H2020 5Growth Project
Grant No. 856709

D6.2: First periodic report of the project

Abstract

This report constitutes the nonfinancial part of the Periodic Report to be delivered two months after the end of the period (M20).

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Disclaimer

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List of Acronyms

5G-NR – 5G New Radio

5Gr-RL – 5Growth Resource Layer

5Gr-SO – 5Growth Service Orchestrator

5Gr-VS – 5Growth Vertical Slicer

AGV – Automated Guided Vehicle

AI – Artificial Intelligence

AMI – Advanced Metering Infrastructure

API – Application Programming Interface

AR – Augmented Reality

BB – Baseband

CB – Context Blueprint

CMM – Coordinate-Measuring Machine

CP – Control Plane

CPE – Customer Premises Equipment

CSMF – Communication Service Management Function

CUPS – Control and User Plane Separation

DSS – Decision Support System

E2E – End-to-End

eCPRI – enhanced Common Public Radio Interface

eMBB – enhanced Mobile Broadband

ExpB – Experiment Blueprint

ExpD – Experiment Descriptor

EVIAB – External Vertical Industries Advisory Board

FG – Forwarding Graph

GPS – Global Positioning System

GUI – Graphical User Interface

HSS – Home Subscriber Server

I4.0 – Industry 4.0

IIoT – Industrial Internet of Things

IRU – Indoor Radio Units

KPI – Key Performance Indicator

LTE – Long Term Evolution

LV – Low-Voltage

LVS3 – Low Voltage Sensor

LX – Level Crossing

MANO – Mobile Network Management and Orchestration

ML – Machine Learning

mMTC – massive Machine Type Communications

MTTR – Mean Time To Repair

NDI – Network Device Interface

NFVI – Network Functions Virtualization Infrastructure

NFVO – Network Functions Virtualization Orchestrator

NG-PON2 – Next-Generation Passive Optical Network 2

NPN – Non-Public Network

NS – Network Service

NSA – Non-standalone

NSD – Network Service Descriptor

NSMF – Network Service Management Function

NTP – Network Time Protocol

OMS – Outage Management System

OTT – Over-The-Top

OWD – One Way Delay

OSS/BSS – Operations Support System and Business Support System

PMT – Project Management Team

PTZ – Pain-Tilt-Zoom

RAN – Radio Access Network

SDI – Serial Digital Interface

SFC – Service Function Chaining

SLA – Service Level Agreement

SO – Service Orchestrator

TCB – Test Case Blueprint

UE – User Equipment

UP – User Plane

URLLC – Ultra-Reliable Low Latency Communication

vEPC – virtual Evolved Packet Core

VIM – Virtualized Infrastructure Management

VM – Virtual Machine

VNF – Virtual Network Function

VPN – Virtual Private Network

VS – Vertical Service

VSB – Vertical Service Blueprint

VSD – Vertical Service Descriptor

WIM – WAN Infrastructure Manager

ZDM – Zero Defect Manufacturing

Executive Summary

The present deliverable called D6.2 presents the Part B of the First Periodic Report that will be delivered before the 28th of January 2021. It mainly includes the information of the scientific work carried out between the 1st of June 2019 and the 30th of November 2020. It is important to highlight that the deadline of D6.2 is the 30th of November 2020, the final data for use of resources is still not available at the end of November 2020. The full financial information will be included in the First Periodic Report in January 2021.

This document includes the Publishable Summary, patents and dissemination activities that will be completed in the Participant Portal too, a description of the technical work carried out by beneficiaries, and an overview of the progress in the first 18 months of the project, including the objectives, the work performed by work package, the deliverables and milestones, the impact and finally the deviations of the project.

1. Summary for publication

1.1. Summary of the context and overall objectives of the project

1.1.1. Project context

5Growth is a 30-month collaborative project. The main objectives of the project are **technical and business validation of 5G technologies through field-trials for vertical industries**. Four vertical pilots across **Industry 4.0, Transportation, and Energy** will be field-trialed on four vertical-owned sites. To conduct the *Trials* that demonstrate the 5Growth specific vertical use cases, 5Growth makes use of the End-to-End connectivity platforms from to ICT-17-2018 projects: 5G EVE and 5G-VINNI, to perform end-to-end testing and validation of service KPIs and 5G capabilities. To interconnect with both ICT platforms, different integration approaches are explored.

Besides validating the current 5G technologies, another major aim is to **develop new technological innovations to enhance the service provisioning and automation process for the verticals with an *AI-driven Automated and Sharable 5G End-to-End Solution*** that will allow these industries to achieve simultaneously their respective key performance targets. Towards this aim, 5Growth is developing a set of innovations by extending the 5G-TRANSFORMER platform, to further enhance the vertical support through (*i*) *enhanced E2E network slicing solutions* which enables automated deployment and operation of slices, including 3GPP-defined RAN slices, customized to support individual specific service requirements of various vertical industries, (*ii*) *closed-loop automation and SLA control* for vertical services lifecycle management, and (*iii*) *AI-driven end-to-end network* solutions to jointly optimize RAN, Transport, Core and Cloud, Edge resources, across multiple technologies, multi-vendors and multi administrative domains (federation).

1.1.2. Project objectives

- Technical and business validation of 5G technologies in the selected four vertical pilots, following a field-trial-based approach on vertical sites (TRL 6-7).
- To design and implement a platform, and the related components, interfaces and algorithms, to empower verticals to provision 5G connectivity and services directly at the verticals' sites.
- To develop AI-driven E2E service orchestration solutions to enable automated multi-level, cross-domain, hierarchical service orchestration with multi-domain management of resources with seamless integration at vertical sites with existing platforms.
- Tight integration with ICT-17 facilities for E2E testing and validating 5G capabilities.
- Vertical-oriented trial-based assessment, incl. 5G-PPP KPIs.
- Communication, dissemination, and exploitation (incl. standardization) of 5Growth results.

1.2. Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

The work in the project has been divided into 4 Technical Work Packages (WPs).

WP1 focused on detailed analysis of business requirements, technical and functional requirements for the four vertical industry pilots (D1.1), and provided an initial techno-economic analysis by defining business modes and methodology for the validation of the business models for 5Growth use cases. Based on that, we estimate the benefits of 5G and 5Growth innovations in the new business cases for the stakeholders.

WP2 is in charge of developing the 5G End-to-End Service Platform, enhancing the modules inherited from 5G-TRANSFORMER to cope with the new requirements from the vertical pilot use cases, particularly to enhance service automation with AI/ML, monitoring and interfacing with vertical customers. WP2 has provided an initial design of 5G E2E Service Platform (see Figure 1) extending from 5G-TRANSFORMER, along with 12 defined innovations reported in D2.1. Among them, a set of selected innovations has been developed and integrated into the 5Growth platform. The first release of the software implementation has been delivered in D2.2 and published as open source on GitHub. A number of Proof-of-Concepts are under development to validate the advances of these innovations.

WP3 is the technical WP in charge of the deployment of vertical pilots at four vertical sites integrating with the ICT-17 platforms, namely 5G-VINNI and 5G EVE. Additionally, it has identified missing functionality required to deploy the envisioned pilots in these platforms (D3.1). WP3 specified ICT-17 in-house deployment containing the technical solution for an in-house business validation of the vertical use cases (D3.2). Finally, it has developed vertical applications and necessary extensions towards the integration and deployment of the pilot over the ICT-17 platforms (D3.3 and D3.4).

WP4 focuses on the validation of the core 5G KPIs, technologies and architectures through verification and validation campaigns in different pilots. WP4 has defined a set of Service KPIs and Core 5G KPIs based on existing 5G-PPP KPIs and has identified the correlation of the core 5G KPIs with respect to technical service KPIs for each pilot use case according to their desired SLAs (D4.1). In addition, verification methodology and tool design are specified in D4.2 along with the design of a new data engineering platform integrating different data sources. D4.2 also reports the initial validation and assessment of the achieved KPIs of each pilot.

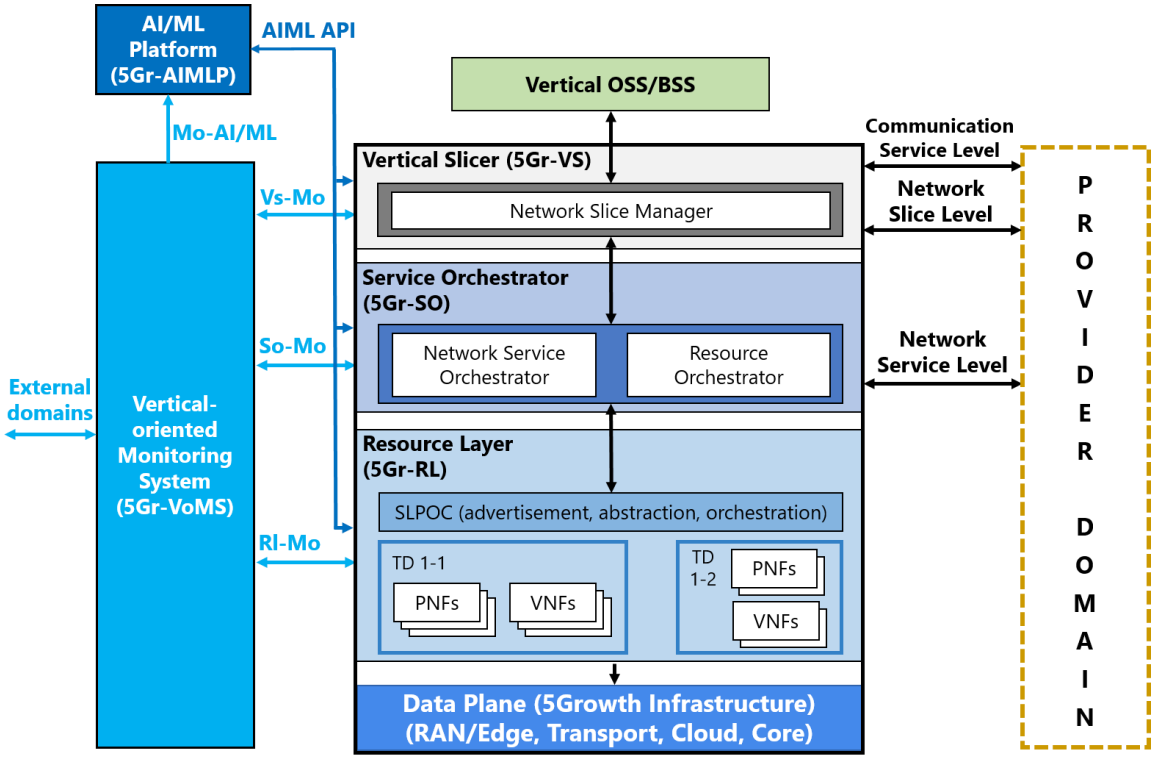


FIGURE 1: 5GROWTH HIGH-LEVEL ARCHITECTURE

1.3. Progress beyond the state of the art, expected results until the end of the project and potential impacts (including the socio-economic impact and the wider societal implications of the project so far)

5Growth targets innovations around five main components, illustrated in Figure 1: (1) 5Growth Vertical Slicer (5Gr-VS): offering a powerful, yet simple and flexible, portal to verticals; (2) 5Growth Service Orchestrator (5Gr-SO): instantiating and orchestrating network services in a smart and automated manner by applying AI techniques; (3) 5Growth Resource Layer (5Gr-RL): integrating compute, storage and networking resources and providing resource isolation for different slices; (4) 5Growth Vertical-oriented Monitoring System (5Gr-VoMS): providing monitoring across a heterogeneous set of services and technological domains; and (5) 5Growth AI/ML Platform (5Gr-AIMLP): offering services to different 5Growth layers to run AI/ML algorithms. These innovations are combined into the 5Growth platform interacting with 5G EVE and 5G-VINNI platforms, providing E2E solutions across multiple facilities and sites for deploying vertical services for different vertical industries, while taking into account both technical and techno-economic requirements from the stakeholders of the value chain. In this way, 5Growth creates a direct socio-economic impact, through lower cost and higher efficiency for the stakeholders, better service (quality and ubiquitous access) to the end users, and lower bills. The overall society will benefit from 5Growth innovations through easier entry for verticals, more flexibility and cost-efficiency, whilst supporting the services envisioned in 5G and beyond.

The 5Growth innovations are expected to give the industrial companies (large, medium, small) in the consortium and the extended European 5G-PPP community a privileged position and competitive advantage in the European and global markets.

Moreover, in order to ensure wide-reach of 5Growth, the consortium has been very active in dissemination efforts. Specifically, 5Growth has delivered:

- 28 scientific publications (15 journals and 13 international conferences/workshops);
- 6 organized (or co-organized) events (e.g., workshops), which were initially planned to be held physically but held eventually online;
- 8 demonstrations at flagship events, out of which 6 were presented online;
- 13 adopted/agreed/accepted standard contributions.

2. Dissemination activities

This section presents the dissemination and exploitation activities undertaken by the 5Growth project during the first reporting period.The dissemination activities follow the plan described in D5.1 [2] and updated in D5.2 [1]. That is, publication of research results (Table 1), talks (Table 2), synergies with other projects (Table 3), event organization (Table 4), technology demonstration (Table 5), and academic activities (Table 6).

The first period of the project was very rich in terms of dissemination activities. Notably, 28 scientific publications have been accepted for publication in peer reviewed journals (15), or presented at conferences and workshops (13) (Table 1); the latter ones include one best fast track paper award. Some of these publications are joint publications with other projects. Furthermore, 5Growth partners have participated to the organization of very successful events and workshops (Table 4) co-located with prestigious conferences or standalone. For example, based on the poll circulated to the attendees, we received positive feedback from the Joint half-day online workshop (5G End-to-End experimentation by verticals in EU projects). Most of these events were co-organized jointly with other projects.

Regarding the academic activities, several students have been enrolled to work on 5Growth topics; specifically, 7 PhD and 7 Master students have been enrolled during the first period.

Partners have also made strong efforts to demonstrate the 5Growth results in events such as ACM Mobicom 2019, IEEE INFOCOM 2020, ACM Mobihoc 2020, or in 5G-PPP Technical Board eWorkshop (Session on Use of AI & ML in networks – Part 1), among others.

2.1. Publications and technical dissemination

The following table presents 5Growth peer-reviewed articles in scientific journals and studies/demos/posters in scientific conferences.

TABLE 1: PUBLICATIONS IN SCIENTIFIC CONFERENCES

Type	Title	Publication/Conference
journal	Beyond 5G Evolution (Guest editorship)	MDPI Electronics
journal	Service Shifting: a Paradigm for Service Resilience in 5G	IEEE Communications Magazine
journal	Reducing Service Deployment Cost Through VNF Sharing	IEEE/ACM Transactions on Networking
journal	DeepCog: Optimizing Resource Provisioning in Network Slicing with AI-based Capacity Forecasting	IEEE JSAC
journal	Is OpenCL Driven Reconfigurable Hardware Suitable for Virtualising 5G Infrastructure?	IEEE Transactions on Network and Service Management

journal	An Edge-based Framework for Enhanced Road Safety of Connected Cars	IEEE Access
journal	On the integration of NFV and MEC technologies: architecture analysis and benefits for edge robotics	Elsevier Computer Networks
journal	Federation of 5G services using Distributed Ledger Technologies	Wiley Internet Technology Letters
journal	Optical transport for industry 4.0	OSA Journal of Optical Communications and Networking
journal	RISMA: Reconfigurable Intelligent Surfaces Enabling Beamforming for IoT Massive Access	IEEE Journal on Selected Areas in Communications
journal	Overview of Architectural Alternatives for the Integration of ETSI MEC Environments from Different Administrative Domains	MDPI Electronics
journal	LACO: A Latency-driven Network Slicing Orchestration in Beyond-5G Networks	IEEE Transactions on Wireless Communications
journal	Decomposing SLAs for Network Slicing	IEEE Communications Letters
journal	Modeling MTC and HTC Radio Access in a Sliced 5G Base Station	IEEE Transactions on Network and Service Management
journal	5Growth: An End-to-End Service Platform for Automated Deployment and Management of Vertical Services over 5G Networks	IEEE Communications Magazine
conference	vrAIn: A Deep Learning Approach Tailoring Computing and Radio Resources in Virtualized RANs	ACM Mobicom'19
conference	SliMANO: An Expandable Framework for the Management and Orchestration of End-to-end Network Slices	IEEE CloudNet'19
conference	PI2forP4: AnActive Queue Management Scheme for Programmable Data Planes	ACM Conext'19
conference	A Q-learning strategy for federation of 5G services	IEEE ICC'20
conference	OKpi: All-KPI Network Slicing Through Efficient Resource Allocation	INFOCOM'20
conference	Handover Prediction Integrated with Service Migration in 5G Systems	IEEE ICC'20

conference	Orchestrating Edge- and Cloud-based Predictive Analytics Services	EUCNC'20
conference	5Growth: AI-driven 5G for Automation in Vertical Industries	EUCNC'20
conference	Information Exchange to Support Multi-Domain Slice Service Provision for 5G/NFV	IFIP Networking 2020
conference	DLT federation for Edge robotics	IEEE NFV-SDN'20
conference	An Intelligent Edge-based Digital Twin for Robotics	IEEE GlobeCom 2020
conference	GANSO: Automate Network Slicing at the Transport Network Interconnecting the Edge	IEEE NFV-SDN'20 (MOBISLICE workshop)
conference	On the Integration of AI/ML-based scaling operations in the 5Growth platform (Best fast track paper award)	IEEE NFV-SDN'20

Table 2 presents 5Growth consortium talks at scientific conferences, seminars, and forums, with the goal of raising awareness on the 5Growth project.

TABLE 2: 5GROWTH TALKS IN SCIENTIFIC CONFERENCES AND TECHNOLOGY FORUMS

Date	Venue	Description
2019-05-22	IEEE ICC 2019	Panelist at IEEE ICC 2019 Workshop: 5G-Trials – From 5G Experiments to Business Validation called Challenges in 5G Trials
2019-05-27	Dagstuhl Seminar 19222 "Control of Networked Cyber-Physical Systems"	Impulsive presentation of 5Growth ("5G Service Automation")
2019-06-20	IEEE EUCNC 2019	Presentation of 5Growth in ICT-19 Session at EUCNC'19
2019-07-23	IEEE EUCNC 2019	Presentation of 5Growth in EMPOWER-PAWR workshop: EUCNC.
2019-07-03	FUSECO FORUM	Presentation of 5Growth (results and WIP) at FUSECO Forum (https://www.fokus.fraunhofer.de/ngni/events/fuseco_forum_2019)
2019-09-03	ICT-19 session by 5G EVE	5G EVE organized a session devoted to discussing collaboration with ICT-19 projects (i.e., 5Growth)
2019-10-08	5G-PPP TB Workshop	5G-enabled Growth in Vertical Industries
2019-11-27	2nd Visions for Future Communications Summit	Slicing with non-public networks – another orchestration challenges for the next decade.

2020-01-13	Nokia Bell Labs (Paris-Saclay, France)	Reinforcement Learning for Slice Resource Allocation
2020-01-13	NYU Tandon School of Engineering	Reinforcement Learning for Slice Resource Allocation
2020-03-09	"Jornadas Electrotécnicas 2020" at Instituto Superior de Engenharia do Porto	Presentation of 5Growth project under the Seminar "Research for beyond the Early 5G Network – EU and PT"
2020-04-14	NMRG virtual meeting	"Metadata-based Aggregation of Telemetry Flows"
2020-05-12	First meeting of 5Growth External Vertical Industries Advisory Board (EVIAB). Available at: https://www.youtube.com/watch?v=7uC0SN0F79g	Presentation of the 5Growth project
2020-05-19	"The role of computing in the post 5G-era: Architectures and enabling technologies", workshop, co-located with ONDM'20 (WS)	"Evolutionary trends in operators' networks for beyond 5G"
2020-05-19	5th IEEE International Workshop on Orchestration for Software Defined Infrastructures (O4SDI), co-located with the 2020 IEEE/IFIP NOMS	"Towards a standardized transport slicing architecture in operator networks"
2020-05-26	5G-PPP TB eWorkshop (Session on Collaboration among infrastructure and vertical validation trials projects)	"An exemplary view from an ICT-19 project: 5Growth – Link with 5G-EVE and 5G VINNI"
2020-05-26	5G-PPP TB eWorkshop (Session on Business Model Validation)	"5Growth business validation"
2020-05-26	5G-PPP TB eWorkshop (Session on Validation and KPIs)	5G-PPP TMV TF on vertical KPIs Industry 4.0
2020-06-09	5G End-to-end Experimentation by Verticals in EU projects workshop	Introductory Panel entitled "Key challenges and requirements for 5G experiments with verticals" and Concluding Panel entitled: "End to end 5G experimentation across multiple EU projects"
2020-09-11	5G From Theory to Practice (5GToP) Workshop, in conjunction with IEEE 5G World Forum (10-12/09)	"Validating 5G in vertical industries: the 5Growth project"

2020-10-14	5G Workshop on "5G Experimentation Facilities and Vertical Trials: Current Status and Future Perspectives" organized by 5GENESIS/NCSR "DEMOKRITOS"	"Validating 5G in vertical industries: the 5Growth project"
2020-09-29	CTIF Global Capsule "23rd Strategic Workshop", theme "Sustainable Green Environments"	Presentation called "5G-enhanced verticals: contributions of the 5Growth project into the railways and energy sectors"
2020-09-23	Event organized (Panel) by 5G Solutions project in collaboration with the IEEE ComSoc EMEA region	Presentation called "The Operator Point of View on Transport Network, Not just phone calls and messages where new telecommunication technologies (5G) are hiding?"
2020-10-02	Talk organized by IEEE ComSoc EMEA	Presentation called "Get Smart – The Challenges in Data-Driven Network Management"
2020-11-11	Keynote at IEEE NFV SDN'19	Keynote called "Serious science and serious engineering - The way of software-based network experimentation"
2020-11-09	Keynote at MOBISLICE III workshop co-located with the IEEE NFV-SDN	Keynote called "Network slicing in practice through service federation"
2020-11-19	Talk at MDPI webinar called "Beyond 5G Webinar"	Talk called "5Growth Network Architectures for 5G and beyond"

2.2. Synergies with other projects

The following table reports collaborative activities with other EU and international research projects (e.g., through 5G-PPP working groups, or working groups of other platforms) towards a coordinated action inside the 5G-PPP. Additionally, project partners regularly attend meetings and actively participate in the activities of the 5G-PPP working groups, including the steering board and technical board, Pre-Standardization, Vision and Societal Challenges, 5G Architecture, Trials, SME, Software Networks, Security, and Test, Measurements and KPI Validation. Let us highlight the participation with multiple presentations in the last 5GPPP TB eWorkshop (listed below) and more presentations accepted in its next edition (taking place in Dec. 2020).

TABLE 3: COLLABORATIVE ACTIVITIES WITH EU AND INTERNATIONAL RESEARCH PROJECTS

Item	Explanation
Joint Paper with project 5GTransformer @ IEEE Communications Magazine	Service Shifting: a Paradigm for Service Resilience in 5G
Joint Paper with projects: 5G-TRANSFORMER, 5G-MoNArch, 5G-TOURS @ ACM Mobicom'19	vrAIn: A Deep Learning Approach Tailoring Computing and Radio Resources in Virtualized RANs

Joint Demo with projects: 5G-TRANSFORMER, 5G-MoNArch, 5G-TOURS @ ACM Mobicom'19	vrAIn Proof-of-Concept — A Deep Learning Approach for Virtualized RAN Resource Control
Joint Paper submitted with 5G-TRANSFORMER project @ IEEE ICC'20	A Q-learning strategy for federation of 5G services
Participation in First technology roadmap for advanced wireless with EMPOWER	Technology roadmap
Joint Paper with project 5G-TRANSFORMER and 5G-Tours project @ IEEE JSAC SI ("Advances in Artificial Intelligence and Machine Learning for Networking")	DeepCog: Optimizing Resource Provisioning in Network Slicing with AI-based Capacity Forecasting
Joint Demo with project 5G MISE Trial in Bari and Matera	Remote Control of a Robot Rover Combining 5G, AI, and GPU Image Processing at the Edge
Presentation of the 5Growth project to 5G-PPP SN WG	Interaction with other projects of the H2020 5G Infrastructure PPP, 5G-PPP SNWG meeting
Brochure for MWC'20 from 5G-PPP Software Network Working Group	Participation of 5Growth project in the brochure of SN WG initially targeting MWC'20 entitled: Cloud Native and 5G Verticals' services
Joint demo: GROWTH (ICT-19 project), 5G-CLARITY (ICT-20 project), and 5G-DIVE (EU-Taiwan ICT23- project) at EUCNC'20 Booth	"Hybrid eMBB-URLLC network slicing for I4.0"
Joint demo with project 5G-TRANSFORMER at INFOCOM'20	NFV Service Federation: enabling Multi-Provider eHealth Emergency Services
Joint demo with project 5G-TRANSFORMER at INFOCOM'20	Arbitrating Network Services in 5GNetworks for Automotive Vertical Industry
5G-PPP White paper on edge computing	Contribution on Edge Computing in 5Growth
Joint paper with 5G-TRANSFORMER and 5G-CORAL projects at Elsevier Computer Networks	On the integration of NFV and MEC technologies: architecture analysis and benefits for edge robotics
Join workshop with 5G-DIVE, 5G-EVE, 5G-VINNI, and 5G-TOURS	5G end-to-end experimentation by verticals in EU project
Joint workshop with 5G-DIVE, co-located with Globecom2020	Intelligent Fog and Edge Infrastructures for Future Wireless Systems
5G-PPP TB eWorkshop (Business model validation session)	Participation in the discussion on business validation with the 5Growth business validation
5G-PPP TB eWorkshop (Use of AI/ML in networks session)	A Deep Learning Approach for vRAN Resource Orchestration
5G-PPP TB eWorkshop (Validation and KPIs session)	Vertical KPIs Industry 4.0
Joint Demo with project 5G-TOURS @ 5G End-to-end experimentation by verticals in EU projects Workshop	Demo entitled: "vrAIn: AI-driven orchestation of vRAN resources"

Contribution to 5G IA white paper on business validation from the "Vision and Societal Challenges Working Group / Business Validation, Models, and Ecosystems Sub-Group"	White paper ""Business Validation in 5G-PPP vertical use cases",
Contribution to white paper: Empowering Verticals industries through 5G Networks - Current Status and Future Trends	White paper: "Empowering Verticals industries through 5G Networks - Current Status and Future Trends"
Joint paper with 5G-DIVE project at MDPI Electronics journal	Paper entitled: Overview of Architectural Alternatives for the Integration of ETSI MEC Environments from Different Administrative Domains
Participation in the report of 5G-PPP Pre-Standardisation Work Group	Report entitled: "5G-PPP Projects Impact on SDO Technical Report"
Participation in the 5GPP TMV working group White Paper on ICT-19 Performance KPIs	White paper name: "Service performance measurement methods over 5G experimental networks"
Joint paper with 5G-DIVE project at IEEE NFV-SDN'20	Paper entitled: "DLT federation for Edge robotics
Joint paper with 5G-DIVE at IEEE Globecom'20 WS AT5G+	Paper entitled: "An Intelligent Edge-based Digital Twin for Robotics"
Joint paper with 5G-DIVE at IEEE NFV-SDN'20 WS MOBISLICE III	Paper entitled: "GANSO: Automate Network Slicing at the Transport Network Interconnecting the Edge"
Joint paper with MonB5G Project in Transaction on Wireless Communications	Paper entitled: "LACO: A Latency-driven Network Slicing Orchestration in Beyond-5G Networks"
EC H2020 5G Infrastructure PPP - PPP T&Ps Summary Table - PPP T&Ps Brochure n°2 - PPP Verticals Cartography	Participation with the pilot entitled: "5Growth: Industry 4.0 Low Latency use cases on shared Network"
5G-PPP projects' brochure to be released early next year.	Phase 3 projects brochure
Contribution to 5G-PPP White paper	"Delivery to 5G Services to Indoors"
Contribution to 5G-PPP White paper	"AI/ML for future networks"
Joint workshop with 5G-DIVE and Empower. MDPI Electronics	"Beyond 5G Evolution" online workshop

2.3. Event organization

The following table reports on the participation of the 5Growth consortium in the organization of dissemination events.

TABLE 4: 5GROWTH ORGANIZED EVENTS

Date	Item	Explanation
2020-06-09	Joint half-day online workshop with 5Growth, 5G-DIVE, 5G EVE, 5G-VINNI, and 5G-TOURS	Open virtual workshop in which 5G projects will present their latest results, including demonstrations.
2020-07-09	First webinar of a series of periodical webinars with Layer123	Powering 5G in industry
2020-09-10	5G from Theory to Practice (5GToP) Workshop	Co-located with IEEE 5G World Forum 2020, Bangalore India, 10-12 Sept. 2020 (https://ieee-wf-5g.org/5g-from-theory-to-practice-5gtop-workshop/)
2020-11-10	IEEE NFVSDN2020	November 10-12, 2020
2020-11-10	MOBISLICE 2020	Co-located with IEEE NFVSDN 2020
2020-11-19	Beyond 5G evolution webinar	MDPI Webinar 2020 (https://electronics-2.sciforum.net/)

Additionally, another event outside the first reporting period has already been accepted (e.g., workshop co-located with Globecom 2020).

2.4. Exhibitions and Technology Demonstrations

Table 5 gathers the exhibitions and technology demonstrations performed in different dissemination events.

TABLE 5: EXHIBITIONS AND TECHNOLOGY DEMONSTRATIONS IN DISSEMINATION EVENTS

Date	Venue	Description
2019-10-21	ACM Mobicom 2019	vrAIn Proof-of-Concept — A Deep Learning Approach for Virtualized RAN Resource Control
2020-03-08	OFC'20	Remote Control of a Robot Rover Combining 5G, AI, and GPU Image Processing at the Edge
2020-05-27	5G-PPP TB eWorkshop	A Deep Learning Approach for vRAN Resource Orchestration
2020-06-09	5G End-to-end experimentation by verticals in EU projects (Online workshop with 5G-DIVE, 5G EVE, 5G-VINNI, 5G-TOURS)	vrAIn: AI-driven orchestration of vRAN resources
2020-07-06	INFOCOM'20	NFV Service Federation: enabling Multi-Provider eHealth Emergency Services

2020-07-06	INFOCOM'20	Arbitrating Network Services in 5GNetworks for Automotive Vertical Industry
2020-07-09	Powering 5G in industry. Layer123 webinar	vrAIn: AI-driven orchestration of vRAN resources
2020-10-12	ACM Mobihoc'20	Scaling Composite NFV-Network Services

Note that the InnoTrans event in which 5Growth is participating was planned to be held the 23rd of September 2020, but it has been postponed to April 2021 due to COVID-19 restrictions.

2.5. Bachelor, Master, PhD Theses and Internships

Table 6 reports bachelor, master and PhD theses as well as internships related to 5Growth.

TABLE 6: 5GROWTH-RELATED BACHELOR, MASTER AND PHD THESES, AND INTERNSHIPS

Type (PhD/Master/Int.)	State (Ongoing /Finished)	Title
Internship	Finished	P4 Programmable Traffic Management
PhD	Ongoing	AI/ML-enabled Software Defined Smart Networks on Distributed and Next generation Architectures
PhD	Ongoing	Smart Networks and IoT
PhD	Ongoing	Artificial Intelligence Driven Next Generation Networking
Master	Ongoing	A new SDN application providing Quality of Service (QoS) for network slicing
PhD	Ongoing	Offloading of 5G functions in accelerated edge data centres
Master	Ongoing	Machine learning techniques for anomaly detection in vertical industries
Master	Ongoing	Machine learning techniques for anomaly detection and resource management in 5G networks
PhD	Ongoing	ML-driven edge network resource allocation
Master	Ongoing	Performance evaluation and design of ML-based solutions for the support of mobile services in 5G systems
Master	Ongoing	Machine Learning for 5G/6G Mobile Networks
Master	Finished	AI-based algorithms and experimental evaluation for beyond 5G
Master	Finished	A Machine-learning Approach for Video Streaming Provisioning at the Network Edge
PhD	Ongoing	Development and Performance Evaluation of Network Function Virtualization Services in 5G Multi-Access Edge Computing infrastructure
PhD	Ongoing	Virtualized Mobile Services at the edge of the network

3. Explanation of the work carried out by beneficiaries and overview of the progress

3.1. Objectives

This section is devoted to the progress towards the fulfilment of the project objectives. For each of the objectives identified in the Description of Action (DoA), we present the details on how they have been tackled technically and by which WP.

