H2020 5G Dive Project
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D4.3: Communication, Dissemination, and Exploitation achievements through the project, exploitation plan after the end of the project and assessment of the contribution of 5G-DIVE in support of 5G

Abstract

The achievements relating to the project's communication, dissemination and exploitation activities are reported for the lifetime of the project. The plan had to be adapted with an additional online presence and video material to handle the effects of the Covid-19 crisis when events were cancelled or made online. Project results have been disseminated through publications, presentations and interviews. Workshops and other events with a focus on the topics of the project have been organised. Contributions to and interaction with standards organisations are reported on, as well as the engagement in open-source software. Exploitation relating to the PoCs, existing products and services, and individual partners are reported on, as well as a report from an exploitation workshop. Dissemination and exploitation actions after the project's completion are provided.

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List of Acronyms

3GPP	3rd Generation Partnership Project, uniting several telecommunications standard development organisations
AP	Access Point
CoDEP	Communication, Dissemination and Exploitation Plan
ETSI	European Telecommunications Standards Institute
NWDAF	Network Data Analytics Function
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IRTF	Internet Research Task Force
ISG	Industry Specification Group
ITU	International Telecommunication Union
ITU-T	ITU Telecommunication Standardization Sector
OCS	Orchestration and Control System
OSS	Open source software
STA	Station
SAC	Standardisation Advisory Committee
SDO	Standards Development Organisation
WG	Working Group

Executive Summary

Achievements in terms of communication, dissemination and exploitation including standardisation are reported for the lifetime of the project and compared with the set targets. The overall purpose of these activities is to fulfil the project's overall Objective 4 on dissemination. For each type of activity, the plans are updated with actions after the end of the project.

The communication and dissemination plan had to be adapted to handle the effects of the Covid-19 crisis, mainly by enhancing the online presence, for example through videos of presentations and demos. The project consortium set up ambitious dissemination targets, of which all have been met or exceeded.

The project is present online with a public website with information in English and Chinese which has a visit count exceeding 60 000 for the duration of the project. The project also has a Twitter channel and is present on other social media. Project members are visible in various video interviews and blog articles. In addition, press releases have been issued, and a project leaflet and poster have been created.

Project results are disseminated with peer-reviewed publications in conferences, workshops, journals, and magazines, as well as through various public presentations. Project members engage in the organisation of special issues of journals and the organisation of workshops specialised on the topics of the project, some of which are done in collaboration with other projects. The project also targets exhibitions at major events, but some of these have been cancelled.

Contributions to and interaction with five standardisation organisations have taken place during the lifetime of the project, and the number of standardisation contributions exceeds the project's target with some margin. The main standardisation organisations are 3GPP, IETF, ETSI, IEEE and ORAN Alliance.

Two open-source software projects, Zenoh and fog05, are driven by project members in the context of the Eclipse Edge Native WG. These two open-source components are central to the development of the 5G-DIVE edge platform. Some additional software from the project relating to the use-case trials has also been released as open source.

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

1. Introduction

This deliverable reports on the project achievements during its lifetime in terms of communication, dissemination, and exploitation including standardisation. The achievements are compared with the targets set in the communication, dissemination and exploitation plan (CoDEP) defined in Deliverable 4.1 [5], and updated in Deliverables D4.2 [7] and D4.2b [13]. The deliverable furthermore includes an update of plans for dissemination with a focus on actions after the conclusion of the project and a report from the exploitation workshop.

The achievements reported in this deliverable are the progress towards fulfilling the project's overall Objective 4 to disseminate and contribute 5G-DIVE results into international research and innovation venues, and to pave the way for their successful exploitation. This overall objective is broken down into three sub-objectives: (1) To develop an outreach communication and dissemination of 5G-DIVE results to all stakeholders including researchers, industrials, and the general public; (2) To develop a proactive standardization plan including roadmaps, intellectual property creation, and contribution in relevant standards; and (3) To develop a plan for the exploitation of 5G-DIVE results into value creation for all stakeholders during the project lifetime and beyond.

The fulfilment of the first sub-objective is largely reported in Sections 2 and 3 on communication, public activities, dissemination and collaboration. The fulfilment of the second sub-objective is addressed in Section 4 on standardisation and open-source activities. The fulfilment of the third sub-objective is addressed in Section 5 on exploitation activities. Each section of the deliverable also includes an update of plans for actions after the end of the project.

The following two subsections comments on the handling of the Covid-19 crisis and summarises the achievements reported in the deliverable.

1.1. Covid-19 Crisis Management

The CoDEP plans of the project (Deliverable 4.1 [5]) were finalised during the beginning of the Covid-19 crisis outside China, but most of the plans were made before the extent of the crisis was known. The project had to make new plans to handle cancelled events, for example, the Mobile World Congress, and to handle the change to online events, for example, the European Conference on Networks and Communications (EuCNC). During the whole project duration, most events have been offering online substitutes, making it possible to participate, albeit in a different way.

It was unavoidable that the communication and dissemination plan for the project was affected and, in some instances, delayed. To enable a better online presence, videos of presentations and demos have been recorded. In addition to cancelled and online events, we were affected by delayed schedules in several of the standardisation organisations we participated in. We, therefore, adjusted some of the dissemination targets in the project amendment approved 06/22/2020.

1.2. Overview of achievements

Table 1-1 provides a summary overview of dissemination achievements for the lifetime of the project. The partners set up ambitious dissemination targets, which all have been met or exceeded!

TABLE 1-1: OVERVIEW OF ACHIEVEMENTS AND PROGRESS TOWARDS TARGETS.

Category		Current count	Target	Comment
Peer-review publications		30	24	Published or accepted
Presentation/talks		13	12	Demos not included
Press releases		11	N/A	
Organisation of workshops and conferences		5	2	
Trade fair (booth, exhibition, etc)		2	2	
Patents		3	3	
Activities with other EU projects		11	4	
Demonstrations		6	4	Some online
Videos		16	N/A	Including presentations and demos
Open source projects		2	1	Fog05 and Zenoh
Standard contributions	adopted	18	5	
	total	63	15	

2. Communication and Public Activities

This section reports communication activities undertaken from the beginning of the project until December 2021. The tables include all activities since the beginning of the project, but the text does not repeat what has already been described in D4.2.

2.1. Report on Activities Undertaken and Achievements

Communication and Public activities are undertaken until December 2021 are reported in Table 2-1,

Table 2-2, Table 2-3, and Table 2-4 respectively for activities relating to (1) project portal and social networks, (2) video interviews and blog articles, (3) Video Interviews and Blog articles, and (4) Videos with presentations and demos of project results.

TABLE 2-1: PROJECT PORTAL AND SOCIAL NETWORKS.

#	Month	Description	Lead partners
1	Oct'19	Release of 5G-DIVE project portal at www.5g-dive.eu.	UC3M
2	Oct'19	Set up a Twitter account @Dive5g, 5G-DIVE LinkedIn group (https://www.linkedin.com/in/5g-dive-project/) and Instagram account (5g_dive).	UC3M
3	Throughout Y1 and Y2	Constant update of the project website with contents on the talks, workshops, demonstrations, and events undertaken and planned. Free access has been given to download public presentations and materials from the partners, subject to partner permission.	UC3M, RISE
4	Throughout Y1 and Y2	Synchronicity between project website and the social media news shared on the project Twitter and LinkedIn accounts.	UC3M, RISE

TABLE 2-2: VIDEO INTERVIEWS AND BLOG ARTICLES.

#	Month	Description	Lead partners
1	Dec'19	Interview with RNE (Public Spanish Radio) Radar 3.0 program. http://www.rtve.es/alacarta/audios/radar-30-en-radio-5/radar-30-radio-5-fake-news-arma-para-desmoralizar-combatiente-01-02-20/5504059/	UC3M, TID, TELCA
2	Jan'20	Article in "The Conversation" a scientific Spanish blog. The article titled "Como controlar drones y robots industriales gracias al 5G", published. https://theconversation.com/como-controlar-drones-y-robots-industriales-gracias-al-5g-130652	UC3M
3	Feb'20	Video interview provided by the Project Coordinator to Zoom NET TV show by RTVE (Public Spanish TV). https://www.rtve.es/alacarta/videos/zoom-net/zoom-net-5g-dive-entrevista-shou-zi-chew-dreams/5526638/	UC3M
4	May'20	Milan Groshev has participated in What makes it tick? – Community that brings European science & tech to the world with the video	UC3M

		"Networks of robots | 5-Minute Science You Never Knew", [Online] https://youtu.be/pPDaB8fRep8	
5	Sep'20	Arturo Azcorra participated in the 34th meeting for the Digital Economy and Telecomunications, organised by Ametic, Santander and UIMP. [Online] https://economiadigitalsantander.es/agenda/	UC3M

TABLE 2-3: PRESS RELEASES AND LEAFLETS.

#	Month	Description	URL	Lead partners	Platform
1	Nov'19	Press release	https://ir.interdigital.com/news-events/press-releases/news-details/2019/InterDigital-Announces-New-5G-Dive-Project-For-5G-and-Beyond-Edge-Solutions/default.aspx	IDCC	Corporate website
2	Nov'19	Press release	https://www.adlinktech.com/en/News_191127025345134 26	ADLINK	Corporate website
3	Dec'19	Press release	https://www.sdxcentral.com/articles/news/adlink-tackles-industrial-iot-as-latest-5g-drive-member/2019/12/	ADLINK	SDX CENTRAL
4	Dec'19	Press release	https://networks.imdea.org/5g-dive-presents-its-technology-cooperation-project-at-national-chiao-tung-university/	UC3M	IMDEA Networks
5	Dec'19	Press release	https://networks.imdea.org/es/el-proyecto-de-cooperacion-tecnologica-europa-taiwan-5g-dive-ha-sido-presentado-en-la-universidad-nacional-chiao-tung/	UC3M	IMDEA networks
6	Dec'19	Press release	https://www.uc3m.es/ss/Satellite/UC3MInstitucional/es/Detalle/Comunicacion_C/1371282496565/1371215537949/Implantacion_de_tecnologia_5G_en_drones_y_robots https://www.uc3m.es/ss/Satellite/UC3MInstitucional/en/Detalle/Comunicacion_C/1371282498910/1371215537949/Deployment_of_5G_technology_in_drones_and_robots	UC3M	UC3M
7	Dec'19	Press Release	https://www.uc3m.es/ss/Satellite?blobcol=urldata&blobheader=application%2Fpdf&blobheadername1=Content-Disposition&blobheadername2=Cache-Control&blobheadervalue1=attachment%3B+filename%3D%225G_DIVE_%28Chinese_version%29.pdf%22&blobheadervalue2=private&blobkey=id&blobtable=MungoBlobs&blobwhere=1371568627153&ssbinary=true	UC3M	Alpha Galileo
8	Jan'20	Leaflet	https://5g-dive.eu/wp-content/uploads/2020/03/Leaflet-MWC20_compressed.pdf	UC3M/IDCC/ RISE	5G-DIVE.eu
9	Jan'20	Poster	https://5g-dive.eu/wp-content/uploads/2020/03/Poster-MWC20_compressed.pdf	UC3M/IDCC/ RISE	5G-DIVE.eu
10	Jan'20	Press release	https://money.udn.com/money/story/10860/4270484	ASKEY	UDN/經濟日報

11	Dec'20	Press release	MOEA Leads Businesses to Showcase Innovative Applications of 5G Private Network and Explore New 6G Development Opportunities at IEEE GLOBECOM https://www.moea.gov.tw/MNS/doit_e/news/News_En.aspx?kind=6&menu_id=5673&news_id=92473	UC3M/EAB/IDCC/III/ITRI/NCTU/ASKEY	MOEA, Ministry of Economic Affairs, Taiwan

TABLE 2-4: VIDEOS WITH PRESENTATIONS AND DEMOS OF PROJECT RESULTS.

