsson 5GC located in Sweden and the servers in the 5TONIC DPC datacenter, where the 5G-DIVE Edge infrastructure is situated.

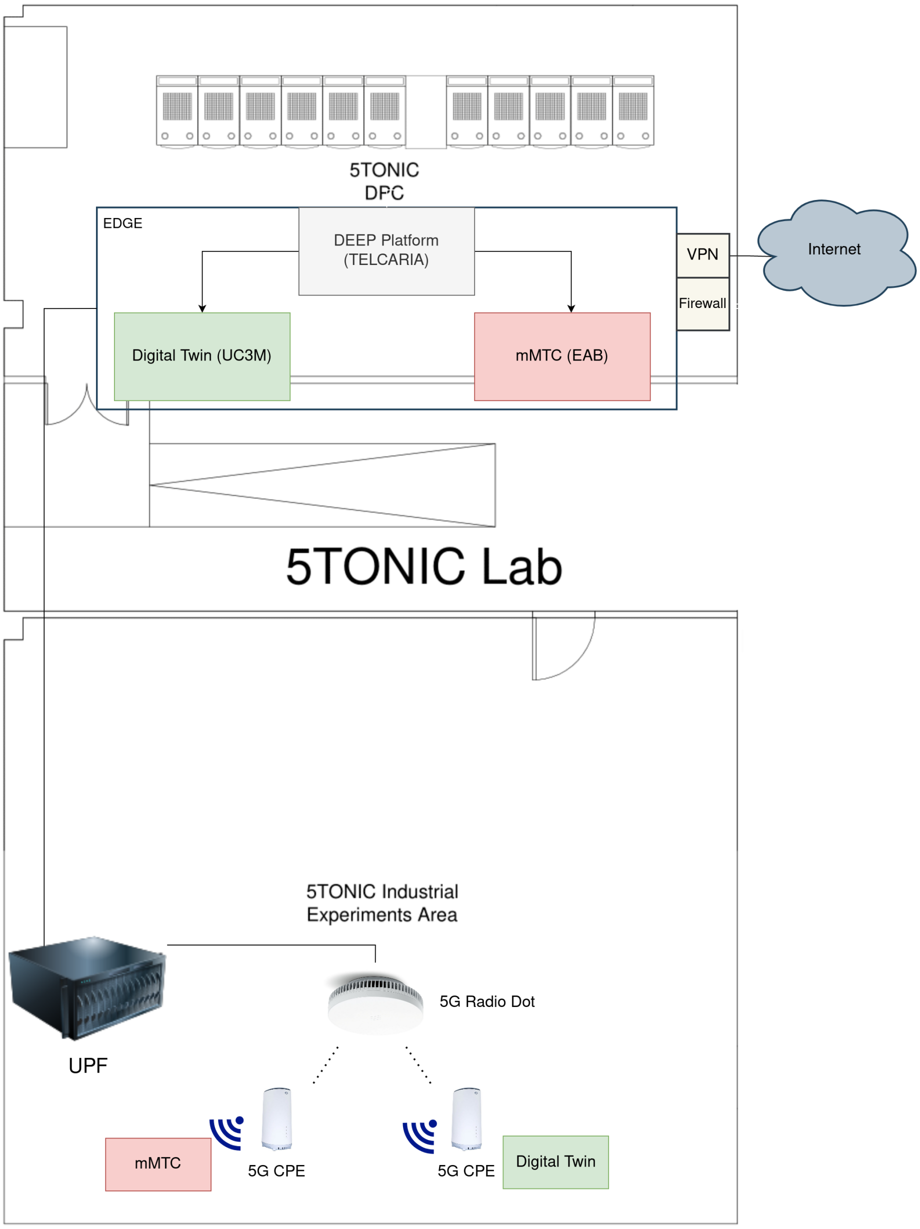

FIGURE 1-9: 5TONIC TRIAL SITE

The second goal is to final validation campaign results available for all the uses case. For this goal, Figure 1-10 presents the setup for the I4.0 trial site to be deployed in 5TONIC. This includes Digital Twin and massive MTC use cases.

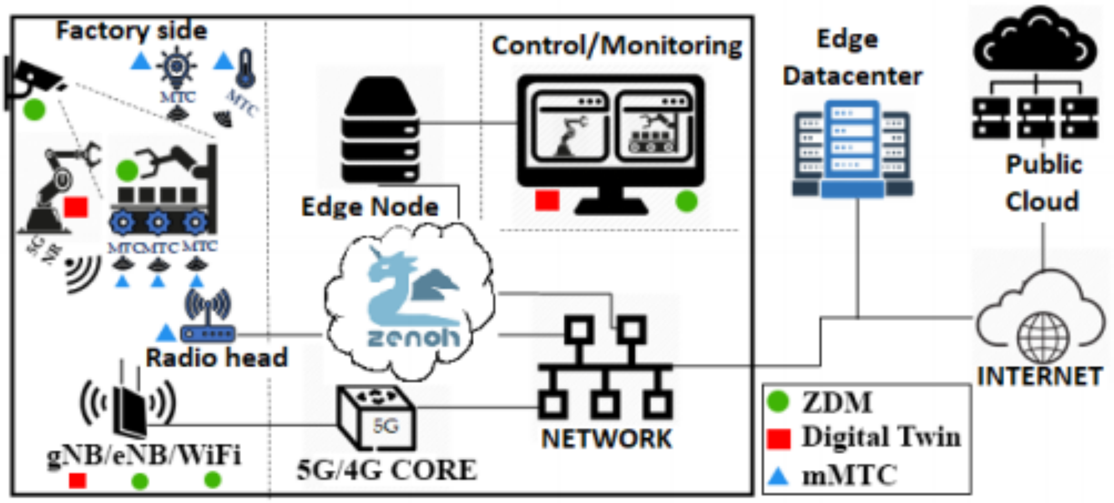

FIGURE 1-10: INDUSTRY 4.0 FIELD TRIAL SITE

The final validation of DT was carried taking into consideration the integration of DT stack with the fog05 platform. Eventually, validation of DT modules distribution along the Cloud-to-things continuum (Fog, Edge, and Cloud) is addressed and provided different scenarios with different performances. The Analytic stack (i.e. IESS) have been developed and processed the data coming from the robot to apply AI/ML and statistical methods for movement prediction, obstacle avoidance and SLA Enforcer.

The final validation of ZDM was carried taking into consideration replication of the experiment with a standalone (SA) 5G network. The integration of the ZDM use case with the other elements of the DEEP platform, namely the DASS, the BASS is done remotely at London site. In addition, a new object detection engine has been described and integrated with AWS Wavelength, Amazon's Edge Computing services (telco-Edge), where the ZDM object detection runs.

The final validation of mMTC was carried taking into consideration developed orchestration features using K8s for automation and auto-scaling. An intelligent application of PHY security enhancement based on RF fingerprinting was developed and integrated into the test. Moreover, the relevant DEEP components of BASS is integrated with other I4.0 use cases in one common DEEP platform (5TONIC).

1.2.3.2. Task 3.2 - Autonomous Drone Scout Field trial and experimentation

This task follows a similar structure as T3.1 but focuses on the specific aspects of the ADS use case.

Both T3.1 and T3.2 will share as much as possible the same goal. In particular, single DEEP platform as highlighted earlier. As in T3.1, at this point, all components are integrated and ready to be deployed in the field trials. In particular, Figure 1-11 depicts the end-to-end solution in the ADS trial site. Briefly, this system consists of three parts: *i)* the drone system; *ii)* Edge datacenter; and *iii)* 5G network. In this trial site, multiple drones are equipped with drone-to-drone communication modules to enable real-time sensory data broadcast for collision avoidance. In addition, drones use the 5G network to transmit other sensors data such as images and GPS location. At the Edge data center, a service gateway is deployed to provide a traffic breakout function which enables receiving sensory data directly to the edge application instead of going through the core network. The drone fleet is managed by cloud drone control software.

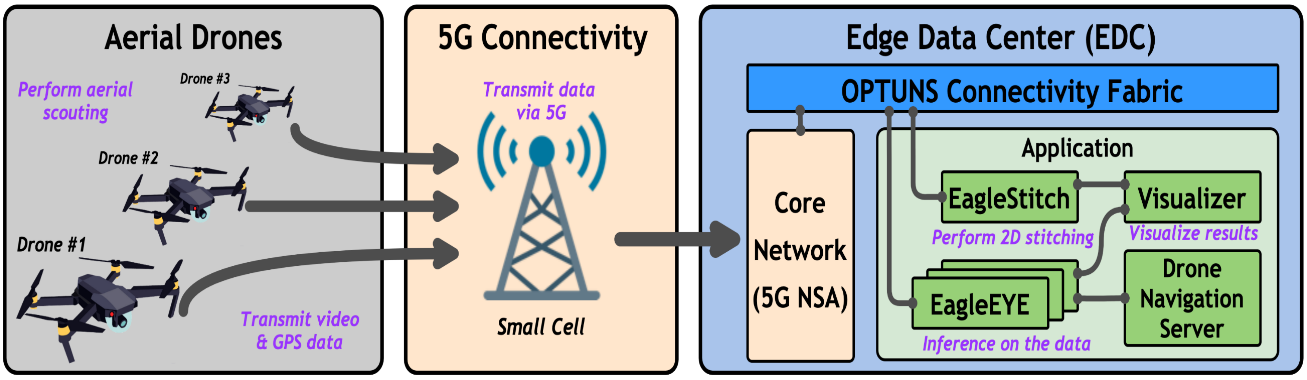

FIGURE 1-11: ADS FIELD TRIAL SITE

The second goal is to final validation campaign results available for all the uses case. For this goal, Figure 1-12 shows the complete connectivity mapping at the edge in support of the ADS mission is depicted. The edge data center is also connected with the BASS instance in 5TONIC lab in Spain for edge infrastructure management and federation. At the edge, is where all of the components that support the disaster relief response system are deployed. The edge data center as well as the gNB/eNB combo small cell are located in the MIRC building. The MIRC building is an 8-story high-rise building located inside the NCTU campus. The gNB/eNB combo small cell is mounted on the sixth floor of the MIRC building, while the edge data center is located in the basement of the MIRC building.

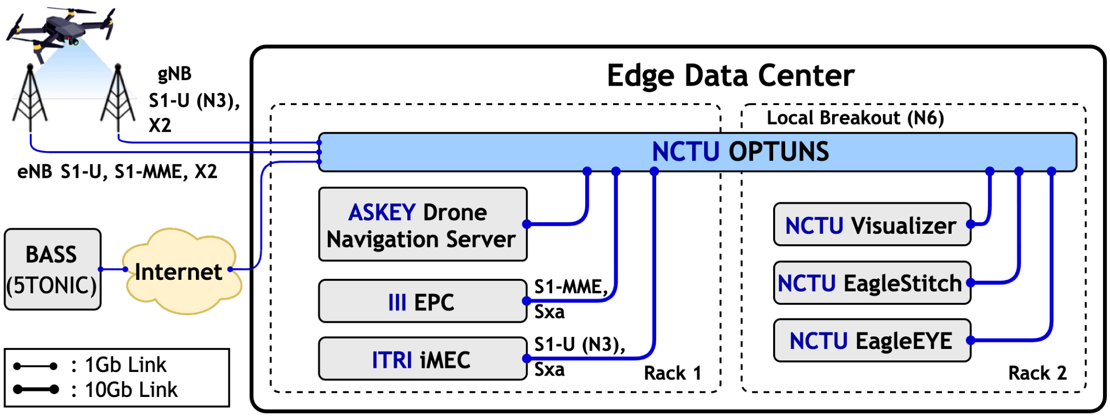

FIGURE 1-12: ADS NETWORK CONNECTIVITY MAPPING

The final validation of ADS was carried taking into consideration replication of the experiment with 5G-NSA solution. As for implementation wise, DCAS considered the drone charging spot for the multiple drone trial and adopted DCAS at the edge. Second, Zenoh is integrated as a data transmission protocol for streaming data from the drone to the edge. And third, updated EagleEYE processing pipeline to better support multiple drone trials.