Objective 1	Validate 5Growth business model	
Description	The analysis of the technical and functional requirements of the different use cases and field trials planned within the project shall spawn a successful business model that is advantageous for mobile operators, service providers and, especially, vertical sectors. The first objective of 5Growth is thus to validate the business viability of the entire project ecosystem.	
R&D Topics	WP/task	Details
Analyze technical and functional requirements of vertical use cases and field trials	WP1/T1.1	• A detailed description of the pilots and the use cases. D1.1 [3]. • A detailed business, functional and technical requirements for all the different vertical pilot use cases has been reported in D1.1 [3].
Survey business models from both 5G infrastructure owner and verticals' perspective	WP1/T1.1	• Identification of the stakeholders in each pilot. • Definition of the business model and the services flow per pilot in D1.1 [3].
	WP1/T1.2	• Identification of the economic flow between the different stakeholders D1.2 [4]. • Estimation of the benefits of the pilots for the stakeholders D1.2 [4].
Verification	WP/task	Details
Report on techno-economic study and validation of business models	WP1/T1.2	• A detailed techno economic analysis including initial analytical results to characterize the techno-ecosystem is reported in D1.2 [4]. • A common methodology for the business model validation is proposed and applied to calculate the overall economic benefits for each use case to a European scale, the details are reported in D1.2 [4].
Present and validate the advantages of verticals in an exploitation-specific workshop with verticals	WP1/T1.2	• 5Growth has contributed to a whitepaper [5] organized by the 5G Public Private Partnership (5G-PPP) and the 5G Infrastructure Association (5G IA) that provides information about business requirements and addressed business cases and solutions for vertical industries. It also discusses in detail several exemplary use cases from eleven different vertical sectors and identifies key 5G

		features that have been used to meet the specified requirements.
Objective 2	Design and develop 5Growth extensions into 5G architecture	
Description	Design and develop the extensions required to incorporate 5Growth main innovations into the 5G baseline architecture, namely, an automated support to vertical sectors through an *enhanced vertical slicer*, orchestration of monitoring and telemetry services in support of the verticals; a network slicing/service orchestration and SLA modelling and control that offers isolation, virtualization, multi-domain management of resources (beyond MANO) and cross-domain orchestration capabilities to enable the operation of the different vertical slices.	
R&D Topics	WP/task	Details
Analyze the 5G-TRANSFORMER architecture and identify the technical gaps and enhancements required to support 5Growth vertical use cases and field trials	WP2/T2.1	• We have performed a functional and technical gap analysis, which has been reported in D2.1 [6]. • Our gap analysis motivated the selection of a set of innovations that will be integrated into the 5Growth baseline platform throughout the project. The selection and its criteria have been reported in D2.1 [6].
Develop novel interfaces between a vertical slicer component and the vertical parties, offering verticals more control over their own services and improved information models	WP2/T2.2	• An innovation identified during our gap analysis concerns the extension of network slices towards the radio access network (RAN). This innovation allows vertical parties to specify better service level requirements that include radio coverage aspects. It requires contributions across all layers of the 5Growth stack, 5Gr-VS, 5Gr-SO and 5Gr-RL. A first release of this innovation can be found in 5Growth Release 1 [7].
Extend the 5G-TRANSFORMER monitoring platform to provide verticals with analytic services and improved SLA-driven control of network slices	WP2/T2.3	• Another innovation identified during our gap analysis concerns extensions on the monitoring platform, the so-called Vertical-oriented Monitoring System (5Gr-VoMS). An initial release of the extended platform has been provided in 5Growth Release 1 [7]. • Another innovation developed during this first reporting period concerns achieving performance isolation at the 5Gr-RL with tighter control of OpenFlow and P4-capable switches [8]. • Additional innovations whose development started during this first reporting period include novel automated NFV-NS scaling mechanisms in 5Gr-SO [7] and better VNF-FG embedding algorithms that help providing improved SLA-driven control of network slices [9].

Design and integrate the components required to extend the baseline 5G architecture to achieve E2E network slicing (spanning RAN, back/fronthaul and computing infrastructure) and service orchestration	WP2/T2.4	A number of innovations have been integrated in 5Growth and released in the context of 5Growth R1 [7]: • Continuous Integration/Continuous Development (CI/CD) framework for the development of 5Growth components; • RAN segments in Network slices; • Enhanced Monitoring Platform; • Automated NFV-NS scaling mechanisms. Since R1, the development of an additional number of innovations has started, namely: • AI/ML platform (5Gr-AIMLP) to assist 5Growth components in AI/ML tasks such as model provisioning and model training; • The integration of O-RAN compliant next-generation RANs; • Anomaly detection mechanisms; • Moving Target Defense (MTD) mechanisms to provide security in external interfaces; • Novel forecasting algorithms; • Support of performance isolation mechanisms with OpenFlow and P4-capable switches at 5Gr-RL; • Extended support to federation and interdomain mechanisms.
Verification	WP/task	Details
Analyze and simulate to pre-evaluate medium and/or large-scale systems	WP2/all tasks	During the first reporting period, we have evaluated a number of mechanisms via simulations. For instance: • A novel AI-driven orchestration mechanism for vRAN/O-RAN networks has been demonstrated [10]; • An AI-driven federation mechanism [11]; • An AI-driven VNF-FG mechanism [9]; • MTD mechanism for security [12]; • Dynamic user profiling and forecasting mechanisms [9]. Additional results will be provided during the second reporting period.
Develop and demonstrate proof-of-concept prototypes (TRL 4)	WP2/all tasks	In addition, small-scale proof of concepts have been created to demonstrate such innovations as: • A novel AI-driven orchestration mechanism for vRAN/O-RAN networks [10]; • Performance isolation over P4-capable networks [8]; • Automated AI-driven NFV-NS scaling [7]; • Additional PoCs will be developed during the second reporting period.

Objective 3	Perform field trials and showcase vertical use cases in field trials	
Description	Integrate and deploy the 5Growth service platform on top of ICT-17 platforms and complementary trial sites (incl. vertical sites) and demonstrate 9 use cases across 4 pilots through field trials.	
R&D Topics	WP/task	Details
Integrate novel 5Growth components developed in WP2 into the 5G baseline architecture	WP3/T3.1 WP3/T3.2	• Selected innovations from WP2 (D3.1 [13], D3.2 [14], D3.4 [16]). • First version of software implementation for the platform (D3.3 [16]).
Deploy the 5Growth system across all trial sites, including software and hardware components for all use cases planned such as, e.g., 5G service-based core, NR (New Radio), unlicensed/licensed spectrum, multi-RAT technologies, Multi-access Edge Computing (MEC)	WP3/T3.3 WP3/T3.4 WP3/T3.5 WP3/T3.6	• Following the analysis and solution proposals described in D3.1 [13] and D3.2 [14], the HW and SW components for all required 5G Radio, Core and Cloud Edge capabilities to support the trials in the scope of the 5Growth project have been deployed in this first reporting period. • First version of software implementation for the platform can be found in D3.3 [15] and pilot plan descriptions in D3.4 [16].
Field trial the 5Growth pilots over the 5G platform deployed by 5G EVE/5G-VINNI, demonstrating vertical use cases including high-density scenarios and very-high-data-volume applications	WP3/T3.3 WP3/T3.4 WP3/T3.5 WP3/T3.6	• The deployed pilot platforms have been tested for 5G network performance level qualification to the demands, especially of very low latency levels and very high data rates, of the use cases to be validated, both over 5G EVE and 5G VINNI platforms. Trial activities on all pilots are started over these deployments. • Status of different pilots and field trial experiments is reported in D3.4 [16].
Verification	WP/task	Details
Demonstrate 4 Industry 4.0 vertical use cases through pilot 1, 2 in field trials (TRL 6/7)	WP3/T3.3 WP3/T3.4	• All 5Growth I4.0 use cases (INNOVALIA and COMAU use cases) have been analysed and planned for integration and validation. In this first reporting period, already, a set of such Use Cases has moved to full integration, execution and initial validation activities, and first demonstrations.

		• Both INNOVALIA M3BOX metrology equipment and INNOVALIA's new 5G-ready software solution enabling remote access of experts are integrated with the 5G environment of 5G EVE at 5TONIC lab. • At COMAU factory the 5G network is installed and all the use cases deployments are in progress including that of robotic systems based on the COMAU industrial robots RACER3. • The status of INNOVALIA and COMAU Industry 4.0 pilots has been reported in D3.4 [16].
Demonstrate 2 transportation vertical use cases through pilot 3 in a field trial (TRL 6/7)	WP3/T3.5	• The setup in IT Aveiro Labs concerns all the 5G and vertical components of 5Growth Transportation use case 1 that will be moved to the pilot site at Aveiro harbor during the second phase of this task • The status and first results of EFACEC transportation pilot is reported in D3.4 [16].
Demonstrate 2 energy vertical use cases through pilot 4 in a field trial (TRL 6/7)	WP3/T3.6	• The setup in IT Aveiro Labs concerns all the 5G and vertical components of 5Growth Energy use cases that will be moved to the pilot site at the selected Secondary Substation in Aveiro University during the second phase of this task. • The status and first results of EFACEC energy pilot is reported in D3.4 [16].
Objective 4	Evaluate technical and functional KPIs through 5Growth field trials	
Description	Validate technical KPIs, core 5G technologies and architectures in the context of different performance requirements of different slice types (eMBB, mMTC, URLLC), considering services linked to specific vertical sectors.	
R&D Topics	WP/task	Details
Validate 5G core technologies and 5Growth service platform (vertical slicer, service orchestration, infrastructure manager) to satisfy functional and technical requirements of vertical use cases	WP4/T4.1	• Definition of Service KPIs and Core 5G KPIs based on existing 5G-PPP KPIs and KPIs defined by the TMV-WG, 5G EVE and 5G-VINNI – specified in D4.1 [17]. • Mapping between Core 5G KPIs and Service KPIs – reported in D4.1 [17]. • Application of the Service KPIs and their mapping with Core 5G KPIs to the different pilots – reported in D4.1 [17]. • Mapping between the identified Service KPIs and the vertical functional requirements for each pilot use case, reported in D4.1 [17].
Validate end-to-end 5G network slicing with differentiated service requirements	WP4/T4.2	• Verification methodology and tool design, reported in D4.2 [18]. • Design of a data engineering platform composed of Data Connect, Data Ingest, Data Analysis, Data Storage and Data Visualization, described in D4.2 [18]:

(eMBB, mMTC, URLLC use cases)		○ data source, ○ data aggregation, ○ data consumers, ○ metadata. • Integration with 5Growth platform, reported in D4.2 [18]: ○ Data descriptors, ○ monitoring platform, ○ innovations. • Integration with ICT-17 platforms, reported in D4.2 [18]: ○ 5G EVE, ○ 5G-VINNI.
Verification	WP/task	Details
Report assessing the achieved KPIs across 5Growth use cases	WP4/T4.3 WP4/T4.4 WP4/T4.5 WP4/T4.6	• Reported the initial validation and assessment of achieved KPIs per pilot use case in D4.2 [18] and summarized in Section 3.6.1: ○ INNOVALIA pilot; ○ COMAU pilot; ○ EFACEC transportation pilot; ○ EFACEC energy pilot.
Objective 5	Dissemination, standardization and exploitation of 5Growth	
Description	Dissemination, standardization and exploitation of all concepts and technologies developed in the 5Growth project.	
R&D Topics	WP/task	Details
Outreach communication to all stakeholders including the general public	WP5/T5.1	• Throughout the first period of project, the website had around 28,000 visitors and 114,000 visits. • 5Growth tweets reached 578 impressions per day. • A YouTube channel has been setup (with more than 100 subscribers at the time of submission of this deliverable). Ten videos have been uploaded (incl. overview and demonstration ones). YouTube videos reached 1.6K visualizations in total. • Promotional material prepared (e.g., leaflets, posters, videos, press releases). • Participation in 4 events for society at large.
Dissemination to relevant industrial and academic communities	WP5/T5.2	• Active participation in industrial events (like series of webinars organized with Layer123 on Powering 5G in industry) and academic-related activities (such as Bachelor, Master and PhD programs). • Organization and participation in multiple technical events (like IEEE NFVSDN, ACM Mobicom, IEEE INFOCOM) to present the project and its results and exchange ideas with other projects.
Maximization of the impact of project innovations through	WP5/T5.2	• The exploitation strategy was reported in the Communication, Dissemination, and Exploitation Plan (CoDEP) for Y2 in D5.1 [19] and updated in D5.2 [20].

coordinated exploitation activities led by the innovation manager		
Contributions to top-tier scientific journals, conferences and magazines	WP5/T5.2	• Multiple submitted, accepted and published papers in top-tier scientific journals, conferences and magazines, as reported in D5.2 [20] and latest update available in this document (D6.2).
Contributions to standardization bodies	WP5/T5.2	• A standardization advisory committee (SAC) was formed from 5Growth experts related to the relevant SDOs (3GPP, IETF, ETSI, IEEE, …). The SAC supported partners to contribute to SDOs and to disseminate the project results. • The Standardization Activity Roadmap (SAR) described in D5.2 [20]. • List of key contributions adopted by the SDOs (3GPP, IETF/IRTF, ETSI, and IEEE), reported in D5.2 [20] with the latest update available in D6.2 (this document).
Generation of IPR	WP5/T5.2	• Partners patented 2 novel systems and/or methods related to the innovation outcomes of the project. • The project also contributed to Open Source projects (like ONOS, e.DO), and most notably, by making publicly available the code for all its software releases, which is available through the GitHub of the project.
Verification	WP/task	Details
At least 10 publications per year in top-tier scientific journals and conferences such as WCNC, ICC, INFOCOM, GLOBECOM, IEEE COMMAG/WIRELESS MAG, IEEE/ACM ToN	WP5/T5.2	• 28 accepted papers in top-tier scientific journals, conferences and magazines, as reported in D5.2 [20] and latest update available in D6.2 (this document).
File at least 5 patent applications	WP5/T5.2	• 2 patent applications filed.
At least 10 adopted contributions to SDOs such as 3GPP, IETF, ETSI, IEEE, ITU	WP5/T5.2	• 39 contributions to SDOs: 8 to 3GPP, 10 to IETF/IRTF, 16 to IEEE, and 5 to ETSI. Out of these 39, 13 of them have been adopted.
Organization of at least 2 workshops	WP5/T5.1	• 6 workshops organized or co-organized by 5Growth during the first reporting period, including Joint half-day online workshop 5Growth, 5G-DIVE, 5G EVE, 5G-VINNI,

		and 5G-TOURS (5G E2E experimentation by verticals in EU projects).
At least 2 demonstrations per year, including one at flagship event such as MWC	WP5/T5.1	• 8 demonstrations at flagship events (incl. ACM Mobicom, IEEE INFOCOM).

3.2. Explanation of the work carried per WP

3.2.1. WP1

This WP aims to revise and refine the technical and functional requirements initially defined per pilot, based on Industry 4.0 cases (INNOVALIA and COMAU), Energy (EFACEC Energia) and Transportation (EFACEC Engenharia e Sistemas). A definition of the different business models and their benefits, as well as the overall effects on the various identified stakeholders is done. Besides, the methodology to be used in the validation of the business models is identified and assessed.

A thoughtful study on the different economic streams and items that constitute each of the business models is also carried out during this work package. This will help to refine the different pilot's use cases from the perspective of the vertical, with special focus on their feasibility and profitability, not only technical but also economical. The core capabilities enabled by the 5Growth project in each pilot can be studied and classified to assess which are to be prioritized from an end-user point of view.

Finally, by M24 and over the last half year, building upon the work undergone throughout the rest of the project, a feasible, enhanced Service Level Agreements (SLA) model will be leveraged to complement the business analysis. This will provide the foundation for a properly defined and validated 5G business layer (OSS/BSS) model to be applied over future advanced network services for vertical industries scenarios.

3.2.1.1. Task 1.1: Analysis of vertical industries' requirements and business model definition

This task was focused on the analysis, revision and refinement of the technical and functional requirements initially defined per pilot while identifying its various stakeholders that could benefit from the improvements accomplished in the 5Growht project to be offered as a new product, service or product-service system. Furthermore, the business relationship between these stakeholders was studied as the base of the business model, while the methodology to be used to validate this business model was identified.

The task was finished with the completion of D1.1 (Business Model Design) [3], which reports the work done in regarding the revision of the functional and technical requirements of the pilots and the definition of the business model designs that will be validated in 5Growth. The main outcome of this task is summarized next.

VERTICAL PILOTS OVERVIEW

INNOVALIA's industry vertical pilot will deploy two use cases. In the first use case, *Connected Worker Remote Operation of Quality Equipment*, it will be explored how 5G technologies can be used to enable remote access to M3BOX, an edge device used to control the Coordinate Measuring Machine (CMM), in order to perform setup and configuration operations that nowadays require an expert to travel to the customer's premises. The second use case, *Connected Worker Augmented Zero Defect Manufacturing Decision Support System* will involve the development of a Machine to Machine (M2M) collaboration system using 5G technologies that will improve the flexibility and productivity of the CMM.

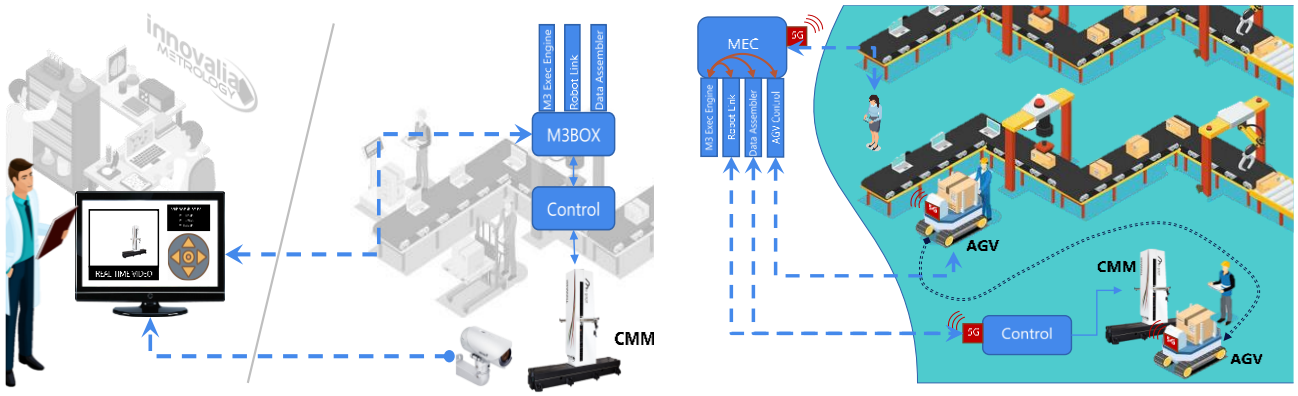


FIGURE 2: P1UC1 AND P1UC2 OVERVIEW (INNOVALIA)

In the case of COMAU's industry vertical pilot there will be three use cases. First, the deployment of *Digital Twin Apps*, that will allow the plant manager to receive live information about the production line through a digital representation of the factory. Second, the development of *Telemetry/Monitoring Apps*, that will provide deeper information, monitoring the status of the equipment installed in the stations (robots, conveyors, motors, and so on), by installing a high number of sensors that use 5G communication technologies. Finally, the last use case will develop *Digital Tutorials and Remote Support*, to enable a high-resolution interface to remotely train and assist the worker on certain tasks.

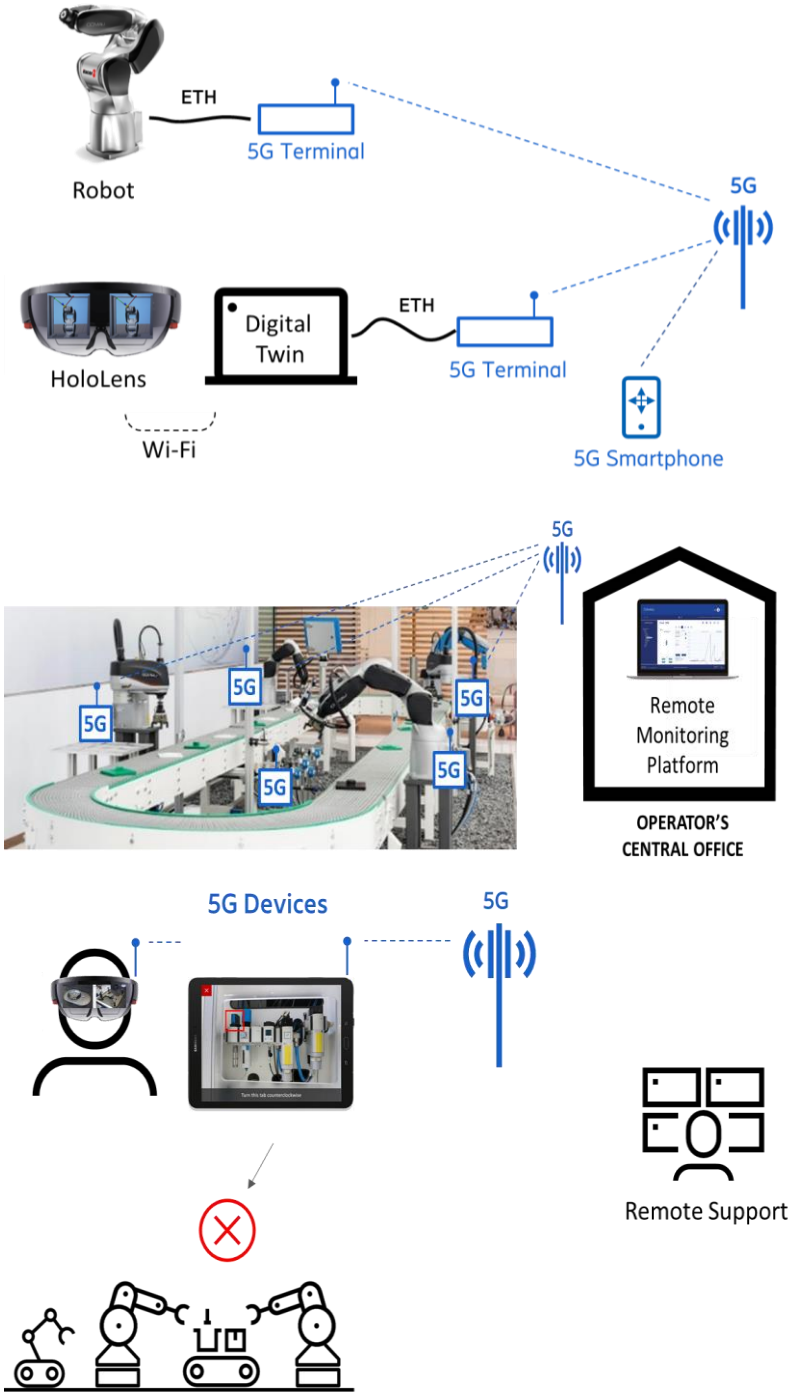


FIGURE 3: DIGITAL TWIN APPS (TOP), TELEMETRY/MONITORING APPS (CENTRE), DIGITAL TUTORIALS AND REMOTE SUPPORT (BOTTOM)

The transportation vertical pilot, led by EFACEC Engenharia e Sistemas, proposes to replace the wired communication used nowadays on a railway level crossing by 5G-based wireless devices. This is the basis to deploy two use cases: *Safety Critical Communications,* which are focused on railways signalling operations and *Non-Safety Critical Communications*, which provide additional information, to reinforce the security and to avoid accidents at Level Crossing area, both to the train driver and to the level-crossing maintenance team.

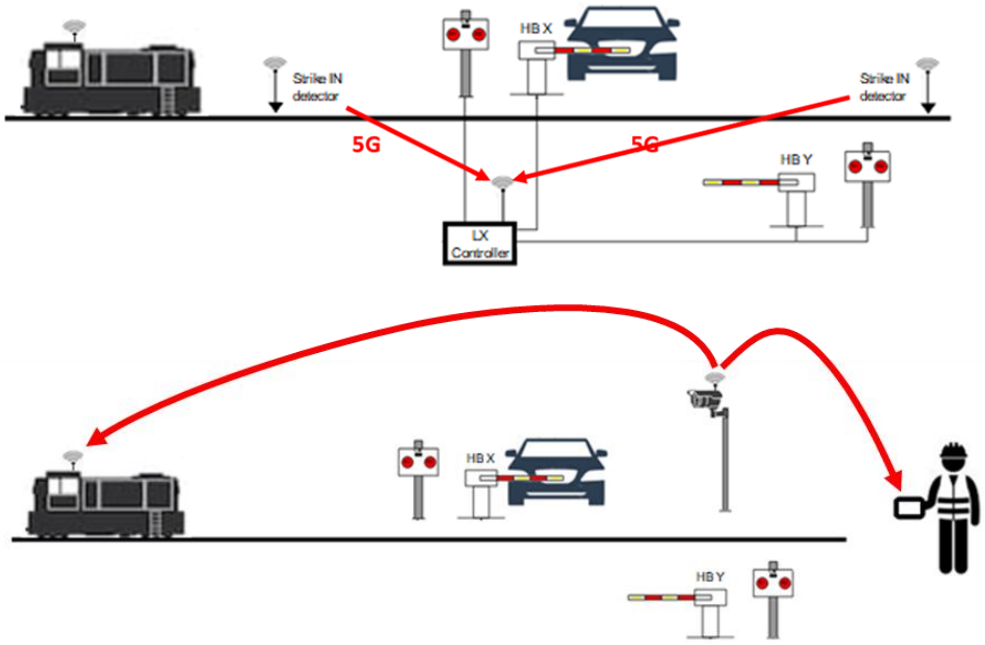


FIGURE 4: SAFETY CRITICAL COMMUNICATIONS (TOP), NON-SAFETY CRITICAL COMMUNICATIONS (BOTTOM)

Finally, EFACEC Energia's energy vertical pilot will involve the deployment of two more use cases. The *Advanced Monitoring and Maintenance Support for Secondary Substations MV/LV Distribution Substation* use case consists of a system to assist the maintenance team when repairing the substation by providing information with augmented reality. The *Advanced Critical Signal and Data Exchange Across Wide Smart Metering and Measurement Infrastructures* use case will deploy a system to use the last gasp of energy before an outage, in order to save and transmit important information to identify and prevent greater problems.

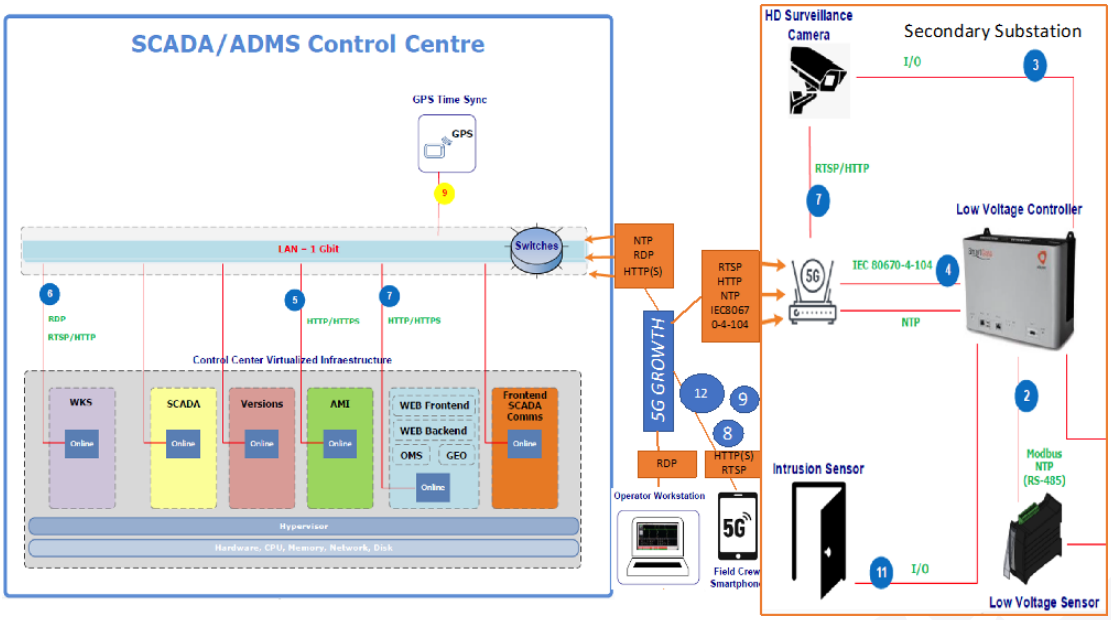


FIGURE 5: ADVANCED MONITORING AND MAINTENANCE SUPPORT FOR SECONDARY SUBSTATIONS MV/LV DISTRIBUTION SUBSTATION

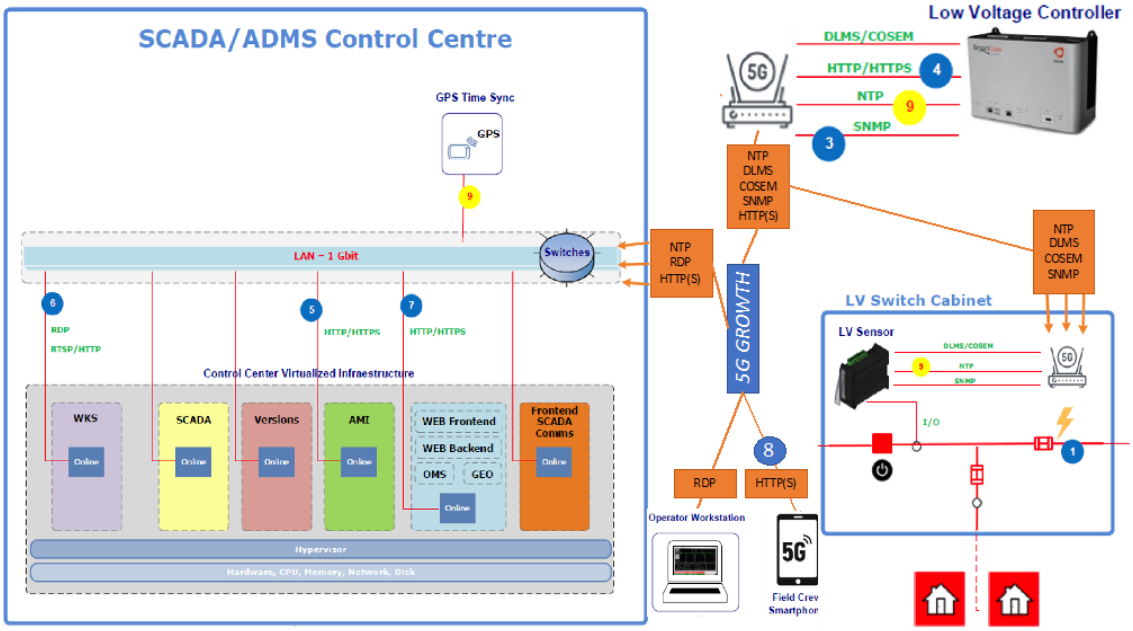


FIGURE 6: ADVANCED CRITICAL SIGNAL AND DATA EXCHANGE ACROSS WIDE SMART METERING AND MEASUREMENT INFRASTRUCTURES

BUSINESS MODEL DESIGN

The main roles identified in the four pilots are, in first place, the customer, which are the verticals, that consume services (network services, indoor coverage, frequency spectrum, and monitoring services and, in some cases, cloud edge/data centre services), which are provided mainly by the operator. On the INNOVALIA use case, there is also another service provider who provides video streaming services to the customer, and to whom the network operator provides the communication and monitoring services. Another role that is not always present is the hardware and software provider. In the 5Growth ecosystem, this role provides the hardware and software to the network operator needed to deploy the solution, and the maintenance services during operation.