#	Month	Description	Lead partners
1	May'20	Networks of robots | 5-Minute Science You Never Knew. What makes it tick? – Community that brings European science & tech to the world	UC3M
2	Jun'20	Assessing 5G need for Digital Twin Applications. 5G end-to-end experimentation by verticals in EU projects. Online workshop. [Online] https://5g-dive.eu/wp-content/uploads/2020/06/12.30-13.00-MilanG-Assesing-5G-need-for-Digital-Twin-applicaitonsI_v2-1.pdf	UC3M
3	Jun'20	EagleEYE: Aerial Edge enabled Disaster Relief Response System. 5G end-to-end experimentation by verticals in EU. Online Workshop. [Online] https://www.youtube.com/watch?v=mauaciCHuVA&feature=youtu.be	NCTU
4	Jun'20	Object Detecti–on Zooming - Remote User. Augmented remote robot control. [Online] https://www.youtube.com/watch?v=vQnLiYmd6vA	IDCC
5	Jul´20	5G DIVE Demo: Remote Driving 1 https://www.youtube.com/watch?v=2js-YfG0J38	
6	Jul´20	5G DIVE Demo: Remote Driving 2 https://www.youtube.com/watch?v=7nV04bzkt9w	
7	Jul´20	5G DIVE Demo: Remote Driving 3 https://www.youtube.com/watch?v=I-6nhhTj5G8	
8	Nov´20	Electronics Webinar – "Beyond 5G Evolution". MDPI and Electronics organized the second webinar on Electronics. Chaired by Prof. Dr. Carlos Jesús Bernardos Cano, the webinar saw three speakers, Dr. Ömer Bulakci, Dr. Alain Mourad and Dr. Josep Mangues-Bafalluy. https://www.youtube.com/watch?v=g1rd6fItqH8	UC3M, CTTC, IDCC
9	Dec´20	Autonomous Drone Scout (ADS) - Use Case 1: Drone Fleet Navigation. https://www.youtube.com/watch?v=J_Q2ziVKuG4	
10	Dec´20	Autonomous Drone Scout (ADS) - Use Case 2: Intelligence for Drones. https://www.youtube.com/watch?v=GcccfPQ4QHg	
11	Dec´20	ZDM Use Case - 1st Technical Review. https://www.youtube.com/watch?v=N0wkxZ7bcWk	IDCC
12	Dec´20	mMTC Demo 1 - First Technical Review. https://www.youtube.com/watch?v=rxGmumbt13A	EAB, RISE, ULUND

13	Dec´20	mMTC Demo 2 - First Technical Review. https://www.youtube.com/watch?v=ePsYi8G-mag	EAB, RISE, ULUND
14	Dec´20	Digital Twin Demo - First Technical Review 5G- Dive. "Edge-assisted Digital Twin over 5G". https://www.youtube.com/watch?v=MIvcJWb0YVE	UC3M TELCA ADLINK
15	Dec´20	GLOBECOM 2020 - Industry Panel 5 (IP-0 ON-DEMAND) - ADVANCED WIRELESS RESEARCH PLATFORMS TOWARDS 6G. Location: Virtual Platform. https://www.youtube.com/watch?v=hvSL14zeEHo	UC3M IDCC
16	Jan´21	Digital Twin demo presented to the ROS community / https://discourse.ros.org/t/uc3m-madrid-5g-ros-zenoh-digital-twin-teleop-technical-review-demo/18287	UC3M TELCA ADLINK

2.1.1. 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: https://5g-dive.eu/. The landing page is reported in Figure 2-1. In addition, 5G-DIVE has provided Chinese translation to key content in order to improve the visibility and impact of the project, an example of the landing page for the 5G-DIVE site can be found in Figure 2-2.

FIGURE 2-1: 5G-DIVE MAIN WEBSITE.

FIGURE 2-2: 5G-DIVE MAIN WEBSITE (CHINESE).

Statistics until December 2021 have been gathered for the website. They are reported in Figure 2-3. It can be observed that, since the last year (i.e., "last 365 days" statistics), the website had almost twenty six thousand visitors, bringing the total to 61,238 visits.

	Visitors	Visits
Today:	30	50
Yesterday:	36	75
Last 7 Days (Week):	227	451
Last 30 Days (Month):	762	2,070
Last 365 Days (Year):	13,057	33,618
Total:	25,547	61,238

FIGURE 2-3: OVERALL WEB PAGE HITS.

In detail, as shown in Figure 2-4, the most popular subpages are the ones related to the consortium events and to project deliverables.

Top 10 Pages

ID	Title	Link	Visits
1	Home Page	/	23,387
2	Consortium	/?page_id=71	2,081
3	Deliverables	/?page_id=26	1,945
4	Project	/?page_id=11	1,133
5	Video Gallery	/?page_id=82	1,021
6	Contacts	/?page_id=69	983
7	Talks	/?page_id=78	854
8	Conferences and Workshops	/?page_id=883	787
9	"5G para Drones y Robots" (SPANISH)	/?p=844	714
10	Far EasTone	/?page_id=452	669

FIGURE 2-4: DETAILS OF VISITED WEBSITE PAGES.

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

- LinkedIn: https://www.linkedin.com/in/5g-dive-project/
- Twitter: https://twitter.com/dive5g

The Linkedin profile is mainly used to advertise the technical work of the project and to follow other activities from a different project. Currently, Linkedin profile shows 677 connections, and we are involved in 9 communication groups.

To show the activities of the Twitter account, we present Figure 2-5 with the impressions earned from January 1st, 2021 to April 1st, 2021 and Figure 2-6 from May 7th, 2021 to August 5th, 2021.

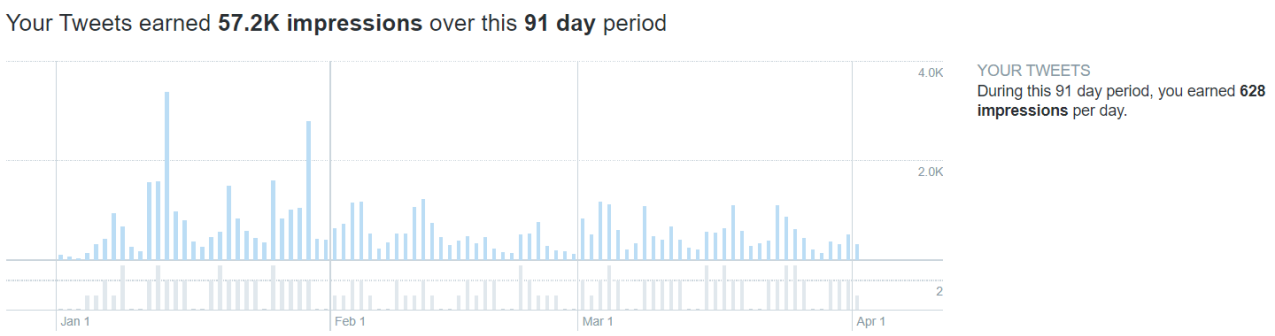

FIGURE 2-5: TWEET IMPRESSIONS FROM JANUARY 1ST TO APRIL 1ST

During the first period (January 1st, 2021 to April 1st, 2021) the project tweets gathered 57 200 impressions, with a total of 111 links (mostly directed to 5G-DIVE website), 227 retweets and 343 likes.

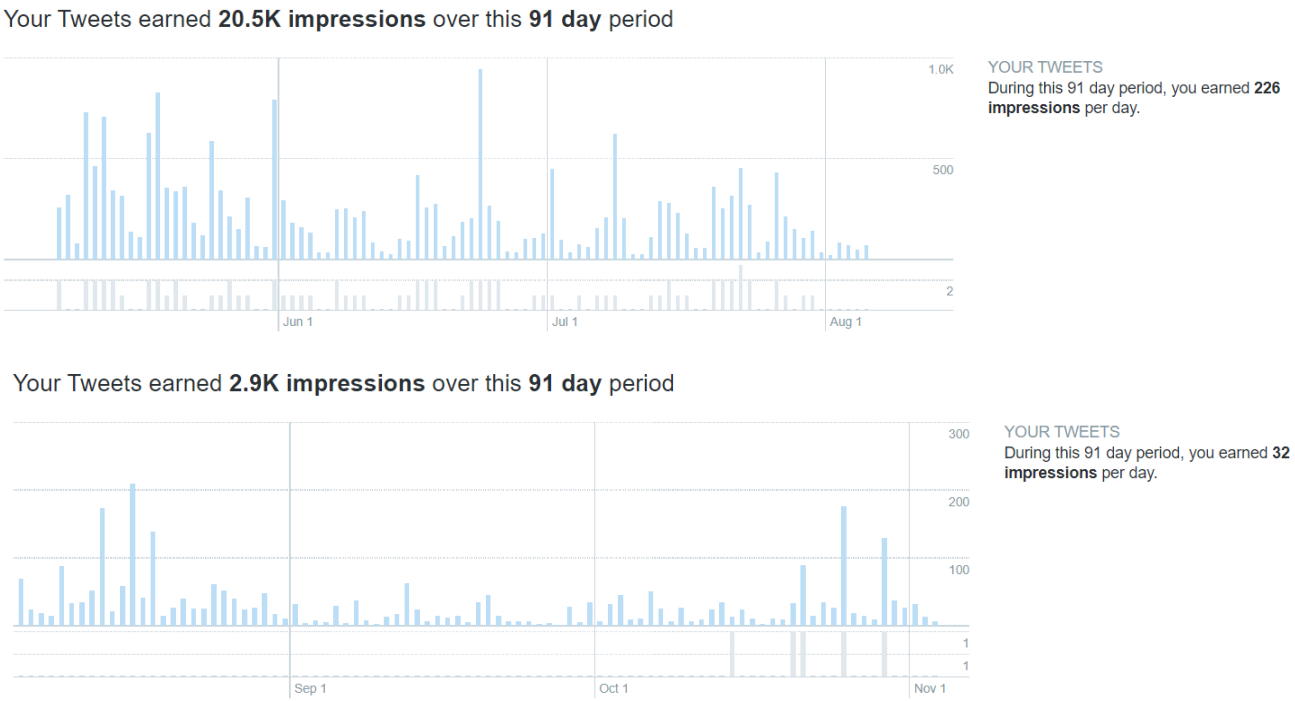

FIGURE 2-6: TWEET IMPRESSIONS FROM MAY 7TH TO AUGUST 5TH AND FROM AUGUST 5TH TO NOVEMBER 3RD 2021

During the period from May 7th, 2021 to August 5th, 2021, the project Tweets earned 20 500 impressions, with a total of 54 links clicks, 40 retweets and 86 likes. This low activity is typical in the summer period.

During the period from August 5th, 2021 to November 3rd, 2021, the project Tweets earned 2900 impressions with a total of 5 links clicks, 9 retweets and 16 likes. This low activity is due to the final project time, centered on more management activities.

The project has been active also on Instagram. The project account is the following:

- Instagram: https://www.instagram.com/5g_dive/

The Instagram profile is mainly used to advertise the activity of the members of the group, the work and achievements of the project and to follow other activities from different projects. Currently, Instagram profile shows 144 followers.

2.2. Actions after the project

We believe it is of utmost importance to keep alive the different channels by which the knowledge generated by the project can be reached, after the project lifetime.

The website will be kept online and with dynamic content until December 2023. After that date, the website will be made static, to reduce the attack surface, and stored under the URL

https://euprojects.netcom.it.uc3m.es/. This site (e.g., 5G-CORAL is stored as https://euprojects.netcom.it.uc3m.es/5g-coral/) allows us to keep the sites running and reachable.

All communication activities, including all the content already present on the web page, will be kept reachable under this static web page.

Media Channels will be used to advertise the next projects the group works on, and based on the new projects approved and their topics, the base of users of the social networks will be invited to the new project social channels.

3. Dissemination and Collaboration Activities

Dissemination and Collaboration activities were undertaken in the project in order to promote the 5G-DIVE project concepts and final results to the international R&D community. The activities were also designed to trigger synergy with other related projects and activities. In this section, we update the reporting from Deliverable 4.2 [D4.2] with the achievement during the second year of the project.

3.1. Report on Activities Undertaken and Achievements

The dissemination and collaboration activities and achievements for the duration of the project are reported in the following sub-sections.

3.1.1. Peer-reviewed Publications

Table 3-1 and Table 3-2 lists all the peer-reviewed publications for the duration of the project. Only published or accepted publication materials are reported. The project has published or accepted for publications 16 peer-reviewed articles in conferences and workshops, 14 peer-reviewed articles in journals and magazines, and organization of 3 special issues of journals and magazines, collected in Table 3-3.

TABLE 3-1: PEER-REVIEWED PUBLICATIONS IN CONFERENCES AND WORKSHOPS.