Besides, it is important to highlight the important milestones in WP3 as follow:

TABLE 1.2: ACHIEVEMENTS PER USE CASE

Use Case	First Year Main Achievements	Second Year Main Achievements
DT	Experiments on 5G connectivity, with edge native Digital Twin service. Achieved low-latency remote control of Digital Twin system over 5G connectivity and studied the potential on device resource savings and the radio network impact to Digital Twin systems. Integrated with the DASS of the DEEP for implementation of the Replay feature.	Developed a Movement Prediction AI model that recovers Digital Twin control commands. The Digital Twin use case was integrated with BASS of the DEEP for exploiting the SLA enforcement feature in order to allocate the optimal minimum number of resources for the service. The use case was also integrated with the IESS for auto-packaging and auto-deployment of the Movement Prediction inference application. Finally, the use case was installed and deployed in the 5TONIC 5G trials where measurements were performed regarding application performance, Movement Prediction performance for commands predictions and vertical resource scaling. The trial results show that the Digital Twin use case achieves the objectives set in the project.
ZDM	Experiments on current 4G connectivity option to find the defective goods and experiments on telemetry solution usage	Integrated the testbed with 5G SA network, as well as other elements of the DEEP platform, namely the DASS and the BASS. ZDM has been deployed in London and integrated remotely with the BASS located in 5tonic. To enhance innovation, an X-App implementing ATSSS functionality has been developed and tested, showcasing the vRAN capacities of the DEEP platform.
mMTC	Experiments on cloud-native design of softwarized IoT stacks facilitating resource-saving and pooling	Integrated the mMTC testbed with BASS of DEEP, further development and optimization of mMTC service implementation for trial measurements, installed and deployed the mMTC trial setup in 5TONIC integrated with DEEP, performed long-term mMTC trial regarding application layer performance with Ethernet and 5G, RF fingerprinting performance for intruder detection, orchestration and automation performance for enhanced system robustness, and scalability with resource utilization. The trial results show that the development of the mMTC use case achieves the objectives set in the project.

ADS-UC1	Experiments on 4G/Wi-Fi to detect a potential collision and performs a collision-avoidance procedure until the risk is resolved.	Integrated 5G-NSA solution for wireless communication from drone to edge. Utilized DCAS in the edge with new developed drone navigation server. Executed drone fleet navigation with multiple drones using DCAS and considering a drone charging spot for the multiple drone trial. Demonstated IDrOS software mobility features.
ADS-UC2	Experiments on end to end 4G network for object detection for PiH	Integrated 5G-NSA solution for wireless communication from drone to edge. Integrated Zenoh as data transmission protocol for drone to edge data streaming. Integrated BASS for automatic service deployment and lifecycle management. Updated Drone Data Processor Module to better support multiple drone trial. Updated EagleEYE processing pipeline to better support for scalability in handling multiple drone input. Completed EagleStitch development to provide panorama 2D stitching of the mission area.

1.2.4. Work package 4 – Communication, dissemination, standardization, and exploitation

The purpose of work package 4 is to fulfil the project's overall Objective 4 to disseminate and contribute 5G-DIVE results into international research and innovation venues, as well as to pave the way for their successful exploitation. This overall objective is broken down into three sub-objectives: *i)* to develop an outreach communication and dissemination of 5G-DIVE results to all stakeholders including researchers, industrials, and general public; *ii)* to develop a proactive standardization plan including roadmaps, intellectual property creation, and contribution in relevant standards; and *iii)* to develop a plan for exploitation of 5G-DIVE results into value creation for all stakeholders during the project lifetime and beyond.

Deliverable 4.2 reports in the progress towards these objectives for the first year of the project. It was revised with updated exploitation plans in Deliverable 4.2b submitted by 2020-12-31 as planned according to the revised DoA. Deliverable 4.3 finally reports on the fulfillment of the objectives for the full lifetime of the project with complete reporting of all dissemination activities. Table 1-3 (from Deliverable 4.3) provides a summary overview of dissemination achievements. The partners set up ambitious dissemination targets. All dissemination targets, except one, has been met or exceeded. We are however humble to these numbers, as it is very hard to set relevant targets that also capture the quality of the dissemination.

TABLE 1-3: OVERVIEW OF ACHIEVEMENTS AND FULFILLMENT OF TARGETS

Category	Current count	Target	Comment
Peer-review publication	30	24	Published or accepted

Presentation/talk		13	12	Demos not included
Press release		11	N/A	
Organization of workshops and conferences		5	2	
Trade fair (booth, exhibition, etc.)		2	2	
Patent		3	3	
Activities with other EU projects		11	4	
Demonstrations		6	4	2 physical, 4 online
Videos		16	N/A	Including presentations and demos
Open-source projects		2	1	Fog05 and Zenoh
Standard contribution	adopted	18	5	
	total	63	15	

The communication and dissemination plan had to be adapted to handle the effects of the COVID-19 pandemic, mainly by enhancing the online presence, for example through videos of presentations and demos. The project consortium set up ambitious dissemination targets, towards which significant progress has been made. Some targets are already met or exceeded.

1.2.4.1. Task 4.1 - Communication and dissemination

The project have been present online with a public website with information in English and Chinese which has a visit count exceeding 20 000 for the first year and totaling over 60 000 to date. The web site is planned to be available until 2023, where a static version of it will be included in the online UC3M project archive (as an example, 5G-CORAL is already archived as https://euprojects.netcom.it.uc3m.es/5g-coral/). The project have also had a twitter channel and have been present in other social media. Project members have been visible in various video interviews and blog articles. In addition, press releases have been issued, and a project leaflet and poster have been created.

Project results have been disseminated with peer-reviewed publications in conferences, workshops, journals, and magazines, as well as through various public presentations. These efforts were increased during the second project year, when more results became ready. Project members engage in the organization of special issues of journals and the organization of workshops specialized on the topics of the project, some of which are done in collaboration with other projects.

The plans for participating in exhibitions and demonstrating the results of the project have not been completely fulfilled due to cancelled events, but some have been replaced with online substitutes. Several of these activities have been subject to replanning due to Covid-19, but despite some difficulty, have largely been following plan. One important part of the replanning is the recording of videos of presentations and demonstrations to make them suitable for online presentation.

1.2.4.2. Task 4.2 - Standardization and exploitation

Contributions to and interaction with five standardization organizations have taken place, and the number of standardization contributions exceed the targets with a margin. The main standardization organizations are 3GPP, IETF, ETSI, IEEE and ORAN Alliance.

Two open-source software projects, Zenoh and fog05, are driven by project members in the context of the Eclipse Edge Native WG. These two open-source components are central to the development of the 5G-DIVE solution.

An exploitation workshop was arranged in collaboration with the 5Growth project. Exploitation activities have been carried out in relation to the developed proof-of-concepts and to products and services of the partners, as well as through other partner activities. Key innovations in the 5G-DIVE architecture platform and the proof-of-concept prototypes have been identified.

1.2.5. Work package 5 – Project Management

The main activities of WP5 have been related to ensure that the project runs successfully, that the partners collaborate each other and the technical objectives are achieved taking care of the time and the costs of the project. The project coordinator (PC) administered the financial contribution, allocating it between the beneficiaries, and activities in accordance with the Grant Agreement. The payments have been done with no delay. The PC kept the records and financial accounting and informed the Commission of the distribution of the financial contribution of the Union. The PC verified consistency between the reports and the project tasks and monitors the compliance of beneficiaries with their obligations.

The project has achieved its objectives, completing all deliverables and milestones according to the Workplan.

During the lifetime of the project there have been two amendments approved. Both of them were done during the first reporting period and have already been reported.

1.2.5.1. Task 5.1 Project administrative, financial, and legal management.

During the duration of the project, 11 plenary meetings were held: the kick-off meeting and ten progress meetings (9 of them online due to COVID-19 crisis).

- Kick-off Meeting on 31st October to 1st November 2019 in Hsinchu, Taiwan at NCTU premises. This meeting focused on the general aspects of the project, the main objectives, and the main activities of each partner. The project board approved to accept ASKEY as new international partner.
- 2nd plenary meeting on 11-12 February 2020 in Madrid, at UC3M. The meeting focused on the development of use cases, Digital twins, and Industry 4.0 and how to transform the innovation results into standards.
- 3rd virtual plenary meeting on 24th March 2020. The meeting was related COVID-19 crisis, and a new agenda was stablished for the upcoming months. The consortium agreed to request an extension of the project and adapt the activities to an online modality.
- 4th virtual plenary meeting on 22nd April 2020. The meeting aimed to approve the Amendment 2 and working on ADS use case and two demos by the end of the year 2021.
- 5th virtual plenary meeting on 24th June 2020 where feedback was provided on the BASS requirements and IESS architecture.
- 6th virtual plenary meeting on 8th and 13th October 2020. The main objective of the meeting was to organize the report and the results obtained during this period for December review meeting.

- 7th virtual plenary meeting on 3rd February 2021. The main objective of the meeting was to continue the technical work on the use cases.
- 8th virtual plenary meeting on 5th April 2021. The meeting talk about the technical work and also about the participation in upcoming events.
- 9th virtual plenary meeting on 7th June 2021. The main objective was to talk about the planification of the last semester of the project and summarizing next project goals.
- 10th virtual plenary meeting on 13th September 2021. The meeting aimed to organize the Integration Week (work on integration in 5TONIC) and the Exploitation Workshop 2021, which present the key aspects inferred by the project's outputs from several perspectives.
- 11th virtual plenary meeting on 9th December 2021. The main objective of the meeting was to comment on the status of the deliverables and the final report, as well as any pending issue.

Weekly technical remote meetings (per WP) were held to allow synchronization between the different partners using a collaborative tool for audioconferences (Zoom). During the conference calls several topics are discussed related to activities which illustrated the WPs update in the period. In a shared calendar, the remote meetings were planned to inform all the partners of the date and hour.

A report of the project progress in terms of technical activities and resources allocation is planned each three months by means the Quarterly Management Reports. A final is planned for the end of the project.

Due to the COVID-19 pandemic, the organization of events and meetings since March 2020 has taken place virtually, always compiling the minutes in a document that allows the presentations and comments to be consulted by all partners.

The Consortium used the following tools for the management of the project:

- Redmine: a web base tool for the description of the activities and the coordination between the partners. A dedicated section has been created as repository of the meeting minutes.
- SVN and GIT repositories: the repository where documentation and software have been stored and shared among the partners.
- Several mailing lists has been created to communicate with the partners, one per WP plus some mailing lists or legal management. A database has been created to group all dissemination activities.
- Zoom is used as video-conferencing tool.
- The 5G-DIVE website is available from the beginning of the project [16]. Moreover, a Twitter account is available at @Dive5g. The account has 207 followers. An Instagram account has been created as well at @5g_dive with almost 100 followers.
- The project has also a LinkedIn account (https://www.linkedin.com/in/5g-dive-project)

1.2.5.2. Task 5.2 Technical coordination, innovation, and quality management

This task is led by NCTU and IDCC (Technical Managers) and assisted by the Innovation Manager (EAB), WP leaders, and the Project Coordinator (UC3M). UC3M as Project Coordinator ensures the project progress towards its objectives. To make sure the project follows the target objectives, periodically the TMs provide a snapshot to the project with the status of the objectives. Typically, this snapshot is provided on every meeting (virtual or physical).