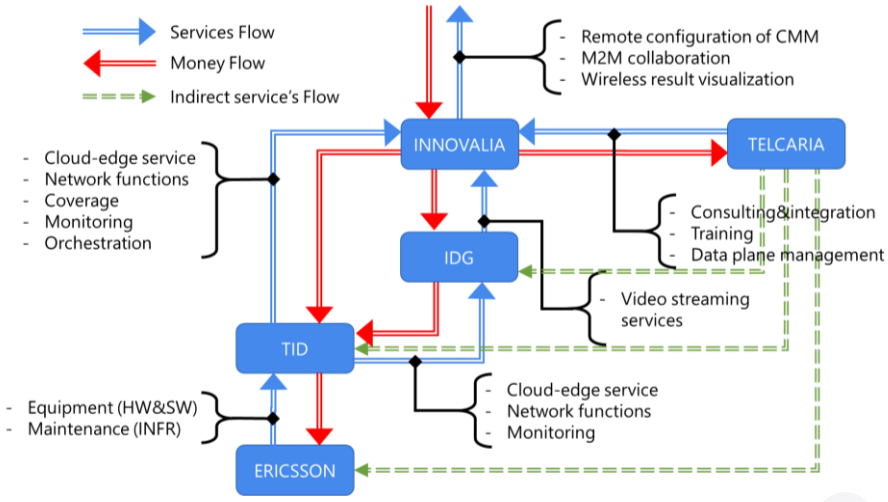


FIGURE 7: INNOVALIA'S PILOT BUSINESS FLOW

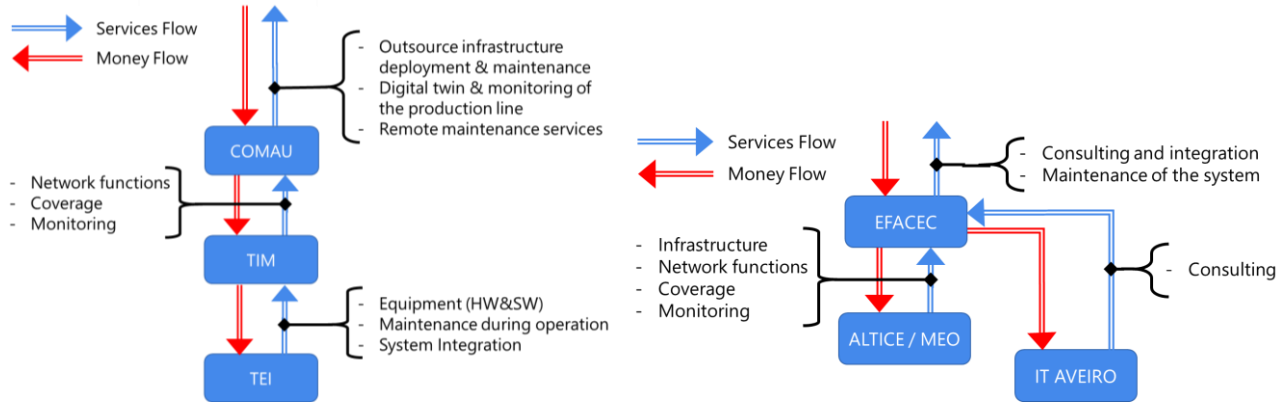


FIGURE 8: COMAU (LEFT) AND EFACEC ENGENHARIA E SISTEMAS & EFACEC ENERGIA PILOTS (RIGHT) PILOT BUSINESS FLOW

Finally, there is one more role to be highlighted, which is the system integrator, that provides consultancy and integration services to the final customer, matching the requirements of the verticals with the services that the other stakeholders can provide, and, in some cases, it also trains the customer to use the new deployments.

To sum up, the key contributions of these tasks were:

- Final detailed description of the pilots and the use cases;
- Business, functional and technical requirements of the use cases;
- Identification of the stakeholders in each pilot;
- Definition of the business model and the services flow per pilot.

3.2.1.2. Task 1.2: Techno-economic analysis and business model validation

The activities of Task 1.2 have been started by refining the outcomes of Task 1.1 by setting the economic model of the business process. It is now focused in performing the techno-economic analysis and establishing the methodology for the business model validation. To this end, T1.2 leader, TIM, first issued a questionnaire to collect information from the partners involved in the pilots. In parallel, discussions on the methodology for the Business Model validation are being addressed also in task T1.2.

This work has been carried out in each pilot by the respective partners participating in WP1. As a notable result, all the contributions and final editing of deliverable D1.2 (Techno-economic analysis and business model validation methodology) [4] were achieved on time, with its submission in August 2020. D1.2 reports a preliminary quantitative evaluation of the economic benefits introduced by 5G technologies into vertical industrial use cases and the activities directly envisaged by 5Growth. In particular, in this task a common methodology for the business model validation was applied to calculate the overall economic benefits for each use case. This has been done taking into consideration the current share of the market by the verticals involved, and some realistic growth predictions taking into account the subsequent business advantage obtained from state-of-the-art 5G technology implementation.

The analysis has been carried out by creating and applying a common methodology, devoted to understanding the economic advantages of adopting the solutions and innovations promoted by 5Growth (and described in deliverable D2.1 [6]). The business analysis aims to evaluate the difference in expenditures between a situation with and without applying 5G technologies, considering the solutions envisaged by 5Growth. In fact, we identify, for each pilot, where the introduction of new technologies can bring benefits from an economical point of view. Some of these benefits refer to investment, other to operational expenditures or new revenues. In order to consider multi-year expense savings and revenues, we introduce the "Yearly Total Value".

All the use cases described in the project have been analysed using this methodology. For each use case, we identify the requirements, in terms of rough economic benefits, i.e. cost saving percentage and qualitatively advantages by identifying the use case peculiarities. There are some additional benefits that have not been considered as they cannot be projected to a European scale, because of the different regulations for the different countries. Additionally, it is worth noting that specific values of costs and benefits are hard to obtain since the technology used is in many cases still far from commercialization. This information is thus scarce and sensible, which implies in some cases working with broad models and to apply some approximations.

Throughout the different pilots, approximately, 50% of the reported benefits are directly attributable to the innovations developed in the 5Growth project. The remaining 50% are obtainable due to the introduction of 5G, not specifically associated with 5Growth. It is important to highlight that the income statement concerns mainly savings on investments, operating costs, or an increase in production and, consequently, in revenues, due to higher sales. Collateral advantages were hardly taken into consideration, since they are difficult to monetise, e.g. lower environmental impact, greater safety, better overall life of citizens...

Last, but not least, it is worth mentioning that 5Growth has contributed to a whitepaper (pending publication) organized by the 5G Public Private Partnership (5G-PPP) and the 5G Infrastructure Association (5G IA) that summarizes the progress and results produced by 5G-PPP projects, while developing some innovative 5G network services and solutions for vertical industries. The white paper provides information about requirements and addressed business cases. It also discusses in detail several exemplary use cases from eleven different vertical sectors and identifies key 5G features that have been used to meet the specified requirements.

In addition to this, different videos are being generated by 5Growth explaining the overall goals of the project as well as the use-case/pilot specifics, including the identified benefits. Some of these videos are already available on the 5Growth YouTube channel[1], while others are under preparation.

The main findings of the task are summarized below per the 5Growth pilot family.

[1] https://www.youtube.com/channel/UCfIAsV6AdEibRteQp2ftpgw

Industry 4.0 Pilot - INNOVALIA

The main benefits for this pilot can be grouped in two large blocks, each corresponding to each of the use cases included: on the one hand, the reduction of trips for the set-up and maintenance of the Coordinate Measuring Machine – CMM (ranging from the reduction of the travel expenses, increasing the availability of experts, reducing the response time and also the maintenance costs); and, on the other hand, the optimization of the usage of the CMM (including this item and the reduction of the lot size). Also considering the additional cost of the technology (spectrum, network slices, edge computing and video platform), the expected benefits on a European scale will exceed 16.9M€. It is worth noting that most of these benefits are in the category of OpEx, which means that the saved money is immediately available for other purposes (contrary to CapEx, which requires a disinvestment to make the money available).

Industry 4.0 Pilot - COMAU

The main economic benefits are a consequence of the introduction of 5G technologies in the factories, simplifying the acquisition and centralization of the information in order to have always updated data, which provides continuous monitoring and simplifies decision making in the production chain. This innovation increases the quality of the resulting product, allowing significant savings, due the reduction in the number of discarded pieces. Additionally, the flexibility of the wireless deployment reduces the costs of a traditional wired deployment, including the civil works and the operational and provisioning tasks. We estimate that, in a European scale, the yearly benefits would almost reach 10.5M€. Similar to the INNOVALIA case, cost savings in the COMAU's pilot are related to OpEx.

Transportation Pilot - EFACEC Engenharia e Sistemas

In this pilot, social benefits are substantial, as it is expected that the deployment of the pilot will significantly reduce the number of accidents and will allow to avoid a 5% of the deaths on railway crossings in Europe.

But the pilot also has significant economic benefits, mainly due to the flexibility of the wireless mobile deployment compared to the wired solution, leading to a reduction in installation, maintenance, and security costs. What makes this pilot particularly interesting in terms of expected benefits, is the replicability of the implementation, as it is considered that the European market could accommodate up to 60,000 new generation level crossings, which would represent a yearly benefit of more than 2.2 billion euros.

Energy Pilot - EFACEC Energia

For the Energia Pilot, one of the main sources of benefit is the reduction of the Energy Not Supplied (ENS), which is measured through the Value of Lost Load (VOLL). However, there are other relevant items, such as the maintenance costs (both local and remote), the edge computing or the network operational costs. When projected on a European scale, the benefits are estimated in the range between 110M€ and 245M€.

3.2.1.3. Deviations

The COVID 19 situation in all Europe have impacted significantly the work of Task 1.2, as it has been difficult in some cases to access the required data from the companies, and some of the expected results have been delayed, though the main objectives have been achieved and D1.2 was submitted on time, as well as a different paradigm introduced by the outbreak is completely modifying the framework of the verticals' business. Because of this, some items of the techno-economic analysis, such as the analysis of the distribution of the costs among the different stakeholders, were not included in D1.2.

3.2.1.4. Corrective actions

A document addressing some aspects not included in D1.2, together with some updates have been provided in an updated version of D1.2. This document is used internally as a living document of the work carried out in the remaining duration of task 1.2 and has been uploaded to the web to provide additional insights to the external community. Furthermore, with the implementation of the different pilots and the different PoC, some of the specific data that is still not neatly defined will be clearer to estimate and updated in the document.

3.2.2. WP2

WP2 is in charge of extending baseline 5G management platforms, with particular focus on that of the 5G-TRANSFORMER project, to accomplish a series of technology innovations that satisfy 5Growth use cases with unprecedented advantages in cost and network performance. 5Growth consists of four key functional blocks inherited, yet vastly evolved, from 5G-TRANFORMER: Vertical Slicer (5Gr-VS), Service Orchestrator (5Gr-SO), Resource Layer (5Gr-RL), and Vertical-oriented Monitory System (5Gr-VoMS), plus a novel functional component devoted to assisting on AI/ML tasks, the AI/ML platform (5Gr-AIMLP). A high-level description of the 5Growth architecture is described in D2.1 [6], and its first release implementation, along with a subset of first-version innovations, in D2.2 [7].

3.2.2.1. Task 2.1: 5G End to End Service Platform

This task supervises the design and development of the 5Growth End-to-End Service Platform, by leveraging the 5G-TRANSFORMER architecture and its software implementation. CTTC is the task leader, with contributions from UC3M, NEC, TEI, NBL, TID, ALB, MIRANTIS, NXW, TELCA, NKUA, POLITO and SSSA. The execution of this task has been done via weekly calls and with dedicated slots in the plenary meetings organized so far. This task coordinates the design and implementation of all the innovations undertaken within Task 2.2, 2.3 and 2.4. To this end, weekly calls for synchronization have been organized since the beginning of the work in WP2. In addition, dedicated slots in each of the plenary meetings organized so far have been used for synchronization, planning and integration of individual innovations into the main platform.

The first activity organized within this task was the analysis of requirements for the extensions to be designed in our baseline platform. The outcome of this task, dutifully reported in D2.1, resulted in a

list of 12 innovations across all the functional blocks of the platform and the interfaces therein, appropriately categorized and allocated into T2.2, T2.3 and T2.4. These are summarized in Table 7.

TABLE 7: SELECTION OF 5GROWTH INNOVATIONS – SUMMARY.

Cluster	Category	Innovation	Brief Description
Architecture	Verticals Support	I1: Support of Radio Access in network slices	Modelling of the RAN requirements in network slice information models, based on latest 3GPP specs. Vertical Slicer logic (e.g. at the arbitration level) to handle the RAN segment of network slices. Additional southbound interfaces to request the creation or usage of network slices in the RAN segment.
		I2: Vertical-oriented Monitoring System	Separating monitoring from the infrastructure and verticals level. Use Mirantis StackLight LMA for infrastructure level monitoring. Vertical level monitoring uses the Monitoring Platform, developed in 5G-TRANSFORMER. Both monitoring subsystems require extending workloads monitoring capabilities, user metrics and parameters addition, monitoring user services according to SLAs, extending trigger rules and improving the monitoring system with AI features.
	Monitoring Orchestration	I3: Monitoring Orchestration	The 5Growth platform will deal with heterogeneous services/slices that need to be monitored in order to satisfy certain requirements, e.g. performance requirements, SLAs, etc. Due to the heterogeneous nature of the services/slices supported by the 5Growth platform, it will not be possible to monitor all of them in the same manner. Therefore, each service/slice will need different monitoring functions depending on what is to be monitored in each case. This innovation will implement a 5Gr-SO software module that manages the monitoring functions (e.g. probes, etc.) needed to monitor different services/slices according to the requirements gathered by the 5Gr-VS, SLAs, etc.
	Control and Management	I4: Control-loops stability	5Growth platform aims to provide closed-loop automation and SLA control for vertical services lifecycle management throughout the system across different layers (VS-SO-RL). This closed loop includes the process of collecting monitoring data from the services and networks, performing real-time data analytics for identifying events and alarms, so as to take proper orchestration decisions for optimization and re-configuration of the system, such as auto-scaling, self-healing and fault-tolerance, anomaly detection and automated troubleshooting, automated authentication and traffic management. Such closed-loop is to provide a continuously and automated SLA management lifecycle. It is envisioned that this closed-loop not only takes place inside each of the layers (5Gr-VS, 5Gr-SO, 5Gr-RL) to carry out their internal automated control of service and/or resources, but also across the layers which interact with each other according to predefined SLAs, policies/rules, mapping models, etc. It is essential to design the 5Growth architecture along with novel mechanisms and models to ensure a stable and closed loop through the system.
		I5: AI/ML Support	This innovation point will look at the opportunities to apply AI and, more specifically, ML techniques using monitoring, telemetry and analytics in the 5Gr-VS and 5Gr-SO to support resource allocation, resource control, etc. It will focus on the identification of training sets of data for the application of ML (and even Deep Learning) techniques to monitor slice deployment and SLA compliance and to support 5Gr-VS operations. It will also concern itself with determining where in the architecture these solutions are best deployed.
	End-to-End Orchestration	I6: Federation and inter-domain	Through federation, 5Growth service providers will extend their offerings by aggregating the service catalogue and resources from other providers. This could be done at the service level (service federation) or at the resource level (resource federation). The diverse nature of services and technologies naturally leads to multi-/inter-domain scenarios in which each domain has its own orchestration deployment that must be coordinated with that of other domains towards an end-to-end service offering. In this context, novel concepts will be explored, such as Distributed Leger Technology (DLT)-based orchestration architectures, the application of intent declarations, or extending coverage for continued network service provisioning to verticals. Furthermore, federation will exploit (and possibly shape) basic functionality of the 5Growth architecture, such as algorithms for smart service orchestration (I8), abstraction and access control mechanisms, request and access to monitoring and measurement data (I2, I3), which in turn, is closely linked with auditability (I11).

		I7: Next-Generation Radio Access Network	Radio Access Network orchestration capabilities, including RAN functions, radio and computing resources, and UE profiling. The design may be inspired by O-RAN reference architecture, which is based on well-defined, standardized interfaces to enable an open, interoperable supply chain ecosystem. In this way, this innovation is the foundation for building virtualized RANs, exploiting open hardware and AI-powered radio control and orchestration mechanisms (e.g. UE profiling –based traffic steering, etc.).
Algorithms	Smart Orchestration and Control	I8: Smart Orchestration and Resource Control	5Growth aims at fully automated network slice lifecycle management. Towards that direction innovations are needed that enable ultra-fast and cost-efficient slice setup and support dynamic slices given their respective service level agreements. Therefore, innovative service orchestration, arbitration and adaptive resource allocation approaches powered by AI/ML (capitalizing on I5) need to be introduced (leveraging 5Growth monitoring capabilities/innovations), within and across domains, that go beyond the current static, use-case-specific, simplistic existing solutions, which do not address the dynamic problem in an end-to-end fashion. Due to the highly dynamic nature of the problem, stability related issues will be investigated in Innovation I4. Furthermore, 5Growth will introduce dynamic resource control algorithms/techniques for performance assurance, enhancing the 5Gr-RL.
	Anomaly Detection	I9: Anomaly Detection	The 5Growth platform, due to heterogeneity of the supported services, requires an AI module in order to monitor deployed slices and better detect unforeseen anomalies between the services of the different slices. The current innovation will exploit the 5Growth AI/ML platform module and the Monitoring Platform of 5Gr-RL/5Gr-SO in order to analyze the network, computing and storage resource utilization, slice-specific KPIs, RAN measurements, data traffic patterns, mobility patterns (if available) so as to identify anomalies, their root causes and predict future anomalies in order to enable fast recovery. Potentially, the aforementioned module will create new types of events/alerts towards 5Gr-VS.
	Forecasting and Inference	I10: Forecasting and Inference	Forecasting based on data analytics might allow to lower the number of required resources and to minimize KPIs such as energy consumption, as well as enable pre-emptive measures to be taken. However, efficient and effective algorithms shall be devised that provide plausible results by the required deadlines. This innovation will develop algorithms for demand prediction to be applied at different level of the 5Growth architecture, such vertical slicer, service, and resource layer. They will be utilized by arbitration, service orchestration and resource orchestration. The algorithm will be based on time series analysis, artificial intelligence, and machine learning.
Framework	Security and Auditability	I11: Security and Auditability	Enable dynamic defense methodologies to protect infrastructure, management, and other network functions against different types of attacks. Mission-critical assets which require strong protection against powerful adversaries (such as state-sponsored actors), and obey the input-output model, shall be protected from unknown vulnerabilities using a Dynamic Heterogeneous Redundancy (DHR) architecture in a CMD (Cyber Mimic Defense)-like approach. Others shall benefit from the exploitation of the exploration space (the basis of Moving Target Defense (MTD)) to curb the asymmetric relationship between the attacker-defender, introducing uncertainty during the information gathering phases, and disrupting the subsequent critical phases required for a successful attack. The 5Growth platform (VS-SO-RL) will deal with multiple request/response exchange between verticals and the platform that need to be guaranteed by integrating non-repudiation mechanisms. Therefore, both actors can demonstrate that a certain request/response has effectively been generated by the other one. To do this, both will save their evidences of both request and response on a private trusted store. The integration of these non-repudiation mechanisms can be applied to support the verification of orchestration SLAs and extended to incorporate monitoring actions and even measurement themselves.
	5Growth CI/CD and containerization	I12: 5Growth CI/CD and containerization	Services containerization, Kubernetes underlay for infrastructure and automated CI/CD allow to automate whole verticals lifecycle and ship the entire platform in an automated way

A more detailed description of these innovations can be found in D2.2. To organize the work and steer the design of the 5Growth platform towards success, T2.1 made a plan release with 2 official

releases, a first release in M12 including a subset of first-version innovations, and a second release in M24. This release plan is summarized in Table 8.

In compliance with such plan, Task 2.1 devoted itself during the first 12 months of this reporting period towards the integration of 5 innovations, some of which (Innovation 12) were entirely designed and implemented within Task 2.1. Namely, a first version of Innovation 1 (RAN segment in network slices), Innovation 2 (VoMs platform), Innovation 4 (Control-loops stability) and two early algorithms for Innovation 8 (smart orchestration and resource control algorithms) were designed across different tasks (T2.2, T2.3 and T2.4) and integrated within T2.1 into Release 1, as planned.

TABLE 8: RELEASE PLAN

Cluster	Category	Innovation	Release 1 (M12)	Release 2 (M24)
Architecture	Vertical support	I1: RAN segment in network slices	X	X
		I2: Vertical-service monitoring	X	X
	Monitoring orchestration	I3: Monitoring orchestration		X
	Control and management	I4: Control-loops stability	X	X
		I5: AI/ML support		X
	E2E orchestration	I6: Federation and inter-domain		X
		I7: Next Generation RAN		X
Algorithms	Smart orchestration and resource control algorithms	I8: Smart orchestration and resource control algorithms	X	X
	Anomaly detection	I9: Anomaly detection		X
	Forecasting and inference	I10: Forecasting and inference		X
Framework	Security and auditability	I11: Security and auditability		X
	5Growth CI/CD and containerization	I12: 5Growth CI/CD and containerization	X	X

To support these activities, among the first activities in WP2, Task 2.1 undertook the full design and implementation of Innovation 12 (5Growth CI/CD and containerization), with the goal of easing development workflows for the remaining innovations. Since its integration, the 5Growth platform enabled continuous integration and development of the different extensions developed within WP2. Figure 9 depicts a high-level illustration of this innovation´s architecture. The implementation details can be found in D2.2. In summary, it provides the following functionality:

- Triggering by a developer's commit in private project repository (SCM polling);
- Creating a virtual environment on OpenStack using pre-created Cloudify blueprint;
- Cloning new changes from the repository, building 5Growth containerizing components in a newly created environment;
- Testing a containerized application;
- Pushing Docker images to the private registry for future use in deployment in case of success or notifying via email in case of failure;

- Deployment of 5Growth components on a new or previously instantiated environment.

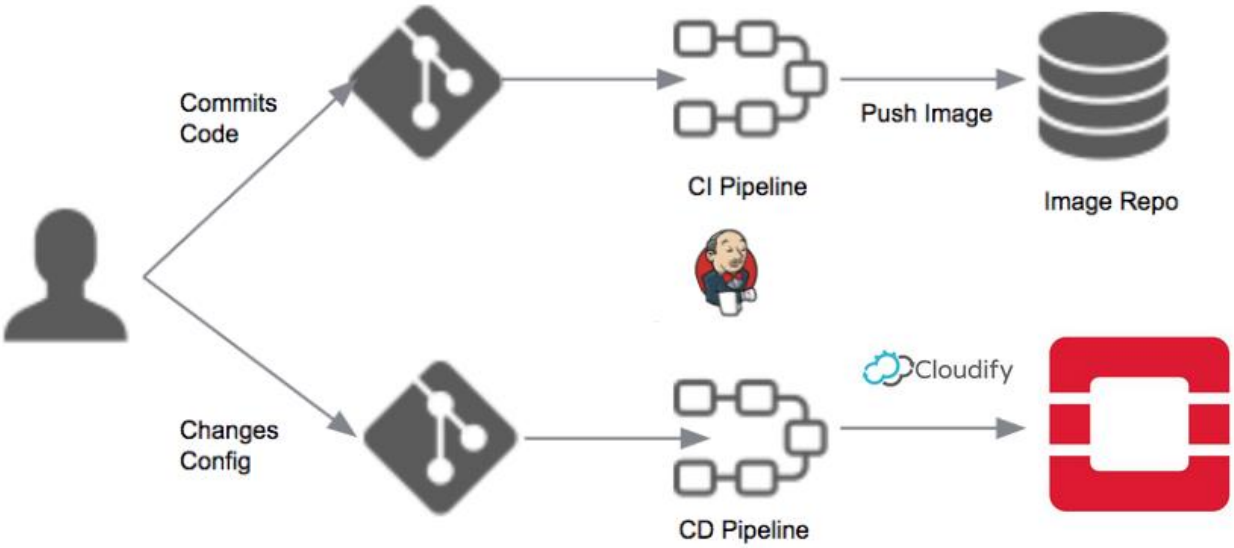


FIGURE 9: HIGH-LEVEL CI/CD ARCHITECTURE

Although each innovation is integrated into the main platform in the context of T2.1, the legwork of their design and development is divided across Task 2.2, Task 2.3 and T2.4 as explained below.

After the release of 5Growth R1 innovations in M12, design and implementation work on other innovations started. In more detail, between M12 and M18, three innovations initiated their design and implementation work (yet unfinished): Innovation 6 (Federation and Inter-domain), Innovation 5 (AI/ML support), Innovation 10 (Forecasting and Inference) and Innovation 11 (Security and auditability). These innovations, in addition to the second version of those innovations integrated in R1, will be integrated within Task 2.1 along the second reporting period of 5Growth.

3.2.2.2. Task 2.2: Enhanced and automated vertical support

Task 2.2 has been led by NXW and supported by UC3M, NEC, NBL, TIM, TID, ALB, MIRANTIS, TELCA, CTTC, IT, NKUA, POLITO and SSSA. All participants in T2.2 contributed to the study of requirements and subsequent elaboration of a time plan to allocate effort to the different design and implementation of innovations relevant for T2.2.

Between M1 and M12, all the effort in T2.2 was devoted to the design and implementation of a first supporting version for the RAN segment in network slices. After a thorough discussion on the architectural modifications required for this innovation (summarized in D2.1), Figure 10 represents the main functional blocks affected by the final design. As shown in this figure, extensions across the three main layers of the stack are required.

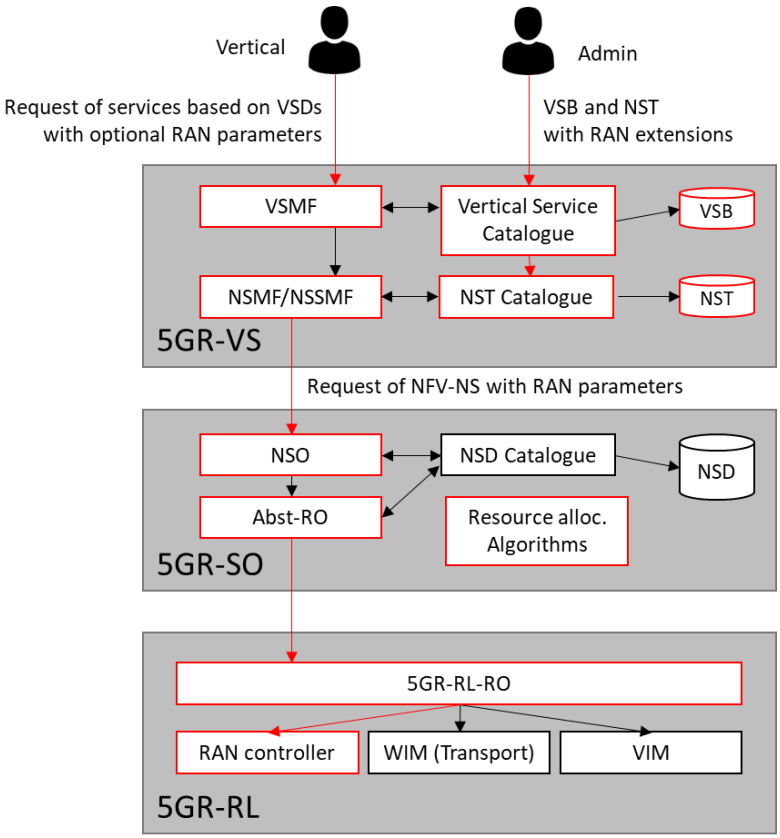


FIGURE 10: FUNCTIONAL BLOCKS AFFECTED BY THE SUPPORT OF THE RAN SEGMENT IN NETWORK SLICES

The work towards R1 (M1-M12) focused on three main aspects:

- RAN modelling in network slices at the 5Gr-VS, including extensions to the NST catalogue, VSB information model, translator, VS LCM, and NS LCM;
- Updates to the VS-SO interface;
- Initial modelling of PNF support and RAN abstractions.

After R1, the work on Innovation 1 was resumed with special focus on the development of 5Gr-RL´s API to manage PNFs. In addition, a series of activities have been performed in the context of Innovation 6 (Federation and inter-domain) and Innovation 11 (Security). Concerning the former, hierarchical multi-domain support, interfacing CSMF and NSMF in the 5Gr-VS across multiple domains have been designed, as depicted in Figure 11. This activity is paramount to interface with ICT17 platforms and in this way support different pilot use cases. In addition to federation at the vertical service level (CSFF-CSFF) and inter-domain (CSMF-NSMF), Figure 11 shows both service and resource federation interfaces at the 5Gr-SO level, which have been developed in Tasks 2.1 and 2.4.

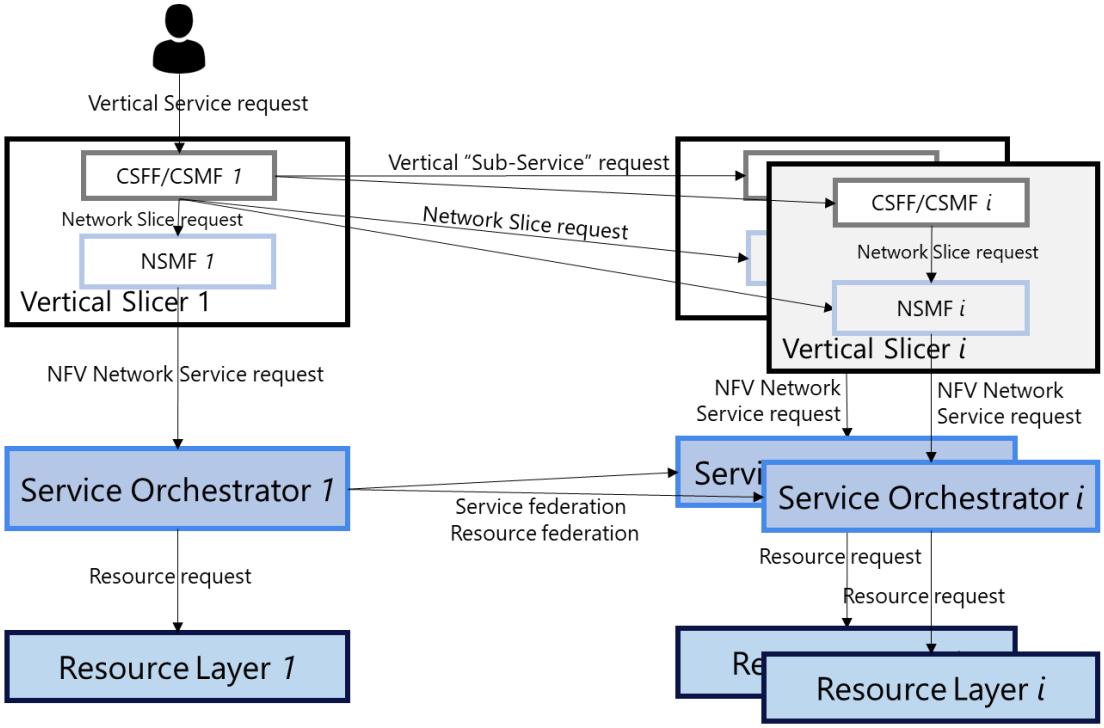


FIGURE 11: DIFFERENT FEDERATION AND INTER-DOMAIN INTERFACES

About the latter, different security approaches have been designed (MTD and CMD). In more detail, the implementation of MTD features at the management plane will be completed by M18. Integration of MTD in the forwarding plane, in addition to the implementation of the designed CMD approach, will be done during the second reporting period. A high level overview of the integration of a MTD network function to the management plane is shown in Figure 12, where an MTD function acts as a trust boundary between the verticals and the platform, and between different vertical slicers interfacing each other.

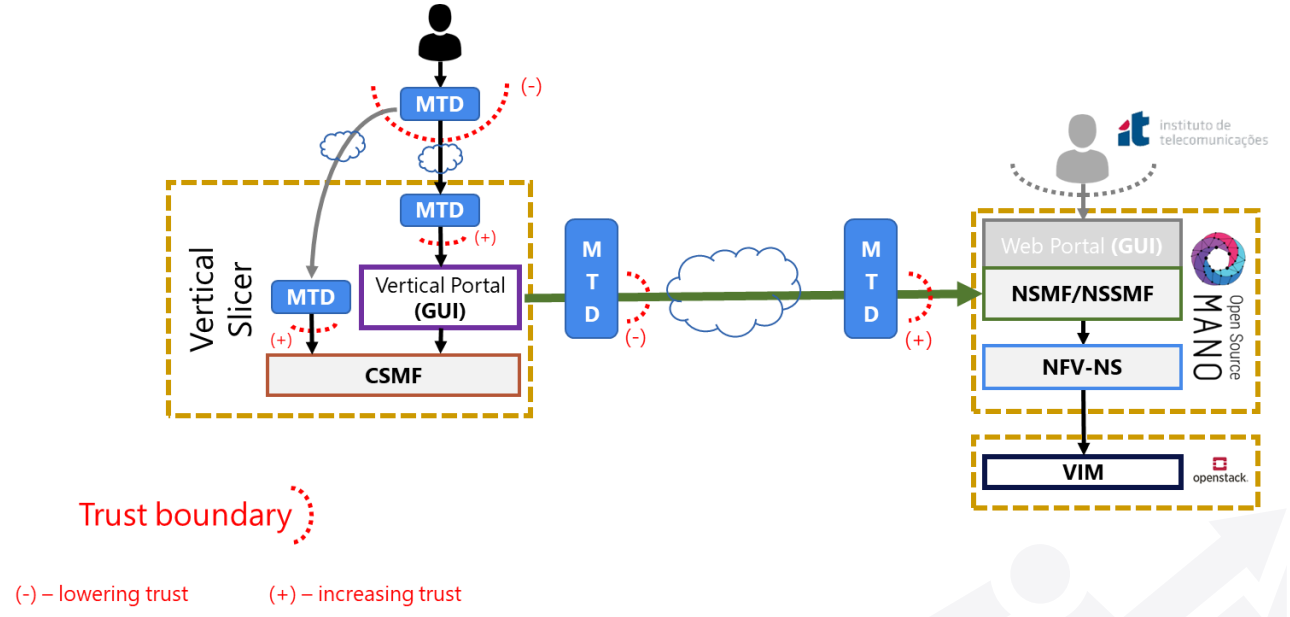


FIGURE 12: MTD/MANAGEMENT PLANE HIGH LEVEL OVERVIEW

3.2.2.3. Task 2.3: Telemetry monitoring, analytics and orchestration

This task is led by MIRANTIS, with contributions from UC3M, NEC, TIM, TID, COMAU, NXW, CTTC, NKUA and SSSA.