#	Type	Month	Description	Partner
1	Workshop	November 2019	Carlos Guimarães, Antonio de la Oliva, Arturo Azcorra. 5G-DIVE: eDge Intelligence for Vertical Experimentation. Global Experimentation for Future Internet – 2019, Coimbra, Portugal.	UC3M
2	Conference	April 2020	Luis M. Contreras, Javier Baliosian, Pedro Martinez-Julia, Joan Serrat. Computing at the Edge: But, what Edge? IEEE/IFIP Network Operations and Management Symposium (NOMS), Budapest, Hungary.	TID
3	Conference	February 2020	Saptarshi Hazra, Thiemo Voigt, Bengt Ahlgren, Chenguang Lu, Daniel Cederholm, Gyanesh Patra. Demo: Multi-Radio Access Technology IoT Gateway. International Conference on Embedded Wireless Systems and Networks (EWSN), Lyon, France.	RISE, EAB
4	Workshop	June 2020	Hergys Rexha, Sebastien Lafond, Jani-Pekka Kainulainen, Giovanni Rigazzi: Towards Very Low-Power Mobile Terminals through Optimized Computational Offloading, CLEEN Workshop at ICC'20, Dublin, Ireland.	IDCC
5	Conference	June 2020	Muhammad Febrian Ardiansyah, Timothy William, Osamah Ibrahiem Abdullaziz, Li-Chun Wang, Po-Lung Tien, Maria C. Yuang. EagleEYE: Aerial Edge-enabled Disaster Relief Response System. EuCNC 2020, Online (Dubrovnik, Croatia)	NCTU

6	Workshop	Sep 2020	Milan Groshev and Carlos Guimarães. Demo: Assessing the need for 5G driven Edge and Fog solution for Digital Twin systems. In ACM WiNTECH, Online (London, UK).	UC3M
7	Conference	Nov 2020	Kiril Antevski, Milan Groshev, Gabriele Baldoni, Carlos J. Bernardos. DLT federation for Edge robotics. 'EEE NFV-SDN'20, Online (Madrid, Spain)	UC3M, ADLINK
8	Workshop	Dec 2020	Luigi Girletti, Milan Groshev, Carlos Guimarães, Antonio de la Oliva, Carlos J. Bernardos. An Intelligent Edge-based Digital Twin for Robotics. IEEE GLOBECOM 2020 Workshops on Advanced Technology for 5G Plus (AT5G+), Taipei, Taiwan and Online	UC3M
9	Workshop	Nov 2020	José Takeru Infiesta, Carlos Guimarães, Luis M. Contreras, Antonio de la Oliva. GANSO: Automate Network Slicing at the Transport Network Interconnecting the E'ge. NFV-SDN'20 Workshop on Mobility Support in Slice-based Network Control for Heterogeneous Environments (MOBISLICE III), Online (Madrid, Spain)	UC3M, TID
10	Conference	May 2021	J. Baranda, J. Mangues-Bafalluy, E. Zeydan, C. Casetti, C. F. Chiasserini, M. Malinverno, C. Puligheddu, M. Groshev, C. Guimarães, K. Tomakh, D. Kucherenko, O. Kolodiazhnyi. Demo: AIML-as-a-Service for SLA management of a Digital Twin Virtual Network Service, (INFOCOM 2021), Online	UC3M
11	Conference	April 2021	L.M. Contreras, J. Ordonez-Lucena. On Slice Isolation Options in the Transport Network and Associated Feasibility Indicators. IEEE International Conference on Network Softwarization (NetSoft) (Tokyo, Japan)	TID
12	Workshop	May 2021	Rexha, H., Lafond, S. Data collection and utilization framework for edge AI applications. WAIN'21 - 1st Workshop on AI Engineering – Software Engineering for AI (Online, originally Madrid, Spain).	AAU
13	Workshop	June 2021	Milan Groshev, Jorge Martin-Perez, Kiril Antevski, Antonio de la Oliva, Carlos J. Bernardos. COTORRA: COntext-aware Testbed fOR Robotic Applications. MobileServerless'21 - 1st Workshop on Serverless mobile networking for 6G Communications	UC3M
14	Conference	July 2021	Milan Groshev, Carlos Guimaraes, Antonio de la Oliva, Robert Gazda. Dissecting the Impact of Information and Communication Technologies on Digital Twins as a Service. IEEE ACCESS.	UC3M, IDCC

15	Conference	October 2021	Saptarshi Hazra, Thiemo Voigt, Wenqing Yan. PLIO: Physical Layer Identification using One-shot Learning. IEEE MASS 2021.	RISE
16	Conference	November 2021	Antonio Cobos, Carlos Guimarães, Antonio de la Oliva and Aitor Zabala. OpenFlowMon: A Fully Distributed Monitoring Framework for Virtualized Environments. MOBISLICE'21 (IEEE NFV-SDN 2021)	UC3M, TELCA

TABLE 3-2: PEER-REVIEWED PUBLICATIONS IN JOURNALS AND MAGAZINES.

#	Type	Month	Description	Partners
1	Journal	November 2019	Osamah Ibrahiem Abdullaziz, Li-Chun Wang, Shahzoob Bilal Chundrigar and Kuei-Li Huang. Enabling Mobile Service Continuity across Orchestrated Edge Networks. IEEE Transactions on Network Science and Engineering.	NCTU, ITRI
2	Magazine	July 2020	Luca Cominardi, Thomas Deiss, Miltiadis Filippou, Vincenzo Sciancalepore, Fabio Giust, Dario Sabella. MEC support for Network Slicing: Status and Limitations from a Standardization Viewpoint. IEEE Communication Standards Magazine.	ADLINK
3	Journal	March 2020	Luca Cominardi, Sergio González-Diaz, Antonio de la Oliva, Carlos J. Bernardos. Adaptative Telemetry for Software-Defined Mobile Networks. Journal of Network and System Management.	UC3M, ADLINK
4	Magazine	March 2020	Mikhail Afanasov and Luca Mottola. The FlyZone Testbed Architecture for Aerial Drone Applications. ACM GetMobile: Mobile Computing and Communications, vol 24, issue 1.	RISE
5	Journal	August 2020	Luis M. Contreras, Carlos J. Bernardos. Overview of Architectural Alternatives for the Integration of ETSI MEC Environments from Different Administrative Domains. Electronics 9(9)	UC3M, TID
6	Magazine	September 2020	I. Sarrigiannis, L.M. Contreras, K. Ramantas, A. Antonopoulos, C. Verikoukis. Application as a Service Function Chain in a Fog-enabled C-V2X Architecture. IEEE Network.	TID
7	Magazine	January 2021	Balázs Németh, Nuria Molner, Jorge Martín-Pérez, Carlos J. Bernardos, Antonio de la Oliva, Balázs Sonkoly. Delay and reliability-	UC3M

			constrained VNF placement on mobile and volatile 5G infrastructure. IEEE Transactions on Mobile Communications	
8	Magazine	March 2021	Carlos Guimarães, Milan Groshev, Luca Cominardi, Aitor Zabala, Luis M. Contreras, Samer T. Talat, Chao Zhang, Saptarshi Hazra, Alain Mourad, Antonio de la Oliva. DEEP: A Vertical-Oriented Intelligent and Automated Platform for the Edge and Fog. IEEE Communications Magazine (IEEE COMMAG)	UC3M, IDCC, RISE, TELCA, ADLINK, Telefonica, ITRI
9	Journal	April 2021	L.M. Contreras, S. Barguil, R. Vilalta, V. Lopez. Architecture for integrating vertical customer programmability control of network functions and connectivity in a slice-as-a service schema. EURASIP Journal on Wireless Communications and Networking	Telefonica
10	Journal	April 2021	Carlos Guimarães, Antonio de la Oliva, Luis M. Contreras. "Support for Availability Attributes in Network Slices in GANSO". Wiley Internet Technology Letters.	UC3M, Telefonica
11	Journal	May 2021	Sergio Gonzalez-Diaz, Roger Marks, Elisa Rojas, Antonio de la Oliva, and Robert Gazda. Stateless Flow-Zone Switching using Software-Defined Addressing. IEEE Access	UC3M
12	Journal	September 2021	Milan Groshev, Jorge Martín-Pérez, Carlos Guimarães and Antonio de la Oliva. Towards Intelligent Cyber-Physical Systems: Digital Twin meets Artificial Intelligence. IEEE Communications Magazine - Special Issue on Networks for Cyber-Physical Systems and Industry 4.0.	UC3M
13	Magazine	May 2021	Gabriele Baldoni, Luca Cominardi, Milan Groshev, Antonio de la Oliva, Angelo Corsaro. Managing the far-Edge: are today's centralized solutions a good fit?. IEEE Consumer Electronics Magazine.	UC3M, ADLINK
14	Journal	July 2021	Milan Groshev, Carlos Guimarães, Antonio de la Oliva, Robert Gazda. Dissecting the Impact of Information and Communication Technologies on Digital Twins as a Service. IEEE Access.	UC3M, IDCC

TABLE 3-3: ORGANISATION OF SPECIAL ISSUES OF JOURNALS AND MAGAZINES.

#	Month	Journal/Magazine	Special issue name	Partners
1	June 2020	Elsevier Pervasive and Mobile Computing	Special issue on Edge Computing in Pervasive Systems	UC3M
2	April 2021	Wiley Internet Technology Letters	Wiley Internet Technology Letters - Special Issue on Mobility Support in Slice-Based Network Control for Heterogeneous Environment	UC3M, TID
3	April 2021	Wiley Internet Technology Letters	Support for Availability Attributes in Network Slices in GANSO	UC3M

3.1.2. Technical Talks

Table 3-4 lists all presentation activities delivered during the project duration, including talks and panels. As reported, 12 talks and 1 panel were delivered at 11 different venues.

TABLE 3-4: TALKS AND PANELS DELIVERED.

#	Type	Month	Venue	Description	Partners
1	Talk	October 2019	EU-TW 5G/B5G workshop	5G-DIVE: eDge Intelligence for Vertical Experimentation	UC3M
2	Talk	November 2019	IEEE CloudNet	Networking the Cloud, Cloudifying the Network	TID
3	Talk	November 2019	Open Workshop on "Research Activities of Mutual Interest" @ IMDEA Networks (Leganés)	5G-DIVE - eDge Intelligence for Vertical Experimentation	UC3M
4	Talk	April 2020	5th IEEE International Workshop on Orchestration for Software Defined Infrastructures (O4SDI), co-located with the 2020 IEEE/IFIP Network Operations and Management Symposium (NOMS 2020), Budapest, Hungary, April 2020 (going virtual)	Towards a standardized transport slicing architecture in operator networks (invited talk)	TID
5	Talk	May 2020	Workshop on The role of computing in the post 5G-era: Architectures and enabling technologies co-located with the 24th International Conference on Optical Network Design and Modelling (ONDM 2020), Castelldefels, Spain, May 2020 (going virtual)	Evolutionary trends in operators' networks for beyond 5G (invited talk)	TID

6	Talk	June 2020	Online workshop "5G end-to-end experimentation by verticals in EU projects"	DEEP: An Intelligence and Automation Platform for Edge and Fog Computing Environments	UC3M
7	Panel	June 2020	Online workshop "5G end-to-end experimentation by verticals in EU projects"	Introductory and concluding panel discussions	UC3M
8	Talk	June 2020	Online workshop "5G end-to-end experimentation by verticals in EU projects"	Assessing 5G need for Digital Twin Applications	UC3M
9	Talk	June 2020	Network Slicing 2020 workshop en IFIP Networking 2020, Paris, France, June 2020 (going virtual)	Transport slicing – ongoing work at IETF with a personal view (invited talk)	TID
10	Talk	June 2020	EuCNC 2020	European Conference on Networks and Communications 2020	NCTU
11	Talk	August 2020	IWPC - International Wireless Industry Consortium www.iwpc.org	Edge Computing and Networking	IDCC
12	Talk	November 2020	Workshop on Autonomous Drone Scout (ADS) in 5G-DIVE, Conference Room 1(1st Floor), MIRC Building, NCTU	Involved 5G-DIVE partners, Operators, Firefighter agency, Taiwan industrial companies, etc.	III, ITRI, NCTU, ASKEY
13	Talk	November 2020	MOBISLICE III (NFV-SDN'20 Workshop), Madrid, Spain	Edge and Fog for Industry 4.0 and Autonomous Drone Scouting with 5G-DIVE	UC3M
14	Talk	June 2021	EuCNC & 6G Summit, Porto, Portugal (virtual conference)	Empowering Industry 4.0 and Autonomous Drone Scouting use cases through 5G-DIVE Solution	

3.1.3. Workshops and conferences

During the lifetime of the project, 5 workshop proposal has been submitted. One workshop has been organized in Year 1 of the project while another 4 takes place in Year 2. Full details are in Table 3-5.