1.2.6. Status of Milestones and Deliverables

TABLE 1-4: STATUS OF DELIVERABLES

Deliverable Progress			
Title	On Schedule	Delayed	Completed
D1.1 - 5G-DIVE architecture and detailed analysis of vertical use cases			X
D1.2 - 5G-DIVE techno-economic Analysis			X
D1.3 - 5G-DIVE final architecture			X
D1.4 - Conclusions on vertical oriented 5G field trials and future outlook			X
D2.1 - 5G-DIVE innovations specification			X
D2.2 - 5G-DIVE components initial implementation			X
D2.3 - Final specification of 5G-DIVE innovations			X
D2.4 - 5G-DIVE components final implementation			X
D3.1 - Definition and setup of vertical trial sites			X
D3.2- Results of initial validation campaign of vertical use cases			X
D3.3 - KPI and performance evaluation of 5G-DIVE platform in vertical field trials			X
D4.1 - Y1 CoDEP including standardization plan			X
D4.2a - Achievements of Y1 and updated CoDEP for Y2 including standardization plan			X
D4.2b - Update to D4.2a with the exploitation plan			X
D4.3 - Communication, Dissemination, and Exploitation achievements through the project, exploitation plan after the end of the project and assessment of the contribution of 5G-DIVE in support of 5G			X
D5.1 - Project portal and communication channels			X
D5.2 - Final project report			X

TABLE 1-5: STATUS OF MILESTONES

	Milestones Progress			
WP	MS	On Schedule	Delayed	Completed
WP1	MS1 - Initial system requirements available			X
	MS2 - Use case analysis finalized Initial architecture available			X
	MS6 - Techno-economic analysis completed			X
	MS12 - Update on architecture available			X
WP2	MS5 - First version of DEEP innovations design and implementation available			X
	MS13 - Final version DEEP Innovations design and implementation available			X
WP3	MS3 - Description of test sites and plan for field trials available			X
	MS7 - Platform working in-house			X
	MS10 - Initial results of in-house validation campaign			X
	MS14 - Components integrated and ready to be deployed in the field trials			X
WP4	MS4 - Initial CoDEP draft and Standardization plan			X
	MS8 - CoDEP for Y1 executed Plan for Y2 available			X
	MS11 - Demonstration at EuCNC or equivalent			X
	MS15 - Demonstration of MWC or equivalent			X
WP5	MS9 - All deliverables and Milestones of Y1 completed			X

1.3. Explanation of the work carried out by each partner

WP1: Vertical industry-centric use cases and system design		
T1.1 Analysis of the vertical industry use cases including their business, functional, and technical requirements, and techno-economic analysis of the solutions	UC3M	• Contribution and review of D1.1 and D1.2 (use case mapping to 5G-DIVE architecture section and Techno Economic Analysis) • Contribution to the definition of the function, technical and business requirements related to the I4.0 use cases. • Elaboration of the business canvas for Digital Twin • Attended WP1 weekly calls
	ADLINK	• ADLINK has contributed to the validation of the functional, business, and technical requirements of the factory of the future Industry 4.0 use cases, within the Data Analytics Support Stratum (DASS). Contributed to the D1.4 in the DASS section. • Presented White Paper 5GPPP-5G and the Factories of the Future, extracted main functional and technical requirements • Joined regular WP1 and contributed to the Initial 5G-DIVE Architecture Discussion. • Contributed to the elaboration of the D1.1.
	EAB & ULUND	• Contribution to I4.0 massive MTC use case definition and requirements in D1.1 • Contribution to the techno-economic analysis regarding stakeholder flow and business model canvases in D1.2.
	IDCC	• Contribution and review of D1.1 (use case mapping to 5G-DIVE architecture section) • Contribution to the definition of the function, technical and business requirements related to the I4.0 ZDM use case. • Contribution to the alignment of the 5G-DIVE solution with current standard state of the art
	TID	• Contribution to the analysis of use cases' KPIs and requirements, identifying methodology to be followed taking the editorship of MS1 document. • Contribution to the analysis of the use cases, stakeholders, KPIs and requirements taking editorship of the I4.0 use case regarding the business, functional and technical requirements section in D1.1. • Editor for the D1.2 taking responsibility of the document structure, organization, and deadlines. • Contribution to the techno-economic analysis by identifying the different stakeholders participating in each 5G-DIVE pilot and their business flows. Based on that, identification of a new stakeholder called the system & service provider to describe the business models from a common view. • Contribution to the techno-economic analysis by evaluating the impact in CapEx and OpEx of the introduction of the 5G-DIVE solution for both I4.0 and ADS considering the associated benefits and costs. • Techno-economic analysis of 5G-DIVE, by identifying ways of modelling benefits on each of the three pillars of the project (5G, edge and AI).
	TELCA	• TELCA has studied the I4.0 requirements, both the Digital Twin and the Zero-Defect Manufacturing use cases. Identifying how artificial intelligence, DASS, BASS and new orchestration and slicing mechanisms will impact the use cases. Moreover, TELCA has analyzed 3GPP TS 22.104 specification to summarise the requirements for the industry 4.0 use cases, contributing to the success of MS1. • Reviewed the whole deliverable 1.2 and contributed to its editorial revision. • Contribution to the analysis of the use cases, stakeholders, KPIs and requirements. Editorship of use cases and requirements section in D1.1.

	III	• Host the WP1 weekly calls and virtual meetings. • Editor for D1.1 and D1.2. • Contribute to D1.1 for ADS use case descriptions in core network parts. • WP1 project management (meeting minutes, follow up, MS1 deliverable) • Presented ITU-T ML5G study
	ITRI	• Analyzed the functional, business, and technical requirements of the iMEC and Drone to Drone in ADS use case. • Finished the network planning, including IP assignment, subnetwork settings, and the wiring plans for underlay 3GPP network and on-the-top ADS network. • Built ITRI iMEC, which not only performs 3GPP local breakout functionalities for lowering transmission latency from Mobile UEs to the serving Applications, but also provides virtualized computing platform for hosting container-based and VM-based application servers. • End-to-End integrated the drones, ASKEY NSA base stations, NCTU OPTUNS fiber network, III NSA EPC, ITRI iMEC and finally to ASKEY drone applications. • For connectivity, we measured End-to-End uplink and downlink bandwidths and latency in term of round-trip-time. We also helped ASKEY and NCTU figure out the balanced setting of video quality and bandwidth usage. • Presented 3GPP TS 23.829 on UAV requirements in Rel. 17 • Contribute to D1.1 regarding ADS use case descriptions, flow, action, actors, etc. • Contributed to the business model canvas of the ADS use cases. • Contribute to D1.2, D1.3 and D1.4. Also, the editor of D1.4. Joined WP1 calls and presented the initial requirements of ADS use case.
	NCTU	• Participated in WP1 weekly calls and virtual meetings. • Refined and analyzed the functional, business, and technical requirements of the ADS use case in terms of intelligence engines and drone system. • Contribution to business model canvas of the ADS use case. • Contribution to D1.1, D1.3, and D1,4 dissemination. • Participated and provided input for the discussion of DEEP platform design to support for ADS use cases. • Participated in the project kick-off meeting and presented the initial design of the ADS use case • Initial discussion on the involvement of edge data center for I4.0 and ADS use cases. Participated in the F2F meeting in Madrid and discussed the refined design of the ADS and its use cases
T1.2 5G-DIVE system design and evaluation for vertical use cases	UC3M	• Contribution to the discussion of the architecture • Analyzing and studying ETSI ENI architecture as a possible reference for the enhancements proposed in 5G-DIVE Contribution to the discussions around the definition of the I4.0 use cases and their requirements • Contribution to the discussion on the 5G-DIVE innovations and how to showcase them in the I4.0 use cases • Design and definition of the 5G-DIVE architecture • Study of relevant standards and industry frameworks, and mapping them with the 5G-Dive architecture • Contribution and review of D1.1 (use case mapping to 5G-Dive architecture section) • Revisited integration of the DEEP platform with 5G-CORAL platform • Defined of the 5G-DIVE high-level workflows • Contributing to the 5G-DIVE architectural paper to be submitted to IEEE COMMAG

		• Leader of architecture definition discussion. • Refinement of DEEP platform: definition of detailed workflows, definition of blueprint and descriptors, federation solutions. • Reviewed and refinement of different options for the integration of the DEEP platform with the underlying Edge infrastructures (including 5G-CORAL) • Revising 5G-DIVE architecture paper ("DEEP: A Vertical-Oriented Intelligent and Automated Platform for the Edge and Fog") submitted to IEEE COMMAG • Contribution to GST-based transport network slicing paper ("Support for Availability Attributes in Network Slices in GANSO") submitted to Wiley ITL • Contribution to 5G-DIVE architecture paper ("DEEP: A Vertical-Oriented Intelligent and Automated Platform for the Edge and Fog") submitted to IEEE COMMAG • Contribution to COTORRA (COmodity Testbed fOR Robotic Applications) submitted to IEEE Netsoft 2021 4th Workshop on Advances in Slicing for Softwarized Infrastructures • Contribution to Digital Twin AI paper ("Towards Intelligent Cyber-Physical Systems - Digital Twin • Attending 5G-DIVE WP1 calls. • Leading and contributions to several discussions on the 5G-DIVE architecture and its DEEP platform, including refinements to the design, vertical service abstraction, semantics for monitoring, integration with 5G-CORAL. • Revising and submitting final version of 5G-DIVE architecture paper ("DEEP: A Vertical-Oriented Intelligent and Automated Platform for the Edge and Fog") accepted to IEEE COMMAG. • Editor, contribution to and review of D1.3. • Analysis of the business and DEEP benefits for the Digital Twin use case.
	ADLINK	• ADLINK has actively participated in the discussion regarding the final architecture refinement. Contributed to D1.4 on the validation of the vertical use cases. • Joined regular WP1 calls. • Contributed to the elaboration of the D1.1 • Contribution to deliverable D1.3. • Contribution to deliverable D1.4. • Continued the participation in the use case analysis, the DEEP architecture design, more in particular the DASS component, and the Techno-Economic Analysis for the factory of the Future Industry 4.0 use cases.
	EAB & ULUND	• Contributions to 5G-DIVE baseline architecture design and the mapping of massive MTC use case component design to the baseline architecture in D1.1. • Contributions to the architectural design regarding use case integration and relation with 5G-CORAL system. • Participating in WP1 meetings and contributing to system design discussions. • Contributions to D1.3 regarding DEEP integration with 5G-CORAL. • Contributions to mMTC requirement validation in D1.4. • Also contributed to the methodology for the requirement evaluation based on the trial results.
	IDCC	• IDCC has actively participated in the discussion regarding the architecture in particular the alignment with industry standards such as 3GPP, ETSI, and ITU-T ML5G. • Elaborated a mapping of the 5G-DIVE solution into current 3GPP standards

		• Participation in the ZDM use case analysis and the DEEP architecture design and the analysis of the technical requirements for the ZDM use case. • Contribution to deliverable D1.4. Joined regular WP1 calls.
	TID	• Contribution to the architecture definition, with focus on the business support aspects. • Contribution to the architecture design, including impacts/progress from standards • Contribution to the design of the 5G-DIVE architectural blocks, including impacts/progress from standards and mappings to them for covering detected gaps in existing state of the art solutions. • Work on the aspects related to SLA design and federation capabilities for 5G-DIVE project. Contribution to deliverable.
	ASKEY	• Analyzed the functional, business, and technical requirements of the 5G CPE 5G gNB and integration 5G technical with Drones in ADS use case. • Participated WP1 weekly calls, joined all open group member discussions, and contributed views and opinions. • Joined the F2F meeting • Discussed the vertical use cases of business and techno-economic analysis • Attended Taiwan 5G Forums promoting 5G DIVE architecture and use case • Attended all scheduled monthly 5G DIVE Taiwanese Partner Meetings discussed and reviewed architecture. Followed up all monthly meetings action items to move forward the project per milestones. • Developing Askey N78 commercial spectrum small cell 5gNB per milestones. • Modifying and tuning Askey N78 commercial small cell 5gNB in supporting 3.7 GHz that Taiwan NCC approved Taiwan local 5G experimental spectrum • Developing and testing 5G CPE Type C dongle • Integrated and validated drone traffic navigation system with NCTU OPTUNS per milestone. • Integrated real time video streaming system with NCTU AI system per milestone. • Application of 5G 3.7-3.8 in N78 experimental spectrum. • Drone TMS UI/UX enhancements.
	FET	• FET discussion on support spectrum allocation in 5G scenario
	TELCA	• TELCA has assisted in the identification of the 5G-DIVE platform main functionalities, especially the BASS and IESS stratums. Additionally, TELCA has contributed to the general architecture definition, designing the architecture definition for the IESS and BASS stratums, including a high-level description of its main components. • Further developed the data model, workflows, and roles for the interaction of the vertical with the BASS, extending the current design with Vertical Service Blueprints. • Studied other projects and standards which tackle SLA definition, negotiation, and enforcement, with the objective of defining the SLA interface, between the BASS and the vertical. The studied items include, 5G TANGO, GSMA, Geysers and ETSI EG202. • TELCA has contributed to D1.3 with a refined version of the architecture, data models and workflows for the BASS and IESS. The changes were the result of an iterative development process, taking results and observations from implementation (WP2) and use-cases integration activities (WP3). Additionally, TELCA has also defined some of the main innovations of the DEEP platform, such