The main work carried out within this task during M1-M12 was devoted to design and implement extensions into the Vertical-oriented Monitoring System (VoMS) in the context of Innovation 2. In more detail, during this time the VoMS has been extended with the following functionality:

- Integration of Kafka´s Message Queueing (MQ) system
- Server holding RVM agent archives and initial script for virtual machines
- Logstash as data collection pipeline
- Elasticsearch for storing, searching and analysing big volumes of data
- Kibana for visualization.

The architecture of the VoMS is shown in Figure 13, and the details of the Release 1 of the system can be found in D2.2.

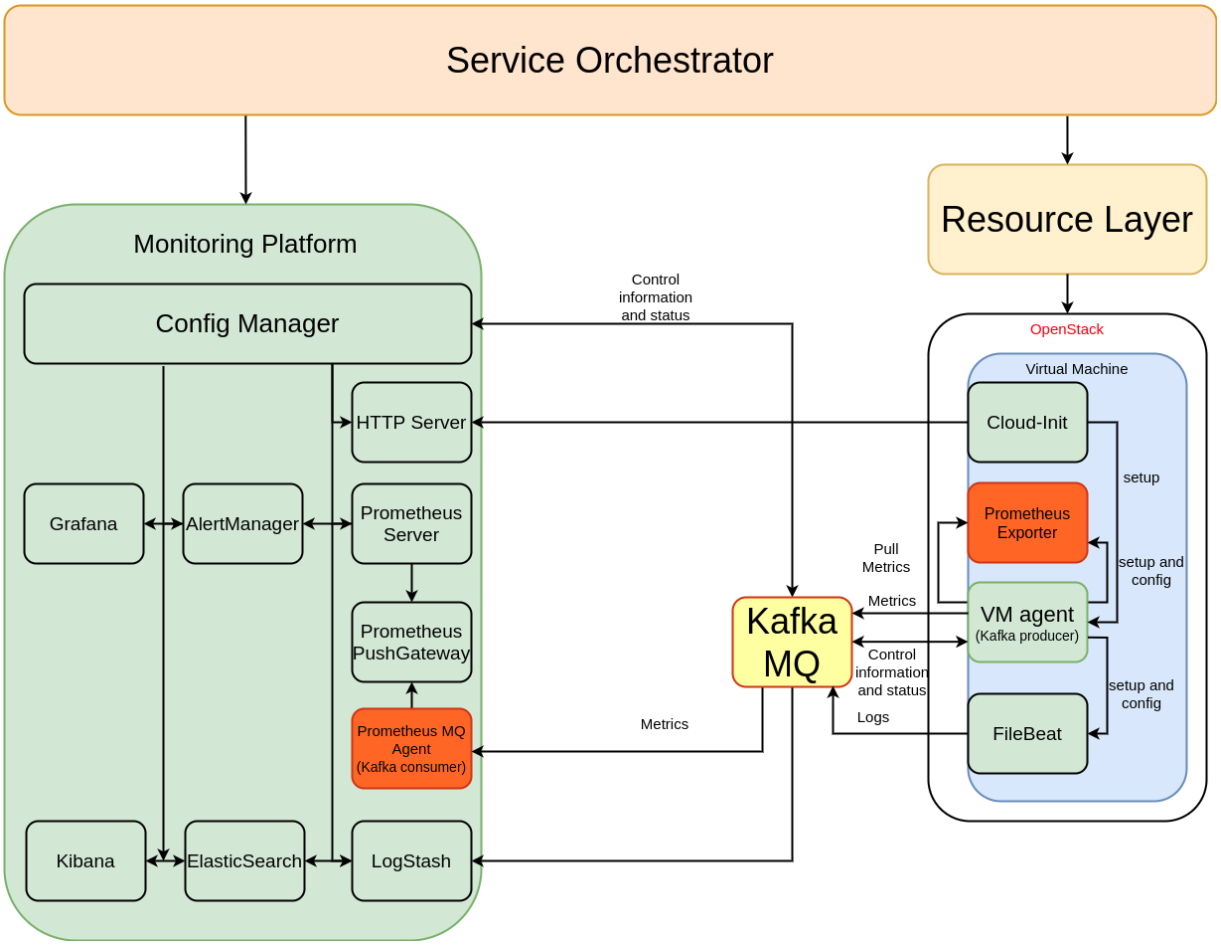


FIGURE 13: VERTICAL-SERVICE MONITORING ARCHITECTURE

Between M12 and M18, this task provided support to feed data to different other functional blocks, with special attention to automated scaling mechanisms within Innovations 5 and 8, and the AI/ML platform within Innovation 4. More specifically, mechanisms to provide native and 3rd party client-

side monitoring probes are under discussion within this task. This will enable 5Gr-SO and 5Gr-VS to scale up/down/in/out slices and/or services based on in-service metrics. Moreover, a full data-feeding pipeline has been designed for the development of the 5Gr-AIMLP, as shown in Figure 14. This activity started in M13 and is currently under implementation.

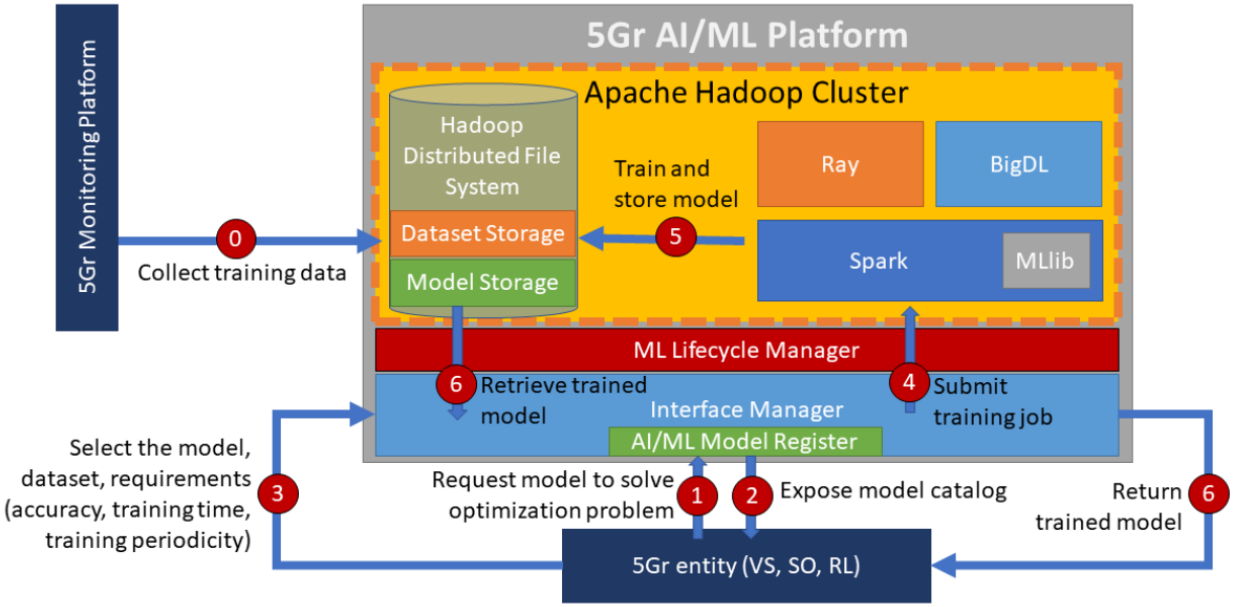


FIGURE 14: INITIAL DESIGN OF 5GR-AIMLP WORKFLOW

3.2.2.4. Task 2.4: Closed-loop automation, SLA modeling and control for vertical service.

Task 2.4 is led by NBL, with contributions from UC3M, NEC, TID, COMAU, MIRANTIS, NXW, TELCA, CTTC, NKUA, POLITO and SSSA.

Between M1 and M12, substantial effort in this task was devoted to the design and implementation of a first version of two innovations: Innovation 4 (Closed-loop stability) and Innovation 8 (Smart orchestration and resource control algorithms).

Enabling the configuration of control-loops as part of the workflows for the management of vertical services requires the interaction with a new entity in the 5Growth architecture, which is the 5Gr-AI/ML platform (still under development and scheduled for Release 2) to provide a set of AI/ML models to support the decision-making process. In Release 1, the scope has been focused on the implementation of a closed-loop in the 5Gr-Service Orchestrator (5Gr-SO) to handle the AI/ML-based scaling of NFV-NS case. In this work, multiple concepts have been explored, for instance applying third-party software tools for distributed large-scale data processing (Apache Kafka, Apache Spark) and defining the necessary interactions with the 5Gr-AI/ML platform, the monitoring platform as well as the rest of the 5Growth platform. The same methodology can be applied to close control-loops in other layers, like the 5Gr-RL to predict and react in case of problems in the transport infrastructure. The work done between M1 and M12 paved the way for the implementation of a closed-loop AI/ML based scaling method for NFV-NS in the 5Gr-SO. This required substantial

extensions in the 5Gr-SO and its interaction with the monitoring platform. Figure 15 highlights the architecture of 5Gr-SO, highlighting (with a green check mark) the different functional blocks extended to support closed-loop service scaling. The details can be found in D2.2. Between M12 and M18, extensions to interact with 5Growth´s AI/ML platform have been defined and are currently under implementation.

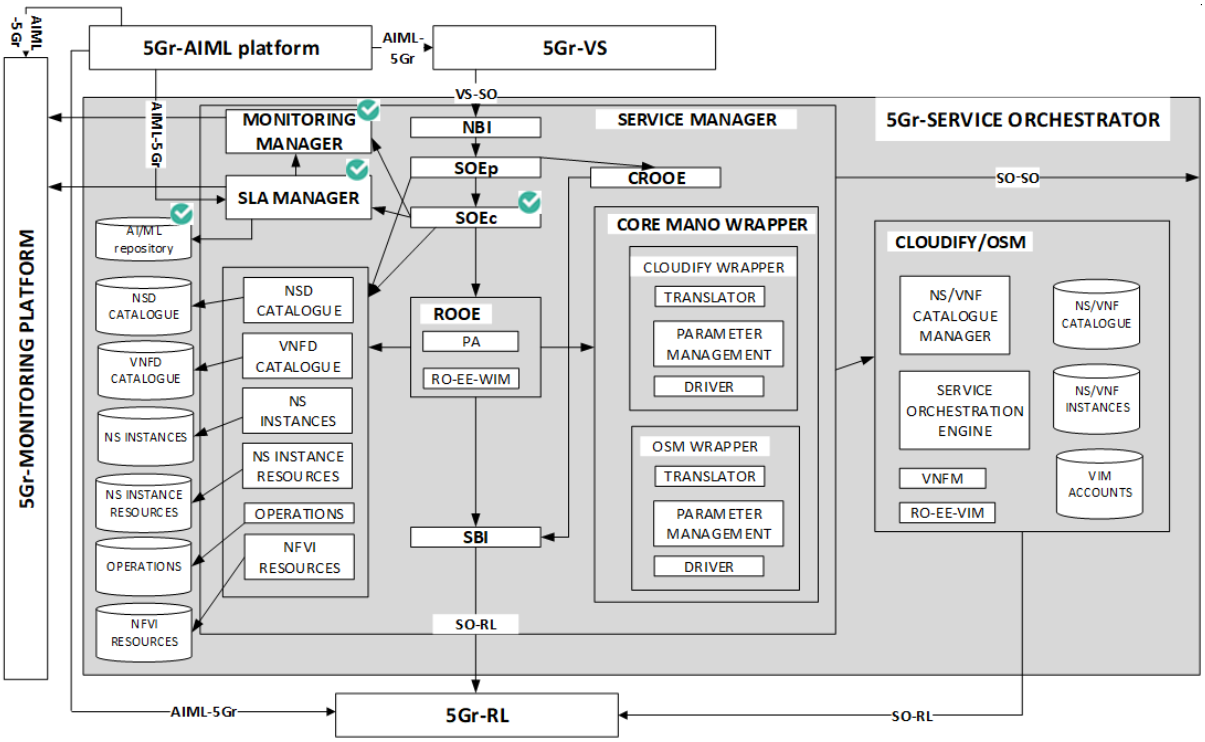


FIGURE 15: HIGH-LEVEL ARCHITECTURE OF 5GR-SO, HIGHLITING THE EXTENSSIONS FOR CLOSED-LOOP AUTOMATED SCALING

Finally, a key innovation under the responsibility of T2.4 is Innovation 8 (Smart orchestration and resource control algorithms). During this first reporting period, a set of key mechanisms have been designed and implemented, including:

- Advanced resource allocation mechanisms at 5Gr-RL:
  - Abstraction computation to derive the LLs between pairs of NFVI PoPs as well as providing aggregated resource information at each NFVI PoP.
  - Expansion of resource selection and computation (e.g., WAN paths) fulfilling the requirements (such as required bandwidth, maximum latency, etc.) needed over the set of LLs supporting a network service.
- Network slice customization and performance isolation:
  - Resource Orchestration logic has been designed and implemented to decide optimal QoS policies
  - SDN applications based on ONOS for OpenFlow and P4 switches
  - SBI components to communication RO algorithm and SDN applications
  - Databases to support stateless RO operation
  - Monitoring driver to configure alarms.

The details of these first approaches were part of R1 in M12 and are reported in D2.2. Additional approaches, in the context of this innovation, such as resource orchestration of virtualized RANs, arbitration at 5Gr-VS and support to I4 for automated scaling are planned for the second reporting period. A high-level overview of this work is shown in Figure 16.

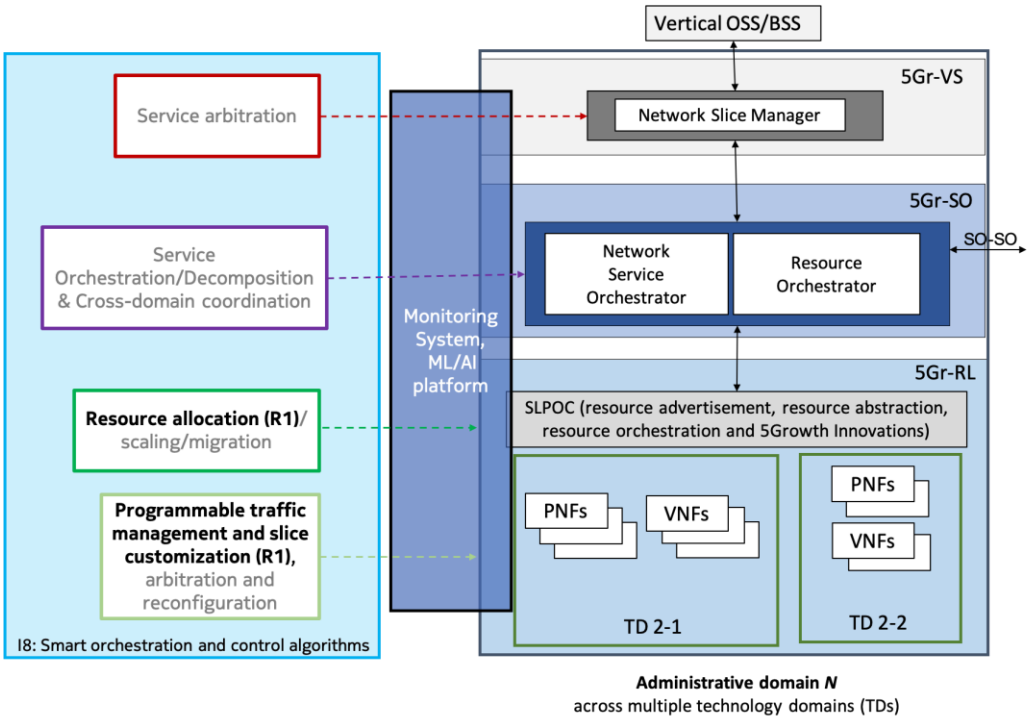


FIGURE 16: SMART ORCHESTRATION AND RESOURCE CONTROL ALGORITHMS

3.2.2.5. Deviations

Globally, the work package is proceeding as planned. No deviations have been noticed during the first period of the project.

3.2.2.6. Corrective actions

No corrective actions needed.

3.2.3. WP3

WP3 is in charge of deploying all 5Growth pilot sites, including software and hardware components for all use cases planned, integrating and executing the vertical use cases over the ICT-17 sites interworking with 5Growth platform.

In order to leverage as much as possible the ICT-17 platform infrastructure (5G EVE and 5G-VINNI), a stepwise approach is followed, using the ICT-17 sites for the first test and validations and planning an integration of the vertical sites into the ICT-17 platforms:

- M12: Limited functionality pilot platform working in ICT-17 premises available

- M18: Full functionality pilot platform working on ICT-17 premises available
- M24-M27: Timeframe for trial in target vertical sites.

Overall, WP3 plan is structured as a set of tasks and activities that, over a common timeline and coordination scheme, accommodates for agile progress of the various 5Growth pilots in parallel. WP3 is led by ERC. The variety of knowledge and skills demanded by WP3 translates into the participation and contribution of all 5Growth partners (with the only exception of NKUA, according to the project plan).

The main outcomes of WP3 are collected in the deliverables released until M18:

- A full feasibility and gap analysis of ICT-17 platforms for supporting each and every 5Growth use case is included in D3.1 [13].
- A detailed technical solution for enabling the experimentation and business validation of each and every 5Growth vertical use case, including the integration options of 5Growth with the selected ICT-17 platforms, is included in D3.2 [14].
- A first version of the platform software will be available in the Git of the project and is included in D3.3 [15].
- A step-by-step plan to the deployment of the pilots in vertical industries is included in D3.4 [16].

Also, a complete, use case by use case, assessment of COVID-19 impact on WP3, and on project related milestones and deliverables, has been performed in order to mitigate such impact to the best possible extent. Such assessment and mitigation plan were included already in D3.2.

3.2.3.1. Task 3.1: ICT-17 facilities gap analysis

This task is about detecting and analyzing the gap in ICT-17 platforms for deploying and executing the 5Growth project. The gap analysis scope is to detect the need of additional resources, such as additional hardware or capacity expansion or activation of additional features in each ICT-17 platform. An additional goal of this task is to select the innovations defined in WP2 to be deployed in 5Growth.

The execution of this task was led by ERC and counted contributions from UC3M, IDG, NBL, TEI, TIM, TID, ALB, MIRANTIS, NXW, TELCA, CTTC, IT, POLITO and SSSA. The work in this task has built upon a variety of complementary perspectives: Use Case needs, ICT-17 platforms, and 5Growth innovation perspectives. Special attention was dedicated to collaborating with the 5G EVE and 5G-VINNI projects, in order to understand ICT17 platform services, capabilities and architecture, provide feedback and jointly align on scenarios and plans for 5Growth-ICT17 integration.

The results of this task are documented in D3.1 [13]. The basic needs, performance requirements and constrains expressed by the 5Growth Vertical partners in relation to the Use Cases they are planning to validate within the project, were collected and summarized in a uniform way. With the goal of meeting those requirements, a set of specific technology and architectural solutions were sketched and proposed, and the potential role that ICT-17 platforms may play for those solutions was also studied for each of the use cases and selected locations. The feasibility of such proposals was

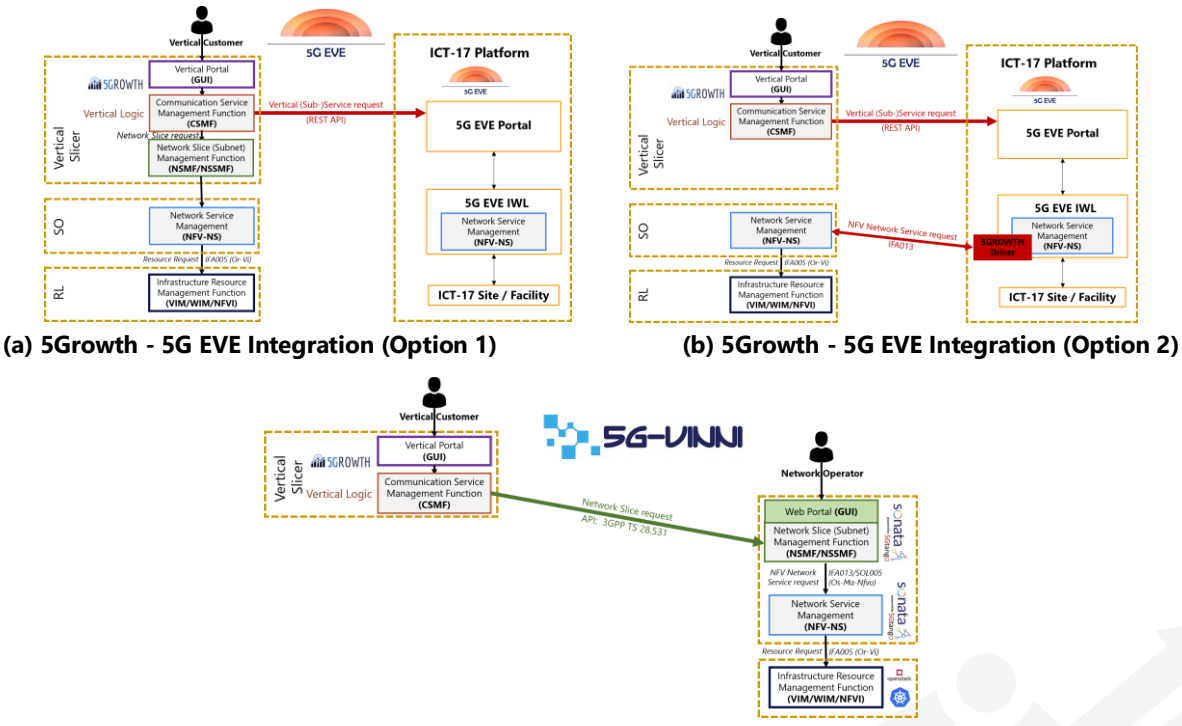
assessed and the main gap areas to be addressed in the 5Growth project were identified. Besides that, a first study and outlook into the further analysis to be performed at project level on the feasible integration models of 5Growth with the selected ICT-17 platforms, was also carried out and documented.

3.2.3.2. Task 3.2: Platform implementation and deployment in ICT-17 and vertical premises

Task T3.2 is a long-lived task that focuses on the actual deployment of the identified resources required for the vertical trials into ICT-17 platforms and vertical sites, which includes the 5Growth platform. In this task, the integration of the different modules developed within WP2 and the general extensions developed to connect the vertical sites to the ICT-17 platform are integrated.

The execution of this task is led by UC3M with key contributions from NEC, ERC, IDG, NBL, TEI, TID, ALB, COMAU, EFACEC_S, EFACEC_E, INNOVALIA, MIRANTIS, NXW, TELCA, CTTC, IT, POLITO and SSSA. The work in this task has been distributed across Vertical Pilots' tracks, all of them securing a plan of actions of analysis, development, deployment and integration activities. This task doubled down on the joint work with 5G EVE and 5G-VINNI (i.e., the targeted ICT17 platforms) projects in order to secure best alternatives for integration and feasible plans for 5Growth-ICT17 integration.

Between M1 and M18, the effort in T3.2 focused on the analysis of the different multi-domain approaches in 5Growth and the requirements of each vertical pilot from the perspective of a Public Network and Non-Public Network integration (PN-NPN). Building up on this analysis, the integration mechanisms between 5Growth and 5G EVE / 5G-VINNI platforms was devised. Figure 17 depicts a high-level illustration of the possible options for both 5G EVE and 5G-VINNI integration.



(a) 5Growth - 5G EVE Integration (Option 1)

(b) 5Growth - 5G EVE Integration (Option 2)

(c) 5Growth - 5G-VINNI Integration

FIGURE 17: HIGH-LEVEL INTEGRATION OPTIONS BETWEEN 5GROWTH AND ICT-17 PLATFORMS

The aforementioned *Option 2 for 5G EVE* and the *single option for 5G-VINNI* integrations are being implemented, as the selected options to be used by the 5Growth vertical pilots and their use cases. For the first code release, the implemented integrations, which components are summarized in Table 9, focus on basic workflows to support e.g. creation, instantiation, and termination operations. Moreover, not only individual module testing was performed, but also integration tests encompassing already 5Growth and 5G EVE / 5G-VINNI platforms.

TABLE 9: 5GROWTH & ICT-17 PLATFORM FIRST IMPLEMENTATION PLAN

	5Growth Platform	ICT-17 Platform
5Growth & 5G EVE Integration	Generic 5Gr-VS level integration approach	5G EVE IWL 5Growth Driver
	5Gr-VS Driver for 5G EVE Portal API	5G EVE IWL Catalogue Driver
5Growth & 5G-VINNI Integration	5Gr-VS driver for SONATA	HTTP REST server for SONATA
		Transformation from JSON to YAML
		SONATA client

The results of this task have been documented in D3.2 [14] (describing the technical solution for experimentation and business validation of the vertical use cases in the scope of 5Growth project) and D3.3 [15] (reporting and documentation its actual implementation).

3.2.3.3. Task 3.3: Integration with vertical systems and execution of the I4.0 INNOVALIA Pilot

This task is devoted to the integration and execution of the I4.0 INNOVALIA Pilot.

The execution of this task is led by ERC and counts on active contributions of NEC, IDG, NBL, TID, INNOVALIA, MIRANTIS, NXW, TELCA and CTTC. Partners focus on the specific use cases of this pilot, while considering the general aspects of deployment over ICT-17 platforms defined at WP3 level, integration of WP2-developed innovations, iterative hand-over to testing and validation activities at WP4, and timely dissemination and communication of results in cooperation with WP5.

Work has been done to prepare the setup in 5Tonic lab for the execution of the use cases, corresponding to the pilot phase I deployment reported in D3.2 [14] and D3.4 [16].

The INNOVALIA 3D-scanner has been installed in 5Tonic lab (as illustrated in Figure 19) and initial use case testing cycles have been executed.

A second room has been provided with 5G coverage as well, as it is needed for INNOVALIA pilot UC1 (see Figure 18).

FIGURE 18: 5G SECOND ROOM

FIGURE 19: CMM IN 5TONIC

Additionally, a 5G Stand Alone network has been deployed in the lab. This involves the deployment of the 5G Core, connecting the 5G RAN equipment to the Core and activating the SA feature.

The execution of UC1 has been achieved over 5G NSA and SA networks. The results are gathered in the following table:

TABLE 10: UC1 EXECUTION RESULTS

Measured metrics	5G NSA (1) Results	5G NSA (2) Results	5G SA (3) Results
RTT Latency (scanner operation)	14 ms	14 ms	14 ms
RTT Latency (video streaming)	15 ms	15 ms	15 ms
Peak throughput (scanner operation)	52 Mbps	90 Mbps	46 Mbps
Peak throughput (video streaming)	52 Mbps	90 Mbps	46 Mbps
Video streaming application data rate	20 Mbps	20 Mbps	20 Mbps

(1) 3,5 GHz frequency band with TDD pattern 7:3 and 50 MHz bandwidth
(2) Adding to (1) an extra LTE 20 MHz bandwidth
(3) 3,5 GHz frequency band with TDD pattern 7:3 and 40 MHz bandwidth

In parallel, there has been analysis and design work done to understand how to deploy the vertical services over the 5Growth and 5G EVE platforms. Basic testing has been already performed using preliminary NSDs and VNFs to validate the full service instantiation workflow involving the new interfaces between 5Growth and 5G EVE.

3.2.3.4. Task 3.4: Integration with vertical systems and execution of I4.0 COMAU Pilot

This task is devoted to the integration and execution of the I4.0 COMAU Pilot.

The execution of this task is led by TEI and counts on active contributions by IDG, TIM, COMAU, MIRANTIS, NXW, CTTC, POLITO and SSSA. Partners focus on the specific use cases of this pilot, while considering the general aspects of deployment over ICT17 platforms defined at WP3 level, integration of WP2-developed innovations, iterative hand-over to testing and validation activities at WP4, and timely dissemination and communication of results in cooperation with WP5.

According to the contingency plan reported in D3.2, the 5G network has been installed and tested in the COMAU premises by end of September 2020 (M16). The 5G Ericsson radio antenna is illustrated in the left picture of Figure 20. The transport layer operating on a ring of optical fiber has been deployed to connect the baseband unit with the antenna and to convey the eCPRI interface protocol through a specific framer. A picture of the lab test measurements is reported in the middle of Figure 20. The deployment of all the use cases is in progress, including the deployment of robotic systems based on the COMAU industrial robots RACER3, illustrated in the right picture of Figure 20.

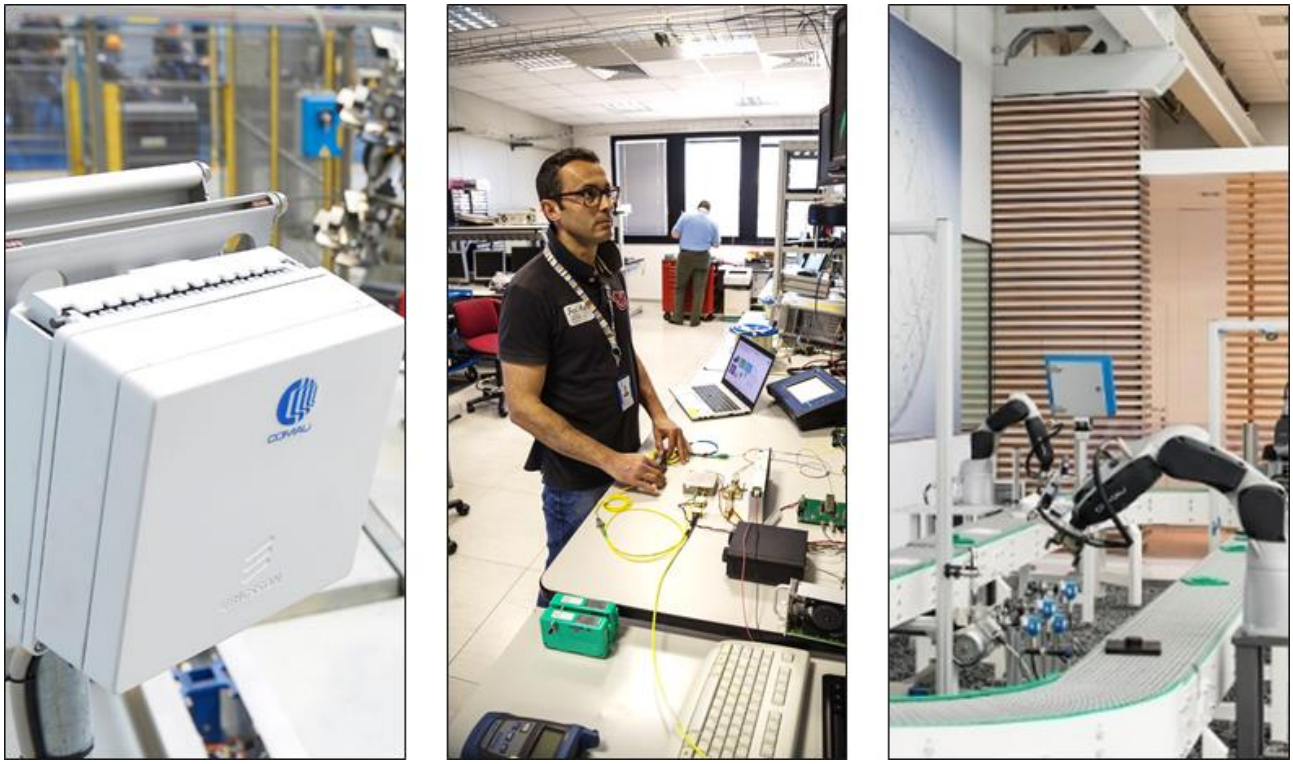


FIGURE 20: COMAU PILOT INFRASTRUCTURE AND ROBOTICS SYSTEMS

Preliminary performance results, tested with UDP and TCP traffic flowing for one week, are summarized in the following table (full details are available in D4.2 [18]). Further tests have been conducted over a fiber ring of about 9 km to measure the transport contribution to the overall E2E latency. Results demonstrate that it is two order of magnitude lower than the radio contribution.