TABLE 3-5: WORKSHOPS AND CONFERENCES ORGANIZED.

#	Event	Month	Status	Workshop	Country	Partners
1	Online	June 2020	Completed	"5G end-to-end experimentation by verticals in EU projects", workshop arranged in collaboration with the projects 5GROWTH, 5G-DIVE, 5G-EVE, 5G-VINNI and 5G-Tours.	Online	UC3M, NCTU
2	IEEE SDN-NFV conference	November 2020	Completed	IEEE Conference on Network Function Virtualization and Software Defined Networks (IEEE SDN-NFV)	Online (Madrid, Spain)	UC3M, TID
3	IEEE SDN-NFV	November 2020	Completed	MOBISLICE III – 3rd edition of Mobility Support in Slice-based Network Control for Heterogeneous Environments (workshop)	Online (Madrid, Spain)	UC3M, TID
4	IEEE Globecom	December 2020	Accepted and later Merged	IEEE GC20 Workshop on "Intelligent Fog and Edge Infrastructures for Future Wireless Systems". https://globecom2020.ieee-globecom.org/workshop/ws-03-workshop-intelligent-fog-and-edge-infrastructures-future-wireless-systems Merged into IEEE GC20 Workshop on Advanced Technology for 5G Plus (AT5G+)	Taipei, Taiwan and Online	UC3M, IDCC, RISE, NCTU
5	Workshop	October 2021	Completed	5GROWTH & 5G-DIVE Exploitation workshop (29 October 2021) – "Experiences from field trial about vertical industry"	Online (Madrid, Spain)	UC3M, RISE, ITRI, NCTU, EAB, TELCA

3.1.4. Exhibitions and Demonstrations

During the lifetime of the project, 6 demonstrations have been showcased and the project has been presented in three exhibition booths, as shown in Table 3-6.

TABLE 3-6: EXHIBITIONS AND DEMOS.

#	Type	Month	Venue	Description	Lead Partners
1	Demo at a conference	December 2019	Workshop. Edge Computing World, San Francisco	Luca Cominardi, Gabriele Baldoni. Edge computing world conference. Demo Presentation fog05 and Robotics ROS2 integration. https://blog.blueberrycoder.com/2019/11/the-eclipse-foundation-at-edge.html	ADLINK
2	Demo at conference	February 2020	International Conference on Embedded Wireless Systems and Networks (EWSN), Lyon, France.	Demo: Multi-Radio Access Technology IoT Gateway.	RISE, EAB
3	Booth	February 2020	2020 ICF (Intelligent Community Forum) Top7, Taoyuan, Taiwan		ASKEY
4	Web exhibition	February 2020	Anritsu Virtual MWC'20 exhibition	Demo: 5G Industry Verticals Test Bed https://www.anritsu.com/zh-tw/test-measurement/technologies/web-exhibit/mwc/pod#pod-3	IDCC
5	Demo at workshop	June 2020	Online workshop "5G end-to-end experimentation by verticals in EU projects"	Live online demonstration: "Assessing 5G need for Digital Twin Applications"	UC3M
6	Demo at workshop	June 2020	Online workshop "5G end-to-end experimentation by verticals in EU projects"	Recorded demonstration: "EagleEYE: Aerial Edge-enabled Disaster Relief Response System"	NCTU
7	Demo at workshop	September 2020	ACM WiNTECH,	Demo: Assessing the need for 5G driven Edge and Fog solution for Digital Twin systems	UC3M

			Online (London, UK)		
8	Booth	December 2020	Globecom 2020	5G-Dive: eDge Intelligence for Vertical Experimentation	UC3M, EAB, IDCC, III, ITRI, NCTU, ASKEY
9	Booth (virtual)	June 2021	EuCNC & 6G Summit, Porto, Portugal (virtual conference)	Exhibition of the project with posters, a video demo and the project leaflet	UC3M, RISE

3.1.5. EU Cross-projects Collaboration Activities

During the lifetime of the project, 5G-DIVE has put an effort towards collaboration with other EU projects as shown in Table 3-7.

TABLE 3-7: EU CROSS-PROJECTS COLLABORATION ACTIVITIES.

#	Venue	Description
1	5G Annual Journal	Project summary article submitted
2	Submitted Workshop proposal for EuCNC'20 (cancelled)	A workshop proposal to EuCNC'20 as a joint action with a number of projects
3	Submitted a Booth proposal with 5GROWTH for EuCNC'20 (cancelled)	A joint booth application was submitted to EuCNC'20.
4	Online workshop	"5G end-to-end experimentation by verticals in EU projects", workshop arranged in collaboration with the projects 5GROWTH, 5G-DIVE, 5G-EVE, 5G-VINNI and 5G-Tours. (see details in Table 3-5)
5	WiNTECH 2020	Organization of Poster/Demo track at the workshop. Joint with EMPOWER project.
6	IEEE SDN-NFV 2020	Organization of MOBISLICE III workshop together with 5GROWTH project. (see details in Table 3-5)
7	Webinar 2020	WEBINAR: "Beyond 5G Evolution" 5GROWTH, 5G-DIVE and EMPOWER co-organize a webinar entitled "Beyond 5G Evolution"
8	Webinar 2021	5GROWTH and 5G-DIVE Research Projects: diferentes acercamientos para el Edge.
9	White paper 2021	Edge Computing for 5G Networks. Projects involved: 5G-VICTORI, 5G-PICTURE, 5G- VINNI, 5G-HEART, 5G-CROCO, 5G-MOBIX, 5GROWTH, 5G-TRANSFORMER, SLICENET, SaT5G.

10	UC3M and 5TONIC sponsors of the MEC Hackaton 2021	Edge Computing World – MEC Hackathon 2021.
11	Online workshop 2021	5GROWTH – 5G-DIVE: Exploitation Workshop Experiences from field trials about the vertical industry. (see details in Table 3-5)

3.2. Actions After the Project

After the end of the project, some of the results and materials related to the final trials will be published and made available to the public at the 5G-DIVE website (https://5g-dive.eu). The aforementioned results and materials cover both use cases which are I4.0 Use Case conducted in the 5TONIC premise (Spain), as well as ADS Use Cases conducted in MIRC building in NCTU campus premise (Taiwan).

As explained in Section 2.2, after 2023 the content will be made static and stored in an online archive for its preservation and reachability. In addition, all dissemination content, including any publication has already been sent to e-archivo, the institutional UC3M repository, for its publication in open access (considering all the embargo procedures and licenses from publishers). All publications from the project will be made available on this repository along 2023.

4. Standardisation and Open Source Activities

This section reports on the 5G-DIVE activities and relevant developments in standards and open source projects. The targets for the 5G-DIVE project on standard contributions are (1) 5 adopted contributions and (2) participation in at least one open source project. The activities reported include: an update of the status of relevant topics in relevant standards and open-source forums; and a report of the contributions from 5G-DIVE consortium partners disseminating work developed within the framework of the 5G-DIVE project. The open-source achievements are reported in two different subsections to discriminate platform- and use case-oriented activities.

4.1. Standardization Achievements

This section summarizes the standardization activities in SDOs like 3GPP, ETSI, IETF, IEEE and reports the standardization achievements during the course of the project. Overall, the standardization activities have all been impacted by ongoing COVID-19 related restrictions such as having virtual meetings instead of face-to-face. Although the specification works have never been stopped since the beginning of the pandemic, the pace has been slower than it used to be. Therefore, the timeline of some study items/working groups has been shifted.

4.1.1. 3GPP

In previous reports, a set of specific study items/working groups has been identified by 5G-DIVE project partners to have a close monitoring activity and to plan contributions to disseminate project achievements. This deliverable provides a status update of the identified items/groups.

- **Enablers for Network Automation (eNA) for 5G** [1]: This study focuses on automation use cases related to UE driven analytics. The study also addresses the interaction between Network Data Analytics Function (NWDAF) and AI Model & Training Service owned by the operator. The completion target date for this item was initially set to June 2021. However, due to the slow pace and arrangements regarding the virtual meetings, the target date was then set to September 2021. In the 3GPP Service and System Aspects September 2021 plenary meeting, this item was reported as 99% complete due to waiting liaison responses from other WGs. In the last plenary meeting, this study is reported as 100% complete. Regarding the future of this study item, there is a new proposal for Release 18 as a 3rd phase of this specific study. This proposal was submitted for discussion and a final decision will be taken in the plenary meeting in December 2021.
- **Enhanced support of Non-Public Networks (eNPN)** [2]: This study focuses on the requirements of non-public networks. The completion target date for this item was initially set to June 2021. However, due to the slow pace and arrangements regarding the virtual meetings, the target date was then set to September 2021. In the last 3GPP Service and System Aspects plenary meeting, this item is reported as 95% complete. Some issues are dependent on other working groups. Therefore, these issues will be addressed by alignment change requests. Regarding the future of this study item, there is a new proposal for Release 18 as the 2nd phase

of this specific study. This proposal was submitted for discussion and a final decision will be taken in the plenary meeting in December 2021.

- **Enhancement of support for Edge Computing (EC) in 5G**: This study covers two main objectives, namely, potential system enhancements and deployment guidelines for enhanced Edge Computing support/use cases. The completion target date for this item was initially set to June 2021. However, due to the slow pace and arrangements regarding the virtual meetings, the target date was then set to September 2021. In the 3GPP Service and System Aspects September 2021 plenary meeting, this item was reported as 95% complete with a note for an issue to be solved on how to guarantee that UE uses the IP address of an Edge Application Server Discovery Function for the subsequent data source name query. In the last plenary meeting, this study is reported as 100% complete. Regarding the future of this study item, there is a new proposal for Release 18 as the 2nd phase of this specific study. This proposal was submitted for discussion and a final decision will be taken in the plenary meeting in December 2021.
- **Enhancement of Network Slicing (eNS)** [3]: This study aims at identifying the gaps that need to be filled in providing support in the specifications owned by 3GPP Service and System Aspects WG2 for the Generic Network Slice Template (GST) attributes. The completion target date for this item was initially set to June 2021. However, due to the slow pace and arrangements regarding the virtual meetings, the target date was then set to September 2021. There is a need for further explanations/clarifications on the work item technical report. Regarding the future of this study item, there is a new proposal for Release 18 as the 3rd phase of this specific study. This proposal was submitted for discussion and a final decision will be taken in the plenary meeting in December 2021.

4.1.2. IETF and IRTF

Following D4.1 [5], the priorities in IETF/IRTF standardization work did not change. Currently, 5G-DIVE is contributing to and/or monitoring the progress of the following working/research groups:

- **Service Function Chaining (SFC) WG.** In 5G-DIVE we are working on fog orchestration control and mobility (function migration) for SFC in fog environments. Due to the relative slow-down of activity of this WG (due to the COVID-19 situation), the WG has not made significant progress. The 5G-DIVE contributions (listed in Section 4.1.6) have been maintained, waiting for the WG to open the discussion for the adoption of new items. We have been approached by Airbus to collaborate on some of the proposed documents.
- **ANIMA WG.** In 5G-DIVE, we continue exploring dynamic monitoring approaches that can be bootstrapped using GRASP extensions in fog environments. This WG has also experienced a slow-down in their progress due to COVID-19. Despite this, we have managed to gather interest from other IETF participants and even added a new co-author to one of our contributions.
- **Distributed Mobility Management (DMM) WG.** The activity of this WG has been slower than usual mainly due to the COVID-19 scenario, but also because the group is in the process of re-scoping its goals and milestones. 5G-DIVE is monitoring and contributing to this WG with SFC mobility solutions (extending the Mobile IPv6 protocol), as listed in Section 4.1.6.