		as Vertical Service Abstraction, Business Automation and SLA enforcement, Active Monitoring system. • TELCA has contributed to D1.4, with an evaluation of the impact of the 5G-DIVE platform and innovations on the use-cases and has collected and discussed all the results from validation and integration tests for the BASS and the IESS. • TELCA has refined the design of architecture, data models and workflows for the BASS and IESS. The changes were the result of an iterative development process, taking results and observations from implementation (WP2) and use-cases integration activities (WP3) and using them to refine and improve the initial design. • TELCA has also defined some of the main innovations of the DEEP platform, such as Vertical Service Abstraction, Business Automation and SLA enforcement, Active Monitoring system. TELCA participated in the editing of D1.3 and attended to WP1 meetings. • TELCA has evaluated the impact of the 5G-DIVE platform and innovations on the use-cases. The result of this activity will be reported in D1.4. TELCA attended WP1 meetings.
	III	• Host the WP1 weekly calls and virtual meetings. • Review the section 3 for D1.2 • Review for D1.3 • Participation in ADS business model canvas discussion. • Review D1.4 outline and chapter description • Confirm the D1.4 timeline and contribution from partners • WP1 project management (meeting minutes, follow up, MS, deliverable)
	ITRI	• Contribution to D1.1 for ADS mapping. • Adding GPU support to iMEC for ADS use case. • Update iMEC to support dual connectivity for 5G-NSA,option 3X. • Contribute to D1.3 in particular Workflow of DEEP. • Joined WP1 conference calls. • Drafting the content structure of D1.4.
	NCTU	• Participated in WP1 weekly calls and virtual meetings. • Participation in overall architecture and workflow discussion. • Participation in the business model canvas for I4.0 and ADS discussion. • Finalizing the workflow of PiH Detection, 2D Stitching, and Drone Data Processor with the DEEP platform for handling multiple drones. • Finalized the mapping of disaster relief response system towards DEEP. • Contributed and provided input for D1.3. • Joined WP1 weekly conference call. • Participated and provided input for the discussion of how the DEEP platform benefits the ADS use case. • Contributed and provided input for D1.4.
	RISE	• Work on aligning IdrOS with the DIVE architecture. Contributed to definition of massive MTC use-case, including contributions to D1.1 (joint work with EAB)

<table>
<tr><th colspan="3">WP2: 5G-DIVE Elastic Edge Platform design towards field trials</th></tr>
<tr><td rowspan="5">T2.1 5G Connectivity substrate</td><td>ADLINK</td><td>ADLINK has contributed to the D2.3 elaboration, to the final version of the DEEP innovation design. In addition, ADLINK have been the editor of D2.4 software implementations delivery that is part of the MS6.
Pointed out that Distributed Ledger Technology (DLT) technology maintains a complete history of transactions, i.e. the data structure is “append only”. This “append only” data structure affects where the technology can be applied.
Joined WP2 calls.
Contributed to the elaboration of D.1
Leading the elaboration of D2.2
Contribution to deliverable D2.3.
Contribution to deliverable D2.4 as editors.
Finalize DASS implementation .</td></tr>
<tr><td>EAB & ULUND</td><td>At a lab premise in Ericsson, established the 5G trial lab setup composed of Ericsson Radio Dot system, BBU, 5G EPC and two 5G CPEs for 5G connectivity and the measurement instruments like IXIA, channel emulator and servers. The measurement results show that 5G latency is much better than 4G. Updated the lab setup with new CPEs which achieves better throughput and has Ethernet ports (instead of USB only on the pervious CPEs. (Joint WP2 and WP3 work.)
Contribution to D2.1 regarding 5G connectivity.
Updated the 5G-trial system design: (1) local deployment of a full 5GC and (2) local deployment of a standalone UPF which is connected to a remote 5GC. The building of the second option is ongoing. (joint WP2 and WP3 work)
As a joint WP2 and WP3 work, lab setup of 5G connectivity is upgraded with 5GC supporting SA. The trial system design is complete. A flight-rack 5G system with a local UPF and remote 5GC is built and later shipped to 5TONIC for I4.0 trials.
Contributions to D2.3 regarding 5G connectivity.</td></tr>
<tr><td>IDCC</td><td>IDCC led the whole of WP2 including editorial leadership on D2.1.
IDCC contributed to the 5G connectivity framework noticeably in the RAN and for the I4.0 ZDM use case.
Coordinated the initial design of the 5G connectivity profile(s) for the Autonomous Drone Scout (ADS) field trial and the Industry 4.0 field trial.
Lead WP2 work across all tasks including presenting the WP2 status update at the Plenary meetings, chairing WP2 conference calls and editing the first WP2 deliverables.
Lead the deliverable D2.3, where the final 5G Standalone solution for I4.0 Trial is presented.</td></tr>
<tr><td>AAU</td><td>AAU contributed to the 5G connectivity and data telemetry framework noticeably in the RAN and for the I4.0 ZDM use case.</td></tr>
<tr><td>ASKEY</td><td>Provided 5G technology architecture and discussed with Taiwan partners, and presented how integrated the Drone with 5G in the architecture.
Participated WP2 weekly calls, joined all open group member discussions, and contributed views and opinions.
Produced prototypes of 4G LTE/5G NR and 4G LTE eNB scheduled to set up in NCTU campus for Drone’s further verification of tasks.
Attended all Taiwanese Partner Meetings.
Completed the 2nd generation of 5G CPE (based on QCM SDX55) development.
Enhanced eNB to have ENDC feature in supporting 5G NSA Option3X architecture.
Validated 5G CPE and 4G eNB connectivity in Askey Lab
5G NSA gNB development in progress</td></tr>
</table>

		• Defined and designed 3 stages for 4G E2Eperformance test. • Initial measurements throughput/latency results for E2E-4G system. • Validated 5G CPE and 4G eNB per Taiwanese partner meeting concluded plan of all units connected test at NCTU. • Help revised D2.1, D2.2, and D4.1 then submitted • 5G CPE (USB dongle type C) development per milestone. • 5G CPE integrated with drone and connected with small cell, iMEC and small cell. • 5G gNB small cell development per project planned milestones.
	TID	• Contribution to the mechanisms of the connectivity in 5G-DIVE by the preliminary analysis of the Slice Templates developments in GSMA and 3GPP and their applicability to the project. • Research on transport slicing concepts as part of 5G-DIVE overall solution for realistic deployment scenarios. Analysis of suitability of O-RAN models to 5G-DIVE scenarios. Contributions to deliverable 2.1. • Work on the setup of slices between Europe and Taiwan for the connectivity substrate including OPTUNS and OpenFlow equipment.
	TELCA	• TELCA has studied the integration of time sensitive networks (TSN) with 5G networks with the objective of propagating Edge and Fog requirements to the 5G network, ultimately creating a common slice across all domains. Currently a preliminary analysis of TSN IEEE standards and 3GPP release 16 stage 1 and 2 has been done.
	III	• Participated in WP2 weekly calls and virtual meetings. • Provided D2.1 the article to describe service based 5G core network architecture and the network slicing. • Designed the NSA EPC architecture to support the testing option3x network for ADS use case. • Contribute to NSA EPC in D2.3 • Contribute NSA EPC in D2.4 • Designed the NSA EPC architecture to support the testing option3x network for ADS use case. Support NSA Option 3X testing
	ITRI	• Present initial Drone to Drone collision avoidance in ADS use case • Presented the involvement in T1.2 for ADS use case. • Present initial iMEC with break out functionality in ADS use case. • Joined WP2 calls • Maps ADS to 5G-contivity platform of 5G-DIVE. • Presents the 5G-NSA Dual Connectivity Option 3A architecture for both ADS and I4.0 applications. • Provided D2.1 the article to describe iMEC functionality and the mechanism of traffic local breakout • Provided Contribute to D2.1, Section 4.1.2 about DCAS working flow/behavior and detailed description. • Provided contribution to D2.3, related to 5G-NSA and ADSUC1. • Agreed with III and ASKEY to build ADS on the 5G mobile network with the non-standalone architecture type: Option 3X. • Assisting ASKEY team to remotely test connectivity of the prototypes of NSA Option 3x base stations. We provide the VPN gateway at ITRI so that those base stations at ASKEY site can connect to the virtualized 5GC and MEC at ITRI site. • Several testing for Option 3X to validate connectivity.
	NCTU	• Participated in WP2 weekly calls and virtual meetings.

		• Participated in connectivity support for the ADS and I4.0 testing and demonstration discussion. • Participated and provided input in the discussion of 5G connectivity solution to support for ADS trial. • Facilitated the 5G connectivity solution field trial, as well as the integration with NCTU OPTUNS. • Contribution to D2.1, D2.2, D2.3, and D2.4 dissemination.
	RISE	• Adaptation of the softwarised multi-RAT gateway for the Industry 4.0 use case. (Joint work with Ericsson.)
T2.2 Computing and virtualization substrate	UC3M	• Presenting the expected contributions of UC3M for WP2 • Contribution to the definition of the functions, applications, and services in the Industry 4.0 field trial • Analysis and studying of different robot manipulators suitable for the I4.0 use cases • Contribution to the discussion regarding the IESS and BASS. • Contribution to the definition of the applications, functions and services requires for ZDM and Digital Twin use-case. • Contribution to the discussion regarding extending the 5G Coral virtualization infrastructure with OPTUNS • Contribution to analysis and selection of robot manipulator. • Leading task on Computing and virtualization substrate. • Analyzed required extensions to the 5GT VSBs and VSDs • Contributed on the discussions regarding I4.0 use cases (Digital Twin and ZDM) • Leading and writing a (on-going) paper on the DEEP platform • Coordination of T2.2 as task leader • Contributed to "An Intelligent Edge-based Digital Twin for Robotics" paper accepted into IEEE Globecom'20 Workshop on Advanced Technology for 5G Plus (AT5G+) • Synch with key partners on the implementation of the DEEP components (IESS, BASS, DASS) • Implemented and tested Docker containers for the Niryo One drivers • Developed and integrated new version of the Digital twin app (CoppeliaSIM based) for the Digital Twin use case • Contributed to D2.1 and D2.2 • Implementation of the web interface for the Digital Twin Build dataset regarding Digital Twin scaling, performance Initial experiments and results on movement prediction AI for Digital Twin • Integration of the BASS and DASS in the Digital Twin use-case and the joystick remote controlled for the Digital Twin • Build dataset regarding Digital Twin scaling performance within the DEEP platform • Contribution and section reviewer of D2.3. • Discussion and implementation of a scenario for network slicing experiments, including OPTUNS, spread across Spain and Taiwan. • Discussion and initial implementation effort of Digital Twin scaling PoC in collaboration with 5Growth project.
	ADLINK	• ADLINK has participated in the refinement of the DASS design, in particular the monitoring and implementation options. The final implementation and evaluation of the DASS component. Final elaboration of the orchestration requirements. Contribution to the D1.3 and D2.4 related to the DASS and OCS implementations. • Ongoing discussion on where the Eclipse Fog05 virtual infrastructure manager can be applied. • Joined WP2 calls.