TABLE 11: COMAU PILOT INITIAL RESULTS

Measured metrics	Downlink	Uplink
Latency (mobile network)	~7.88 ms	~10.83 ms
Peak Throughput (UDP)	~692 Mbit/s	~23.3 Mbit/s
Peak Throughput (TCP)	~653 Mbit/s	~22.9 Mbit/s

Latency (Transport network)	44 microseconds	44 microseconds

It is worth noticing that the trade-off between throughput and latency is tuneable to serve each use case with the most appropriate performance: for example, for latency critical use cases, it is possible to achieve a better latency by reducing the throughput.

In parallel, there has been analysis and design work done to understand how to deploy the vertical services via the 5Growth platform enabling the RAN slice feature, which allows the partitioning of radio resources for the traffic of the COMAU use case services. Basic testing has been already performed using preliminary NSDs and VNFs to validate the full-service instantiation.

The integration with the 5G EVE platform is in progress, with the objective of showing the automated provisioning of a distributed COMAU service, with components of the application deployed in COMAU premises and in the 5G EVE facility in Turin. This integration follows the principles defined in 5Growth for the interaction with the ICT-17 platforms. The interaction between the 5Gr-VS and the 5G EVE Portal is mediated through a dedicated driver developed in the project and it allows to request the deployment and execution of an experiment for the COMAU use case under the coordination of the 5G EVE platform. A further driver in the 5G EVE Interworking Framework has been implemented to instantiate the service components at the COMAU premises, requesting the provisioning of the associated network service to the 5Gr-SO operating on the COMAU resources.

3.2.3.5. Task 3.5: Integration with vertical systems and execution of Transportation EFACEC_S Pilot

This task is devoted to the integration and execution of the Transport EFACEC_S Pilot.

The execution of this task is led by ALB and counts on active contributions of EFACEC_S, MIRANTIS, NXW, CTTC, IT and SSSA. Partners have been focusing on the specific use cases of this pilot, while considering the general aspects of deployment over ICT17 platforms defined at WP3 level, integration of WP2-developed innovations, iterative hand-over to testing and validation activities at WP4, and timely dissemination and communication of results in cooperation with WP5.

According to the contingency plan defined on D3.2, to M18 there is a fully functional 5G SA network encompassing an Open 5G Core and 5G SA RAN ASOCs (CU+DU, RU) deployed at IT Labs Aveiro. Furthermore, the EFACEC_S setup that concerns all the relevant components necessary to evaluate the use case 1 and use case 2 are in place and the first preliminary KPIs measurements were carried out. The setup in IT Labs Aveiro concerns all the 5G and relevant vertical components that will be deployed in the pilot site, Aveiro harbor, during the second phase (after M18) of this task. Phase 1 guaranteed that all the use cases requirements, interoperability and performance, were meet before the deployment on the pilot site, which is a more demanding environment.

FIGURE 21: EFACEC_S USE CASES 1&2

3.2.3.6. Task 3.6: Integration with vertical systems and execution of Energy EFACEC_E Pilot

This task is devoted to the integration and execution of the Energy EFACEC_E Pilot.

The execution of this task is led by ALB and counts on active contributions of EFACEC_E, MIRANTIS, NXW, CTTC and IT. Partners focus on the specific use cases of this pilot, while considering the general aspects of deployment over ICT-17 platforms defined at WP3 level, integration of WP2-developed innovations, iterative hand-over to testing and validation activities at WP4, and timely dissemination and communication of results in cooperation with WP5.

According to the contingency plan defined on D3.2 to M18, there is a fully functional 5G SA network encompassing an Open 5G Core and 5G SA RAN ASOCs (CU+DU, RU) deployed at IT Aveiro Labs. Furthermore, the EFACEC_E setup that concerns all the components necessary to evaluate the use case 1 is on place and the first preliminary KPIs measurements were carried out. The setup in IT Aveiro Labs concerns all the 5G and vertical components of use case 1 that will be moved to the pilot site at the selected Secondary Substation in Aveiro University during the second phase of this task.

FIGURE 22: EFACEC_E UC1 – SECONDARY SUBSTATION AUTOMATION IN IT LAB AND CONTROL CENTER SOFTWARE IN DATACENTER

3.2.3.7. Deviations

Work package activities of T3.1 and T3.2 were completed in full scope, quality and according to time plan.

Tasks T3.3, T3.4, T3.5 and T3.6 were timely started but then seriously affected from the violent start of the COVID-19 pandemic in the countries where 5Growth pilots are planned for execution, and to-date pilot and trial activities accumulated a delay of 3 months vs the original time plan.

3.2.3.8. Corrective actions

From the very start of COVID-19 outbreak, given that the nature of day-to-day pilot implementation activities demands frequent and physical presence in the labs and premises selected for hosting 5Growth pilots, special attention was put on identifying critical risks and defining and implementing mitigation plans.

Emphasis on corrective actions was aimed to (*i*) minimizing the effect on WP3 mid-term plan, prioritizing development and online coordination activities vs high-touch integration and testing activities in labs until access restrictions would be raised, and (*ii*) intensifying the coordination with other work packages, for not only preventing side effects on potentially affected work packages (with WP4) but also anticipating alignment with other ongoing project developments (with WP2) and accelerating early results on the Dissemination and Communication space (with WP5).

With this mitigation plan WP3 has been able to remain very active towards its mid-term goals and contributing to projects goals within and beyond WP3 in a cost-effective way along the first wave of COVID-19 pandemic. However, the contingency plans for catching up with the delayed pilot implementation activities, due to critical access restrictions to the labs where pilots are to be integrated for hand-over to WP4, cannot make up for the long period of access restrictions and a delay of 3 months over the original plan is currently estimated.

3.2.4. WP4

WP4 main objective is to evaluate core (network) and service (application) KPIs through 5Growth field trials, validating the applicability of 5G technologies to the different use cases considered by the project pilots. This does not only include the execution of the different verification campaigns, but also the definition of the measurement and testing methodologies applied in the campaigns. WP4 will provide a detailed description of these methodologies and a series of tools to enable the automation of the verification procedures, the processing of the measurement data and the reproducibility of the verification results. This way, WP4 is committed not only to perform pilot verification, but also to do so in a systematic way that would guarantee scientific (engineering) quality and contribute these findings and tools for their application elsewhere.

The work in WP4 is aligned with WP2 and WP3, addressing three innovate/deploy/validate cycles during project lifetime. WP4 applies the appropriate releases produced by WP3, that incorporate the

modules produced in WP2, and selects the applicable experimental environment for the corresponding cycle, comprising:

- Data sources and consumers, including the metadata for them.
- External tools to be applied, available through the project tool catalogue.
- Specific measurement methods, documented in the deliverables.

Pilot use cases are validated in the context of the successive releases of the experimental environments, and reported in the associated deliverable, including the environment characteristics and the outcome of the verifications run during the period. As said above, these reports are planned to apply the successive WP3 releases:

- M18: Initial validation results, at ICT-17 premises.
- M23: Results of full verification campaigns performed at the 5G ICT-17 facilities.
- M27: Results of full verification campaigns performed at the pilot sites.

According to this plan, the work package is structured in six tasks:

1. An analysis task dedicated to the characterization of the different KPIs (T4.1).
2. A design task focused on the definition and deployment of the experimental environments (T4.2).
3. Four verification tasks, one per pilot, concentrated on the actual execution of the validation campaigns for the corresponding pilot (T4.3 to T4.6).

Main outcomes of WP4 are collected in the deliverables released until M18, D4.1 [17] and D4.2 [18], comprising:

- The identification of core 5G KPIs, surveying the original 5G-PPP KPIs plus the considerations brought by the 5G IA TMV-WG, and our supporting ICT-17 project 5G EVE and 5G-VINNI.
- The definition of general service KPIs, and the mappings between the identified service KPIs and the vertical functional requirements listed in D1.1 for each use case.
- The mapping between the identified core KPIs and the service KPIs.
- A description of the available measurement methodology and tooling, including the use of WP3 release and the application of WP2 innovations.
- The results of the first verification campaigns at the different pilots.

D4.1 provided a formal definition of the KPIs identified by the 5Growth project, with the purpose of evaluating the four different vertical pilots of the project on Industry 4.0, Transportation, and Energy. The KPIs defined are divided into two categories: Core 5G KPIs and Service KPIs. The former KPIs are defined as the technical KPIs that can be directly measured on the use cases' infrastructure and network. On the other hand, the latter KPIs are defined as the key performance indicators that allow validating a business and industrial scenario from the vertical point of view.

The Service KPIs are identified taking into consideration the business and functional requirements of the verticals gathered in D1.1, with the objective of validating the correct operation of the 5G use cases deployed using the 5Growth platform. However, due to their high-level definition, they are not directly measurable over the use cases infrastructure. This is the reason why the deliverable includes

a mapping between Core 5G KPIs and Service KPIs, in such a way that by measuring specific combinations of Core 5G KPIs, certain Service KPIs can be correlated. The Service KPIs identified, along with their corresponding mapping to Core 5G KPIs, are applied to each of the pilot use cases, with the goal of defining the KPIs that need to be fulfilled in order to demonstrate that the performance delivered by the implementation of the different use cases satisfy the expected requirements defined in D1.1.

Finally, D4.1 includes an assessment on the impact of the lockdowns caused by COVID-19 in WP execution, with each pilot describing how the KPI verification can be affected by the pandemics.

As the first deliverable in a series of three, focused on reporting verification results, the structure of D4.2 provides the general pattern for further contents in D4.3 and D4.4, that will be arranged around the same idea of combining reports on the evolution of methodology and tooling, and the analyses of verification results. The verification methodology and associated tooling provide the common substrate to the execution of verification campaigns, working to enhance their quality, guarantee repeatability and reproducibility as essential features of experimental reports, and contributing to a better understanding of the mechanisms to aggregate and process telemetry data for data-enabled network management. The validation campaigns are intended to collect evidence about the fulfilment of the core 5G and service KPIs in the contexts of the different pilots, analyzing the collected data and producing reports to verify the applicability of 5G technologies in the associated scenarios. D4.2 details the validation goals for each service KPI (as defined in D4.1, section 3) per each pilot in the reported campaign, as shown in the following table.

TABLE 12: SERVICE KPIS CONSIDERED BY EACH PILOT IN THE FIRST VALIDATION CAMPAIGN

	Industry 4.0 (INNO)	Industry 4.0 (COMAU)	Transportation (EFACEC_S)	Energy (EFACEC_E)
5GR-SKPI-1	X			
5GR-SKPI-2	X	X	X	X
5GR-SKPI-3	X	X		
5GR-SKPI-4	X	X	X	X
5GR-SKPI-5	X			
5GR-SKPI-6	X			
5GR-SKPI-7	X	X		
5GR-SKPI-8	X			
5GR-SKPI-9	X			
5GR-SKPI-10			X	X
5GR-SKPI-11				

The successive WP4 deliverables will be structured around the same idea of combining reports on the evolution of methodology and tooling, and the analyses of verification results. WP4 foresees these contents will evolve according to the scheme depicted in the figure below

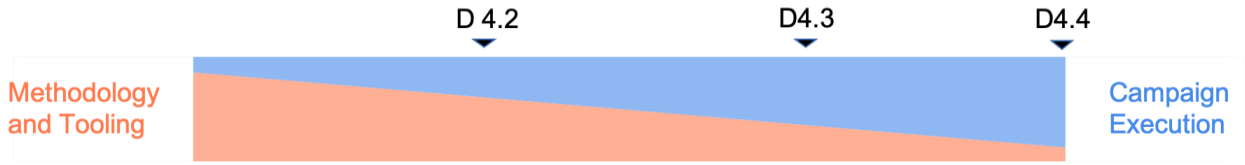


FIGURE 23: FORESEEN EVOLUTION OF WP4 DELIVERABLE CONTENT

where the amount of information focused on methodology and tooling will decrease, while the one reporting results and analyses from verification will increase, as the project matures.

3.2.4.1. Task 4.1: Service KPI identification and core KPI characterization

This task applied the service requirements, and the architecture and functional extensions identified in other WPs to:

- Analyze well-known core KPIs (as defined in D4.1), adapting them in the framework of the project industrial scenarios, and identify and describe any additional core KPIs required by these scenarios.
- Define service KPIs, establishing their relationships with the core KPIs.

This task was led by TELCA, with contributions from UC3M, NEC, IDG, NBL, TID, ALB, COMAU, EFACEC_S, EFACEC_E, INNOVALIA, NXW, CTTC, IT, NKUA, POLITO and SSSA. The work in this task is reported in D4.1, with most of its content produced by T4.1, and in the further refinement on the connections between core and service KPIs provided in D4.2 [18]. The following table summarizes the outcome of the analysis of these mappings.

TABLE 13: MAPPING BETWEEN 5GROWTH SERVICE KPIS AND CORE 5G KPIS

5GR-SKPIs	Core 5G KPIs										
	CKPI-1	CKPI-2	CKPI-3	CKPI-4	CKPI-5	CKPI-6	CKPI-7	CKPI-8	CKPI-9	CKPI-10	CKPI-11
5GR-SKPI-1					X	X					
5GR-SKPI-2	X	X									
5GR-SKPI-3		+	+	X	X					X	X
5GR-SKPI-4		X	X					X	X		
5GR-SKPI-5	X				X						
5GR-SKPI-6		X	X		X						
5GR-SKPI-7	X	X	X	X	X		X				
5GR-SKPI-8	+	X	X								
5GR-SKPI-9	-		X		X						
5GR-SKPI-10					X						
5GR-SKPI-11	X		+								

3.2.4.2. Task 4.2: Verification methodology and tooling

Task 4.2 is in charge of the definition and implementation of the methodology for the different verification campaigns, the identification of measurement techniques and the corresponding tools, and the integration of the different data sources, processors and data consumers to support the report of verification results. Task 4.2 provides the common substrate to the execution of verification campaigns, working to enhance their quality, guarantee repeatability and reproducibility as essential

features of experimental reports, and contributing to a better understanding of the mechanisms to aggregate and process telemetry data for data-enabled network management.

This task is led by TID, with UC3M, IDG, NBL, ALB, COMAU, EFACEC_S, EFACEC_E, INNOVALIA, MIRANTIS, NXW, TELCA, CTTC, NKUA and SSSA as contributors. The work done in this task is reported in D4.2, constituting the bulk of deliverable contents, specifically:

- The measurement procedures applied by the different pilots, both for core and service KPIs, in the framework of the applicability of these measurements to identify the performance conditions that will support the assessment of service operation, as shown in Figure 24.

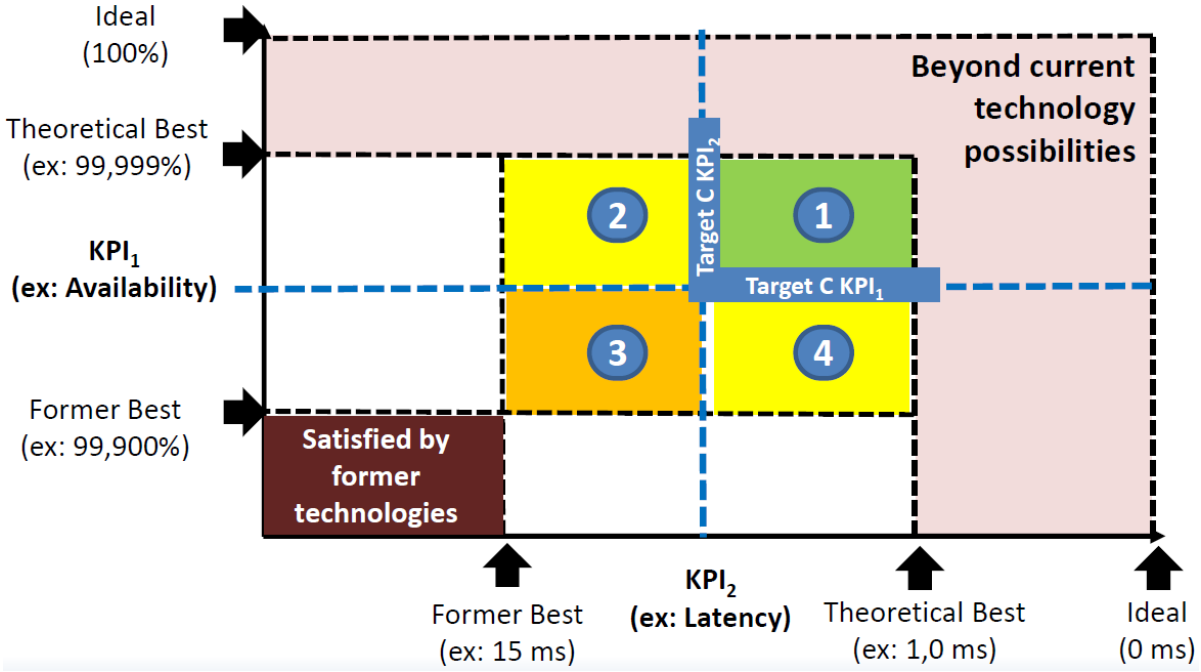


FIGURE 24: MEASUREMENT PROCEDURES

- A description of the external tools used for performing (or deriving) the required measurements, including those used for integrating monitoring platforms and the commercial network testing tools in use at the ICT-17 testbeds. A design of a catalogue for these tools is provided as well.
- An analysis of the components of the 5Growth *data infrastructure*, including data sources of all nature, data aggregation mechanisms and data consumers, together with the metadata gluing these components. A discussion on how this data infrastructure can be integrated with the other components of the 5Growth architecture and the different ICT-17 sites is provided as well, as summarized in Figure 25.

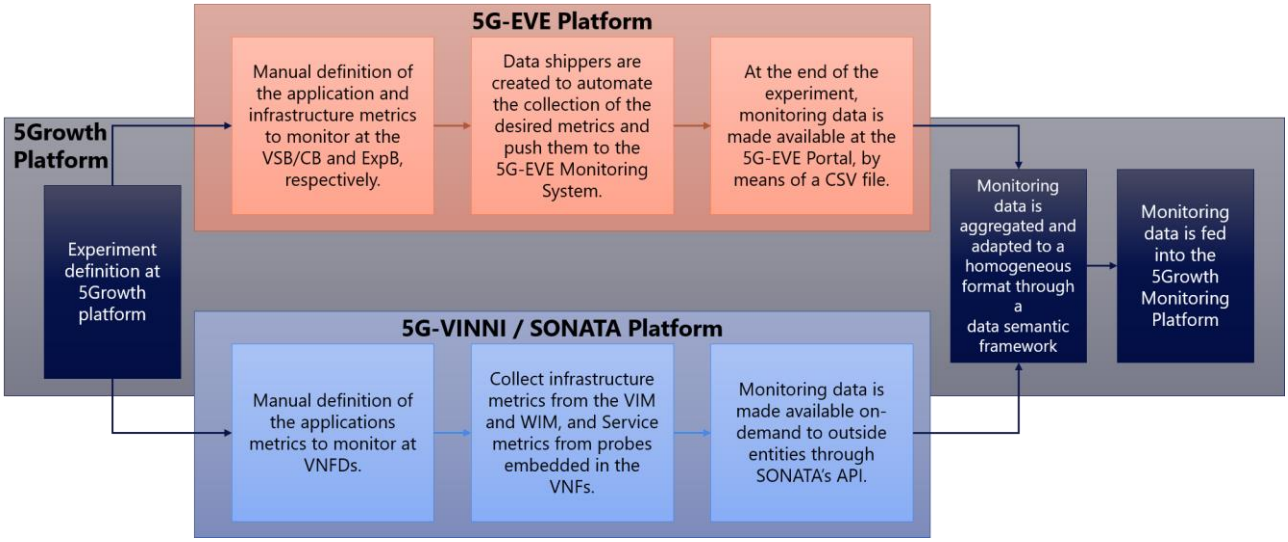


FIGURE 25: HIGH-LEVEL WORKFLOW FOR MONITORING DATA BETWEEN 5GROWTH AND ICT-17

3.2.4.3. Tasks 4.3 to 4.6: Verification and validation campaigns for the different pilots

These tasks perform the necessary validation campaigns to collect evidence about the fulfilment of the core 5G and service KPIs in the contexts of the different pilots, analyzing the collected data and producing reports to verify the applicability of 5G technologies in the associated scenarios. The concrete goals and participants in each of these tasks are as follows:

- Task 4.3, on the I4.0 INNOVALIA pilot. Led by INNOVALIA, with NEC, ERC, IDG, NBL, MIRANTIS, NXW, TELCA and CTTC as participants.
- Task 4.4, on the I4.0 COMAU pilot. Led by COMAU, with IDG, TEI, MIRANTIS, NXW, CTTC, POLITO and SSSA as participants.
- Task 4.5, on the transportation EFACEC_S pilot. Led by EFACEC_S, with ALB, MIRANTIS, NXW, CTTC, IT and SSSA as participants.
- Task 4.6, on the energy EFACEC_E pilot. Led by EFACEC_E, with ALB, MIRANTIS, NXW, CTTC and IT as participants.

For each of these tasks, a measurement architecture has been designed and deployed, and is reported in D4.2 [18].

For Task 4.3, the measurements are mainly obtained by means of set of probes placed in the network so they can inspect the packets and obtain the desired metrics. Most of these probes are deployed on the router installed at the same rack as the user plane component of the 5G EPC or the 5GCore (5GC).

In Task 4.4, the measurements were performed on a testbed with a setup comprised of two PC Engines APU2C4 embedded boards (APU_108 and APU_109) at either ends of the mobile infrastructure (i.e., from the 5G CPE to the EPC), connected to the infrastructure devices by Gigabit Ethernet links.

Since they share the testbed, both Task 4.5 and Task 4.6 have run their validation campaign using similar measurement deployments, with end-to-end tests between GbE/10GbE/100GbE ports (depending on the available Ethernet ports) to characterize IP connection through a 5G terminal (DUT) connected to a mobile network backbone, with the test equipment connected to both sides simultaneously. The test included several traffic flows, defined according to the worst conditions that can load the 5G terminal.

The following figure illustrates the measurement setups for the first validation campaign run by the different tasks.

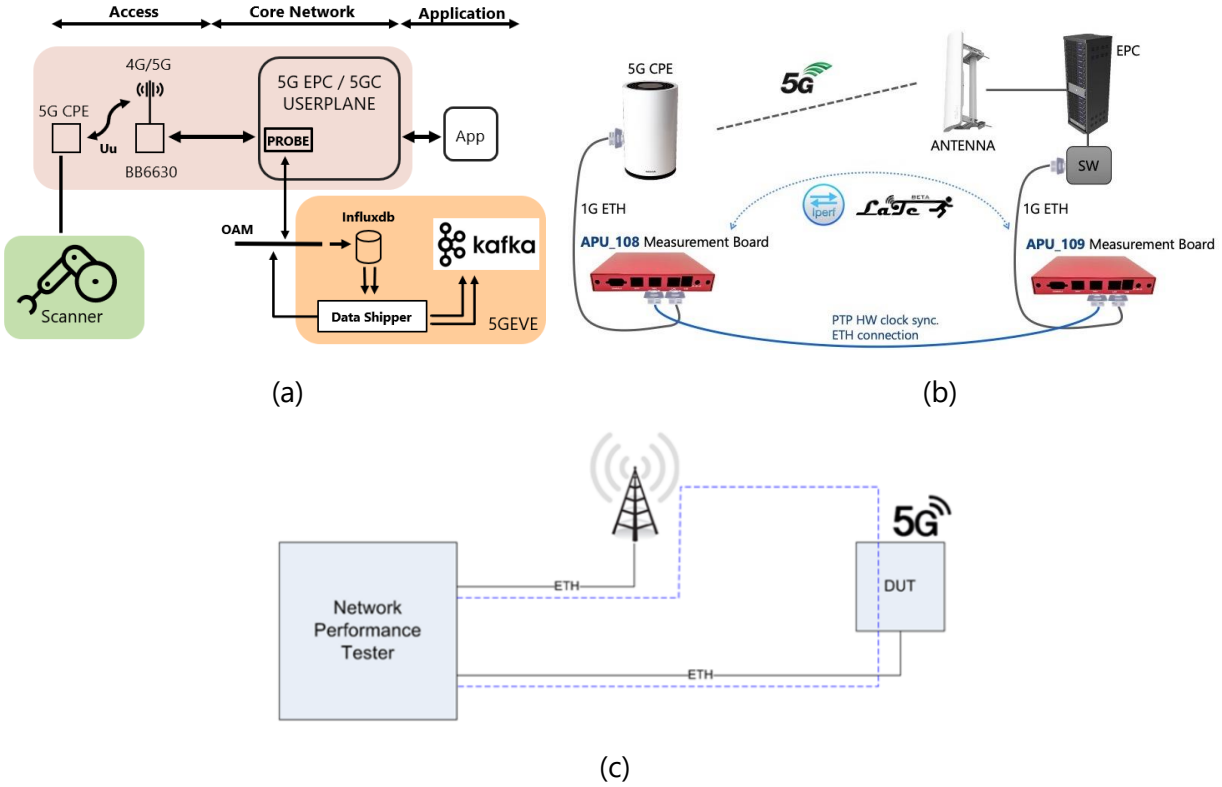


FIGURE 26: MEASUREMENT SETUPS FOR (A) TASK 4.3, (B) TASK 4.4, (C) TASKS 4.5 AND 4.6

These tasks have performed the analysis of the COVID-19 impact on their corresponding pilots, provided in D4.1 [17], though the tasks had not been formally initiated by its time of delivery. The main results of these tasks are reported in the corresponding sections of D4.2 [18], one per pilot. These sections describe the results of those measurements that could be performed for the available use cases, including the experience and lessons learned so far. As said above, successive WP4 deliverables (D4.3 and D4.4) will bring an increasing contribution from these tasks, as the project platform matures.

3.2.4.4. Deviations

While Task 4.1 was completed according to the initially proposed plan, and Task 4.2 goes according to the original schedule, the impact of the lockdowns caused by COVID-19 is estimated in two month-delay with respect to this originally planned schedule.

3.2.4.5. Corrective actions

Given the nature of WP4 activities and the dependency of actual validation campaigns on unrestricted access to pilot sites, the team recommended to ask for a two-month extension, according to the following schedule (Figure 27).

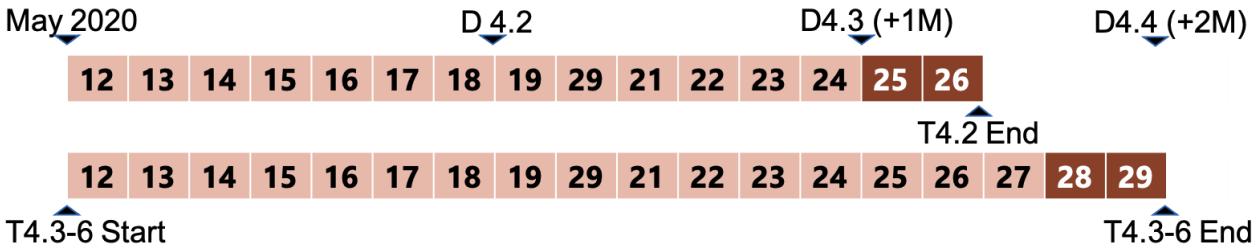


FIGURE 27: WP4 RESCHEDULE PROPOSAL

Though not directly affected by the impact of lockdowns, the same extension is proposed for T4.2 as for T4.3-6, which would allow for a better alignment of the methodologies and data infrastructure with pilot requirements.

3.2.5. WP5

As far as this project is concerned, and in accordance with common practice at the EU level [21][22], Communication includes all the activities related with the promotion of the project and its results beyond the project own community. This includes the interaction with other research projects (e.g., H2020 5G-PPP) as well as communication of its research in a way that is understood by the non-specialist, e.g., the media and the public. Dissemination includes activities related with raising awareness of its results in a technical community working on the same research field. In general, this will be done through publications, and participation and organization of technical events. Finally, exploitation (in accordance with the European IPR Helpdesk) covers activities aiming at using the results in further research activities other than those covered by the project, or in developing, creating and marketing a products or processes, or in creating and providing a service, or in standardization activities.

Though a brief global overview is provided in the following paragraphs, the detailed work carried out in WP5 is reflected in various sections throughout this document. Communication activities (i.e., the outcome of Task 5.1) are presented in this section, Dissemination activities (i.e., the outcome of Task 5.2) are presented in Section 2, and Exploitation activities (including standardization) are presented in Section 3.5, and are also an outcome of Task 5.2. Finally, Section 4 refers to D5.2 [1] for an updated communication, dissemination, and exploitation plan (CoDEP) of 5Growth.

In accordance with the communication, dissemination, and exploitation plan (CoDEP) presented in the DoA (see Figure 28), the first reporting period includes the *Raise Awareness* and part of the *Presentation of Results* phases. The former is mainly devoted to publicizing the scope and approach of 5Growth. This phase started with the preparation of communication material as well as the website and social media and with the publication of multiple press release (project-wide and per-partner).

Therefore, Task 5.1 had an initial starring role. As a consequence, various project partners presented the project in various events, gave lectures on project-related topics, and prepared the website and social media of the project (including videos of demonstrations and workshops). This allowed achieving the milestone set for M3 (August 2019), which also included the preparation of communication material, such as the leaflet and poster. Since the project started, there has been a steady increase of the web and social media impact, for instance, reaching around 114,000 visits in total on the web or 550+ Twitter impressions per day. Communication actions for society at large were also carried out. In fact, several talks targeting general public were also given during this period.

Though dissemination actions were also undertaken during the initial period of the project, dissemination and exploitation (Task 5.2) increased in importance during the second phase of CoDEP. A number of papers (15 in Journals and 13 in conferences/ workshops) were accepted and/or presented in international journals and conferences (e.g., IEEE/ACM Transactions on Networking, IEEE Communications Magazine, IEEE Transactions on Network Service and Management, ACM Mobicom, ACM Conext, IEEE INFOCOM, IEEE NFV-SDN, IFIP Networking).

Despite the COVID-19 impact, one event was co-organized jointly with other 5GPPP projects (5G EVE, 5G-VINNI, 5G-Tours) and also 5G-DIVE, and another co-organized event was also approved and will be co-located with Globecom'20. Furthermore, other online and regular events were organized by 5Growth (e.g., Layer123 5Growth webinar, workshop co-located with 5G World Forum). In addition to jointly organized events, the project is regularly participating in 5G-PPP working groups, and preparing joint papers and white papers. The project also regularly participates in 5G-PPP COMMS group, an action aiming at joint dissemination strategy of all 5G-PPP projects, hence 5Growth regularly exploits these joint channels. A remarkable achievement in this respect is the selection of one of the 5Growth pilots to be included in the top 10 list of the 2nd ed. of the EC H2020 5G Infrastructure PPP - PPP T&Ps Brochure n°2.

The project also carried out multiple regular and online demonstrations in renowned conferences (e.g., Mobicom, Mobihoc, OFC, INFOCOM) and in the 5G-PPP TB eWorkshop, as well as in other online events organized by 5Growth. Furthermore, multiple talks in several events were also given and multiple theses (Master and PhD) were/are supervised by 5Growth researchers.

As for standardization, a standardization advisory committee (SAC) was specifically created to coordinate the work, continuously refine the roadmap and maximize impact of 5Growth standardization activities. As part of these roadmap, 39 contributions to various SDOs were submitted: 10 to IETF/IRTF, 8 to 3GPP, and 5 to ETSI, and 16 to IEEE.