- **Reliable and Available Wireless (RAW) WG.** This WG was just created before the COVID-19 situation, and it is one of the few that has made more progress despite the lack of in-person meetings. Some of the use cases and potential technologies currently considered by the RAW WG are very much related to 5G-DIVE. One example is edge robotics, which is very much in the scope of RAW. Different contributions, as listed in Section 4.1.6, have been made, including being editors of the use cases adopted WG document and co-authors of the OAM framework WG document.
- **Dynamic Host Configuration (DHC) WG.** We actively participated in this WG, as some mechanisms explored in 5G-DIVE might make use of DHCP (for local MAC addressing). A couple of contributions from the project have been published as RFCs, as listed in Section 4.1.6.
- **Network Management Research Group (NMRG).** AI-based network management is a topic covered by 5G-DIVE which is relevant to the NMRG WG. While no contributions have been made at this point, we continue monitoring the progress and we plan to participate in the future.
- **COIN proposed research group (COINRG).** The project initially contributed to this WG with some work on discovery mechanisms at the edge. In the latest months, we have been monitoring the activities of this WG.

In addition to the WGs identified in D4.1, a recently created WG, see details below, is also added to the list of 5G-DIVE priority WGs.

- **MAC Address Device Identification for Network and Application Services (MADINAS) WG.** This recently created WG (first met at IETF 112) is looking into issues related to the use of MAC randomized addresses. This is potentially relevant, as there are scenarios where this might be beneficial. We are co-chairing the WG and have also contributed currently in the process of becoming adopted by the WG.

4.1.3. ETSI

5G-DIVE consortium has been monitoring several ETSI Industry Specification Groups (ISGs) relevant to the targeted solution and where applicable contributing to some of these ISGs as reported in section 4.1.6. The status of these ISGs is reported briefly hereafter:

- **ETSI MEC ISG** is in its third two-year cycle with a focus on the evolution towards cloud native paradigm. Importantly for 5G-DIVE, a new study ETSI GR MEC 036 "Study on MEC in resource constrained terminals, fixed or mobile" has launched recently (July 2020). This study focuses on how resource constrained devices, such as terminal units, mobile hosts and personal devices, can be used to support cloud computing at the edge. This study is led by IDCC, and three joint contributions with UC3M have already been made within the 5G-DIVE solution framework.
- **ETSI ENI ISG** completed its second two-year cycle (Release 2) that is focused on data and action interoperability, and work on Release 3 has started. Release 3 will focus on further developing standards for a Cognitive Network Management System that uses one or more closed control loops to make its decisions. This is supported by additional detailed use cases, requirements, and Proof of Concept projects (PoCs). The System Architecture is enhanced by providing detailed specification of Internal and External Reference Points, along with an information

model and a set of data models, the next release will specify the APIs and Interfaces. These enhancements provide access to an extensible framework that can host different AI algorithms that augment control and management mechanisms to adaptively adjust services offered based on changing user needs, business goals, and environmental conditions.

- **ETSI NFV ISG:** This group is currently running its fourth two-year cycle, complementing the previous work on many areas conforming to what is referred as "Release 4" specification. There are several aspects from this release relevant to 5G-DIVE. Among them, the support of lightweight virtualization technologies like OS containers, important when considering resource constrained virtual infrastructures as the ones that could be found at the edge and fog. Also, the analysis of enhancements in NFV for accompanying the deployment of 5G networks, or multi-tenancy aspects (such as isolation or resource sharing) of relevance for cloud-based environments.
- **ETSI ZSM ISG**: The activity on ZSM is in its second two-year cycle of development. The relevant work in ZSM for 5G-DIVE is mainly concentrated in the activities related to lifecycle management and closed loop design and operations. Also interesting for the project, specifically when looking at potential multi-domain scenarios, is the cross-domain service orchestration and automation that can involve the provision of services through multiple administrative domains. The focus of recent plenary meetings was on discussing/defining the priorities for the next 2 years.
- **ETSI PDL ISG**: The activity in this group is in its first two-year cycle focused on addressing the adoption of blockchain technologies in the telecommunication industry, initially focusing on business use cases, architectures, interfaces and data models. Even if it is incipient, it can have an interesting potential for 5G-DIVE use case scenarios extremely sensible to security, robustness and accounting. The idea of leveraging smart contracts, dealt through distributed ledger mechanisms, as a form of relationship among parties is promising when thinking about the realistic exploitation of 5G-DIVE outcomes.

4.1.4. IEEE

Following D4.2 [7], the priorities in IEEE standardization work did not change. Currently, 5G-DIVE is monitoring progress in four main areas:

- **IEEE 802.1:** 5G-DIVE is monitoring the IEEE 802.1 TSN for possible relevant activities regarding the industrial profile and the IEEE 802.1CQ activity, aiming at the distribution of local MAC addresses to IEEE 802 compliant equipment.
- **IEEE 802.11bc:** Activity within the WLAN group aiming at developing new technologies for the broadcasting of information from the access point (AP) or the stations (STAs), relevant for the industrial and drone use cases of 5G-DIVE.
- **IEEE 802.11be:** Activity that will yield to WiFi 7. Apart from the expected increase in the density of users and bandwidth available to end-users, this standard aims at deeper integration with TSN networks, which may be relevant to industrial and drone use cases.

- **IEEE 802.**11bi: Activity to improve the privacy of WLAN. This activity works towards the definition of new mechanisms to improve the privacy of the WLAN end user. Although yet to be completed, this work goes into the line of defining a mechanism to hide privacy related fields in the WLAN headers, such as the source MAC address.

4.1.5. O-RAN

The O-RAN alliance [4] is promoting the interoperability of disaggregated RAN solutions producing different specifications for virtualization, operation, control and management of them. Apart from the interest in 5G-DIVE for the potential of disaggregated RAN from an architectural point of view, it is of relevance for the project the consideration of AI-based mechanisms for its applicability to radio resource control. Currently, 5G-DIVE is monitoring the progress of the following working/research groups:

- **WG1 on Use Cases and Overall Architecture Workgroup.** The architectural approach of disaggregated RAN could be applicable to 5G-DIVE scenarios, where components of the disaggregated RAN could lay on different administrative domains (i.e., vertical premises and operator facilities). The use cases considered so far in O-RAN are also inspirational for analysing additional scenarios in 5G-DIVE, such as for instance RAN sharing cases.
- **WG2 on the Non-real-time RAN Intelligent Controller and A1 Interface Workgroup.** This group considers the introduction of AI/ML mechanisms for the near-RT RAN Intelligent Controller (RIC), which could be considered as complementary to the same kind of capabilities being developed within 5G-DIVE.
- **WG9 on Open X-haul Transport Work Group.** Because of the fact of disaggregating the RAN, the distinct components of the radio access need to be properly interconnected. This group is specifying the transport connectivity for the full environment and the co-existence with other services in the field, which is important when considering the integration of 5G-DIVE scenarios, leveraging on O-RAN, with other services existing in the network.

4.1.6. Standardization Achievements

The target for the 5G-DIVE project is 10 adopted contributions to SDOs, such as 3GPP, IETF, ETSI, IEEE, ITU over the lifetime of the project. Up until now, the project has reported a total of 63 standard contributions where 18 out of 63 contributions are adopted. The spread of contributions among the relevant SDOs is as follows:

- 3GPP → Total: 15; Adopted: 6; Overall contribution ratio: 23.8%
- IETF → Total: 25; Adopted: 2; Overall contribution ratio: 39.7%
- ETSI → Total: 4; Adopted: 3; Overall contribution ratio: 6.3%
- IEEE → Total: 19; Adopted: 7; Overall contribution ratio: 30.2%

Table 4-1 provides more details on the status of the standardization effort in 5G-DIVE project.

TABLE 4-1: STANDARD CONTRIBUTIONS IN 5G-DIVE.

#	Date	SDO	WG	Title	Authors	ID	Status	Partners involved
1	Nov'19	IETF	ANIMA	Autonomic setup of fog monitoring agents	CJ. Bernardos, A. Mourad	draft-bernardos-anima-fog-monitoring-01	ID-Exists	UC3M, IDCC
2	Nov'19	IETF	RAW	RAW use cases	G. Papadopoulos, P. Thubert, F. Theoleyre, CJ. Bernardos	draft-bernardos-raw-use-cases-01	ID-Exists	UC3M
3	Nov'19	IETF	ALTO	Use of ALTO for Determining Service Edge	LM. Contreras, D. Lachos, C. Rothenberg	draft-contreras-alto-service-edge-00	ID-Exists	TID
4	Nov'19	IETF	TEAS	Considerations for defining a Transport Slice NBI	LM. Contreras, S. Homma, J. Ordonez-Lucena	draft-contreras-teas-slice-nbi-00	ID-Exists	TID
5	Nov'19	IETF	TEAS	Transport Network Slice YANG Data Model	X. Liu, J. Tantsura, I. Bryskin, L. Contreras, Q. Wu	draft-liu-teas-transport-network-slice-yang-00	ID-Exists	TID
6	Mar'20	IETF	RAW	RAW use cases	G. Papadopoulos; P. Thubert; F. Theoleyre; CJ. Bernardos	draft-bernardos-raw-use-cases-03	ID-Exists, Update	UC3M
7	Mar'20	IETF	DHC	SLAP quadrant selection options for DHCPv6	CJ. Bernardos; A. Mourad	draft-ietf-dhc-slap-quadrant-05	ID-Exists, WG adopted	UC3M, IDCC
8	Mar'20	IETF	SFC	Service Function discovery in fog environments	CJ. Bernardos, A. Mourad	draft-bernardos-sfc-discovery-04	ID-Exists	UC3M, IDCC
9	Mar'20	IETF	SFC	Service Function Chaining Use Cases in Fog RAN	CJ. Bernardos, A. Rahman, A. Mourad	draft-bernardos-sfc-fog-ran-07	ID-Exists	UC3M, IDCC
10	Mar'20	IETF	SFC	Distributed SFC control operation	CJ. Bernardos, A. Mourad	draft-bernardos-sfc-distributed-control-operation-00	ID-Exists	UC3M, IDCC
11	Mar'20	IETF	SFC	NSH extensions for local distributed SFC control	CJ. Bernardos, A. Mourad	draft-bernardos-sfc-nsh-distributed-control-00	ID-Exists	UC3M, IDCC
12	Mar'20	IETF	DMM	SFC function mobility with Mobile IPv6	CJ. Bernardos, A. Mourad	draft-bernardos-dmm-sfc-mobility-00	ID-Exists	UC3M, IDCC

13	Mar'20	IETF	DHC	SLAP quadrant selection options for DHCPv6	CJ. Bernardos, A. Mourad	draft-ietf-dhc-slap-quadrant-06	Standards Track (update)	UC3M, IDCC
14	Jul'20	IETF	SFC	Distributed SFC control for fog environments	CJ. Bernardos, A. Mourad	draft-bernardos-sfc-distributed-control-02	ID-Exists	UC3M, IDCC
15	Sep'20	IETF	intarea	IPv6-based discovery and association of Virtualization	CJ. Bernardos, A. Mourad	draft-bernardos-intarea-vim-discovery	ID-Exists	UC3M, IDCC
16	Sep'20	IETF	SFC	NSH extensions for local distributed SFC control	CJ. Bernardos, A. Mourad	draft-bernardos-sfc-nsh-distributed-control	ID-Exists, Update	UC3M, IDCC
17	Sep'20	IETF	SFC	Distributed SFC control operation	CJ. Bernardos, A. Mourad	draft-bernardos-sfc-distributed-control-operation	ID-Exists, Update	UC3M, IDCC
18	Sep'20	IETF	DMM	SFC function mobility with Mobile IPv6	CJ. Bernardos, A. Mourad	draft-bernardos-dmm-sfc-mobility	ID-Exists, Update	UC3M, IDCC
19	Apr'20	3GPP	SA2	23.501 CR2269R2 (Rel-16, 'F'): Enablers for multiple SCPs (23.501)	Oracle Corporation, Verizon UK Ltd, Nokia, Nokia Shanghai-Bell, Samsung, Ericsson, ITRI, CATT, AT&T, ZTE, InterDigital	S2-2003269	Accepted	ITRI, IDCC
20	Apr'20	3GPP	SA2	23.502 CR2208R2 (Rel-16, 'F'): Enablers for multiple SCPs (23.502)	Oracle Corporation, Verizon UK Ltd, Nokia, Nokia Shanghai-Bell, Samsung, Ericsson, ITRI, CATT, AT&T, ZTE, InterDigital	S2-2003270 (https://www.3gpp.org/ftp/tsg_sa/WG2_Arch/TSGS2_138e_Electronic/Docs/S2-2003270.zip)	Accepted	ITRI, IDCC
21	Sep'20	3GPP	SA2	23.748: Update to Solution #39: EAS relocation coordinated with PSA change.	Huawei, HiSilicon, InterDigital Inc., Apple, ITRI	S2-2005982 (https://www.3gpp.org/ftp/tsg_sa/WG2_Arch/TSGS2_140e_Electronic/Docs/S2-2005982.zip)	Accepted	ITRI, IDCC
22	Oct'19	3GPP	SA2	23.748: Application	ITRI	S2-1909645 (https://www.3gp	Merged into S2-1910422	ITRI, IDCC