		• Contributions to D2.2 by adding software released details of Eclipse fog05 and Eclipse zenoh • Finalized implementation and evaluation of DASS component in Eclipse Zenoh. • Contribution to deliverable D2.3. • Contribution to deliverable D2.4 as editors.
	EAB & ULUND	• Adaptation of the softwarised multi-RAT gateway for the Industry 4.0 use case. (Joint work with RISE.) • Implementation of Cloud native design for LoRa stack virtualization. • Investigation of resource pooling for vRAN of IoT. • Design and development of the large-scale emulation testbed for LoRa stacks. The test results show a great potential for resource scaling and pooling. (joint WP2/WP3 work) • Updated the IoT testbed with K8s integrated, ready to further develop for BASS support. • Contribution to D2.1 regarding the massive MTC use case. • K8s integration is done for both LoRa and 802.15.4 testbeds. The testbeds are ready for BASS integration. • Contributions to D2.3 and D2.4 regarding mMTC system design and implementation, as well as 5G SA solution.
	IDCC	• IDCC led the whole of WP2 including editorial leadership on D2.1. • IDCC contributed to the edge computing solution for the I4.0 ZDM use case including constrained Edge devices. • IDCC has also been leading the WP2 final specification deliverable D2.3. • Training and deployment of a new defective object detection engine. • Design and implementation of the final DEEP platform version.
	ASKEY	• Joined WP2 calls • Produced prototypes of 4G LTE/5G NR and 4G LTE eNB scheduled to set up in NCTU campus for Drone's further verification of tasks. • (Gopro) Real time video streaming system integrated with NCTU AI (OPTUNS) system. • Packet test in between real time video streaming system and NCTU AI (OPTUNS) system • Drone control system test: Packet test in between 5G CPE on drone and 4G eNB • (Gopro) Real time video streaming system from 5G CPE to 4G eNB that integrated with 4G EPC and iMEC. • Optimize real time video streaming system from 5G CPE to 4G eNB then connecting to NCTU AI (OPTUNS) system. • Drone control system integrated with 4G eNB via application control validation. • 5G gNB small cell development per project planned milestone. • 5G CPE (USB dongle type C) development per milestone • MEC and 4G core EPC integration and validation in 5G NSA architecture. • More test on drone remote control system for field trial usages. • Discussed and validated 2D image stitching design.
	TELCA	• TELCA has performed a survey of the SLA management and enforcement frameworks available (FIWARE and 5GTANGO SLA), identifying which frameworks can be taken as a baseline for the project BASS. Moreover, TELCA has analyzed a wide set of AutoAI/ML platforms and has reduced the extensive list into a subset of platforms which satisfy 5G-DIVE IESS requirements. Additionally, TELCA based in WP1 architecture has further defined both the detailed architecture of the IESS and the BASS. Finally, TELCA has developed the first release of the former BASS and IESS stratums, considering the requirements identified for each stratum.

		• Refined the data model of the BASS and the IESS, which includes adding a new interface between the SLA & Policy Management of the BASS and the IESS, which will enable the capability of requesting trained models on demand. • Added several capabilities to the vertical service descriptors, such as the support for environmental variables, consistent ordered deployment, Init components, and the node component affinity. • Addition of a web GUI, enable file logging, new state monitoring for the components, mounting devices, and the ability to deploy components in privileged mode. • Added the capability of comparing component images by their fingerprint, support Node port as headless service deployment, and the ability to load images consistently to the container registry (sequential loading). • Added the multi-region support to BASS deployments, which allow vertical services to be located under different regions with different resource orchestrator owners and technologies. • Implemented the Vertical service new data model, developing the Vertical Service blueprints. • Experimented with multiple service mesh solutions, such as istio, which allow a transparent communication between regions. • Preliminary study for the design of the active monitoring support for the BASS, exploring different monitoring approaches, such as the use of InfluxDB and Telegraf to extract custom metrics for a vertical service. • The support for multiple regions has been extended to support Fog05 as a resource orchestrator. • BASS integration tests have been performed in collaboration with other partners to ensure correct operation of the system. • The BASS North bound interface has been improved in terms of usability. • Integration between BASS and IESS, the BASS is capable of fully leveraging the IESS for automatic training and model storage. • IESS development has produced improvements in the AI/ML Catalogue and included a new feature for the packaging of inference applications as well as the support for new ML platforms. • TELCA contributed to D2.3 and D2.4. • TELCA has continued the development of the BASS. The support for multiple regions has been extended to support the Fog05 resource orchestrator. Integration tests have been performed in collaboration with other partners to ensure correct operation. The development of Active Monitoring and the SLA enforcement framework has begun. The Northbound Interface has also seen many improvements in terms of usability. • TELCA has refined the interaction workflows between the BASS and the IESS, improving the integration of the two components. Furthermore, the IESS development has produced improvements in the AI/ML Catalogue and included a new feature for the packaging of inference applications as well as the support for new ML platforms.
	ITRI	• Decomposed and presented iMEC system and map the components into 5G-CORAL architecture (In particular EFS components). • Joined WP2 calls. • Decomposed and presented Drone-to-Drone system and map the components into 5G-CORAL architecture (In particular EFS components) • Discussed and agreed with ADLINK on the strategy for integrating iMEC and Fog05. • Study 3GPP TS 23.288 and TS 29.520

		• Mapped ADS use case into virtualization platform including defined and refining EFS/OCS/DEEP components. • Implemented the initial version of drone collision avoidance (DCA) as an EFS application. • Release iMEC software with a brief explanation to D2.2. • Release DCAS software with a brief explanation to D2.2 • Release final iMEC software with a brief explanation to D2.4. • Release final DCAS software with a brief explanation to D2.4. • Joined and discussed Zenoh Tutorial and discussion of the possibilities in ADS use case • Upgraded 4G MEC to 5G MEC, which continues supporting traffic local breakout. • Performed Kubernetes and related software upgrades on 5G MEC for cooperating with III's 5G Core. • Update the computing substrate related to DCAS and reported in D2.3. • Contribute to D2.4 and D2.3 related to DCAS, IMEC, ADSUC1, and ADSUC2.
	NCTU	• Participated in WP2 weekly calls and virtual meetings. • Mapped the planned intelligence engines to 5G-CORAL EFS architecture. • Finalized the design of EagleEYE Person in need of Help (PiH) detection system. • Finalized the EagleEYE deployment architecture using Kubernetes, and BASS. • Implemented EagleEYE intelligence engine as an EFS application. • Presented the applicability of simulated Drone in 2D and 3D environments to enhance scalability. • Participated in the discussion of DEEP platform integration to the vertical use case. • Integration of DASS, IESS, and BASS into the ADS use case. • Contribution to D2.1, D2.2, D2.3, and D2.4 dissemination.
	RISE	• Further developed the Multi-RAT gateway for the Massive MTC use-case with focus on automating configuration and deployment. Started integration with BASS. • Definition of the EFS services/applications for the massive MTC use case and mapping to the 5G-Dive architecture; Design and implementation of IQ samples service, which collects radio samples from the USRP and publishes the IQ samples to the EFS service platform using the SigMF specification. • Investigation of large testbed simulation, mainly exploring techniques in which we can incorporate the current radio environment in our simulation, and thus include scalability of PHY functions too. Investigation of cloud-native design of the IEEE 802.15.4 networking stack. A single network-layer for multiple PHYs has been implemented following cloud-native design principles, and a demo prepared for the year one review. • A fog support layer for iDrOS based on fog05 has been implemented allowing iDrOS instances to migrate as an atomic unit across fog05 instances. A software architecture for iDrOS has been created that can be plugged in as a fog05 orchestrator. Initial evaluation has been carried out, specifically the measurement of migration and startup times as well as memory/processing overhead, showing shorter migration times compared to Docker containers. • Review of deliverables D2.1 and D2.2 • Completed integration of MTC use case with BASS. • Contributions to and review of Deliverable 2.3.

T2.3 Intelligence Engines	UC3M	• Presenting the expected contributions of UC3M for WP2 • Analyzing how the intelligence can be of use in the I4.0 use case • Contribution to the discussion regarding how to leverage intelligence engines in both I4.0 use cases • Contributed to D2.1 • Ongoing development of several Intelligent engines for the Digital Twin use case • Contribution and section reviewer of D2.3. • Contribution to D2.4. • Improve ad-hoc experiments and results on movement prediction AI for Digital Twin, including the test of new AI/ML algorithms. • Implementation of the movement prediction AI as a ROS module and integration with the Digital Twin prototype.
	ADLINK	• ADLINK has actively participated in the discussion regarding the Industry 4.0 UCs and how the modules should be packages e.g., containers, VMS, native applications. Active participation in WP2 regular calls. • Ongoing discussion over the ETSI Experiential Network Intelligence (ENI) and the ITU-T ML5G references architectures and how it can be applied • Implementation of fog05 driver which integrates BASS & fog05 • Joined regular WP2 calls.
	IDCC	• IDCC contributed to the intelligence framework design. • IDCC developed the intelligent engine for the ZDM use case. • IDCC has been working on intelligent RAN control applications in line with O-RAN alliance work, mainly around traffic steering and multi-access management. • Design and implementation of the final Intelligent Engines for the I4.0 and ADS use cases.
	TELCA	• TELCA has studied the state of the art of artificial intelligence and machine learning to the applicability of SDN and NFV, functionalities such as, load balancing, elephant flow detection, QoS optimization, routing, traffic matrix prediction, congestion detection and avoidance can be enhanced with proper AI/ML algorithms. Furthermore, TELCA has studied MLP FFNN algorithm as an alternative to the LSTM RNN algorithm, to solve the network traffic matrix forecasting overfitting problems. Additionally, TELCA has also contributed to the survey of distributed ledger technologies, analyzing the Hyperledger fabric project. Moreover, TELCA has analyzed the feasibility of Q-Learning reinforcement learning algorithms to optimize by tuning CPU and RAM parameters the service response times. Finally, TELCA has implemented the first release of the reinforcement algorithm based on DQN which is part of the SLA Enforcement Closed Loop. • Improved the reinforcement algorithm based on DQN which is part of the SLA Enforcement Closed Loop included in the BASS Architecture. This intelligent engine decides to scale vertically either up or down (based on multiple metrics) the components deployed as part of a vertical service. • Improved the simulated environment to be able to scale the tests and improve the results. • Explored the possibility of integrating the BASS SLA enforcement capabilities with the Digital Twin use case. TELCA has deployed a replica of the Digital Twin use-case on hardware with constrained resources to emulate a realistic scenario, with the objective of building of a dataset which includes the resource usage, resource limits and end-to-end latency experienced by the robot controller. The SLA-Enforcer was able to handle the training and execution of a Deep Reinforcement Learning algorithm to learn from built dataset and to perform dynamically resource re-allocation with

		respect to the desired end-to-end latency. Results show that the SLA-Enforcer managed to keep the resources as low as possible while keeping the end-to-end latency close to the target value, in this case both values of 500ms and 1000ms were tested. • TELCA has explored the integration of the Movement Prediction intelligence engine for the Digital Twin use-case with the IESS. TELCA has designed a solution to train a custom ML algorithm with the IESS and then package the corresponding inference application.
	NCTU	• Participated in WP2 weekly calls and virtual meetings. • Conducted and presented a survey for convolutional neural network (CNN) and discussed its applicability for ADS use case pattern recognition application. • Participated in F2F meeting in Madrid and presented the plan for the intelligence engines development. • Lead the effort in surveying the state-of-the-art AI techniques and its applicability for intelligent engine. • Presented the status of intelligence engine developed by partners and their plans towards contributing it to the IESS. • Leading T2.3 in finalizing the design and development of intelligence engines for vertical use cases. • Worked on the development of EagleEYE module to perform PiH detection. In this work, EagleEYE is able to support for multiple concurrent drone streams. • Worked on the development of EagleStitch module to perform 2D Stitching of a surrounding disaster impacted area. • Worked on the development of Drone Data Processor to perform drone image tagging to help the processing at the edge when handling for multiple drones' input. • Leader for D2.3 dissemination. • Contribution to D2.1, D2.2, D2.3, and D2.4 dissemination. • Finalizing the EagleEYE, EagleStitch, Drone Data Processor system and its key module design for ADS Use Case 2. • Integration of the EagleEYE, EagleStitch, Drone Data Processor system to NCTU edge data center.
	RISE	• Have introduced support for ML execution as part of the Multi-RAT gateway infrastructure to be able to support, e.g., intelligent RAT selection and other functions using radio sample data. • Design of an RF security service for the massive MTC use case using the radio signatures of the transmitting device to authenticate the device (RF fingerprinting). We completed a survey of existing literature for robust device identification using radio frequency characteristics. Existing methods could not be extended to identify devices joining the network after the initial deployment. Towards this end, we developed contrastive deep learning-based methods that extract and learn the key differentiating characteristics between two devices. This allows us to identify new devices using just the network association message sent by the device by comparing it to other known or unknown devices. In experiments across 44 devices from three different chipsets, we show that we can identify unseen devices with accuracy of over 90%, outperforming the state of the art by over 20%. Evaluation of robustness with respect to noise and impact of receiver and unknown device classification with respect to noise, chipset, and choice of receiver. • Finalization of the RF fingerprinting module. • Contributions to and review of Deliverable 2.3.