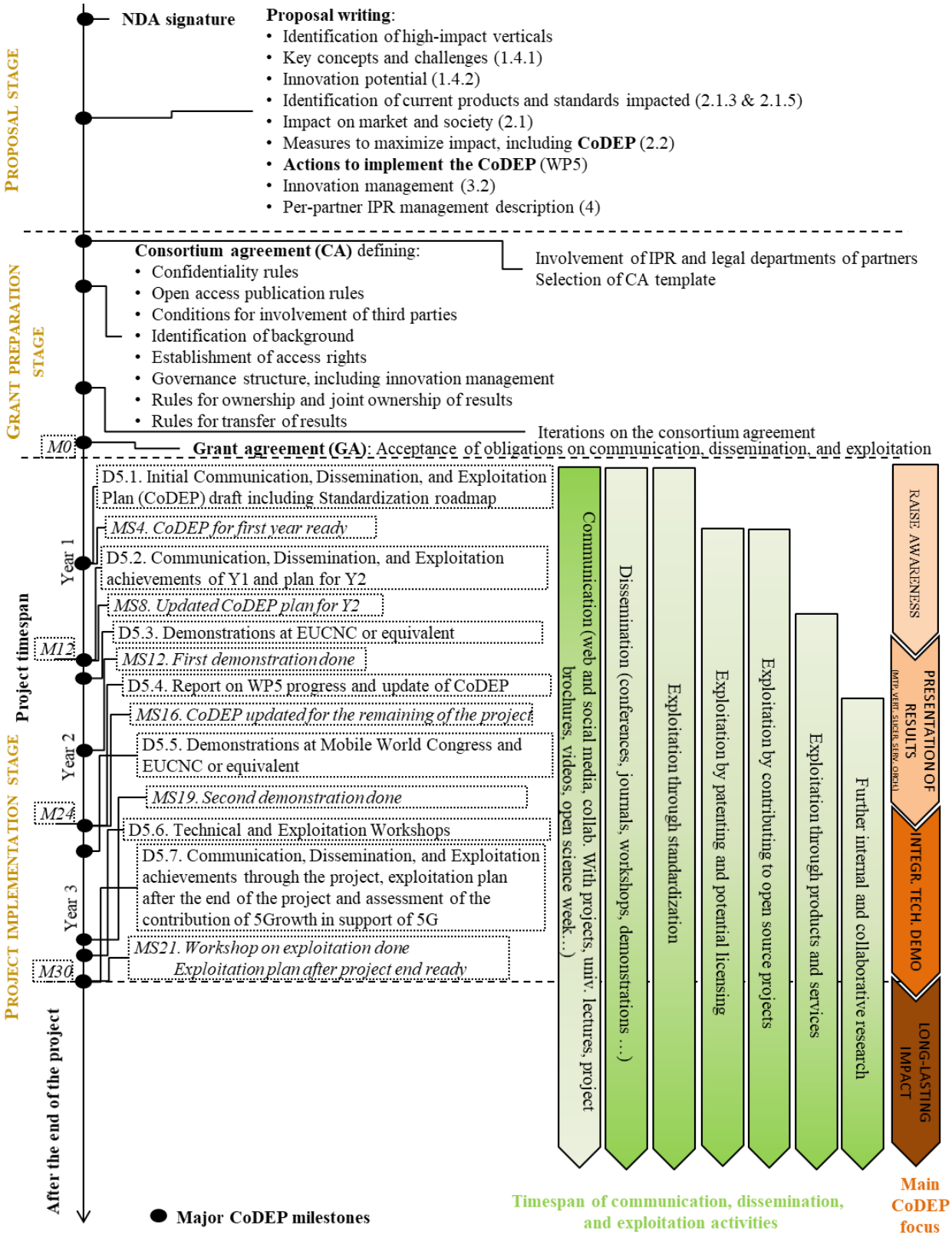


FIGURE 28: 5GROWTH COMMUNICATION, DISSEMINATION, AND EXPLOITATION PLAN (CODEP)

As mentioned above, the following subsection focuses on communication activities since dissemination and exploitation are reported in Section 2 of this document.

3.2.5.1. Task 5.1: Communication activities

This section reports on the communication activities undertaken to publicize the objectives and outcomes of 5Growth to an as wide as possible audience, with particular emphasis on actions specifically targeting a non-technical audience. In particular, all 5Growth partners promote the project to the general public at large, and many activities (e.g., social media and video post, press releases and news release, communication articles published, etc.) were carried out, as presented in the following subsections. In this sense, a long list of press releases was produced by various partners (including operators, vendors, and academic partners) to publicize the project. Furthermore, project, WP and task leaders generated the generic publicity material (posters/leaflet) and prepared the initial content for the web. From then on, the content in the web is periodically updated according to the information sent by partners in the CoDEP record, which are then moved to the website and other social media channels. Various partners (e.g., CTTC, SSSA, EFACEC_S) participated in events for society at large to explain the scope and potential impact of 5Growth. Several videos prepared by various partners (e.g., UC3M, CTTC, NEC, ERC, COMAU, TEI, EFACEC_S) have also been uploaded to the project YouTube channel. Furthermore, academic partners also produced lecture material for graduate and undergraduate courses on topics related with 5Growth.

In this section, we report the achievements for the first periodic report of the project related to communication activities. Overall, the project overcame its targets as reported in Table 14.

TABLE 14: COMMUNICATION ACTIVITIES ACHIEVEMENTS AND TARGETS

Type	Achieved	Target (per year)
Press Releases and News	18	2
Poster	1	1
Leaflet	3	1
Communication Presentations	5	1

Additionally, the project produced 10 communication videos, 2 communication articles and prepared 5 course syllabi in which 5Growth-related concepts were included.

3.2.5.1.1. News and press releases

The first official project press release was issued on July 27 2019, in Madrid, Spain. Additionally, partners also released their own internal (company-wide) and external press releases. Project news are available at: http://5growth.eu/blog/. Other relevant activities are publicized through the various

social media accounts of the project. A list of some of the news on 5Growth that have appeared, either published by partners or as news in other websites are:

- http://ir.interdigital.com/file/Index?KeyFile=398573395
- https://www.5tonic.org/news/5tonic-selected-5growth-project-validate-advanced-5g-trials-across-multiple-vertical-industries
- http://5growth.eu/2019/09/03/plenary-meeting-in-pisa/
- https://www.santannapisa.it/en/news/5g-infrastructure-and-telecommunication-systems-santanna-school-partners-eu-project-test
- http://5growth.eu/2019/09/17/5growth-in-torino-italy/
- https://www.uc3m.es/ss/Satellite/UC3MInstitucional/es/Detalle/Comunicacion_C/1371277997033/1371215537949/Europa_prepara_cuatro_pruebas_reales_del_5G_en_aplicaciones_industriales
- https://5growth.eu/svn/5growth/execution/WP5/T5.1_Communication_activities/Press%20Releases%20and%20news/191017_UC3M_PressRelease_EuropePrepares4Real5GtestIndustrial_Spanish.docx
- http://5growth.eu/2019/10/16/europe-prepares-four-5g-pilots-in-industrial-applications/
- https://www.innovaspain.com/5growth-pone-a-prueba-la-tecnologia-5g-en-la-industrial-espanola/
- http://5growth.eu/2019/11/18/510/
- https://www.layer123.com/articles/Layer123%20to%20host%20a%205Growth%20webinar%20series%20on%205G%20use%20in%20industry
- http://5growth.eu/2020/07/02/layer123-to-host-a-5growth-webinar-series-on-5g-use-in-industry/
- http://5growth.eu/2020/07/02/online-workshop-layer123-5growth-powering-5g-in-industry-9-july-2020-10am-cet/
- https://5growth.eu/2020/10/08/%f0%9f%92%bbworkshop-5g-trials-in-europe-5g-experimentation-facilities-and-vertical-trials/
- https://5growth.eu/2020/11/15/best-fast-track-paper-award-in-ieee-nfv-sdn-2020/

The following figures (Figure 29 and Figure 30) present the poster and leaflet of the 5Growth project.

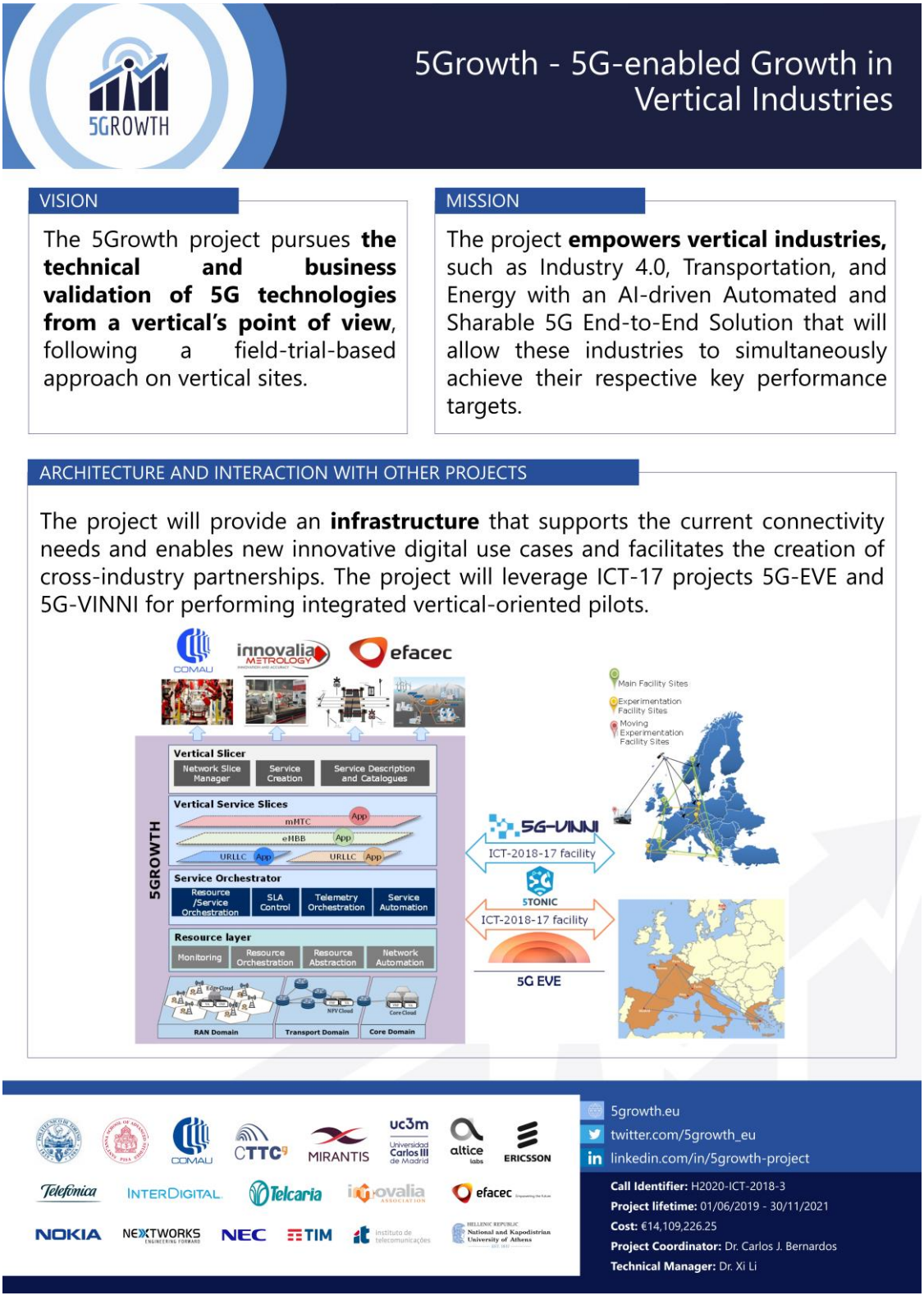


FIGURE 29: 5GROWTH POSTER

5Growth: 5G-enabled Growth in Vertical Industries

PROJECT COORDINATOR

Carlos J. Bernardos
UNIVERSIDAD CARLOS III DE MADRID (UC3M)

TECHNICAL MANAGER

Xi Li
NEC LABS EUROPE (NEC)

PARTNERS

START DATE: 01/06/2019

END DATE: 30/11/2021

COST: 14,109,226.25 €

MORE INFORMATION

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@5growth_eu

linkedin.com/in/5growth-project

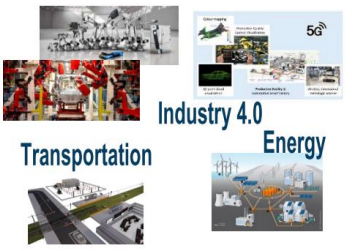
MAIN OBJECTIVES

The objective of 5Growth is the technical and business validation of 5G technologies from the verticals' points of view, following a field-trial-based approach on vertical sites (TRL 6-7). Its vision is to empower verticals industries, such as Industry 4.0, Transportation, and Energy with an AI-driven Automated and Sharable 5G End-to-End Solution that will allow these industries to simultaneously achieve their respective key performance targets. Towards this vision, 5Growth will automate the process for supporting diverse industry verticals through:

A vertical portal in charge of interfacing verticals with the 5G End-to-End platforms, receiving their service requests and building the respective network slices on top,

- Closed-loop automation and SLA control for vertical services lifecycle management, and
- AI-driven end-to-end network solutions to jointly optimize Access, Transport, Core and Cloud, Edge and Fog resources, across multiple technologies and domains.

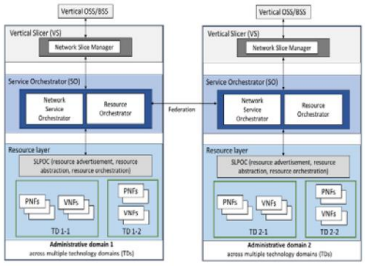
VERTICAL PILOTS AND USE CASES



CONCEPTS & CHALLENGES

5G platform for multi-RAT, multi-platform, multi-domain mobile networks that bridges the gaps resulting from Phase 1/Phase 2 projects while leveraging the potentials of ICT-17 platforms to deliver end-to-end services. Main challenges:

- Design and implementation of a platform, and the related components, interfaces and algorithms, to empower verticals to provision 5G connectivity and services directly at the verticals' sites.
- Automated multi-level, cross-domain, hierarchical service orchestration with multi-domain management of resources with seamless integration at vertical sites with existing platforms.



- Vertical-oriented trial-based assessment, incl. 5G PPP KPIs.
- Tight integration between 5Growth and ICT-17 testing facilities with the goal of measuring KPIs and validating 5G capabilities.
- Quantification of the advantages of the use of slicing, virtualization and orchestration.

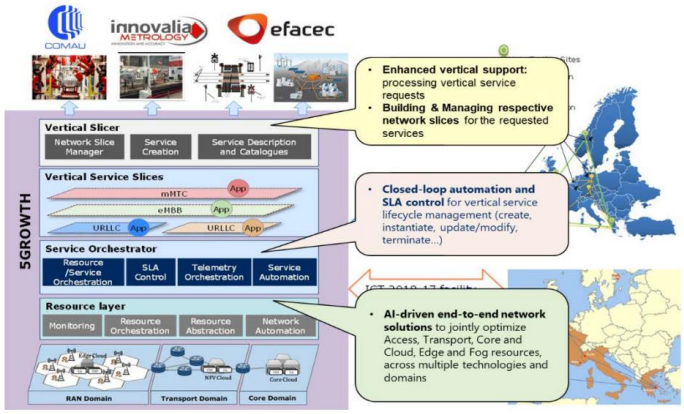


FIGURE 30: 5GROWTH LEAFLET

3.2.5.1.2. Web, social media, and project communication material

The project website has been established at the beginning of the project and it is reachable at the following URL: http://5growth.eu/. Recently a new section entitled "Vertical Industries" includes vertical related activities (e.g., the External Vertical Industries Advisory Board). The landing page is reported in Figure 31.

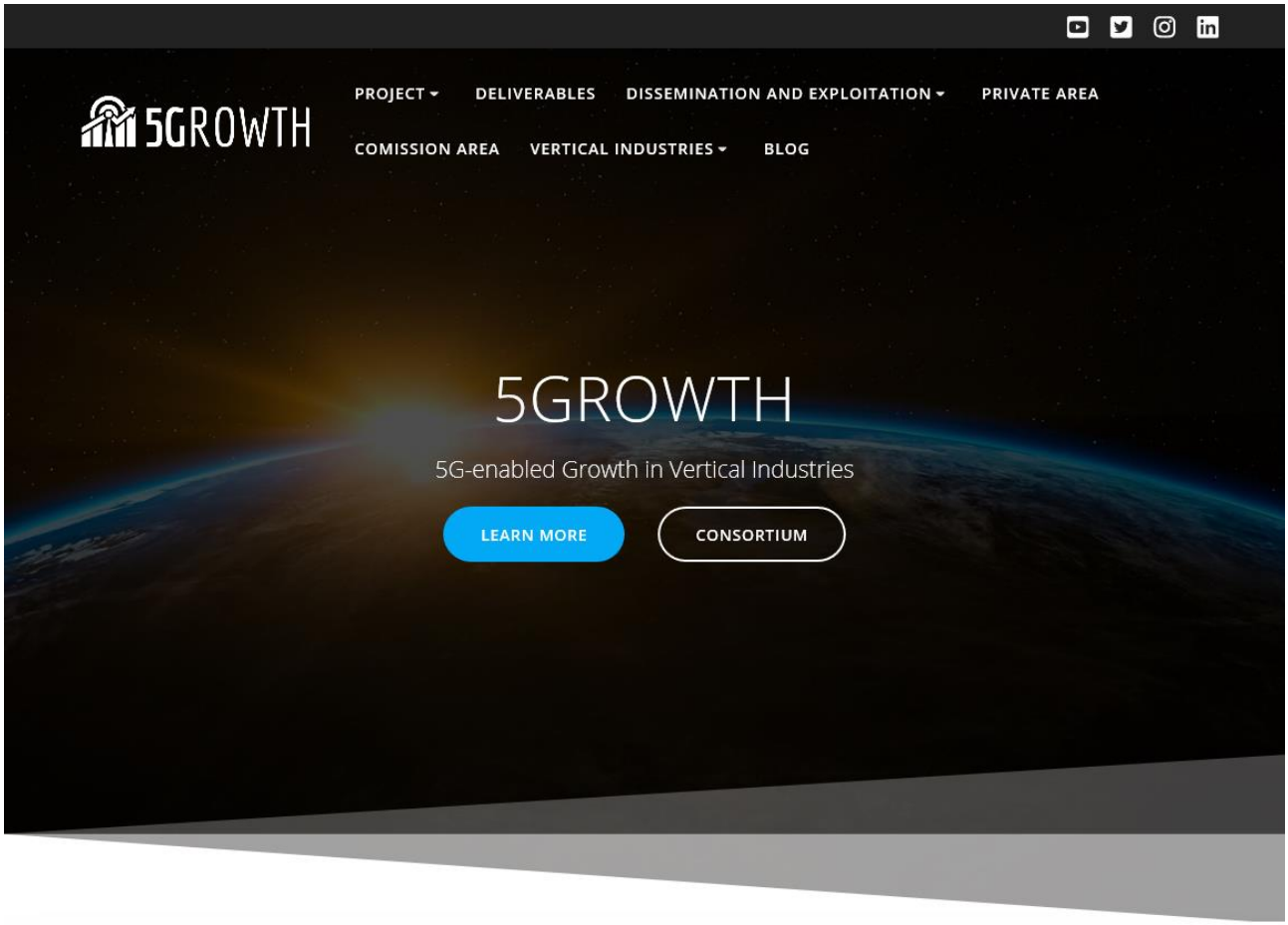


FIGURE 31: 5GROWTH WEBSITE LANDING PAGE

Statistics have been gathered for the website. They are reported in Figure 32. It can be observed that, since the beginning of the project (i.e., "last 365 days" statistics), more than 114,000 visits have been achieved.

	Visitors	Visits
Today:	46	101
Yesterday:	24	70
Last 7 Days:	325	980
Last 30 Days:	1,339	3,585
Last 365 Days:	20,294	67,470
Total:	28,359	114,403

FIGURE 32: OVERALL WEBPAGE HITS (MEASURED ON NOV. 9, 2020)

In detail, as shown in Figure 33, and depending on the period, the most popular subpages are the ones related to the consortium events or the consortium itself, though in general the deliverables and publications pages are among the top ones (in addition to the landing page).

Top Pages

ID	Title	Link	Visits
1	Home Page	/	6,279
2	5GROWTH in Torino, Italy	/2019/09/17/5growth-in-torino-italy/	886
3	Plenary Meeting in Pisa	/2019/09/03/plenary-meeting-in-pisa/	418
4	Deliverables	/deliverables/	343
5	Home Page	/index.php	301
6	Europe prepares four 5G pilots in industrial applications	/2019/10/16/europe-prepares-four-5g-pilots-in-industrial-applications/	243
7	Consortium	/project/consortium/	184
8	Project	/project	177
9	Project	/project/	161
10	Consortium	/project/consortium	149

FIGURE 33: DETAILS OF VISITED WEBSITE PAGES (SEP.-NOV. 2019)

The project has been very active in other social media such as LinkedIn and Twitter. LinkedIn and Twitter accounts are the following:

- LinkedIn: www.linkedin.com/in/5growth-project
- Twitter: https://twitter.com/5growth_eu?lang=es

As for LinkedIn, the number of connections, defined as contacts you know personally and who you trust on a professional level, that the 5Growth profile gathered since the beginning of the project, has been steadily growing, reaching 460 as of the time of writing.

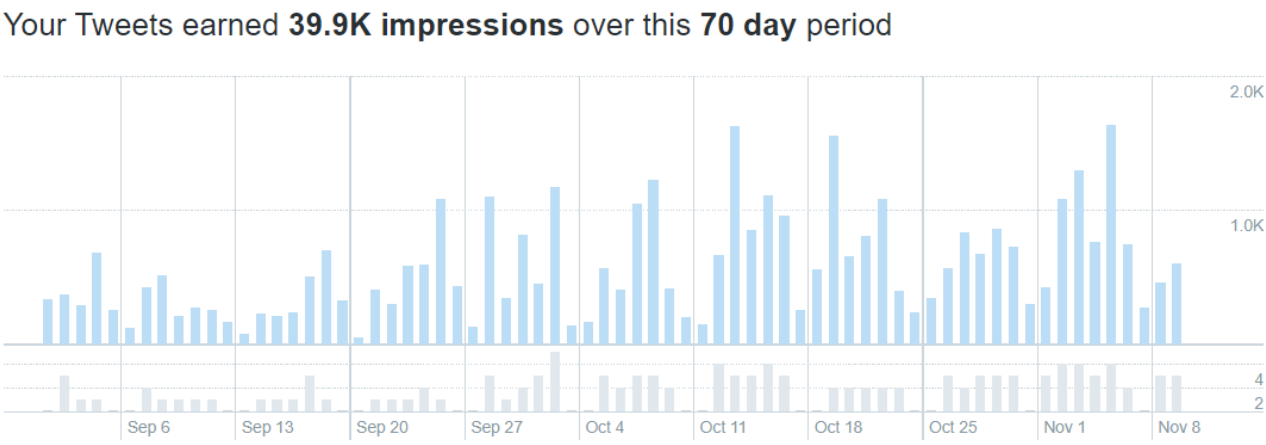


FIGURE 34: SAMPLE TWITTER STATISTICS

Figure 34 depicts a recent sample or tweet impressions, defined as a count of how many times a tweet has been viewed. As shown, the project is reaching a high number of impressions with a peak of almost forty thousand for this 70-day period (Sept.-early Nov. 2020). This results in 578 impressions per day.

Activities are also present on Instagram as reported in Figure 35. The Instagram account of the 5Growth project is https://www.instagram.com/5growth_h2020/

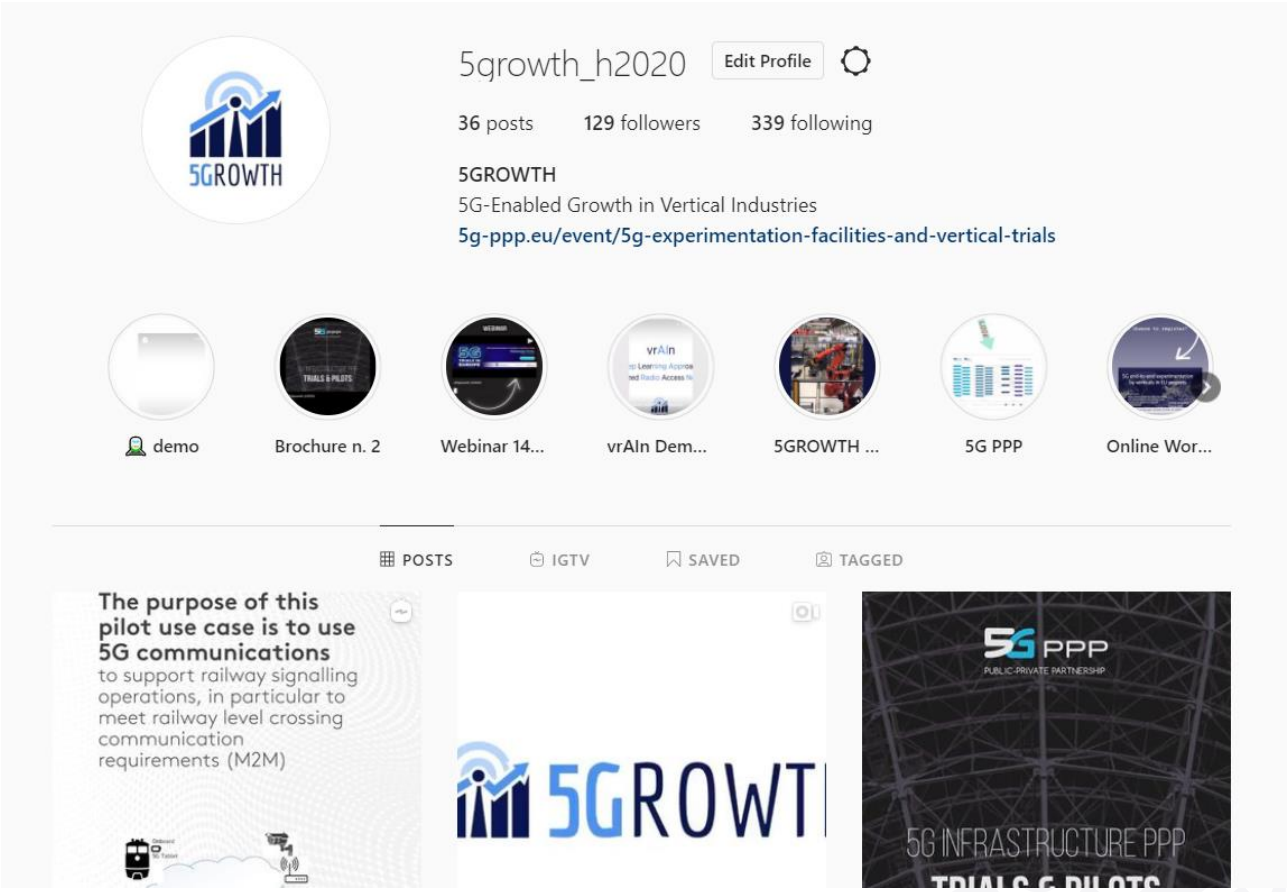


FIGURE 35: EXAMPLE OF INSTAGRAM ACTIVITIES

Finally, the 5Growth project has an active YouTube channel through which talks, demos, and communication videos are published. The uploaded videos are:

TABLE 15: LIST OF VIDEOS PUBLISHED IN THE 5GROWTH YOUTUBE CHANNEL (AS OF NOV. 30, 2020)

Item	Explanation
Presentation of 5Growth in ICT-19 session @ EUCNC'19	Presentation given at EUCNC'19 in the ICT-19 session. Available at 5Growth channel: https://youtu.be/73tJLtfZfgg, and also at EUCNC channel https://youtu.be/O_-DOIxjQYE (starting at 1:02:26)
Introduction video to 5Growth	https://www.youtube.com/watch?v=wPt5v9V52f4
First meeting of the 5Growth External Vertical Industries Advisory Board (EVIAB)	https://www.youtube.com/watch?v=7uC0SN0F79g
5G end-to-end experimentation by verticals in EU projects Online Workshop	https://youtu.be/YMn5WMIaEV8
Online Workshop – Layer123/5Growth: Powering 5G in Industry	https://www.youtube.com/watch?v=AsrpwH6zudM
5Growth: 5G-enabled Growth in Vertical Industries	https://www.youtube.com/watch?v=A6otrNNL_bY
Demo: vrAIn Proof-of-Concept. A Deep Learning Approach for Virtualized RAN Resource Control	https://www.youtube.com/watch?v=1I8mcnHQcW8
5G for Industry 4.0: COMAU pilot, Video Describing COMAU Pilot	https://youtu.be/tlyQBmRbNf0
Transportation Pilot during the Aveiro Tech Week	https://www.youtube.com/watch?v=IH5PIs6QbvI
Second meeting of the 5Growth External Vertical Industries Advisory Board (EVIAB)	https://www.youtube.com/watch?v=7AioiT_qeGQ

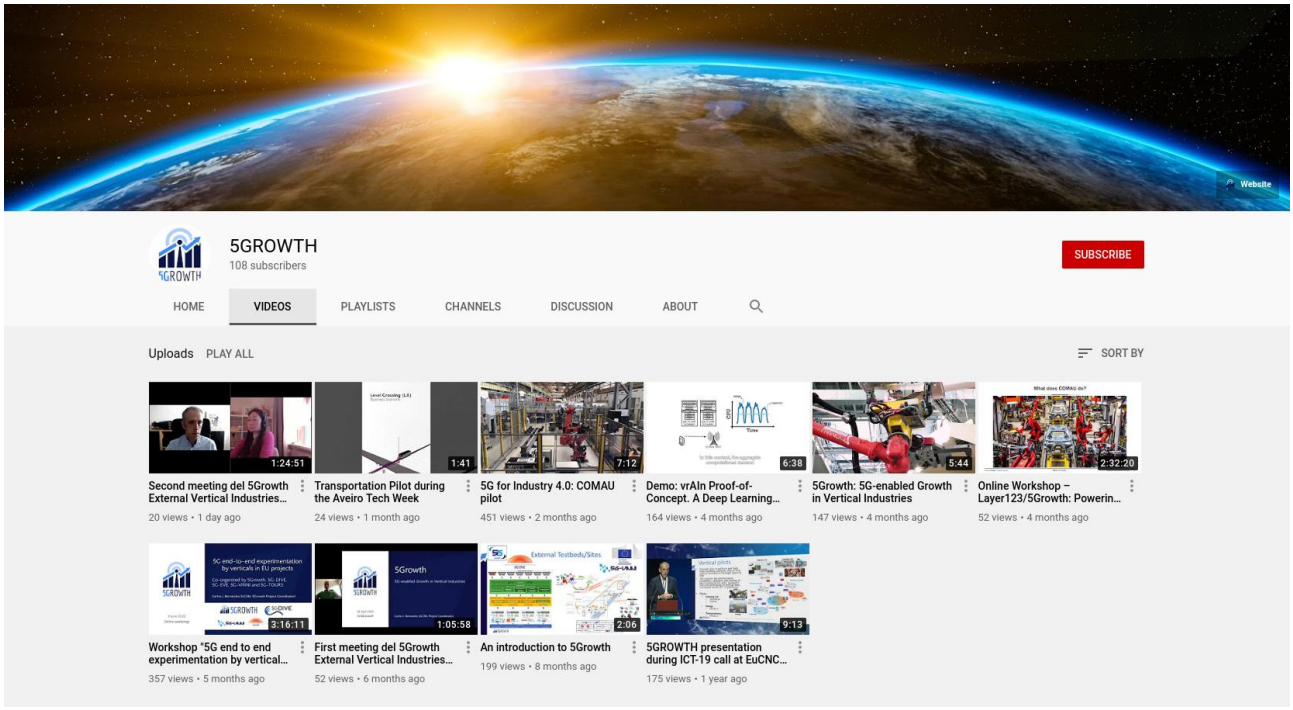


FIGURE 36: VIDEO FROM THE 5GROWTH YOUTUBE CHANNEL

3.2.5.1.3. Communication talks and other actions

Five communication talks (Table 16) have been given since the project started as part of the Raise Awareness Phase of the CoDEP. In this sense, the focus is on explaining the high-level goals, main building blocks, and verticals involved, including the general technological framework of the project to the general public.

TABLE 16: COMMUNICATION TALKS

#	Title	Event
1	The 5Growth project	Internet Festival, Oct. 10-13, Pisa, Italy https://www.internetfestival.it/en/home
2	5G Networks: Why? What? How?	24th Science week, Nov 8-17, Castelldefels, Spain http://www.cttc.cat/24th-science-week/
3	The 5Growth project	Aveiro TechDays. Dissemination of 5Growth project by Aveiro Harbour, Aveiro, Portugal. October 2019. http://ww2.portodeaveiro.pt/sartigo/index.php?x=7090
4	5G challenge (virtualization and edge computing)	Demonstration to general public during Bright researchers' night 2019. Sep. 27-28, 2019, Pisa, Italy. http://www.bright-toscana.it/bright/
5	5G Networks (and beyond)	25th Science week, Nov. 17, online http://www.cttc.cat/25th-science-week/

Additionally, internal communication actions have also been undertaken inside the partner organizations, through internal news and talks.

Furthermore, two communication articles about the project were also published:

- "Projeto 5Growth valida comunicações avançadas de 5G," in Power:on magazine (Efacec's internal magazine) (in Portuguese)
- "Overview of 5Growth", in European 5G Annual Journal 2020.

Finally, academic partners of the consortium prepared several courses on SDN/NFV-related topics that are taught to graduate and undergraduate students, which benefit from the 5Growth work. A preliminary list of the courses is presented in Table 17.