				server discovery for enhanced Edge Computing		p.org/ftp/tsg_sa/WG2_Arch/TSGS2_135_Split/Docs/S2-1909645.zip)		
23	Oct'19	3GPP	SA2	23.748: Key Issue for the discovery of edge application server	Huawei, HiSilicon, Ericsson, Nokia, Futurewei, Sandvine, ITRI, Toyota, CATT, vivo, Deutsche Telekom, OPPO, Tencent, Samsung, LG Electronics, Alibaba Group	S2-1910422 (https://www.3gpp.org/ftp/tsg_sa/WG2_Arch/TSGS2_135_Split/Docs/S2-1910422.zip)	Accepted	ITRI, IDCC
24	Nov'19	3GPP	SA2	23.748: Key Issue on edge relocation (FS_enh_EC)	Qualcomm Incorporated, NTT DOCOMO, AT&T, Nokia, Nokia Shanghai Bell, Samsung, Ericsson, LG Electronics, Sandvine, Interdigital, ITRI, Deutsche Telekom, Lenovo	S2-1912612 (https://www.3gpp.org/ftp/tsg_sa/WG2_Arch/TSGS2_136_Reno/Docs/S2-1912612.zip)	Accepted	ITRI, IDCC
25	Nov'19	3GPP	SA2	23.748: New key issue on 5GS enhancements to support Edge and PSA Relocation	InterDigital Inc., ITRI	S2-1911795 (https://www.3gpp.org/ftp/tsg_sa/WG2_Arch/TSGS2_136_Reno/Docs/S2-1911795.zip)	Merged into S2-1912354	ITRI, IDCC
26	Nov'19	3GPP	SA2	23.748: New key issue on deployment consideration to enable seamless change of EC Application Server, serving UEs	InterDigital Inc., ITRI	S2-1911794 (https://www.3gpp.org/ftp/tsg_sa/WG2_Arch/TSGS2_136_Reno/Docs/S2-1911794.zip)	Posted	ITRI, IDCC
27	Nov'19	3GPP	SA2	23.748: Solution for application	ITRI	S2-1911919 (https://www.3gp	Posted	ITRI, IDCC

				server discovery based on NEF registration.		p.org/ftp/tsg_sa/WG2_Arch/TSGS2_136_Reno/Docs/S2-1911919.zip)		
28	Jul'20	ETSI	MEC	MEC036 Update to Section 4 Overview	Debashish Purkayastha, Alain Mourad, Carlos Bernardos, Marco Liebsch	MEC(20)000258	Accepted	IDCC, UC3M
29	Jul'20	ETSI	MEC	MEC036 Use case Zero Defect Manufacturing	Debashish Purkayastha, Alain Mourad, Carlos Bernardos , Marco Liebsch	MEC(20)000259	Accepted	IDCC, UC3M
30	Jul'20	ETSI	MEC	Use case Mission critical vehicular and mobile node application	Debashish Purkayastha, Alain Mourad, Carlos Bernardos , Marco Liebsch	MEC(20)000261	Accepted	IDCC, UC3M
31	Sep'20	IETF	SFC	Service Function Chaining Use Cases in Fog RAN	CJ. Bernardos, A. Rahman, A. Mourad	draft-bernardos-sfc-fog-ran-08	ID-Exists, Update	UC3M, IDCC
32	Sep'20	IETF	SFC	Service Function discovery in fog environments	CJ. Bernardos, A. Mourad	draft-bernardos-sfc-discovery-05	ID-Exists, Update	UC3M, IDCC
33	Nov'20	IETF	ANIMA	Autonomic setup of fog monitoring agents	CJ. Bernardos, A. Mourad	draft-bernardos-anima-fog-monitoring-03	Experimental	UC3M, IDCC
34	Dec'20	IETF	DHC	Structured Local Address Plan (SLAP) Quadrant Selection Option for DHCPv6	CJ. Bernardos, A. Mourad	RFC 8948	Published	UC3M, IDCC
35	Jan'21	IETF	SFC	Distributed SFC control for fog environments	CJ. Bernardos, A. Mourad	draft-bernardos-sfc-distributed-control-03.txt	Experimental	UC3M, IDCC
36	Sep'19	IEEE	802.11	Constraints of OCB transmission	Antonio de la Oliva	2019/1642r0	Submitted	UC3M
37	Jan'21	IEEE	802.11	RCM Rogue Containment Use case	Antonio de la Oliva		Submitted	UC3M
38	Nov'19	IEEE	802.11	Service Discovery on eBCS Info frame	Antonio de la Oliva	2019/1978r1	Submitted	UC3M
39	Nov'19	IEEE	802.11	Service Discovery Advertisement	Antonio de la Oliva	2019/2017r0	Submitted	UC3M

40	Nov'19	IEEE	802.11	Update on proposed SFD text for R3.5.3	Antonio de la Oliva	2019/2069r1	Submitted	UC3M
41	Apr'20	IEEE	802.11bc	Discovery STA service consumption	Antonio de la Oliva	2020/322r1	Submitted	UC3M
42	Oct'20	IEEE	802.11bc	CC31 Resolution for CIDs assigned	Antonio de la Oliva	2020/1418r0	Reviewed	UC3M
43	Oct'20	IEEE	802.11bc	This contribution solves comments assigned to Antonio de la Oliva regarding the advertisement of throttling characteristics for eBCS UL.	Antonio de la Oliva	2020/1419r4	Reviewed	UC3M
44	Jan´21	IEEE	802.11bc	Discussion on 9.4.5.100	Antonio de la Oliva	2021/314r0	Accepted	UC3M, IDCC
45	Mar´21	IEEE	802.11bc	Supporting document for CIDs 1011, 1012, 1046, 1047 and 1069	Antonio de la Oliva	2021/341r2	Accepted	UC3M, IDCC
46	Mar'21	IEEE	802.11bc	Resolution for CIDs assigned to Antonio for sections 9.4.5.100	Antonio de la Oliva	2021/176	Discussion	UC3M, IDCC
47	Jan'21	IEEE	802.11bc	Resolutions for CIDs assigned to Antonio during LB252 for 11bc D1.0	Antonio de la Oliva	2021/79r0	Discussion	UC3M, IDCC
48	Jan'21	IEEE	802.11bc	Resolution for CIDs assigned to Antonio for sections 9.4.5.100 and 9.6.7.102	Antonio de la Oliva	2021/155r0	Discussion	UC3M, IDCC
49	Nov'20	IEEE	802.11bc	Revision of Enhanced Broadcast Request/Response ANQP-element	Antonio de la Oliva, Stephen McCann, Xiaofei Wang	2020/1769	Adopted	UC3M, IDCC
50	Nov'20	IEEE	802.11bc	Revision of Enhanced Broadcast Services ANQP-element	Antonio de la Oliva, Robert Gazda, Stephen McCann, Xiaofei Wang	2020/1671r1	Discussion	UC3M, IDCC

51	Jun'21	IEEE	802.11bc	Message sequence diagrams for arc discussion	Antonio de la Oliva	2021/979	Accepted	UC3M, IDCC
52	Mar'21	ETSI	MEC	Eclipse Zenoh and ETSI MEC	Luca Cominardi	MEC(21)000116r1 _Eclipse_Zenoh_ and_ETSI_MEC	Noted	ADLINK
53	May'21	3GPP	RAN3	Summary of offline discussion on CB: #1203_SONMDT_ SuccessHO	Jim Miller	R3-212659	Discussion	IDCC
54	May'21	3GPP	RAN3	Improving RAN visibility over CHO and DAPS procedures via SHR and RLF reports	Jim Miller	R3-212268	Available	IDCC
55	May'21	3GPP	RAN3	Data Forwarding Optimization Use Case for AI	Jim Miller	R3-212269	Available	IDCC
56	May'21	3GPP	RAN3	Mobility Optimization Use Case for AI	Jim Miller	R3-212271	Available	IDCC
57	May'21	3GPP	RAN3	TP for TR 37.817 Mobility Optimization Use Case	Jim Miller	R3-212868	Approved	IDCC
58	Jun'21	IETF	RAW	Operations, Administration and Maintenance (OAM) features for RAW	CJ. Bernardos, G. Mirsky, G. Papadopoulos, F. Theoleyre	draft-theoleyre-raw-oam-support	ID-Exists	UC3M
59	Jul'21	IETF	DetNet	Framework of Operations, Administration and Maintenance (OAM) for Deterministic Networking (DetNet)	Carlos Bernardos, Georgios Papadopolous, Fabrice Theoleyre, Greg Mirsky	draft-tpmb-detnet-oam-framework	ID-Exists	UC3M
60	Nov'21	IEEE	802.11bc	Revision of Enhanced Broadcast Services ANQP-element	Antonio de la Oliva	2020/1671	Accepted	UC3M, IDCC
61	Aug'21	3GPP	RAN3	Discussion on Standardization impacts of Mobility	Jim Miller	R3-213787	Available	IDCC

				Optimization Use Case for AI				
62	Sep'21	IEEE	802.11bi	Stalking in public spaces use case template	Antonio de la Oliva Joseph Levy	2021/1246r2	Accepted	UC3M IDCC
63	May'21	IEEE	802.11bi	Smart_home_use_case_template	Antonio de la Oliva Joseph Levy Amelia Andersdotten	2021/841	Accepted	UC3M IDCC

4.2. Open Source Achievements

This section describes the open source achievements during the project as well as future plans on the achieved activities.

4.2.1. Platform-oriented open source achievements

As mentioned in D4.2b [13], 5G-DIVE is contributing to two projects to the Eclipse Edge Native Working Group. The Eclipse fog05 project, which is the main part of the 5G-DIVE's Edge and Fog System (EFS) and includes the implementation of the Orchestration and Control System (OCS). Eclipse fog05 is an open source project that provides decentralised infrastructure for provisioning and managing computing, storage, communication and I/O resources available anywhere across the network. Eclipse fog05 addresses highly heterogeneous systems even those with extremely resource-constraint nodes. The latest release of Eclipse fog05 at the time of writing this deliverable is the v0.2.2 version and was published on October 8, 2020. For more information, please refer to the 5G-DIVE deliverable D2.4 [11] 5G-DIVE component's final implementation.

The other project that is part of the Eclipse Edge Native Working Group is Eclipse Zenoh. This project contains the final implementation of the Data Analytics Support Stratum (DASS) which is a key part of the DEEP platform. The goal of the DASS is to bring a data-centric abstractions and connectivity to devices that are constrained with respect to the nodes' resources, such as computational and storage, power and network. The latest release of Eclipse Zenoh at the time of writing this deliverable is at version v0.5.0-beta8 and was published on March 31, 2021. For more information about this software component please refer to the 5G-DIVE deliverable D2.4 5G-DIVE components final implementation [11].

ADLINK participated in the ETSI NFV & MEC IOP Plugtests 2021, which was organized by ETSI and took place from 1 to 15 October 2021. The official report is now publicly available at [8]. During this event, ADLINK tested Eclipse Zenoh interoperability with a MEC platform successfully, more information can be found at [8]. In addition, ADLINK participated in the elaboration of the MEC security: Status of standards support and future evolutions white paper [9] which was released in May 2021.

4.2.2. Use case-oriented open source contributions

In addition to the platform-oriented open source contributions, in the 5G-DIVE project, the Digital Twin use case[1] is public as open source contribution. The Digital Twin use case is an open-source git hub project that implements the Digital Twin as a network service. It splits the Digital Twin service into 7 virtual functions that can be deployed over single or multiple hosts in the cloud-to-thing continuum. This implementation of the Digital Twin use case can serve as an exemplary implementation of a network service that researchers can use to test and validate their orchestration and network management algorithms. For more specific information about the implementation please refer to the 5G-DIVE deliverable D2.4 [11] W

In mMTC use case developed in 5G-DIVE, we developed two key concepts for the IEEE 802.15.4 Network Stack: Asynchronous MAC and RAN Interface selection. These two concepts have been integrated into our custom Contiki-NG implementation and are available as an open-source repository. Medium access for SDRs is different and the inherent delays in the SDR stacks must be considered for successful communication, hence the asynchronous MAC can be useful to the broader SDR community for end-to-end communication to the IoT nodes. State of the art commercial IoT Nodes are including two physical layers for robust communication. In our current implementation of Contiki-NG, it is able to support multiple interfaces with CSMA medium access. It can serve as an exemplary implementation and can be generalised to other medium access protocols. In addition, we also plan to release some of our RF-Fingerprinting codes as open source as a reference implementation for intelligent service design with radio samples.