WP3: 5G Technology validation and Field trials		
3.1 I4.0 field trial	UC3M	• Contribution and review of D3.1Identification of features and functionalities to be showcased in Digital Twin and ZDM use cases • Contribution to the discussion regarding the implementation of Digital Twin and ZDM use cases • Initial implementation of Digital Twin Application • Contributed to the definition of experiments on the Digital Twin use case • Setup a Digital Twin experiment in a simulated environment • Contributed to the deployment and execution of a set of experiments on 5TONIC regarding the Digital Twin • Contributed to "Demo: Assessing the need for 5G driven Edge and Fog solution for Digital Twin systems" demo paper accepted and presented in ACM WiNTECH'20 • Done experiments regarding the Digital Twin use case at 5TONIC: gathering results • Leading the discussion about BASS integration in the Digital Twin use case with TELCA • Leading the discussion about DASS integration in the Digital Twin use case with ADLINK • Contribution to Digital Twin AI paper ("Towards Intelligent Cyber-Physical Systems: Digital Twin meets Artificial Intelligence") submitted to IEEE COMMAG special issue • Implementation of the web interface for the Digital Twin • Build dataset regarding Digital Twin scaling performance • Preparation of the Digital Twin demo for the review meeting • Leading Digital Twin paper extension experiments and paper • Integration of the BASS and DASS in the Digital Twin use-case • Integration of the joystick remote controller for the Digital Twin • Contribution to Digital Twin paper extension experiments and paper • Contribution to EuCNC paper submitted by the consortium • Contribution to and review of deliverable D3.2 • Build dataset regarding Digital Twin scaling performance within the DEEP platform (i.e., using the SLA Enforcer) • Improve experiments and results on movement prediction AI for Digital Twin • Contribution to the Digital Twin journal extension paper • Building realistic dataset regarding movement prediction AI for Digital Twin • Working on the integration of fog05 in the Digital Twin use case • Addressing Scalability for the Digital Twin use-case • Contribution to the Digital Twin journal extension paper • Working on the integration of fog05 in the Digital Twin use case • Addressing Scalability for the Digital Twin use-case • Writing UC3M contribution for deliverable D3.2 • Contribution to paper "Dissecting the Impact of Information and Communication Technologies on Digital Twins as a Service". • Contribution to the revision of the paper "Towards Intelligent Cyber-Physical Systems: Digital Twin meets Artificial Intelligence" submitted to IEEE COMMAG special issue • Contribution to D2.4. • Improve ad-hoc experiments and results on movement prediction AI for Digital Twin, including the test of new AI/ML algorithms. • Implementation of the movement prediction AI as a ROS module and integration with the Digital Twin prototype

		• Setting up a 5G interfacing node for the robotic arm in the Digital Twin use case to be used in the pilot trials in 5TONIC • Discussion and initial implementation effort of Digital Twin scaling PoC in collaboration with 5Growth project • Integration of the movement prediction feature in the Digital Twin use case. • Implementation of the obstacle avoidance feature. • Contribution to deliverable D3.3. • Integration of the movement prediction feature with the BASS. • Integration of the movement prediction feature with the IESS. • Integration, testing and validation of fog05 / Kubernetes joint deployment using the BASS. • Work on the Obstacle Avoidance algorithm. • Work on the integration of the feature above with the ROS. Motion Planning framework and its robot visualization software. • Work on the integration of the feature above with the Digital Twin simulator. • Providing support for the 5TONIC test trials. • Defining experiments for the Digital Twin use case and the measurements to be taken to validate the integration of the use case with the DEEP platform. • Integration of the SLA Enforcer in the DEEP platform with TELCA.
	ADLINK	• ADLINK has coordinated the integration and deployment for I4.0 use cases: Digital Twin, Zero Defect Manufacturing and mMTC. Initially with the in-lab validation in 5TONIC for the 1st year implementation and the transition to the realistic scenario. Active participation in the WP3 regular calls. Due to Covid-19 restrictions the final integration and deployment test trial was moved from the initially planned in Taipei, Taiwan to the 5TONIC lab, in Madrid, Spain. • Join regular WP3 calls • Active contribution to the elaboration of D3.1 • Industry 4.0 UCs integration and deployment was moved to 5TONIC (UC3M premises). • Contributions to D3.3.
	EAB & ULUND	• At a lab premise in Ericsson, established the 5G trial lab setup. The measurement results show that 5G latency is much better than 4G. Updated the lab setup with new CPEs which achieves better throughput and has Ethernet ports (instead of USB only on the pervious CPEs. (Joint WP2-WP3 work.) • Contribution to D3.1 regarding 5G trial lab setup and massive MTC trial site definition. • Ordered the indoor radio supporting Band n79 that will be used for the final trial in Taiwan. • Design and development of large-scale emulation testbed for LoRa stacks. The test results show a great potential for resource scaling and pooling. (joint WP2/WP3 work). • Contribution to D3.2 regarding mMTC testbed and DEEP integration • As the editor, led D3.2 to complete on time. • Updated the 5G-trial system design: (1) local deployment of a full 5GC and (2) local deployment of a standalone UPF which is connected to a remote 5GC. The building of the second option is ongoing. (joint WP2 and WP3 work) • Further developed the IoT testbed with K8s, ready for BASS support. • Lab setup of 5G connectivity is upgraded with 5GC supporting SA. The trial system design is complete. • K8s integration done for both LoRa and 802.15.4 testbeds. The testbeds are ready for BASS integration.

		• The 5G SA trial system using n79 band was built and successfully tested with two Askey UEs in the lab. The results so far show good improvement in UL throughput comparing to the NSA setup tested before. Latency is also improved. • Integrated the mMTC testbed with BASS and further development regarding SW implementation improvements. • Installed the 5G system in 5TONIC in Spain for I4.0 final trial, providing the connectivity between UEs and the 5TONIC data center and between UEs and Internet. User plane traffic breaks out locally for lower latency and control plane is handled remotely from 5GC in Sweden for robustness. • Together with RISE, deployed the mMTC setup in 5TONIC integrated with DEEP as part of I4.0 trial and performed long-term mMTC trial. The mMTC service run in the 5TONIC data center where digital twin service is also running. • 5G system setup and mMTC trial results are documented in D3.3.
	IDCC	• IDCC contributed to the field trials definition on the ZDM use case. • IDCC has trialed the ZDM use case in two setups, one in the lab, and another one using 5G-VINNI UK facility. IDCC has also been working to trial the ZDM use case using a commercial 5G network (Vodafone) integrating an Edge solution. This will be reported upon in the second reporting period. • Integration work with 5G network from Vodafone UK and AWS Wavelength component. • Design, development and testing of an edge intelligent for the ZDM use case platform in cooperation with AAU. • Integrating the DASS component with the ZDM use case in cooperation with AAU. • Integrating the BASS component with the ZDM use case in cooperation with AAU. • Contributions to D3.3. • Attended regular WP3 calls.
	AAU	• AAU contributed to the field trials definition on the ZDM use case. • Deployment and test of an edge intelligent engine over 5G connectivity for the ZDM use case platform. • Integrating the DASS component with the ZDM use case. • Integrating the BASS component with the ZDM use case. • Integration of the edge intelligent engine with Vodafone/AWS wavelength.
	FET	• FET must fulfill the previous agreement to provide available radio spectrum (TDD 2600MHz) for this trials.
	TELCA	• TELCA has contributed to the description of the software and hardware components which could potentially be used to validate the innovations TELCA is participating. Moreover, TELCA has also started the integration activities of the BASS with the industry 4.0 use case. • Assisting in the integration of the Digital Twin use case for the first project demonstration. • Developed supporting material for the partners serving as guides for the K3s and BASS installation and operation. • Developed the SLA Enforcement Closed Loop algorithm and its integration with the digital twin use case, has presented to the partners its first results. • Contacted peer to peer with all the pilot owners to identify new BASS and IESS requirements, which could potentially translate to new features. • Studied the development for each use case of the BASS vertical service descriptors and has recommended potential modifications on some pilots to adapt to the BASS.

		• As part of the Digital Twin integration, TELCA has deployed locally a replica of the testbed to generate data from local experiments which could potentially be used in SLA enforcement algorithms. • Elaborated an integration roadmap for the second year. • Supported all the pilot owners in the integration with the BASS and the IESS. • Organized and coordinated dedicated, peer to peer meetings in order to perform tests of the use-cases and provided computing and networking resources when necessary. • Attended WP3 meetings and has periodically reported the integration status of all the use-cases. • Configured a testing scenario for the deployment of the pilot network service and executed validation tests for every pilot. • Supported the integration of the pilots with the IESS. • Participated in the planning and preparation of the field trials for the industry 4.0 use cases, helping configure computing and networking resources at 5TONIC. • TELCA has completed the integration of the pilots with the BASS. TELCA has organized dedicated technical meetings with each pilot owner, configured a testing scenario for the deployment of the pilot network service, and executed validation tests. Computing and networking resources were provided when necessary. TELCA has also supported the integration of the pilots with the IESS.
	III	• Joined WP3 weekly calls. • Participated in the F2F meeting in Madrid. • Discussed the integration plan with ITRI iMEC and Askey eNB/gNB • Support spectrum application for N79 for field trials in NSA EPC part.
	ITRI	• Measurements with edge DC from Adlink facilities. • Discussed the integration of I4.0 and joined I4.0 integration call. In particular, discussed the 5TONIC integration for all I40. Use case. • Agreed on long validation measurements. • Defined 4 stages for performance testing I4.0 • Discussed the integration plan of BASS/IESS/DASS • Completed Spectrum application for N79 for field trials in Taiwan, under review by NCC now. • Joined WP3 calls. • Discussed I4.0 use cases integration in 5Tonic.
	NCTU	• Participated in WP3 weekly calls and virtual meetings. • Participated in the F2F meeting in Madrid and discussed the possibility of utilizing OPTUNS as a computing infrastructure for I4.0 use cases. • Supporting partners in the integration of OPTUNS as a computing infrastructure for use cases. • Participated and provided input in the discussion of I4.0 field trial and experimentation. • Participated and involved in the discussion for BASS/IESS/DASS integration for ADS in Taiwan. • Integrated DASS into the ADSUC2 processing pipeline. • Integration and implementation of BASS and IESS for ADSUC2. • Contribution to D3.1, D3.2, and D3.3 dissemination.
	RISE	• Use-case mapping of Massive MTC to the 5G-DIVE architecture, trial site design and technical requirement; contribution to D3.1 (joint work with EAB) • Contribution to and review of Deliverable 3.2 • Integration of the mMTC modules with BASS (joint work with Ericsson). • Preparation for the trial: Improving the modules, adding evaluation methods.

		• Implemented containerisation of the RF Fingerprinting method. • Together with EAB, deployed the mMTC setup in 5TONIC integrated with DEEP as part of I4.0 trial and performed long-term mMTC trial. The mMTC service run in the 5TONIC data center where digital twin service is also running. • Contributions to and review of Deliverable 3.3
T3.2 Autonomous Drone Scouting field trial	IDCC	• Contribution to the ADS framework review and coordination with ITRI for complementing the ADS trials with on-drone intelligence experiments. • Design and development of a new intelligent engine to enhance the ADS use case, including simulation of on flight drones, drone telemetry data collection.
	ASKEY	• Joined WP3 calls • Drone firmware development • Drone control firmware coding • GPS sensor interface • Backend server interface • Drone hardware development • Drone hardware spec design • Drone assembly and integration • NCTU Site survey • Confirmed trial site targeted NCTU building • Confirmed eNB installation location • Tested GPS signal strength and stability on the targeted trial site • Frontend Web page development • Control Page design • Control Page development • Testing • Backend System development • Drone interface protocol development • Frontend control page interface • Drone interface development • Database design • Data format design • Backend system interface • Smallcell & CPE test • test 4G Smallcell/5G small cell • test CPE • test Smallcell and CPE connectivity • Attended all Taiwanese Partner Meetings • Drone field trail with 5G E2E test in Topology. • 4-stage task plan to move forward ADS2 • 1st stage: Remote test (image object detection) between NCTU and Topology; • 2nd stage: Local unit (image object detection) test in NCTU; • 3rd stage: Function IIoT connectivity test; • 4th stage: Performance test and measurement in NCTU are in progress • More drone field trial testing in NCTU per planned milestones. • More autonomous drone fleet test under project design scenarios per Taiwanese partner meetings. • More testing done with 5G E2E real time video streaming in field trials per Taiwanese partner meetings. • More functioning test on drone remote control per Taiwanese partner meetings.