TABLE 17: LECTURES AND COURSES

#	Title	Host organization
1	Master in NFV and SDN for 5G networks	UC3M Telematics Department Link
2	Advanced Communication Networks	NKUA Dept. of Informatics and Telecommunications Link
3	Intelligence at the Edge of 5G for enabling 5G services	TIM Academy on 5G and Edge Computing Link
4	Cloud Computing (Master Course)	Politecnico di Torino Link
5	Software networking (Master Course)	Politecnico di Torino Link

3.2.5.2. Task 5.2: Dissemination and Exploitation

All activities related with dissemination are reported in Section 2.

All partners participated to the various dissemination activities of the project. Several conference and journal papers were published by multiple partners. Furthermore, partners have also actively participated in 5G-PPP working group activities towards coordination of efforts with the other projects. This is reflected by the regular active participation to meetings, as authors of documents produced (including white papers published and ongoing, brochures), or joint organization of events. Many events physical, and more recently, online (due to COVID-19) were organized by multiple partners (also in cooperation with other projects. Multiple demonstrations have also been presented in physical and online events and participation through talks in multiple events has also been spread across all partners. Finally, academic partners have also initiated (and in some cases finished) multiple theses. All these activities are listed in detail in Section 2.

3.2.5.3. Deviations

During this first reporting period, the project achieved all its milestones in due time and progress was as expected. So, no deviations had to be handled. Given the lockdown situation due to COVID-19, which, in some cases, prevented access to pilots and labs for prototype development and deployment, the project refocused efforts in communication and dissemination activities that were not initially planned in the final intensity they were done. This allowed producing more papers and

videos, as well as other material (e.g., participation in the 5G-PPP trials and pilots brochure). Furthermore, the number of online events with 5Growth participation and (co-)organization also increased.

3.2.5.4. Corrective actions

No corrective actions needed.

3.2.6. WP6

The management of the project, dedicated WP in the DoA, is led by UC3M.

The main activities in this period are related to ensure that the project runs successfully, that the partners successfully and efficiently collaborate and that 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 European Commission of the distribution of the EU financial contribution. The PC verified consistency between the reports and the project tasks and monitors the compliance of beneficiaries with their obligations.

In M1, the Deliverable D6.1 (Project Handbook) was delivered on time. It includes the management procedures for the proper development and implementation of the project.

During this reporting period, three amendments have been carried out, but two of them were Commission initiated (related to H2020 program updates). The main changes implemented in the consortium-requested amendment (May 2020) are listed below:

- Termination of InterDigital Germany GmbH (IDG) as partner. Its linked third party, InterDigital Europe Ltd. (IDCC) will take the baton.
- Substitution of WP leaders of WP1 and WP3.
- Logo has been changed for the new one in the DoA.
- Other minor changes and updates.

The Project Management Team (PMT) started in early March 2020 analyzing the impact of COVID-19 in anticipation of possible scenarios. We finalized a first assessment of potential scenarios and we worked on a set of contingency plans as well as on the changes that might be required to the project plan, due to the unavoidable delays that the COVID-19 pandemic has generated, especially in a project like 5Growth, where integration and validation activities are key.

Due to the COVID-19 pandemic, different actions have been taken. Deliverables D3.2 and D4.1 included considerations regarding COVID-19 impact. Many trips and meetings have been cancelled. Partners did all in their hands to avoid cancellation or penalty costs associated to the cancelled trips, but this has not been always possible.

We have been in direct and constant communication with our Project Officer since the beginning and we have continued to do so at each step in the process. One of the actions agreed with him is

to propose a 2-month extension of the project to cope with the encountered delays. It is worth noting that reaching this 2-month period involves significant effort from the partners, as delays due to COVID-19 have been longer in some activities and we have planned intensified efforts to catch-up with some of these delays.

3.2.6.1. Task 6.1: Project administrative, financial, and legal management

In this period (M1-M18) seven plenary meeting were held: the Kick-off Meeting and three progress meetings:

- Kick-off Meeting on June 11-12, 2019 in Madrid (hosted by UC3M). This meeting focused on the general aspects of the project, the main objectives and the main activities of each partner. Special efforts were put into working out the best ways of interacting between WP2, WP3 and WP4.
- 2nd plenary meeting on September 17-19, 2019 in Turin (hosted by POLITO). The meeting focused on the first technical deliverables as well as on the approaches for the integration with ICT-17.
- 3rd plenary meeting on January 14-16, 2020 in Aveiro (hosted by IT). The main topics discussed during the meeting were the planning for the first experiments, and the preparation of EuCNC 2020 (all this had to change due to COVID-19).
- 4th plenary meeting on March 31 to April 2, 2020, hold virtually due to COVID-19. The meeting on assessing the impact of COVID-19, while still progressing on the planned technical work.
- 5th plenary meeting on July 14-16, 2020, hold virtually due to COVID-19, followed by a short (virtual) meeting on July 23. In this meeting, the approach followed was slightly different, making the whole meeting in plenary mode (instead of combining it with parallel WP-specific sessions), to adapt better to the virtual/remote format.
- 6th plenary meeting on September 30, 2020, followed up by another meeting on October 9, both hold virtually. Both meetings followed a plenary mode, and we decided to keep them as half-day duration to focus the effort on the experimental activities that took place those days. The meeting focused on the preparation for the first technical review of the project.

Initially, weekly technical remote meetings (per WP) were held to allow synchronization between the different partners using a collaborative tool for audioconferences (gotomeeting). As the project made more progress, some of these meetings have changed to bi-weekly frequency. A shared calendar is used to reflect and share the planned remote meetings to keep the partners informed about 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 of the Quarterly Management Reports. A final report is planned for the end of the project (M30).

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

- Redmine: a web-based 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. This includes a shared calendar for meetings bookkeeping.
- SVN repository: the repository where documentation and software have been stored and shared among the partners.
- Several mailing lists have been created in order to communicate with the partners: 5growth-all, 5growth-wp1, 5growth-wp2, 5growth-wp3, 5growth-wp4, 5growth-wp5, 5growth-wp6, 5growth-pb, 5growth-pmt, 5growth-admin and 5growth-contact.
- Private git repositories to host the code developed in the project and allow for faster tests and integration.
- Public GitHub repositories, where we upload the open source components of each major release: https://github.com/5growth

The 5Growth website is available from the beginning of the project (https://5growth.eu). Moreover, Twitter (https://twitter.com/5growth_eu/), Instagram (https://www.instagram.com/5growth_h2020/), LinkedIn (https://www.linkedin.com/in/5growth-project/) accounts and a YouTube channel (https://www.youtube.com/channel/UCfIAsV6AdEibRteQp2ftpgw) have been created.

3.2.6.2. Task 6.2: Technical coordination, Innovation and Quality management

This task is led by NEC as technical manager, and UC3M and TEI participate as project coordinator and innovation manager, respectively. NEC as the project technical manager, leads the technical innovations for the project and coordinating the work of all WPs. UC3M as project coordinator ensures the project progresses towards its objectives. TEI as the innovation manager has monitored the innovation and exploitation activities.

5Growth has set-up an External Vertical Industries Advisory Board (EVIAB). The EVIAB is a body that provides non-binding technical advice to the management of 5Growth. EVIAB is composed of accomplished representatives from other verticals/sectors not represented in the project with expertise relevant to the goals of 5Growth: SEGITTUR, GMV and SigFoX. Current members of the EVIAB are:

- Carlos Romero, Director of Research, Development and Innovation of SEGITTUR.
- Enrique Domínguez Tijero, technical leader at GMV.
- Juan Carlos Zúñiga, lead of the standardization and IP strategies at Sigfox.

The informal nature of an advisory board gives greater flexibility in structure and management. The EVIAB meets with the Project Management Team (PMT) to provide their feedback and advice on technical directions and potential challenges. The PMT further informs the EVIAB about public deliverables, and the EVIAB promotes results gained within 5Growth.

5Growth has met the EVIAB twice during the first reporting period: 28 April 2020 and 12 November 2020, both online due to the COVID-19 situation. During these meetings, 5Growth presented the

status and results of the project, and the EVIAB provided valuable insights and recommendations. Both meetings were recorded and published on the 5Growth YouTube channel.

3.2.6.3. Task 6.3: Interaction with other projects of the H2020 5G Infrastructure PPP

Within 5G-PPP, the project participates in the cross-project work groups (WGs), where the work of multiple projects can converge into identifying the shared issues and developing supported program level position on technical and strategic items. 5Growth project partners participate to multiple 5G-PPP working groups, namely (we indicate the 5Growth representative partner in brackets):

- Pre-Standardization (IDCC): active participation in the pre-standardization Working Group including (*i*) providing inputs on 5Growth standardization activities captured in a standardization Impact report released in November 2020 by the WG, and, (*ii*) presenting on the B5G standardization roadmap including topics of particular relevance to 5Growth such as support of industry verticals, private networks, related requirements and enabling technologies in the short, medium and long terms towards Network 2030.
- Vision and Societal Challenges (IT): organization of the "2nd Visions for Future Communications Summit, Technologies and Services Towards 6G", on the 27th and 28th of November 2019, Lisbon, Portugal; and, participation and organization of periodic conference calls.
- 5G Architecture (NEC): active participation to the 5G PPP Architecture WG. The 5Growth project will be presented on Dec. 11. 2020, and will also contribute to the next planned Architecture WG white paper.
- Trials (ERC): attendance to periodic conference calls.
- SME (TELCA): attendance to periodic conference calls.
- Software Networks (NBL): active participation to the 5G PPP Software Networks WG and attendance to periodic conference calls. The 5Growth project was presented in February 2020. 5Growth contributed to a 5GPPP SN WG brochure for MWC 2020 on "Cloud Native and 5G Verticals' services" and a 5GPPP-SN WG workshop proposal for EUCNC 2020 (that did not take place due to the Covid-19 breakout). The project also contributed to the 5GPPP SN WG white paper "Edge Computing for 5G Networks".
- Security (TID): attendance to periodic conference calls.
- Test, Measurements and KPI Validation (ERC): attendance to periodic conference calls.

Their scope is described at: https://5g-ppp.eu/5g-ppp-work-groups/. This participation includes presenting and representing the project in all periodic meetings that are organized and participation in joint actions (e.g., co-organization of events, joint documents/papers, joint demonstrations).

Additionally, the project also participates in the 5G-PPP boards towards a tight coordination with the rest of 5G-PPP projects: the project coordinator in the steering board and the technical manager in the technology board.

3.2.6.4. Deviations

Overall, the work package is proceeding as planned.

3.2.6.5. Corrective actions

No corrective actions needed.

3.3. Deliverables

Deliverable Progress			
	On Schedule	Delayed	Completed
D1.1			X
D1.2			X
D1.3	X		
D2.1			X
D2.2			X
D2.3	X		
D2.4	X		
D3.1			X
D3.2			X
D3.3			X
D3.4			X
D3.5	X		
D3.6	X		
D4.1			X
D4.2			X
D4.3	X		
D4.4	X		
D5.1			X
D5.2			X
D5.3			X
D5.4	X		
D5.5	X		
D5.6	X		
D5.7	X		
D6.1			X
D6.2			X
D6.3	X		

3.4. Milestones

Milestones Progress			
	On Schedule	Delayed	Completed
M1			X
M2			X
M3			X
M4			X
M5			X
M6			X
M7			X
M8			X
M9			X
M10			X
M11			X
M12			X
M13	X		
M14	X		
M15	X		
M16	X		
M17	X		
M18	X		
M19	X		
M20	X		
M21	X		

3.5. Exploitable Results

3.5.1. Exploitation on commercial products and PoCs developed internally to the companies

According to the exploitation plan, this first part of the activity, has been devoted to defining, design and implement some relevant features with the target to assess them in experimental environment of the pilot or as specific proof of concepts. Table 18 reports the target commercial product or platform with the corresponding 5Growth component as declared in the plan, with the corresponding status at M18 in the last column.

TABLE 18: EXPLOITATION TABLE

Short Name	Platform/ product	Description of impact on platform/product	5Growth component	Status at M18
ALB	Operations Support Systems portfolio	This portfolio is currently in the process of evolution to a new generation of OSS systems, which will benefit from lessons learned about orchestration and	Vertical Slicer/ Service Orchestrator	The learning process concerning orchestration and management of 5G infrastructures is an ongoing activity mainly focused on SONATA platform. The KPIs

		management of 5G infrastructure through the development and evaluation of the EFACEC use cases. http://www.alticelabs.com/en/operations_support_systems.html		collected so far on the context of EFACEC_S and EFACEC_E use cases, as well our experience with SONATA platform, has been very positive. We expect that this technology will give us an important contribution for the design of a new generation of ALB OSSs.
COMAU	Operations Support Systems in production lines	5Growth 5G Pilots will allow COMAU to evaluate the evolution of its Operation Support Systems in production lines towards 5G. Specifically, use cases developed and experimented in 5Growth will target the innovative networking platform (https://www.comau.com/en/innovation-and-digital-transformation/ingrid)	5G Pilot	The 5G Pilot has been set in COMAU premises and initial measurements have been done to assess the requirements of the 5G. The use cases 1 and 2 have particular impact on Ingrid platform, that includes MES (i.e the system that manages the production lines). Moreover, the transport measurements done in this first period assessed the feasibility of leverage on a shared network for more services including URLLC. This allows to further reduce TCO and potentially increase the advantages of the use of 5G technology.
EFACEC_E	GSmart & view4grid	A current main concern to EFACEC is the competitiveness of its products and systems. The 5Growth project results will allow EFACEC to strengthen its portfolio of solutions for Smart Grids by adding innovative communications features to the products' configuration options. The major benefits will impact on EFACEC's portfolio for Smart Grids' applications integration and deployment, a set of solutions designed to implement flexible management and monitoring over an entire smart electrical infrastructure, including high-level platforms with management software and web user interfaces, smart meters and sensors, data concentrators and distributed	5G Pilot Vertical Slicer/ Service Orchestrator	The first phase of Energy pilot is in place at IT Aveiro Lab, comprehending Use Case 1 "Advanced Monitoring and Maintenance Support for Secondary Substation MV/LV distribution substation". Preliminary measurements took place to assess the requirements of the 5G communications. This use case has a strong impact on the future strategy of MV/LV power network management, since URLLC and eMBB provide the means to extend the power network real-time supervision and control to the Secondary Substations.

		controllers, or any other type of IP capable device. https://www.efacec.pt/en/automation/		
EFACEC_S	DigiXSafe	Participation in the project will allow EFACEC_S to develop new signaling systems products, it will open new commercial windows over the market of next generation of signaling systems that are under the standardization and digitalization efforts resulted from of the EULYNX consortium project and Shift to Rail Join Undertaking towers 2020. https://www.efacec.pt/en/transportation/	5G Pilot	EFACEC have defined the roadmap for the new signaling systems named Xsafe (DigiXsafe). According to this roadmap, Xsafe 4.0 will be released in the 3rd Quarter of 2022, which will support 5G technology and the outcomes of 5Growth.
INNOVALIA	Metrology Software M3	The participation of INNOVALIA in the 5Growth Project will allow the extension of its portfolio of products and services offering not only the remote control of its Quality Control Equipments but also a decision support system based on the Augmented Reality to achieve the strategy of Zero Defect Manufacturing (ZDM) using the MEC to reduce the processing time of the captured data. The impact will be directly located in the Metrology Software M3 offered by INNOVALIA Metrology. https://www.innovalia-metrology.com/metrology-products/metrology-software/	5G Pilot	Pilot outputs in this reporting period include the identification and assessment of the feasibility of the use case of remote control of Quality Control Equipment. Innovalia M3 Box SW system has already been adapted for deployment in a 5G distributed environment. Business validation involves, on the one hand, determining the maximum radius of operation (max distance between the expert and the factory where M3Box is deployed), and, on the other hand, validating the possibility to decouple the deployment of robot link SW system from the M3Box 3D Scanner equipment. At the time of writing this report test cases for such goals are being executed at 5TONIC lab, and collecting extensive data for reaching to accurate conclusions.
ERC and TEI (Ericsson)	IOT Accelerator	Ericsson IoT Accelerator is a platform to develop market and manage secure IoT solutions. IoT Accelerator can benefit from the experience gained in 5Growth in relation to the IoT pilots and	Vertical Slicer, Service Orchestrator, Resource Layer	The implementation and test of the RAN SLICING allowed to demonstrate a new function in managing vertical use cases that extend current platform. A test bed in MELA center in Roma is

		relevant use cases and possibly can incorporate functionalities that could emerge from the vertical partners in the consortium. https://www.ericsson.com/ourportfolio/iot-solutions/iot-accelerator?nav=offeringarea613		set up for demonstration to customer about such new functions. The evaluation of INNOVALIA use cases is also helping evaluate the practical interwork of public and non-public networks, basing on the underlying 5G EVE platform features, to evaluate novel features for IoT orchestration solutions.
	Cloud Packet Core	Especially driven by the expected verticals cooperation's and experimentation in the 5Growth project pilots, the Cloud Packet Core platform can be enhanced especially in relation to Massive IoT support (Introducing network slices for massive IoT with a decoupled lifecycle from consumer eMBB service) and support of enterprise with dedicated instances for critical enterprise deployments, like manufacturing sites. https://www.ericsson.com/ourportfolio/cloud-core/cloud-packet-core	Service Orchestrator, Resource Layer 5G Pilot	The Innovation "Support of Radio Access in Network Slices" [I1] enables the capability to segregate the traffic for different vertical and traffic profile considering also the transport contribution. This allows providing differentiated classes of services and dedicated instances for different traffic profiles. This is a qualifying element to enable the support of more services, including low latency, on a shared networks. The slicing takes into account of the transport resources as well that is a very relevant aspect to guarantee suitable QoS. Moreover such innovation improves the automation and optimization of the infrastructure resources when more services must be supported in the same infrastructure. Tests have been performed on the 5Growth platform, integration on the COMAU pilot will be completed in the second period.
	Ericsson NFVI	Ericsson NFVI solution consists of software and hardware products as well as support and system integration services forming a complete solution for telecom operators. 5Growth can bring important elements to the platform, both in the resource layer aspects, being hardware	Vertical Slicer, Service Orchestrator, Resource Layer	Many of the innovations released in this first period (Release 1) such as "Support of Radio Access in Network Slices", "Smart Orchestration and Resource Control Algorithms", "Vertical-oriented Monitoring System" are relevant for the realization of the Ericsson NFVI

		products part of the NFVI solution, and in orchestration and virtualization functionalities. RAN-Transport solutions under definition in 5Growth projects, are under discussion internally to Ericsson for analyzing possible impact on product. At the moment, it is necessary a more consolidated assessment in PoC and experimentation, but the joint cooperation with Telefonica and TIM are considered as valuable feedback for future deployment in products. https://www.ericsson.com/ourportfolio/digital-services-solution-areas/nfvi?nav=fgb_101_0363		solutions. The Innovation is a good candidate to provide efficient solutions to optimize the transport and radio resources when the vertical use cases are supported. Several models for 5G Core functions distribution have been evaluated, and specific evaluation activities of their advantages and feasibility for the use cases of Innovalia are ongoing, in this first reporting period. That is delivering new inputs for consideration at portfolio strategy level.
IDCC	360-Degrees Adaptive Viewport Video Streaming over 5Growth	The platform showcases the concept of microservices-based design by distributing several computing tasks necessary to deliver a high-resolution 360 video streaming service to terminals with different resources and capabilities. This platform will be enhanced in 5Growth by incorporating 5Growth vertical slicer and resource layer, with the goal of demonstrating the impact of these two key components in terms of latency reduction and advanced scalability.	Vertical Slicer, Resource Layer	The 360 video streaming platform has been assessed against the end-to-end application level latency requirements of the INNOVALIA Pilot. As a result, the 360 video streaming was replaced with a professional industrial camera to get round the bottleneck latency with the 360 camera stitching functionality. The new video streaming platform combines on the same camera functionalities requiring high-bandwidth (high-resolution uplink video streaming) and low-latency (real-time augmentation and actioning based on the video stream feed analytics, as well as remote control of the camera titling and zooming capability). This is making the case for simultaneous support of 5G eMBB and URLLC slices support on the same (camera) device. This is being integrated as part of the INNOVALIA Pilot in 5Growth and is being augmented with AI-based object detection quite relevant for

				exploitation in several I4.0 applications.
MIRANTIS	Mirantis MOSK - Mirantis OpenStack on Kubernetes (This product replaces the declared product MCP- Mirantis Multicloud Platform).	MOSK - Mirantis OpenStack on Kubernetes. This product leverages on the container isolation, state enforcement, and declarative definition of resources provided by Kubernetes to deploy and manage OpenStack clusters.	Resource Layer, 5G Pilot	Mirantis announced the new generation of the product - MOSK - Mirantis OpenStack on Kubernetes. This leverages on the container isolation, state enforcement, and declarative definition of resources provided by Kubernetes to deploy and manage OpenStack clusters. MOSK replaced MCP. Comparing to MCP, this new product has advantages such as containerization of OpenStack services, reconciliation of resource state, and declarative resource definition. Currently, Mirantis team researches the advantages and approaches to use MOSK for the Pilots instead of MCP. This could potentially improve the platform reliability and time to market index, and it can simplify the management.
	K0s, which is, Mirantis Open Source product.	k0s is the simple, solid & certified Kubernetes distribution that works on any infrastructure: public & private clouds, on-premises, edge & hybrid. It's 100% open source & free.		Since k0s was announced just recently, there were no research done yet against using it in 5Growth infrastructure. In this first phase of the project, the work carried out was only the considering of using K0s as a K8s distribution to make the platform more lightweight, less dependent for the resources, portable, and less expensive for the operational resources. The next step would be to experiment with the k0s distribution as the main k8s platform to run 5Growth containers on the edge.
NEC	iPASOLINK VR Family	NEC iPASOLINK VR family (microwave backhaul): The iPASOLINK VR delivers enhanced wireless signal processing performance. The	Resource Layer	5Gr-RL´s traffic management schemes, being developed in the scope of WP2, are inspiring new features to support slicing in iPASOLINK VR products.

		design of Resource Layer abstractions and interfaces with data-plane equipment will directly impact the potential evolutions of this product family. http://www.nec.com/en/global/prod/nw/pasolink/products/ipasolink_VR4.html		
	NEC iPASOLINK EX family	In a lightweight, compact 23cm squared enclosure, iPASOLINK EX Advanced realizes industry-leading 10Gbps single link capacity features. The design of Resource Layer abstractions and interfaces with data-plane equipment will directly impact the potential evolutions of this product family. http://www.nec.com/en/event/mwc/leaflet/pdf_2017/i_pasolink_ex_advanced.pdf	Resource Layer	5Gr-RL´s traffic management schemes, being developed in the scope of WP2, are inspiring new features to support slicing in iPASOLINK EX products.
	NEC E-RAN (MEC platform)	NEC's In-Building Small Cell Solutions are easy to install and can be used for WiFi like fast deployment. 5Growth innovations on control loops for service orchestration and programmable traffic management schemes can potentially be integrated into the evolutions of this product. http://www.nec.com/en/global/solutions/nsp/sc2/sol/s02.html	Service Orchestrator	5Gr-RL´s traffic management schemes, being developed in the scope of WP2, are inspiring new methods to support slicing into NEC E-RAN products.
	NEC Active Antenna System	NEC Active Antenna System (28GHZ NR --- currently a prototype, expected to be ready by the beginning of the project). 5Growth innovations on network slicing can potentially have an impact over the evolutions of this product. http://www.nec.com/en/event/mwc/leaflet/pdf_2017/tailored_5g_network.pdf	Resource Layer	N/A. The activity carried out in first period has not impact on this product. The activity planned for the second period will be more focus on the area of NEC Active Antenna System.
	WizHaul (Transport resource management)	SDN/NFV-based centralized resource management orchestrator for mobile transport domains. 5Growth novel orchestration algorithms for monitoring and prediction	Service Orchestrator, Resource Layer	5Gr-RL´s abstractions on the transport side have steered the evolution of WizHaul.

		and automated closed-loop resource management will have a potential impact on the evolution of this product.		
	OVNES (Network slice broker)	The 5G Network slice broker is a piece of software integrated on a network controller or orchestrator. It acts as a mediator between tenants' slice requests and physical network resources availability. 5Growth novel orchestration solutions for SLA monitoring and management and automated network slice management will have a potential impact on the evolution of this product.	Vertical Slicer, Service Orchestrator	On the one hand, the vertical service descriptors and network slice templates defined within 5Gr-VS are motivating new network slice information models within OVNES. On the other hand, the integration of O-RAN-like interfaces into 5Gr-SO to support virtualized RANs are being integrated into OVNES.
	Net2Vec	Net2Vec is a flexible high-performance platform that allows the execution of deep learning algorithms in the communication network. The monitoring platform of 5Growth and its interfaces with high-speed data processing platforms can have an impact on the evolutions of this product.	AI/ML Platform	5Gr-AIMLP, being designed in the scope of WP2, is inspiring new AI/ML workflows for the evolution of Net2Vec.
NBL	Mobile, fixed and converged broadband access	The outcome of 5Growth is also expected to impact significantly NOKIA's software-defined access solutions on mobile and fixed access networks. It is foreseen the potential adoption of suggested 5Growth enhancements on programmable traffic management schemes, in NOKIA access nodes. A domain-specific language such as P4 will be adopted for this purpose and extended appropriately to allow programmability independently of the access technology employed, thus impacting NOKIA's entire mobile and fixed access product portfolio.	5G Pilot, WP2 innovations	NBL established the end-to-end testbed including P4 over a variety of access technologies. Several active NOKIA internal projects are ongoing using the testbed for programmable data-plane traffic management.

	AirScale Cloud RAN	The AirScale Cloud RAN solution consists of the AirScale Cloud Base Station Server and the Nokia AirScale Radio Network Controller (RNC). The anticipated 5Growth innovation on programmable traffic management at the RAN is expected to complement the innovations for this product suite. https://networks.nokia.com/solutions/airscale-cloud-ran	Vertical Slicer, 5G Pilot	NBL monitored the status of AirScale C-RAN solution in NOKIA and cooperated internally to deliver programmable traffic management to future RAN product suite.
	Cloud and Edge Computing Nokia AirFrame DC	The Nokia AirFrame Data Center solution offers a flexible range of data center infrastructure portfolio. 5Growth research on tools for closed-loop control, such as programmable traffic management schemes, can be potentially adopted to improve future offerings in the Nokia AirFrame Data Center. https://networks.nokia.com/solutions/airframe-data-center-solution	Vertical Slicer	NBL monitored the status of AirFrame DC solution and can potentially influence the closed-loop control scheme in the future product.
	Digital Operations Suite	The DO Suite provides and agile and modular orchestration for managing service orchestration across virtualized and hybrid networks. It is expected that 5Growth enhancements to the Vertical Slicer and Service Orchestrator (e.g., algorithms for arbitration across coexisting services, service utilization demand forecasting for appropriate vertical service dimensioning, service decomposition etc.) can steer DO innovation. https://networks.nokia.com/portfolio/service-orchestration	Vertical Slicer, Service Orchestrator	NBL had transferred algorithms for resource allocation and SLA decomposition into NOKIA digital operation center.
	CloudBand Network Director	CloudBand Network Director is an NFV resource and network service orchestrator, built for OpenStack and VMware. It provides two main functions. As a network service orchestrator, the system onboards network	Service Orchestrator Resource Layer	NBL monitored the NOKIA's CloudBand network director solution and will provide influence future product.

		services, automates their lifecycles, and provides monitoring and troubleshooting tools. As a resource orchestrator, it administers, monitors and optimizes NFV infrastructure resources across geographically distributed NFV infrastructure) nodes. 5Growth innovations pertaining to SLA-driven service management automation, resource allocation algorithms, automated optimization and self-* properties, etc., are expected to impact the (future) list of features of the CloudBand Network Director. https://networks.nokia.com/products/cloudband		
NXW	Symphony	Symphony is an integrated and open platform for smart buildings, including domotics, media services, A/V communications, video-surveillance, energy management, etc. The adoption of the resource virtualization combined with Vertical Slicer will allow evolving Symphony towards an integrated set of virtualized and distributed services able to exploit 5G technologies to improve the scalability and simplify the automated deployment and customization of the system in wider environments, towards smart city solutions. http://www.nextworks.it/en/products/brands/symphony	Vertical Slicer	As internal activities of the company, some Symphony components have been virtualized and deployed in containers. An extended version of the Vertical Slicer (under development in the company using as baseline the 5Gr-VS) can be adopted to automate the orchestration of these Symphony software modules within eMBB and URLLC network slices, dedicated to the videosurveillance, media and A/V services, and to domotics services respectively. The analysis of further extensions to address the requirements of deployments targeting Industry 4.0 environments is in progress

TELCA	Alviu	Alviu is a flexible and resilient control system that enables the integration of cloud and network services through a centralized and dynamic administration. On top of this, it reduces equipment expenses and offers a wider range of White Box Switches to enterprises. The innovations of 5Growth vertical slicer and service orchestration will impact directly on how Alviu slices and manages network infrastructure. https://www.telcaria.com/#serviceModal1	Service Orchestrator, Vertical Slicer	5Growth innovations especially the Smart orchestration innovation, have been exploited by Alviu, enabling engineers to explore new ways of deploying and monitoring Alviu components. Including the ability to add new network equipment to potentially support P4 software and hardware switches, which could enable novel ways of managing and slicing the network.

3.5.2. Exploitation on standards

5Growth thrust into standardization bodies is significant with a considerable amount of contributions bringing 5Growth technology and innovations into key SDOs forums such as 3GPP, ETSI MEC, IETF and IEEE.

As shown in Table 19, 5Growth, despite of the impact of COVID-19, is achieving its goals as the project has been able to bring a significant number of contributions to key SDOs out of which 13 of them have been adopted or agreed. The following table summarized the current status of the standardization effort in 5Growth.

TABLE 19: STANDARDS CONTRIBUTIONS

Date (yy/mm/dd)	Target SDO	ITEM/Activity	Status (Agreed/Accepted/Submitted/Approved)	Explanation
19/09/16	IEEE 802.11	https://mentor.ieee.org/802.11/dcn/19/11-19-1642-00-00bc-constraints-of-ocb-transmission.pdf	Submitted	This contribution is an analysis of the use of OCB (out of the Context of a BSS) for data frame transmission in .11bc. Does not have a direct matching to a 5Growth task but was needed for .11bc.
19/09/17	IEEE 802.11	https://mentor.ieee.org/802.11/dcn/19/11-19-1665-00-0rcm-rcm-rogue-containment-use-case.docx	Submitted	Use case presented for the RCM study group on Randomisation of MAC addresses. This use case studies the effects of randomisation of MAC addresses in rogue AP containment environments. This mechanism may be used in controlled scenarios, such as the I4.0 in order to avoid user created APs to be used in an area with controlled interference.
19/11/09	IEEE 802.11	https://mentor.ieee.org/802.11/dcn/19/11-19-1978-00-00bc-	Submitted	This contribution proposes a mechanism for service advertisement coupled with group

		service-discovery-on-ebcs-info-frame.pptx		security. The AP is broadcasting a set of eBCS services. Each service is secured by a key. This key is used to proof origin authentication. The proposed mechanism enhances the eBCS Info frame (in charge of distributing the keys to the eBCS clients, so that each Info frame can carry more than one service and more than one key. This technology is relevant for the I4.0 use cases, where different sensors or machines can receive broadcast instructions or software updates, for example, which are authenticated using this contribution.
19/11/11	IEEE 802.11	https://mentor.ieee.org/802.11/dcn/19/11-19-1978-01-00bc-service-discovery-on-ebcs-info-frame.pptx	Submitted	This is a contribution to IEEE 802.11bc. We believe IEEE 802.11bc can be used within the I4.0 and Railway scenarios since it can be used to connect low complexity sensors used in both scenarios. This contribution specifically deals with the authentication of the origin of the broadcast, and therefore can be used in critical systems such as the railway scenario.
19/11/11	IEEE 802.11	https://mentor.ieee.org/802.11/dcn/19/11-19-2017-00-00bc-service-discovery-advertisement.pptx	Submitted	This is a contribution to IEEE 802.11bc. We believe IEEE 802.11bc can be used within the I4.0 and Railway scenarios since it can be used to connect low complexity sensors used in both scenarios. This contribution specifically handles the way the services being broadcasted in the area are advertised.
19/11/12	IEEE 802.1CQ	cq-aoliva-statemachineexplanation-1119-v1.pdf	Submitted	Update to IEEE 802.1CQ
19/11/12	IEEE 802.1CQ	http://www.ieee802.org/1/files/public/docs2019/cq-aoliva-statemachine-1119-v1.pdf	Submitted	Update to IEEE 802.1CQ
19/11/13	IEEE 802.11	https://mentor.ieee.org/802.11/dcn/19/11-19-2069-01-00bc-update-on-proposed-sfd-text-for-r3-5-3.docx	Submitted	This is a contribution to IEEE 802.11bc. We believe IEEE 802.11bc can be used within the I4.0 and Railway scenarios since it can be used to connect low complexity sensors used in both scenarios.
19/11/13	IEEE 802.11	https://mentor.ieee.org/802.11/dcn/19/11-19-2069-00-00bc-update-on-proposed-sfd-text-for-r3-5-3.docx	Submitted	Above
19/11/13	IEEE 802.1CQ	http://www.ieee802.org/1/files/public/docs2019/cq-aoliva-PALMAPAD-1119-v1.pdf	Submitted	This contribution forms part of IEEE 802.1CQ. This standard defines a mechanism to assigning multicast and unicast local MAC addresses to end stations. This is relevant as a way of reducing the cost of sensors which do not need to have a hardwired MAC address. This will potentially impact any scenario using sensors.