[1] https://github.com/milangroshev/niryo-one-digital-twin

5. Exploitation Activities

As part of the last deliverable in WP4, the focus of this section is to give an update regarding the exploitation activities that happened in the last period of the project and provide a description of the exploitation plans after the project. Section 5.1 presents an update regarding 5 developed PoCs. Possible exploitations related to the existing products, services and solutions of industrial partners are described in Section 5.3, while Section 5.3 presents the exploitation plan of each partner after the project. Finally, key innovations identified from 5G-DIVE works, as well as the contributions related to 5G for each use case, are summarized in Section 5.2.

5.1. Proof of concepts

5.1.1. Digital Twin PoC

This PoC is one of the use cases targeted under the Industry 4.0 pilot and it is led and developed by UC3M. It focuses on the design, development, and implementation of an Intelligent Edge- and Fog-assisted Digital Twin, envisioning scenarios where physical robotic systems are remotely operated by either a human and/or an AI-based agent. Currently, we exploit the use of Robot Operating System (ROS) as a robotics middleware that provides common robotic functionality and common interfaces to interact with a different set of robots. Such an approach eases the extension of the developed solution to fit diverse robotic systems with different purposes and capabilities. In this PoC, a robotic arm is used as the robotic system example. The different software components of the robotic arm have been already offloaded towards the cloud-to-thing continuum, being identified their requirements and different deployment approaches (over 5G or 4G) that can enable the proper operation of the robotic arm. Moreover, existing visualization tools have been extended to support our solution and new web and joystick interfaces are being developed for controlling the robotic arm. Results showcase the feasibility of the developed solution, pointing out its potential application into real Industry 4.0 environments. The Digital Twin PoC was extended with the AI-based Movement Prediction feature and was integrated with the DEEP platform. For example, the monitoring, life-cycle management, and orchestration configuration are done through the BASS which reduces the operational complexity. The SLA latency requirements are fulfilled with optimal resource allocation by exploiting the BASS SLA-enforcer and the Movement Prediction AI model was integrated with the IESS offering auto-packaging and auto-deployment of the AI inference application.

5.1.2. Zero Defect Manufacturing PoC

The Zero-Defect Manufacturing (ZDM) PoC is designed to investigate and demonstrate a data-driven E2E solution that integrates 5G, fog, edge and cloud for product-oriented ZDM. The use case consists of a three-part setup namely factory side with production line, an edge side that monitors and supervises manufacturing process and cloud side with data lake-based telemetry collection system. It is demonstrated that the production line can be monitored in real-time and defective items on the production line can be detected by an AI-based object detection algorithm that is running on the edge. It is also demonstrated that the edge node can supervise the manufacturing process by sending

commands to the controllers in the production line to remove defective items. Meanwhile, telemetry data collected from wireless interfaces both at the factory and edge side as well as from computing nodes at the edge node is stored in a data lake deployed in the cloud. Currently, this demo is executed using two access technologies, namely Wi-Fi and 4G. The steps of the ZDM PoC for the second year of project execution will be on (i) establishing 5G connectivity between the production line setup and fog/edge/cloud devices; (ii) enabling intelligent RAN applications on multi-access management; and (iii) improving capabilities and performance of the object detection algorithm.

In the second year, 5G connectivity has been introduced in the use case leveraging on commercial 5G network solutions. The defect detection engine has been updated to simulate a more realistic environment, with a completely new trained engine being introduced. A demonstration of RAN intelligent application on multi-access management has also been executed. Besides the elements that were planned for the second year and were achieved, the ZDM use case also evolved with a new IE that aims at reducing energy and importantly, bandwidth consumption.

5.1.3. Massive MTC PoC

As one of the use cases of Industry 4.0 pilot, this PoC is co-developed by Ericsson Research, Lund University and RISE. The PoC has been further developed and integrated for the final Industry 4.0 trial in 5TONIC lab, Spain. An mMTC service acting as an IoT gateway (GW) is deployed in a Kubernetes cluster. For example, in the trial, the Kubernetes cluster is deployed on the three VMs provided by 5TONIC data center. The mMTC service provides the full stack of the IoT GW based on the IEEE 802.15.4 protocol from PHY layer (L1) to the application layer (LWM2M server). A LWM2M client is also installed in each IoT node. Therefore, an end-to-end application layer connection between the mMTC service in the edge and each IoT node deployed in the field is established based on LWM2M. In the trial, the sensor data, i.e. temperature values, were read from the IoT nodes at a certain frequency, e.g. 1 reading per minute per IoT node, configured on the mMTC service side. In addition to the IoT GW stack, an RF fingerprinting function is included as part of the mMTC service as well to enhance the network security. In the RF fingerprinting function, an AI-based algorithm based on a deep neural network is developed for intruder detection when an unauthorized IoT node (e.g. an attacker) tries to get access to the network. The mMTC service is designed following the micro-service architecture, where each component such as 802.15.4 PHY, Contiki (802.15.4 higher layers and Leshan server for LWM2M) and RF fingerprinting are developed as microservices. Therefore, orchestration and automation features, such as auto pod-restart, pod-level redundancy, node-level redundancy, autoscaling, are supported with Kubernetes, which enhances the system availability, robustness and reliability. The mMTC service is also integrated with 5G-DIVE DEEP platform. For example, life-cycle management, orchestration configuration and active monitoring can be done through BASS in DEEP, which reduces the operational complexity.

5.1.4. Drone Fleet Navigation PoC

Traditionally, drones are navigated through a set of GPS coordinates, which are pre-loaded into the drone navigation software. This scheme, known as Waypoint navigation, does not allow autonomous

modification to the flight path. In this PoC, we display enhancing the current navigation system to enable local and remote data processing as well as a dynamic change to flight trajectory for the drone fleet. To accomplish this, a coordination mechanism among drones in the drone fleet with edge and fog computing is required. At the edge, the Drone Navigation Server can remotely monitor and control each drone. At the fog, each drone uses fog-to-fog communication to share GPS data with each other to support Drone Collision Avoidance System (DCAS). The DCAS will interact with Drone Navigation Server through the mobile network. The developed DCAS at the fog node on each drone will detect potential collisions and take over the control of the drone autonomously to avoid the collisions using virtual cylinders to detect potential collisions. In our demo scenario, two drones flaw in the ITRI campus with the Drone Navigation Server to control the drones to take off and set the drones to fly to different destinations. During the flight, the drones will be too close, and then DCAS on each drone will detect potential collisions and take over the control of the drone for a period of time. After the potential collision is resolved, the drone control returns to the Drone Navigation Server to continue the mission.

In the second year, we adopted the DCAS at the edge utilizing the 5G-NSA network. In addition, we developed a new navigation server system, which allows us to monitor several drones simultaneously. Finally, we update the demo scenario to allow three drones to validate DCAS and run drone swapping with DCAS based on the detection of the low battery of one drone of the fleet. It is important to highlight, the new drone navigation server can support a large number of drones simultaneously. It was verified for supporting fifty drones and DCAS functionality has been activated.

5.1.5. Intelligent Image Processing for Drones PoC

This section elaborates on the PoC of intelligent image processing for drones developed by NCTU. It aims to validate and demonstrate the proposed edge-enabled aerial image processing architecture in a virtualized environment. In the second year of the project, we have successfully shown a complete end-to-end deployment of such edge infrastructure, as well as intelligent applications for use in a disaster relief mission. The intelligent applications are deployed and orchestrated by Kubernetes or via the BASS in any available servers spread across multiple racks in the NCTU OPTUNS edge data centre. This type of architecture, as well as deployment method, enables the scaling capability of the intelligent applications to satisfy end-to-end real-time requirements of the Person in need of Help (PiH) detection and localization. In the trial, we have successfully highlighted the capability of this architecture to perform PiH detection and localization, as well as 2D stitching of the surrounding area at the edge. The images are captured from the drone video streams and then transmitted via the 5G network.

5.2. Key Innovations Identified

In this section, we show the identified innovation elements by the completion of the project. In the following, Table 5-1 lists the innovation elements regarding 5G-DIVE architecture design and DEEP platform components, while Table 5-2 presents the innovation elements identified so far from the developed PoCs of different use cases. In addition, it is also identified that the innovations and the corresponding works are done in 5G-DIVE contribute also to 5G eco-system development in general.

The main contributions are through the use case trials which have tested 5G networks in the Industry 4.0 trial field in 5TONIC lab in Spain and the ADS trial field in Taiwan. The trial results verify that 5G is needed to fulfill the requirements of these use cases, while 4G would cause service quality issues. Such findings of each use case regarding its contributions related to 5G are also summarized in Table 5-2.

TABLE 5-1: IDENTIFIED INNOVATION ELEMENTS REGARDING 5G-DIVE ARCHITECTURE AND DEEP PLATFORM

	Innovation elements identified in Year 1	Partner
5G-DIVE Architecture	Architecturally, a DEEP platform is added to the Edge/Fog system where 7 innovation elements were identified: • **Vertical Service Abstraction**: A vertical abstraction layer is provided that enables the vertical industries to define their services solely based on their knowledge domain. (Year 1 and 2) • **AI/ML-based Intelligence Support**: Tools that facilitate the definition, online/offline training, ad cross-validation of AI/ML models. (Year 1 and 2) • **Data Distribution and Unification:** A data distribution service to handle the scale at which data is produced and consumed, especially when an increasing number and heterogeneity of devices compose the computing, storage, and networking infrastructure. (Year 1 and 2) • **Enhanced Monitoring:** Extended physical and virtual resource monitoring by integrating vertical application-level monitoring, provided directly by the applications themselves or collected through monitoring probes, to accurately assess the performance of the vertical services. (Year 2) • **External Federation:** Facilitates the integration of federated services and resources as part of the vertical industry domain. (Year 2) • **Locality and Privacy:** Exploits the locality offered by an Edge and Fog infrastructure to process and analyze sensitive data where it is generated, thus enabling strict privacy and low latency response. (Year 1) • **Business automation:** Business automation within the 5G-DIVE architecture that is related to SLA modeling, management and enforcement. (Year 2)	All
DEEP platform components	BASS • Novel MANO automation for business processes, i) not requiring highly-skilled operators, ii) seamlessly optimizing of the deployed services and iii) declarative vertical service control, leveraging the ability to describe desired states, so the vertical only need to know the desired state, not how to deploy and manage it. (Year 1) • Consistent deployment of vertical services: conditional ordered deployment of the components of a vertical service. (Year 1)	TELCA

	• Pluggable MANO platforms, where Kubernetes has been integrated in the first year, and Fog05 will be integrated in the second. (Year 1 and 2) • Vertical KPIs-driven scaling: providing the capability to scale services with Vertical defined KPIs. SLA Closed loops will be jointly coupled with the deployment of the different vertical services, optimizing the deployment and its life cycle. (Year 2) • Active Monitoring Framework for the automatic collection and storage of service metrics. Basic infrastructure metrics (i.e., CPU usage, RAM usage, Network usage) are automatically collected after the deployment. Custom or advanced metrics (i.e., at the application level) can be integrated with the monitoring system through customizable probes, offered in a catalogue. (Year 2)	

	DASS
	• A named data networking-based framework for decentralised data sharing and management. (Year 1 and Year 2)
	  ○ Protocol updates, reorganization of underlying networking layer, better architecture for traffic scheduling, Rust-base refactoring. (Year 1)
	  ○ Data pub/sub with geo-distributed storages, queries and computations. Support for additional backends for time-series and relational DBs (Year 1)
	  ○ Supports intermittent and constrained embedded devices with Zenoh-pico implementation. (Year 2)
	  ○ ROS2 integration and Zenoh bridge for DDS, which reduces discovery traffic between nodes. (Year 2)
	  ○ Performance optimization, stronger reliability, scalability, and congestion control (Year 2)
	• Contribution to the open-source Eclipse Zenoh project, which is part of the Eclipse Edge Native Working Group (Year 1 and Year 2).
		ADLINK

	IESS (about developed intelligent engines in IESS)
	• Automated retraining flow of AutoML/AutoAI against target accuracies/losses. (Year 1)
	• Pluggable AutoML/AI platforms. In the first year, we have integrated H2O.ai. In the second year, we integrated Keras and the stats model. (Year 1 and Year 2)
	• Storage of the models in a standard format to be used inside the DEEP platform. (Year 2)
	• Developed various intelligent engines used for different use cases (Year 1 and 2)
	  ○ Intelligent Engine 1: real-time drone image processing for detecting persons in need of help.
	  ○ Intelligent Engine 2: a DRL-based SLA enforcer algorithm developed in a simulated environment.
		TELCA, NCTU, RISE, UC3M, IDCC, AAU

	○ Intelligent Engine 3: a contrastive-learning-based deep learning model for device identification from their radio characteristics. ○ Intelligent Engine 4: a VAR-based Movement Prediction algorithm for predicting robot control commands.	