		• More drone field trial testing in NCTU. • More autonomous drone fleet tests under project scenarios per follow-ups from Taiwanese partner meetings. • Discussed and designed new UI/UX of the drone navigation control system. • More functional tests with drone remote control per Taiwanese partner meeting. • Validation of 5G CPE integrated with drone and connected with small cell and iMEC. • In process of 5G gNB small cell development per project planned milestones. • Modifying commercial spectrum (3.3-3.57) 5G Sub6 SC in supporting (3.7-3.8) 5G experimental spectrum. • iMEC and 4G core EPC integration and validation under 5G NSA Option 3x architecture. • Finish of validation of 2D image stitching integration. • More autonomous drone fleet tests under project scenarios per follow-ups from Taiwanese partner meetings. • Integrated real time video streaming system with NCTU AI system per milestones. • System integration and validation among of 5G E2E, EPC and IMEC. • Validation of a fleet of 3 drones run through the entire system design flow (Drone to 5G E2E to AI in the NCTU field).
	FET	• FET must fulfill the previous agreement to provide available radio spectrum (TDD 2600MHz) for this trials.
	III	• Contribute in D3.1 for core network architecture of E2E ADS system. • discussion on integration of 4G E2E system. • Integrate testing with ITRI's Imec and Askey's eNB to a full functional LTE network. • Provide and integrate the NSA EPC with ITRI iMEC. • Join WP3 weekly meeting. • Joined Taiwanese monthly conference call • Joined TW side monthly F2F meeting. • Upgraded Non-standalone EPC architecture of the type of Option 3X. • Planned the core network architecture for interconnecting iMEC and eNB and Support integration tests with ITRI iMEC and Askey eNB/gNB. • Contribute to D3.3 in NSA EPC part. • Join and discuss the integrated 5G NSA base station from ASKEY, NSA Core from III, and iMEC from ITRI at NCTU trial field, The end-to-end system integration of gNB/iMEC/EPC/Eagle EYE has been completed. Debug the problem for the user plane. Once the problem is resolved, the application can be integrated into the test of core network. • Join the integration of drone fleet navigation and DCAS (Drone Collision Avoidance System), completed the application layer test of 2 drones, and the target of 3 drones will be tested soon. • Contribute to D3.3 in NSA EPC part.
	ITRI	• Provide the Editorial of D3.1. • Initial discussion on integration of ADS. • Survey on the trial site to plan the eNB, gNB and flying area of drones including GPS measurements. • Provide the presentation on iMEC implementation and collision avoidance. • Demo Drone Collision Avoidance function with the emulator. • Initial Integrating Drone Collision Avoidance function with end-to-end connectivity and drone navigation server in the edge. • Planned the network architecture for interconnecting iMEC, virtual EPC, and eNB • Made the IP assignments and cabling plan for ADS system

		• Setup iMEC with Kubernetes and Openstack servers to host localized drone applications. Subsequently, we integrated iMEC into OPTUNS network • Performed LTE messaging tests between iMEC and EPC • • Integrated ITRI's iMEC, III's EPC, and Askey's eNB to a full functional LTE network. • Evaluated end-to-end bandwidth and latency performance of the network. • Deployed serving application for drones on iMEC. • Drone to drone communication evaluated (supports at least 120 meters with 3~6ms latency) • Initial evaluation of DCAS with 1 real drone and 1 pseudo drone • Contribute to ADS Demo Scenario • Support Askey to submit drone flight application (drone operation manual) • Upgraded iMEC to run on Intel fiber NIC for integrating NCTU OPTUNS and leverage SRIOV functionality to accelerate the speed of packet switching. • Upgraded iMEC to the 5G Non-standalone architecture of the type of Option 3X. • Performing integration tests with 5G EPC from III. • Completed the integration of the ADS drones, EPC, and both the AI engine from NCTU and Drone navigation Apps from ASKEY running on iMEC. • Contribution for D3.2 ToC ”Results of initial validation campaign of vertical use cases” • Completed ADSUC1/ADSUC2 field trial plan and road map • Completed ADSUC1 with 3 drones and DCAS adopted in the edge. • Stress test for the new navigation server up to 50 drones. Long and short validation measurements for ADSUC1/ADSUC2. • Overcome several technical issues when integrating the 5G-NSA solution. • Contributed to D2.3 extensively especially for ADSUC1/ADSUC2. • Contributed to D3.3 extensively especially for ADSUC1/ADSUC2. • Editorial of D3.3. • Run numerous field trials including 3 drones, 5G-NSA and updated versions of DCAS and Eagle Eye. • Joined Taiwanese monthly conference calls. • Set up MEC servers for accommodating ADS application servers, such as map stitching, and the human detection of those in need of help. • Perform connectivity test between virtualized servers through OPTUNS network. • Provide D3.3 ToC ”KPI and performance evaluation of 5G-DIVE platform in vertical field trials”. • Working on ADSUC1/ADSUC2 field trial as possible • Integrated 5G NSA base station from ASKEY, NSA Core from III, and iMEC from ITRI at NCTU trial field, The end-to-end system integration of gNB/iMEC/EPC/Eagle EYE has been completed, but the current test encounters a connection establishment problem in the user plane and is being processed; once the problem is resolved, the application can be integrated into the test (Working on dual connectivity of gNB and eNB with the core network). • Completed the integration of drone fleet navigation and DCAS (Drone Collision Avoidance System), completed the application layer test of 3 drones.
	NCTU	• Participated in WP3 weekly calls and virtual meetings. • Finalized the OPTUNS connectivity mapping for field Trial preparations. • Participated and provided input in the discussion of ADS field trial and experimentation. • Involved in the deployment, and integration of Taiwanese partners software/hardware component to support for the ADS field trial.

		• Collaborated with other Taiwanese partner for the integration of various software modules with EagleEYE, EagleStitch and Drone Data Processor. • Contribution to D3.1, D3.2, and D3.3 dissemination. • Facilitated the monthly discussion for Taiwanese partners. • Participated in the development, deployment, and integration of Taiwanese partners software/hardware component in the NCTU OPTUNS edge data center infrastructure to support for the ADS field trial. This integration and deployment covers for the 5G connectivity, aerial drones, edge, as well as the software components deployed at the edge. • Collaborated with the Taiwanese partners for the ADS Use Case 1, and ADS Use Case 2 field trial at NCTU. • Worked on the integration of ADS use case integration with the DEEP platform BASS, IESS, and DASS.
	RISE	• Contributed to D3.1 with a discussion on the 5G and site requirements for the drone field trial • Review of Deliverable 3.2 • Contribution of material for the updated periodic report review. • Planned evaluation of the iDrOS drone operating system, started running microbenchmarks, and began paper preparation. • Contributions to and review of Deliverable 3.3

WP4: Communication, Dissemination, and Exploitation		
T4.1 Communication activities	UC3M	• Submitted position paper for GEFI 2019 Workshop (accepted and published) • Presentation of 5G-DIVE project at Open Workshop on "Research Activities of Mutual Interest" (workshop at IMDEA Networks, Leganés, Spain) • Publication of a Press Release • Submitted paper to MobiHoc • Participation in the EU-TW 5G/B5G workshop held in Taipei • Contribution to the elaboration of the 5G-Dive poster and leaflet • Contribution to the 5G-Dive article for 5G annual journal • Review of a section in D4.1 • Leading and writing a (on-going) paper on the DEEP platform • Contributing to a paper focusing on the Digital Twin • Attended and presenting DEEP platform on "5G end to end experimentation by verticals in EU projects" webinar • Prepared materials for the Portuguese/Spanish 5Growth & 5G-DIVE webinar • Accepted Peer-review publication: "Demo: Assessing the need for 5G driven Edge and Fog solution for Digital Twin systems" Authors, Milan Groshev, Carlos Guimarães Venue, ACM WiNTECH 2020, London (UK) (going virtual) • Accepted Peer-review publication: "Demo: Assessing the need for 5G driven Edge and Fog solution for Digital Twin systems" Authors, Milan Groshev, Carlos Guimarães Venue, ACM WiNTECH 2020, London (UK) (going virtual) • Leading 5G-dive architecture paper ("DEEP: A Vertical-Oriented Intelligent and Automated Platform for the Edge and Fog") submitted to IEEE COMMAG • Contribution to Digital Twin AI paper ("Towards Intelligent Cyber-Physical Systems: Digital Twin meets Artificial Intelligence") submitted to IEEE COMMAG special issue • Keynote on NFV-SDN'20 MOBISLICE III Workshop on "Edge and Fog fo I4.0 and Autonomous Drone Scouting with 5G-DIVE"

		• Contribution to 5G-DIVE architecture paper ("DEEP: A Vertical Oriented Intelligent and Automated Platform for the Edge and Fog") submitted to IEEE COMMAG • Leading Digital Twin paper extension experiments and paper • Contribution to GST-based transport network slicing paper ("Support for Availability Attributes in Network Slices in GANSO") submitted to Wiley ITL • Contribution to EuCNC paper submitted by the consortium • Contribution to Digital Twin journal extension paper. • Contribution to COTORRA (COmodity Testbed fOR Robotic Applications) submitted to IEEE COMMAG • Contribution to Orchestration in the far Edge ("Managing the far-Edge: are today's centralized solutions a good fit?") submitted to IEEE Consumer Electronic Magazine • Revising and submitting final version of 5G-DIVE architecture paper ("DEEP: A Vertical-Oriented Intelligent and Automated Platform for the Edge and Fog") accepted to IEEE COMMAG • Contribution to paper "Dissecting the Impact of Information and Communication Technologies on Digital Twins as a Service". • Contribution to the revision of the paper "Towards Intelligent Cyber-Physical Systems: Digital Twin meets Artificial Intelligence" submitted to IEEE COMMAG special issue. • Co-chair co-representing 5G-DIVE project on accepted ZNSM 2021 workshop. • Attended EuCNC 5G-DIVE booth.
	ADLINK	• ADLINK has participated in the regular WP4 meetings. ADLINK's CTO Angelo Corsaro presented a session in the EclipseCon 2020, regarding Edge Robotics with ROS2 and Eclipse Zenoh. Eclipse Zenoh contains the DASS implementation. https://www.eclipsecon.org/2020/sessions/edge-robotics-ros2-and-eclipse-zenoh • Got one accepted paper in IEEE Consumer Electronics Magazine. https://zenodo.org/record/4923689#.YN26qOgzabg • Participation on regular WP4 meetings. • Dissemination of Eclipse Zenoh (DASS implementation) in the Eclipse Edge Native Working Group.
	EAB & ULUND	• Demo paper published: "Demo: Multi-Radio Access Technology IoT Gateway" in EWSN 2020. Demonstration of the multi-RAT gateway at the EWSN conference. • Contribution to D4.1. • Review of D4.2a and contribution to D4.2b. • Contribution to the IEEE COMMAG paper regarding the DEEP platform ("DEEP: A Vertical-Oriented Intelligent and Automated Platform for the Edge and Fog"). • Contribution to the joint WP2 and WP3 EUCNC paper. • Accepted paper "Virtualized LoRa Testbed and Experimental Results for Resource Pooling" in WF-IoT 2021. • Ericsson Research Day 2020 demo. • GLOBECOM 2021 demo. • A conference paper regarding resource pooling of mMTC use case is presented in IEEE World Forum on Internet of Things. • Ericsson Research Day 2021 demo. • Contributions to D4.3.
	IDCC	• Participated in all communication activities including press release and leaflet, and the CoDEP plan, as well as inputs to D4.1 and D4.2. • Contribution to leaflet, poster, etc. in preparation for MWC'20