19/11/13	IEEE 802.1CQ	cq-Marks-Oliva-update-2019-11-13-1119.pdf	Submitted	Update to IEEE 802.1CQ
20/01/08	IETF	https://datatracker.ietf.org/doc/draft-bernardos-raw-use-cases/	Submitted	Relevant to 5Growth due to the inclusion of the I4.0 use case -> This document describes different use cases of interest for reliable and available wireless networks, which is basically deterministic networking for wireless. This is extremely relevant for 5Growth use cases, especially Industry 4.0. This use case is reflected in the document. It is an individual contribution, recently adopted as WG document.
20/01/08	IETF	https://datatracker.ietf.org/doc/draft-mcbride-edge-data-discovery-overview/	Submitted	This document describes some issues and challenges of discovery data and resources at the edge of the network. This is relevant for 5Growth, as some of the applications considered in our pilots (such as Industry 4.0) might benefit from these mechanisms to optimize the overall performance in automation scenarios.
20/02/13	IEEE 802.11bc	https://mentor.ieee.org/802.11/dcn/20/11-20-0135-00-00bc-sfd-text-for-section-9-6-33.docx	Submitted	This is a contribution to IEEE 802.11bc. We believe IEEE 802.11bc can be used within the I4.0 and Railway scenarios since it can be used to connect low complexity sensors used in both scenarios. This contribution specifically handles the way the services being broadcasted in the area are advertised.
20/03/07	IETF	https://datatracker.ietf.org/doc/draft-ietf-dhc-slap-quadrant/	Adopted	It is relevant for I4.0 use cases, where a massive number of devices need connectivity and might benefit from the local addressing assignment mechanisms described in the draft -> This document describes extensions to DHCP to allow a requester (client or hypervisor) indicate the preference of the type of local address to obtain. This is applicable to 5Growth scenarios, e.g. in Industry 4.0. It is an adopted WG document at the very end of the publication process as RFC.
20/03/09	3GPP SA5	S5-201596 Rel-16 Study Item "study on non-public networks management"	Accepted	Relevant contribution for 5Growth network slicing mechanisms as means of NPN provisioning in industrial 4.0 scenarios. This is related to D3.1, because the contribution treats the use of slicing (following a NSaaS model) to provisioning public network integrated with NPNs, emphasising the public-private integration. In this sense, it is related with Section 3.4 of D3.1 ("Initial study on ICT-17 integration with 5Growth").

20/03/09	IETF	https://datatracker.ietf.org/doc/draft-bernardos-dmm-sfc-mobility/	Submitted	In some scenarios, distributed SFC control might be useful to provide extra resilience. This document describes Mobile IPv6 extensions to enable function migration in distributed SFC scenarios. It is an individual submission.
20/03/09	IETF	https://datatracker.ietf.org/doc/draft-bernardos-sfc-nsh-distributed-control/	Submitted	This document specifies several NSH extensions to provide in-band SFC control signaling to enable distributed SFC control solutions. This might be applied to some of the 5Growth use cases, to enable extra resilience by supporting distributed control. It is an individual submission.
20/03/09	IETF	https://datatracker.ietf.org/doc/draft-bernardos-sfc-distributed-control-operation/	Submitted	In some scenarios, distributed SFC control might be useful to provide extra resilience. This document describes a general framework for distributed SFC operation. It is an individual submission.
20/04/28	IEEE 802.11bc	https://mentor.ieee.org/802.11/dcn/20/11-20-0322-01-00bc-discovery-sta-service-consumption.pdf	Submitted	This is a contribution to IEEE 802.11bc. We believe IEEE 802.11bc can be used within the I4.0 and Railway scenarios since it can be used to connect low complexity sensors used in both scenarios. This contribution specifically handles the way the services being broadcasted in the area are advertised.
20/07/01	IEEE 802.1CQ	Private draft (only voting members)	Submitted	IEEE 802.1CQ draft standard.
20/07/14	IRTF NMRG	https://datatracker.ietf.org/doc/draft-contreras-nmrg-interconnection-intents/	Submitted	This contribution aims to become one of the use cases of the NMRG for intent-based systems. Its applicability within 5Growth would be related to, on one hand, how verticals can express through intents their slice needs, on another hand, how service providers can express interconnection intents among themselves for achieving that services.
20/07/20	IETF OPSAWG	https://datatracker.ietf.org/doc/draft-claise-opsawg-service-assurance-architecture/	Submitted	This document addresses the combination of different measurement sources by means of a semantics-aware data aggregator, proposed to be integrated in the IETF SAIN architecture.

20/07/20	IRTF COINRG	https://datatracker.ietf.org/doc/draft-mcbride-edge-data-discovery-overview/ --> this one is already reported by Carlos J. (UC3M), Diego (TID) joined in the new submission https://tools.ietf.org/html/draft-mcbride-data-discovery-problem-statement/ --> this one is new, contributed by Carlos J. (UC3M), Diego (TID)	Submitted	This document focuses on the problem of actually locating data, throughout a network of data servers, in a standardized way. This is again related to 5Growth, due to its potential applicability to the pilot use cases.
20/09/07	ETSI NFV TST	https://portal.etsi.org/webapp/WorkProgram/Report_WorkItem.asp?WKI_ID=58429	Submitted	Support to these work-items as targets for measurement techniques and tools, data aggregation, and the communication of pilot results as proofs-of-concept to ETSI NFV.
20/09/07	IEEE 802.11bc	https://mentor.ieee.org/802.11/dcn/20/11-20-1418-00-00bc-802-11bc-cc31-resolution-for-cids-assigned-to-antonio.docx	Reviewed	This is a contribution to IEEE 802.11bc. We believe IEEE 802.11bc can be used within the I4.0 and Railway scenarios since it can be used to connect low complexity sensors used in both scenarios. This contribution specifically removes the use of the Service Advertisement Frame since its use has been added to the eBCS Info frame.
20/09/07	IEEE 802.11bc	https://mentor.ieee.org/802.11/dcn/20/11-20-1419-04-00bc-802-11bc-cc31-resolution-for-cid-355.docx	Reviewed	This is a contribution to IEEE 802.11bc. We believe IEEE 802.11bc can be used within the I4.0 and Railway scenarios since it can be used to connect low complexity sensors used in both scenarios. This contribution specifically solves a security issue when the AP was advertising no throttling characteristics for eBCS UL traffic.
20/09/15	ETSI ZSM	https://portal.etsi.org/webapp/WorkProgram/Report_WorkItem.asp?WKI_ID=59231	Accepted	Report of the capabilities provided by OSM, as reference orchestrator for the integration of project innovations at 5TONIC, to support multi-domain closed-loop operations
20/09/15	3GPP SA5	S5-204463 Rel-17 work item "Management of non-public networks (OAM_NPN)"	Accepted	The interconnection of vertical and ICT-17 facilities is allowing the project to analyze the implications of the integration of non-public networks (NPNs) and public network services to address industrial environment requirements. This is one in a series of contributions related to the concepts and results available.

20/09/15	3GPP SA5	S5-204465 Rel-17 work item "Management of non-public networks (OAM_NPN)"	Accepted	The interconnection of vertical and ICT-17 facilities is allowing the project to analyze the implications of the integration of non-public networks (NPNs) and public network services to address industrial environment requirements. This is one in a series of contributions related to the concepts and results available.
20/07/01	ETSI MEC	MEC(20)000258 (must be a member of ETSI)	Accepted	This contribution outlined the E2E architecture framework for an intelligent edge and far edge integrated with an E2E 5G system.
20/07/01	ETSI MEC	MEC(20)000259 (must be a member of ETSI)	Accepted	This provided a description of the 5Growth I4.0 use case on zero defect manufacturing and the role of edge in supporting this use case.
20/07/01	ETSI MEC	MEC(20)000261 (must be a member of ETSI)	Accepted	This provided a description of the 5Growth I4.0 use cases involving robots/AGVs and the role of edge in supporting this use case.
20/11/09	IETF TEAS WG	https://datatracker.ietf.org/doc/draft-llc-teas-dc-aware-topo-model/	Submitted	The relation with the project is to facilitate the joint topological view of both networking and computing resources available. This can be useful for assisting on orchestration decisions in the provider side both single- and multi-domain scenarios.
20/10/18	3GPP SA2	S2-2005788	Accepted	This provides a solution for low latency switching of user plane functions between MNOs for edge deployments.
20/10/18	3GPP SA2	S2-2005942	Accepted	This provides service continutity when it is necessary to switch between a private and public network temporarily.
20/10/18	3GPP SA2	S2-2006257	Accepted	This provides terminal inputs of quality of experience to the data analytics enhancements to improve network performance.
20/11/15	3GPP SA1	S1-204435	Accepted	This provides a description of switching terminal connections from terminal to terminal to local network via a gateway.
20/11/15	3GPP SA1	S1-204436	Accepted	This provides a description of switching hosting environments via a gateway.

3.5.3. Patents

The project has filed two patent applications:

- one by NEC entitled "A method for anomaly detection of cloud services based on mining time-evolving graphs", and
- one by NBL in the area of "Application-aware congestion control".

More patents are currently under preparation.

3.6. Impact

As planned, 5Growth is contributing to all the target impacts defined in ICT-19-2019: Advanced 5G validation trials across multiple vertical industries. In the following, details about the main aspects achieved in this first period of activity are reported.

Expected Impact 1 *Validated core 5G technologies and architectures in the context of specific vertical use cases and deployment scenarios, from high to low density regions*.

As reported in Section 0, in this first period of activity, all pilots developed in 5Growth reached a good level of technical validation by assessing the technology for the mobile infrastructure (radio and core) and the architectural component developed in the 5Growth platforms. As reported in D3.4 [16] an advanced status of the pilot has been reached. Moreover, for each pilot, the particular aspects of the infrastructure have been assessed and validated by a first set of measurements that showed full compliance with relevant KPI as reported in D4.2 [18]. INNOVALIA pilot has been able to test a use case using the shared 5G infrastructure provided by a mobile network operator with good performance, thus validating that shared 5G infrastructure deployments can be cost-effective while guaranteeing performance. The mobile infrastructure of COMAU pilot has been set and assessed in COMAU premises. In addition, a low latency transport infrastructure has been set and assessed in order to support critical uses case for latency in a shared infrastructure. This allows 5Growth to experiment shared network scenarios also for low latency use cases. This approach enables new business cases and facilitates the access to vertical use cases by also SMEs, and it can, in principle, open the way to new use cases. EFACEC_S and EFACEC_E also set up all the activities targeting the availability of a fully functional 5G infrastructure (RAN and Core) in a Lab environment (@IT Aveiro) where it is integrated with the use cases and tested interoperability and performance tests (KPIs).

Expected Impact 2 *Validated core technologies and architecture for differentiated performance requirements originating from eMBB, mMTC, URLL use cases, notably for end-to-end slicing and virtualization*.

In this first period, relevant effort has been dedicated to design and implement relevant innovations in the 5Growth architecture with the target to facilitate the automation and management of the several use cases also in wide geographical areas. As reported in D2.2 [7] and in D3.4 [16], technical validation has been done on a range of use cases with different service requirements from eMBB, mMTC, and URLLC use cases. 5Growth platform Release 1 (R1) included a series of innovations related to E2E slicing and virtualization. Specifically, a novel automated NFV-NS scaling mechanism at the 5Gr-SO, and a new RAN model for the 5Gr-VS that allows creating network slices end-to-end. In addition, algorithms for network service embedding were implemented. R1 implementation of 5G End-to-End Service Platform, reported in D2.1 [6], has been published as open source on GitHub.

R2 will provide further innovations, including a novel machine learning platform, slice isolation guarantees, and security mechanisms. The pilots reached a good level of implementation of the different use cases both over shared site facilities that brings benefits in terms of E2E service orchestration of multi-domain resource and in vertical premises. A first release of software has been developed and published for the integration of the 5Growth platform with 5G EVE and 5G VINNI

platforms, providing the benefit of allowing the dynamic deployment of vertical services with different performance requirements and experiment-related monitoring to validate such performance.

Expected Impact 3 *Viable business models for innovative digital use cases tested and validated across a multiplicity of industrial sectors, including demonstration of required network resource control from the vertical industry business model perspective.*

As reported in D1.2 [4] for each pilot, a specific business model has been identified and analysed.

Such business model reported the actors and their role, providing a structured view of potentiality and open points in the vertical scenarios and poses concrete starting points to complete the analysis in the second period. In this first period of activity, the 5Growth project defined a model that allowed us to identify the business requirements, their mapping on service and related technical requirements, as reported in D1.1 [3], D3.1 [13], D3.2 [14], and D.3.4 [16].

Expected Impact 4 *Impactful contributions towards standardization bodies, involving vertical actors, for what concerns the second phase of 5G standardization. Participation of key European industrial partners with high standardization impact is desired*.

As reported in Section 3.5.1, the activity carried out in this first period allowed to provide a remarkable number of contributions to various standard development organization (SDOs). A total of 39 contributions have been submitted to IETF/IRTF, 3GPP, ETSI, 3GPP, and IEEE. Furthermore, as of the time of writing, 13 of them have been accepted in the corresponding body, which we believe is also a remarkable achievement considering the substantial reduction in the number of meetings that the COVID-19 situation imposed. Multiple partners have been involved in the various contributions, including industrial partners, hence contributing to the impact of such contributions in European industry.

Expected Impact 5 *Validation of relevant KPIs with services linked to specific vertical sectors. The trials planned in the project will validate the 5G-PPP KPIs applying the 5G technologies.*

We later explain (in Section 0) how all the pilots of 5Growth project have provided a first set of measurements of relevant KPIs. On the basis of the business requirements defined in D1.1 [3], their mapping on service and related technical requirements, have been defined and reported in D1.1, D3.1 [13], D3.2 [14], and D.3.4 [16]. The validation method by measurement procedures has been defined in D4.2 [18], reporting also some initial measurements values. The method presented to 5G PPP was included in the ongoing white paper entitled "Service performance measurement methods over 5G experimental networks" by the 5G-PPP Test Measurement and Validation (TMV) Working Group vertical task force. The method is based on mapping the service KPIs to the network KPIs adopted in the project. As shown in Figure 37, for all the considered Proof of Concept (PoC), Core KPIs and Service KPIs are defined independently. Then a mapping is performed between Core KPIs and Service KPIs. Although this mapping is independent of the specific PoC, the experience gained in PoC use cases can help to perform the mapping.

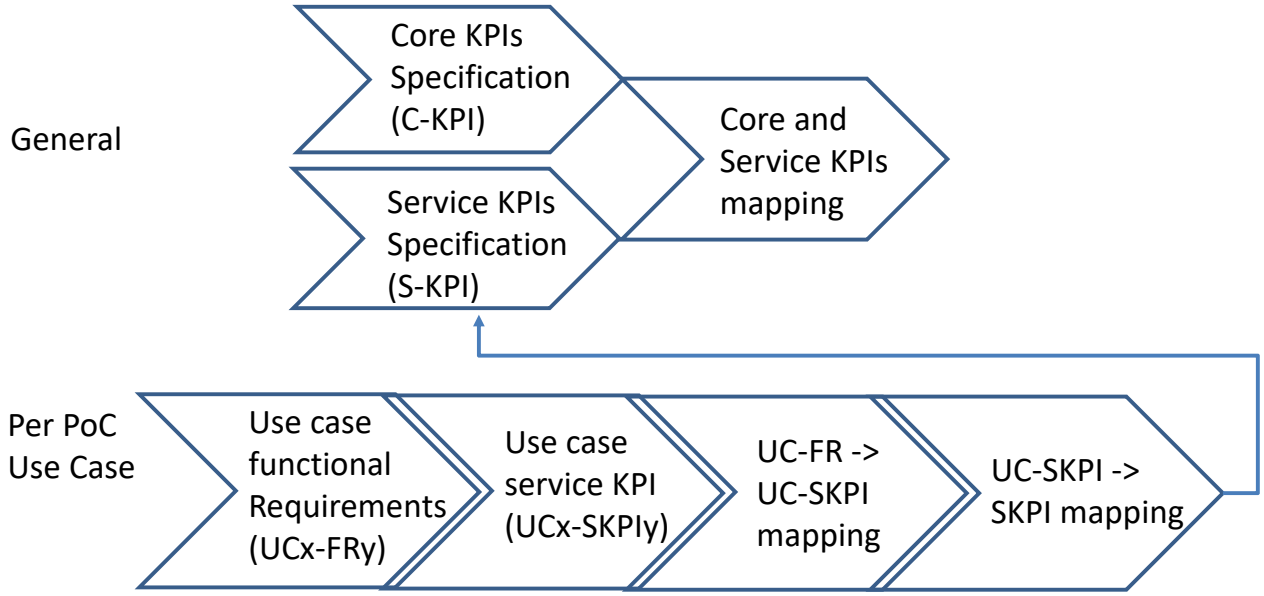


FIGURE 37: PROCEDURE FOR MAPPING SERVICE KPIS TO NETWORK KPIS

Then, for each PoC use case the Functional requirements (UCx-FR) and the use case service KPIs (UCx-SKPIy) are defined. The use case functional requirements are mapped into use case services KPIs. Use case service KPIs are finally mapped into the service KPIs generally defined. In this way, a relationship is established between use case functional requirements and Core KPIs.

Expected Impact 6 *Europe 5G know how showcasing***.**

As presented in Section 2, an important part of the dissemination work is devoted to the organization of events and technical demonstrations in which the results of the project are showcased. The initial part of the project was mainly devoted to the development of the innovations and the evaluation of initial deployments of the pilots. Therefore, as innovations are being integrated in the WP3 pilots, they will also be showcased in real-life environments, such as factories (INNOVALIA, COMAU), ports (EFACEC_S), and the electric grid (EFACEC_E), connected through 5G networks, including access, transport and core. In fact, the initial framework and results of the COMAU pilot (industry 4.0) were selected in the top 10 projects highlighted in the second edition of the 5G-PPP trials and pilots brochure, being 5Growth the only ICT-19 project selected for this publication.

As of the time of writing, eight demonstrations have been showcased in various events, including ACM Mobicom, IEEE INFOCOM, or the 5G-PPP TB eWorkshop. Some of them were held online (due to COVID-19). Some videos of these demonstrations and pilots are available on the YouTube channel of the project.

Additionally, multiple publications and talks have also been delivered in multiple events, which also presented 5Growth results. In fact, one of the papers of the project was awarded the Best Fast Track paper award in IEEE NFVSDN 2020 for its contribution on the integration of AIML in the 5Growth stack towards automated network management.

3.6.1. Progress towards the 5G-PPP Key Performance Indicators

Next we summarize the progress and status of the project in regards of the 5Growth contribution to 5G-PPP KPIs.

Objective 1	**Validate 5Growth business model (WP1)**
KPIs	**Details on the progress of KPIs assessments**
Reduce today's network management OPEX by at least 20% compared to today	During the first reporting period, the innovation in 5Growth was analyzed to define different business models geared towards achieving net reductions in operational costs (of over 20%). This is achieved by the reduction of the infrastructure cost, such as less cables or less hardware usage (because of the ability to share resources across verticals). It also gains from an increased energy efficiency, reduction in travel (new business model) and faster reaction times. An overall better control of the systems in place is explored, with benefits ranging from the economic and environmental benefits of Zero-Defect manufacturing and more resilient systems, to saving lives because of the prevention of train accidents. Further work needs to be done in future periods to obtain concrete values once the technology to be deployed reaches adequate levels of maturity.
European availability of a competitive industrial offer for 5G systems and technologies	The different benefits and cash flows are explored in this WP, with collaboration between verticals, network operators and manufacturer vendors from Europe. The business models studied are therefore by-design analyzed to study the industrial viability of 5G-driven systems and technologies to provide realistic solutions to be implemented by the verticals in the short to mid-term. So far, all use cases present business models that would leverage European companies to achieve a greater competitiveness in the vertical's respective markets.
Economic support of a novel range of services of societal value like U-HDTV and M2M applications	Some of the use cases and business models defined in this work package include implementations of both U-HDTV and M2M communication. Indeed, 4K video streaming with low latency is a fundamental part in INNOVALIA Pilot's UCs for precise remote control of a CMM. In COMAU's UC3, eMBB is required to deliver un-interrupted video streaming to multiple users with high definition formats. In Efacec Sistemas' use cases, U-HDTV transmitted through 5G technology will allow the monitoring of train crossings in-real-time to avoid accidents. And in Efacec Energia use cases, the HD video will allow the control of the infrastructure and implement contingency and service restoration measures in substations. The machine -to-machine collaboration will be specifically addressed in INNOVALIA's second use case, leveraging 5G for communications between the CMM and an AGV. The use cases for Efacec Sistemas will also deploy this technology for railway level crossing communication requirements that are safety critical for train detectors.
Reach a global market share for 5G equipment & services delivered by European headquartered ICT companies at, or above, 43% global market share in communication infrastructure.	The companies participating in this project are Europeans, and thus the business models and innovations explored would mainly benefit European stakeholder's, helping to achieve the goal of 43% global market share in communication infrastructure.

Objective 2	Design and develop 5Growth extensions into 5G architecture (WP2)
KPI	**Details on the progress of KPIs assessments**
Reduce network management OPEX by at least 20% compared to today.	During the first reporting period, WP2 has designed a series of innovations targeting this KPI. In the context of Innovation 7 "Next-Generation RANs", we have designed and developed a small proof-of-concept of a novel AI-driven vRAN orchestration mechanism. Experimental results [10] have showed OPEX savings over 25% in use of computing resources using this approach as compared to legacy allocation policies. A live demo has been showcased in several events[2]. In the context of Innovation 6 "Federation and Inter-domain", we have designed a federation mechanism, founded on AI/ML, to opportunistically federate resources taking advantage of a predictive pricing mechanism. Simulation results [11] using real traces from a cloud provider show gains over 40%, compared to greedy approaches. In addition, additional architectural innovations are designed to indirectly assist in reducing OPEX cost, such as novel NFV-NS scaling mechanisms in 5Gr-SO, arbitration algorithms in 5Gr-VS and forecasting algorithms [9].
Create a secure, reliable and dependable Internet with a "zero perceived" downtime for services provision.	During the first reporting period, we have developed MTD (Moving Target Defense) mechanism to protect 5Growth platform´s external interfaces from harmful behavior [12]. This is particularly relevant in the context of inter-domain communication with ICT-17 and other platforms. Moreover, Release 1 of 5Growth platform [7] integrates a first version of a novel 5Gr-SO scaling mechanism to react upon different user behaviors using AI/ML, which contributes actively to providing "zero-perceived" downtime for service provisioning. Specifically, novel VNF-FG embedding algorithms show, via simulations, that reinforcement learning can attain over 30% less SLA violations than traditional optimization methods [9]. Finally, novel performance isolation mechanisms with bandwidth and delay guarantees, will assist to provide reliable service and mitigate SLA violations [8]. In addition, we have initiated work in additional innovations concerning anomaly detection and user profiling, and smarter path computation algorithms, which contribute to this KPI.
Reduce the average service creation time cycle from 90 hours to 90 minutes.	5Growth Release 1 (R1) introduced novel mechanisms for provisioning service that include RAN segments [7]. This approach saves time compared to an approach where RAN segments are orchestrated in a decoupled manner. Moreover, novel architectural innovations such as a novel AI/ML platform assist AI-driven mechanisms with faster deployment of ML models into 5Growth components. An illustrative example is the first release of a NFV-NS scaling mechanism included in R1 [7].
Facilitate very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people.	During the first reporting period we have worked to extend the network slicing model towards RAN segments [7], provide tighter performance isolation mechanisms [8], optimize the use of resources in next-generation RANs [10], and integrate AI-driven scaling mechanisms that adapt to the behavior of the users [9]. All these mechanisms contribute towards reducing the CAPEX/OPEX of networks, indirectly favoring very dense deployment of wireless communication links.

[2] Video available at: https://www.youtube.com/watch?v=1I8mcnHQcW8

Objective 3	Perform field trials and showcase vertical use cases in field trials (WP3/WP4) Industry 4.0 - INNOVALIA Pilot
KPI	**Details on the progress of KPIs assessments**
Provide 1,000 times higher wireless area capacity and more diverse service capabilities compared to 2010	During this reporting period, in the INNOVALIA pilot, several of the service KPIs identified in D4.1 and related to this 5G-PPP KPI have been evaluated and reported in D4.2. In particular: 5GR-SKPI-3 (Device mobility), 5GR-SKPI-4 (High-resolution real-time video quality), 5GR-SKPI-5 (Radius of operation), 5GR-SKPI-6 (Integrated multitype communication) and 5GR-SKPI-7 (Extensive network coverage in vertical premises). The relevant core KPIs on the throughput were measured. The tests were performed in a test scenario with a 5G NSA network deployed at 5TONIC lab. In the initial 5G validation, we achieved the peak throughput of 52 Mbits/sec (with 3.5 GHz frequency band with TDD pattern 7:3 and 50 MHz bandwidth) and 90 Mbits/sec (adding extra LTE 20 MHz bandwidth) for both scanner operation and video streaming
Create a secure, reliable and dependable Internet with a "zero perceived" downtime for services provision	During this reporting period, in the INNOVALIA pilot, several of the service KPIs identified in D4.1 and related to this 5G-PPP KPI have been evaluated and reported in D4.2. In particular: 5GR-SKPI-1 (Service setup time), 5GR-SKPI-2 (Synchronization between communication components), 5GR-SKPI-8 (Service operation time) and 5GR-SKPI-9 (Service operation capacity). The relevant core KPIs on the latency were measured. The tests were performed in a test scenario with a 5G NSA network deployed at 5TONIC lab. The initial experimental results reported in D4.2 demonstrated 15ms RTT for the synchronization between the joystick and the scanner as well as between the video camera to the display

Objective 3	Perform field trials and showcase vertical use cases in field trials (WP3/WP4) Industry 4.0 - COMAU Pilot
KPI	**Details on the progress of KPIs assessments**
Provide 1000 times higher wireless area capacity and more diverse service capabilities compared to 2010	During this reporting period, for the COMAU pilot, several of the service KPIs identified in D4.1 and related to this 5G-PPP KPI have been evaluated and reported in D4.2. In particular: 5GR-SKPI-3 (Device mobility), 5GR-SKPI-4 (High-resolution real-time video quality), 5GR-SKPI-7 (Extensive network coverage in vertical premises. The relevant core KPIs on the throughput were measured. For the validation campaigns, an optical 5G transport network is tested in this pilot to connect the Baseband Units to the Radio Units of the radio cells, implementing centralized RAN architecture, where Baseband units serving several radio sites are centralized in a single location. Being an NSA (non-standalone) configuration, both a 5G and a 4G radio base stations are used to connect the User Equipment. The initial experimental results reported in D4.2 showed that for UDP traffic the DL average throughput over a week was around 944 Mbit/s and UL average throughput was 61.12 Mbit/s, while for TCP traffic the DL

	average throughput measured over a week was approximately 821 Mbit/s and UL average throughput measured was 59.01 Mbit/s
Create a secure, reliable and dependable Internet with a "zero perceived" downtime for services provision	During this reporting period, for the COMAU pilot, one of the service KPIs identified in D4.1 and related to this 5G-PPP KPI has been evaluated and reported in D4.2. In particular: 5GR-SKPI-2 (Synchronization between communication components). In the same tests scenarios, the initial experimental reported in D4.2 demonstrated low latency performance achieved. The average RTT over the whole measurement week is 16.51 ms (the average DL latency was 5.42 ms and the average UL latency was 6.1 ms) while the maximum RTT over a week was 140.26 ms (the maximum DL latency was 120.98 ms, and the maximum UL latency was 57.04 ms). In terms of packet loss, the achieved packet loss is around $2*10^{-6}$

Objective 3	**Perform field trials and showcase vertical use cases in field trials (WP3/WP4) Transportation – EFACEC_S Pilot**
KPI	**Details on the progress of KPIs assessments**
Provide 1000 times higher wireless area capacity and more diverse service capabilities compared to 2010	During this reporting period, for the Transportation pilot, one of the service KPIs identified in D4.1 and related to this 5G-PPP KPI has been evaluated and reported in D4.2. In particular: 5GR-SKPI-4 (High-resolution real-time video quality). The relevant core KPIs on the packet loss, jitter and throughput were measured. The tests were performed in a test scenario with a full RAN and 5G core deployed at IT Aveiro lab, we achieved the following results: • Packet loss with UDP-16Mbit/sec - 0.083% • Jitter (average) – 2.6 ms Upstream and downstream throughputs were in the order of 60 Mb/s and 400 Mb/s, respectively
Save up to 90% of energy per service provided	During this reporting period, for the Transportation pilot, it has not been possible to evaluate any of the KPIs related to this 5G-PPP KPI. This will be studied and reported in future deliverables
Create a secure, reliable and dependable Internet with a "zero perceived" downtime for services provision	During this reporting period, for the Transportation pilot, two of the service KPIs identified in D4.1 and related to this 5G-PPP KPI have been evaluated and reported in D4.2. In particular: 5GR-SKPI-2 (Synchronization between communication components) and 5GR-SKPI-10 (Service availability). The relevant core KPIs on the RTT and latency were measured. The tests were performed in a test scenario with a full RAN and 5G core deployed at IT Aveiro lab, we achieved low latency performances: • RTT (average) – 40 ms (the minimum achieved value was 20 ms) • Latency (average) – 20 ms (the minimum achieved value was 7 ms)

Objective 3	Perform field trials and showcase vertical use cases in field trials (WP3/WP4) Energy – EFACEC_E Pilot
KPI	**Details on the progress of KPIs assessments**
Provide 1000 times higher wireless area capacity and more diverse service capabilities compared to 2010	During this reporting period, for the Energy pilot, one of the service KPIs identified in D4.1 and related to this 5G-PPP KPI has been evaluated and reported in D4.2. In particular: 5GR-SKPI-4 (High-resolution real-time video quality). The relevant core KPIs on the packet loss, jitter and throughput were measured. The tests were performed in a test setup using with 5G SA network with a real RAN (ASOCS) and a real 5G Core (Open5GCore). We achieved the following results: • 0% Packet loss with UDP traffic up to 60 Mbits/sec (throughput) • Jitter below 1.698 ms
Create a secure, reliable and dependable Internet with a "zero perceived" downtime for services provision	During this reporting period, for the Energy pilot, two of the service KPIs identified in D4.1 and related to this 5G-PPP KPI have been evaluated and reported in D4.2. In particular: 5GR-SKPI-2 (Synchronization between communication components) and 5GR-SKPI-10 (Service availability). The relevant core KPIs on the RTT were measured. The tests were performed in a test setup using with 5G SA network with a real RAN (ASOCS) and a real 5G Core (Open5GCore), we achieved the average RTT about 20 ms (the minimum value about 10 ms)
Facilitate very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people	During this reporting period, for the Energy pilot it has not been possible to evaluate any of the KPIs identified in D4.1 and related to this 5G-PPP KPI. This will be studied and reported in future deliverables

Objective 5	Dissemination, standardization and exploitation of 5Growth (WP5)
KPI	**Details on the progress of KPIs assessments**
Generate patents	2 patents submitted
Establish and make available 5G skills development curricula	Lectures taught at five different postgraduate and industrial courses 14 master and PhD theses directly related with 5Growth research topics

4. Update of the plan for exploitation and dissemination of result

The communication, dissemination, and exploitation plan (CoDEP) presented in the proposal is periodically refined according to the evolution of the project and the activities considered of interest.

The initial plan was presented in D5.1 [2], along with early achievements. D5.2 [1] presented the achievements during the initial period of the project as well as a refinement of the plan for the following period. It is not repeated here for brevity. The reader is referred to the above documents.

5. Deviations from Annex 1 and Annex 2

5.1. Tasks

No deviations.

5.2. Use of resources

As the first reporting period of the project closes on November 30th, 2020, the final information of resources (PMs) used during the first reporting period (M1-M18) will not be available before December 15th, 2020. The final version of the Periodic Report will be complete before the deadline (January 28th 2021).

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