		• Inputs to Globecom workshop • Three video demonstrations on the ZDM use case (one with Vodafone/Amazon, one with Anritsu for Anritsu MWC virtual booth, and a third one for IDCC MWC virtual booth) • Three press releases on ZDM pilots.
	FET	• Contributed to D4.1
	TID	• Project dissemination with presentation in IEEE CLoudNet 2019 and paper accepted in NOMS 2020. • Paper submitted on MEC federation. Work on additional papers disseminating 5G-DIVE concepts. • Joint paper with UC3M submitted to Globecom workshop on transport slicing. Several talks at different events. • Work on additional papers disseminating 5G-DIVE concepts. • Internal actions in TID disseminating 5G-DIVE concepts (IoT business unit and internal project on MEC). • Work on submission of scientific papers about transport slicing and isolation.
	TELCA	• TELCA has communicated 5G-DIVE project in an interview to the national Spanish radio, describing the objectives and the impact that the project may have. • Contributed to the 5G-DIVE architecture paper submitted to COMMAG, presenting the initial results of the intelligent engine developed. • Contributed with results from the Digital Twin SLA enforcement experiment to an academic paper submitted to IEEE Communications Magazine, with title "DEEP: A Vertical-Oriented Intelligent and Automated Platform for the Edge and Fog".
	III	• Participated in WP4 weekly calls and virtual meetings. • Participated in dissemination and standardization plans.
	ITRI	• Published journal paper in IEEE Transaction on Network Science and Engineering (collaborated work with NCTU) • Contribute to the collaborated paper on ADS for use cases targeting EuCNC 2021 • Follow on ICT'20 planned activities • Joined WP4 Telco
	NCTU	• Participated in WP4 weekly calls and virtual meetings. • Published journal paper in IEEE Transaction on Network Science and Engineering (collaborated work with ITRI). • Wrote a conference article on NCTU's intelligent engine. • Participated in dissemination and standardization plans. • Accepted Peer-review publication: "EagleEYE: Aerial Edge-enabled Disaster Relief Response System" Authors, Muhammad Febrian Ardiansyah, Timothy William, Osamah Ibrahiem Abdullaziz, Li-Chun Wang, Po-Lung Tien, Maria C. Yuang, Venue EuCNC 2020, Online (Dubrovnik, Croatia)" • Contributed to GLOBECOM workshop proposal and the dissemination of call for papers. • Participated with a video demo at "*5G end-to-end experimentation by verticals in EU projects*" workshop. • Collaborated in EuCNC2021 joint paper collaboration between WP2, and WP3. • Participated and presented a joint presentation with ITRI at "5GROWTH - 5G-DIVE: Exploitation workshop". • Contribution to D4.1, D4.2, and D4.3 dissemination.

	RISE	• Demo paper published: Saptarshi Hazra, Thiemo Voigt, Bengt Ahlgren, Chenguang Lu, Daniel Cederholm and Gyanesh Patra. Demo: Multi-Radio Access Technology IoT Gateway. EWSN 2020. Demonstration of the multi-RAT gateway at the EWSN conference. • Demonstration of the multi-RAT gateway at EWSN conference. • Planning and organization of the writing of D4.1 as document editor, writing of abstract, executive summary, introduction, conclusions, and other general parts of the deliverable; furthermore, reviewing the whole document; • Contributed to the Globecom workshop proposal, which then was approved. • Editor for Deliverable 4.2 incl planning, writing abstract, executive summary, introduction, conclusions and preparing dissemination tables. • Editor for Deliverable 4.2b, including writing parts of chapter 5. • Led WP4 online meetings and other WP leader tasks. • Preparation of and participation in updated periodic report review; contributed to preparation of demo booth at EuCNC. • Contributed to the planning of final deliverable (D4.3). • Organization of the writing of D4.3 as editor, writing of abstract, executive summary, introduction, conclusions, and other general parts of the deliverable; furthermore, reviewing the whole document.
T4.2 Dissemination, Exploitation and Standardization	UC3M	• Participation in the SAC • Submission of several contributions related to the project to the IETF • Contributed to D4.2 with IETF/IRTF text • Contribution to standardization activities. • Preparation of activities and revision of the documents.
	ADLINK	• ADLINK has released the DASS component into Eclipse Zenoh v0.5.0-beta.9, written in Rust. This release includes the following updates [17] . Released on November 24, 2021. • Contributions regarding which SDOs and Open Source projects are the most important for the 5G-Dive. • Joined the WP4 calls. • Participation in the elaboration of D4.1 • Pushed latest versions of Eclipse Zenoh & Eclipse fog05 to the Eclipse Foundation repository. • Exploitation: Pushed commits Zenoh to the Eclipse Foundation official repository. https://github.com/eclipse-zenoh/zenoh
	EAB & ULUND	• Contribution to D4.1. • Review of D4.2a and contribution to D4.2b. • Participation to WP4 meetings. • Demonstrations in GlobeCom 2020. • Contribution to D4.3 regarding exploitation activities.
	IDCC	• Led the effort on Standards including the SAC leadership and dissemination into 3GPP, IETF, and ETSI. • Contribution to D4.1 an D4.2. • Contribution to a magazine paper accepted, and led a paper accepted at EuCNC 2021 conference. • Two patents filled • Providing inputs to 5G-PPP pre-standards group input form 5G-DIVE • 5 Contributions to 3GPP RAN3 and SA1. • Contributed inputs to the 5GPPP pre-stand WG.

	TID	• Monitoring of standardization bodies especially for the development of slice templates (GSMA, 3GPP). Contribution to IETF network slicing design team. • Contribution to D4.1 on several standardization activities. • Contribution to O-RAN on transport solutions for functional radio splits. • Contributing to the work presented at different standardization bodies. Participation to plenary and SAC meetings. Identification and description of standardization targets, in terms of SDOs and open-source communities. Refinement of exploitation and dissemination plans. Contribution to some SDOs (e.g. O-RAN).
	III	• Contribute D4.2 for core network parts. • Contribute D4.3 for 5G NSA core network for ADS use cases in Taiwan demo site.
	ITRI	• 3GPP SA2 contributions (cosigned with IDG) on mobile edge computing key issues in Rel 17 (S2-1911795 and S2-1911794) • Participation in the kick-off meeting for the Standardization Advisory Committee (SAC) • Contributed on 3GPP alignment with 5G-DIVE • Joined WP4 calls
	NCTU	• Participated in WP4 weekly calls and meetings. • Contribution to D4.1, D4.2, and D4.3 dissemination.
	RISE	• Deliverable editing (Deliverables 4.1 and 4.2) and WP leadership as described for Task 4.1. • Leading WP4 online meetings during the period; preparation of and participation in updated periodic report review. • Contributed to the planning of the exploitation workshop and planning of final deliverable (D4.3) • Contributed to the execution of the exploitation workshop • Organisation of the writing of D4.3 as editor, writing of abstract, executive summary, introduction, conclusions, and other general parts of the deliverable; furthermore, reviewing the whole document

WP5: Project Management		
T5.1 Project administrative, financial, and legal management	UC3M	• Task leadership • Administrative coordination among partners • Editor of the Deliverable D5.1 • Editor of QMRs and presentation templates • Relationship with the European Commission • Management of budget • Management of collaborative tool for audioconferences (Zoom); Maintenance of SVN; Maintenance of mailing list; Maintenance of web hosting, Twitter project account, Instagram, LinkedIn. • Virtual meeting organization. • Plenary meeting organization (February 2020) • Editor and submission of 2 Amendments • Technical review management
	ITRI	• Report the budget and technical status of 5G-DIVE project to 5G-office
T5.2 Technica l	UC3M	• Leading the Project Management Board and the Technical Management Team
	IDCC	• Technical steering of the project.
	EAB	• As innovation manager, leading the innovation related activities. • Presented innovation update in the updated 1st period review.

		• Contributions to D4.2b and D4.3 regarding innovations.
	ITRI	• Helped to find the source of EPC to complete the ADS architecture • Lead ADS use case in term of defining the requirements, functions, components… etc. from all the involved partners • Invited ASKEY into 5G-DIVE project to be part of ADS use case • LTE Band 3 spectrum application for the phase 1 field trial of ADS use case. • 5G N79 spectrum application for the field trial of I4.0 use case. • Approved ADS spectrum application • Joined in organizing a monthly meeting to follow the progress from Taiwanese partners on ADS use cases. • Host two workshop for ADS in 2020 and 2021. • 5G N79 spectrum application approved for the field trial of I4.0 use case. finished several versions and then revised them according to NCC revision. • Followed up on spectrum issue where final ADS spectrum application already has been approved.
	NCTU	• Facilitated and organized monthly meetings for Taiwanese partners to coordinate the efforts of the ADS system integration and field trial. • Participated for quarterly and Periodic reports preparations. • Contribution to D4.1, D4.2, and D4.3 dissemination.

2. Deviations from Annex 1

During this second period of the project, it main focus has been on testing and validating the different use cases. During this period we have faced several challenges which have materialized on a deviation from the workplan regarding the ZDM use case. It has been impossible to test ZDM within the 5tonic test site due to travel restrictions and border import costs to ship the ZDM equipment to the lab. Therefore the project decided to address these challenges following the next two-fold approach:

- ZDM has been remotely integrated with the DEEP platform. Specifically it has followed a similar approach to ADS, where the local 5tonic BASS is able to deploy and launch the ZDM system, deployed in London and using Vodafone 5G connectivity.
- In addition, and to improve the innovation brought by ZDM to the project, IDCC has focused on implementing an X-App (following O-RAN terminology) implementing ATSS functionality. Showcasing how the DEEP platform can serve as host of 3GPP NFs and highlighting the excellent value proposition of DEEP in the multi-technology arena for the edge.

We believe this deviation from the Workplan reinforce the value of the project. The experimental validation of both ZDM functionalities has been provided in D3.3, as part of the ZDM validation. The specific definition of the X-App has been added as an appendix to D2.3.

3. References

[1] D1.1: 5G-DIVE architecture and detailed analysis of vertical use cases. Lead by III. Delivered 31st March 2020

[2] D1.2: 5G-Dive techno-economic Analysis. Lead by TID. Delivered 30th November 2020

[3] D1.3: 5G-DIVE Final Architecture. Lead by UC3M. Delivered 29th June 2021

[4] D1.4: Conclusions on vertical oriented 5G field trials and future outlook. Lead by ITRI. Delivered 30th December 2021.

[5] D2.1: 5G-DIVE innovations specifications. Lead by IDCC. Delivered 30th September 2020

[6] D2.2: 5G-DIVEcomponents initial implementation. Lead by ADLINK. Delivered 30th September 2020

[7] D2.3: Final specification of 5G-DIVE innovations. Lead by NCTU. Delivered 30th June 2021.

[8] D2.4: 5G-DIVE components final implementation. Lead by ADLINK. Delivered 30th June 2021.

[9] D3.1: Definition and setup of vertical trial sites. Lead by ITRI. Delivered 31st March 2020

[10] D3.2: Results of initial validation campaign of vertical field trials. Lead by EAB. Delivered 28th February 2021.

[11] D3.3: KPI and performance evaluation of 5G-DIVE platform in vertical field trials. Lead by ITRI. Delivered 31st December 2021.

[12] D4.1: Y1 CoDEP including standardization plan. Lead by RISE. Delivered 31st March 2020

[13] D4.2: D4.2 a: Achievements of Y1 and updated CoDEP for Y2 including standardization plan. Lead by RISE. Delivered 30th September 2020

[14] D4.4: D4.2 b: Update to D4.2a with the exploitation plan. Lead by RISE. Delivered 31th December 2020

[15] D5.1: Project portal and communication channels. Lead by UC3M. Delivered 31st October 2020.

[16] 5G-DIVE website (https://5g-dive.eu/)

[17] Eclipse Zenoh release v.0.5.0-beta.9 changelog [Online] Available: https://github.com/eclipse-zenoh/zenoh/releases