TABLE 5-2: IDENTIFIED INNOVATION IN DIFFERENT USE CASES

Pilot	Innovation elements identified in Year 1	Partner
Industry 4.0	Digital Twin PoC • Digital Twin edge native design (Year 1 and 2). ○ Digital Twin stack design over Fog devices, Edge and Cloud. ○ DASS integration for publishing robot sensor data. ○ Low-latency remote control in Digital Twin systems over 5G. ○ Resource pooling for potential resource savings. ○ Understanding radio network impact on Digital Twin systems. • Movement Prediction function (Year 2) ○ Developed AI model based on VAR ○ Validation of Digital Twin command recovery mechanism in IEEE 802.11 networks via simulation and experimentation ○ Study of periodicity, co-integration, and stationarity of Digital Twin control commands • BASS integration for Digital Twin (Year 1 and 2) ○ The simplified and abstracted management interface ○ Supporting multi-orchestration by utilizing K3S and Fog05 orchestration in a single deployment ○ Using SLA-enforcer for optimal minimum resource allocation • DASS integration for Digital Twin (Year 1) ○ Developed Replay Feature based on Zenoh • IESS integration for Digital Twin (Year 2) ○ Auto-packaging and auto-deployment of Movement Prediction as a service • Contribution related to 5G ○ 5G NSA and 5G SA were available for the duration of the whole project where we investigated the impact that different RATs (e.g., LTE, Wi-Fi and 5G) have on Operational	UC3M, TELCA

	Digital Twins and what are the specific benefits that 5G can offer. The trial results show that a new set of high precision tasks that require low latency and small moving offset are achievable with 5G. In addition, the results show what are the potential for device resource savings that can be achieved with computational offload to the edge.	

	Zero Defect Manufacturing PoC
	• Data-driven E2E solution integrating 5G, Fog, Edge and Cloud.
	  o AI-based object detection adapts to the latency requirements considering cloud, edge, constrained edge/fog. (Year 1 and 2)
	  o Telemetry data from UE and network/computing nodes exposed to an AWS-based data lake. (Year 1 and 2)
	  o Data framework for enabling intelligent RAN applications focusing on multi-access management in the factory (ATSSS X-App), e.g., 5G and WiFi. (Year 2)
	  o Energy and bandwidth consumption efficiency for video streaming. (Year 2)
	• Contributions related to 5G
	  o A commercial 5G network is used as part of the testbed and connectivity performance is evaluated to demonstrate the feasibility of computing resources for intelligence at the Edge.
		IDCC

	Massive MTC PoC
	• Cloud/Edge native design of mMTC. (Year 1 and 2)
	  o End-to-end testbed based on IEEE 802.15.4. (Year 1 and 2)
	  ▪ Microservice-based design with Kubernetes (Year 2)
	  ▪ The developed mMTC service provides the full stack of the IoT GW based on the IEEE 802.15.4 protocol from PHY layer (L1) to the application layer (LWM2M server). (Year 1 and 2).
	  o A large-scale emulation testbed based on LoRa. (Year 1)
	  ▪ Showcasing RAN function resource pooling and performance impact on a large scale.
		EAB, ULUND, RISE

	▪ Resource orchestration and service autoscaling of RAN and higher-layer network functions. • RF fingerprinting function (Year 1 and 2) o Developed AI model based on deep neural network • BASS integration for mMTC life cycle management (Year 2) o Simplified and abstracted management interface o Supporting automation features, such as pod-restart, pod-level redundancy, node-level redundancy, load balancing and autoscaling. • Contributions related to 5G o 5G network was tested in the mMTC trial, where 5G provides wireless connectivity between the radio head and the mMTC service in the edge. The trial results showcase that 5G can be used as a wireless fronthaul interface to serve other mMTC RATs.	
Autonomous Drone Scout	Drone Fleet Navigation PoC • Edge native design for drone collision avoidance (Year 2). • Fog native design for drone collision avoidance (Year 1). • Scalable drone navigation server manages up to 50 drones simultaneously on one Web control (Year 2). o A collaborative approach between on-board application and Edge navigation service considering the latency constraints for drone collision avoidance (Year 1 and 2). • Contributions related to 5G o In the ADS trial, 5G NSA network is utilized to provide wireless connectivity between the drone and the aerial disaster relief system running at the edge. The results show that 5G connectivity can be used to support a disaster relief mission.	ITRI/ASKEY
	Intelligent Image Processing for Drones PoC • Edge native design for drone image processing. (Year 1 and 2) o Person in need of Help (PiH) real-time object detection and localization at the edge with decentralized design and support for scalability, and autoscaling.	NCTU/ITRI/ASKEY/ III

	○ Utilization of OPTUNS edge data center network architecture for providing high bandwidth and ultralow latency network for rack-to-rack and server-to-server communication. • Integration with 5G-DIVE DEEP platform (Year 2) ○ DASS integration provides for a lightweight and efficient drone-to-edge data transmission protocol. ○ BASS integration provides for automatic lifecycle management, as well as rapid service deployment in multiple regions. • Contributions related to 5G ○ In the ADS trial, 5G NSA network is utilized to provide wireless connectivity between the drone and the aerial disaster relief system running at the edge. The results show that 5G connectivity can be used to support a disaster relief mission.	

5.3. Existing or New Products, Services and Solutions

The following products/services from the partners that will (or may) get impacted by 5G-DIVE results. Furthermore, as described in Section 4.2.1, ADLINK is the main maintainer and key contributor of Eclipse Zenoh[2] and Eclipse fog05[3] open-source projects, which have direct impacts from 5G-DIVE results. Any product and services that will use any of these two projects will therefore be impacted from 5G-DIVE results.

5.3.1. Ericsson Cloud RAN

Ericsson Cloud RAN[4] is a cloud-native software solution handling compute functionality in the RAN. Cloud RAN is a viable option for communications service providers to have increased flexibility, faster delivery of services, and greater scalability in networks. In the journey towards the world's highest capacity Cloud RAN, Ericsson Cloud RAN is now enhanced with support for 5G mid-band and with Ericsson Cloud Link[5] for high performance in combined footprint. These latest enhancements to Ericsson's portfolio will enable service providers to seamlessly evolve towards cloud-native technologies and open network architectures with the vision that our customers can deploy cloud-native networks, virtually everywhere, on any cloud, and server platform.

[2] http://zenoh.io/
[3] https://fog05.io/
[4] https://www.ericsson.com/en/networks/offerings/5g/cloud-ran
[5] https://www.ericsson.com/en/ran/cloud#bluefield

The mMTC PoC developed in 5G-DIVE fits very well with the vision of Ericsson Cloud RAN product. The knowledge and experiences obtained in the mMTC PoC development and trials in 5G-DIVE can be exploited to impact the evolution of Ericsson Cloud RAN product, when mMTC services are to be supported.

5.3.2. Telcaria SD-WAN solution (Alviu)

Telcaria offers to its customers, SD-WAN solutions based on commodity hardware, providing zero-touch configuration and fast deployment of branch offices network services. The innovations and advanced features offered by the Business Automation Support Stratum (BASS) are ideal candidates to improve the management of SD-WAN systems. Specifically, Telcaria is interested in integrating the automated service lifecycle provided by the BASS for the management of the Virtual Network Functions (VNFs) in order to provide also zero-touch management in its products. Another targeted innovation is the definition of network services through high-level descriptors that are technology-agnostic and can be reused to deploy softwarized networking components on several heterogeneous environments. Finally, Telcaria is going to exploit the automated monitoring features of the BASS to gain increased visibility on the SD-WAN infrastructure and to quickly identify and fix issues. In the long term, the collected monitoring data is going to be organized in a dataset to be used as input for the Intelligence Engines Support Stratum (IESS). Machine learning techniques offered by this component of the DEEP platform can reveal non-trivial insights and correlations in the data, leading to further improvements in the automation of deployment, configuration, and management of VNFs.

5.3.3. ITRI Intelligent Multi-Access Edge Computing

ITRI Intelligent Multi-Access Edge Computing (iMEC) is the generic x86 computing platform which locates between 3GPP Random Access Network and Core Network. It provides a virtualized computing platform for hosting container-based and VM-based applications. 3GPP NSA-enabled Serving Gateway Function is one of the main container-based applications running on iMEC. This function not only cooperates with NSA EPC from III to build a private NSA mobile network in NCTU, but also performs local breakout to shortcut data streams from drones to ADS application servers on iMEC.

IMEC itself runs on x86 generic servers. An Intel(R) E3-1225 grade server is sufficient to provide basic NSA functionality. More powerful servers like Intel(R) E5 grade with Nvidia Tesla accelerators are added as auxiliary computing nodes to iMEC for hosting AI engine and data hosting framework for ADS use cases to identify persons in need of help more quickly.

5.3.4. Askey 5G USB Dongle

In 2021 Q1, Askey launched a new “5G NR Sub-6 USB Dongle” product. The EV sample was provided in May 2021. It's USB Type C interface with USB3.0 spec and will be a better solution than we proposed WWLC610 M.2 5G NR Module, which is being used in the present 5G ODU mounted on the Drone we did on our field trial on ADS in 5G DIVE.

Askey already integrated above mentioned USB Dongle with Drone at Action Phase III as the 5G NR Transceiver in our 5G DIVE plan. By doing so, we curtail more loading as much as weight on Drone. It extends the time when Drones fly in the air on public safety scouting missions. The use of this dongle will allow ASKEY to validate its design for drone-based applications, potentially opening a new flow of revenue for the company. Also, this dongle is used for I4.0 use cases.

5.4. Additional partner exploitation plans

In D4.1 [5], a partner-specific plan was provided. In general, the plan is still valid up to date. In this section, an update is provided. One common perspective is regarding the exploitation of the developed PoCs and the corresponding results. Each PoC development work has produced at least 1 demonstrator which will be used to promote the development innovation and research results internally within the companies and externally in conferences, industrial events, etc., contributing to increasing the impact of the project.

5.4.1. UC3M

UC3M is planning to exploit the results of the project in order to extend its current experimentation capabilities on top of 5TONIC. Two activities are currently planned that are the direct result of the project's results. On the one hand, UC3M is working together with Telefonica in order to build a federation proof of concept of ETSI MEC with the University Carnegie Mellon (UCM) Living Edge Laboratory. This laboratory is the main hub of innovation for the Open Edge Consortium. The experiment may include the federation of different MEC implementations from different vendors in a roaming use case.

On the second hand, UC3M is taking benefit of the Digital Twin use case to open the door to the establishment of new relations with some verticals in the area of I4.0. Currently, UC3M is discussing the application of this technology with INNOVALIA and the PSA group.

Finally, as an academic institution, UC3M aims at gathering all the know-how developed within the project and providing it to society by developing Master and Bachelor syllabus. Specifically, the 5G-DIVE project may contribute to the Master in Connected Industry, in addition to the Master in 5G already indicated in the DoA.

5.4.2. ADLINK

The 5G-DIVE results directly impact the Eclipse Zenoh, which is an implementation of the DASS component, and Eclipse fog05 which is an implementation of the OCS module. As mentioned earlier, ADLINK is the main maintainer and key contributor of both open source projects. ADLINK is planning to exploit 5G-DIVE results to improve the data connectivity solutions, tools and professional services needed to build systems with the required: platform coverage, performance, scalability, efficiency, flexibility and robustness.

In particular, the 5G-DIVE results that impact Eclipse Zenoh, as the DASS implementation, are regarding the support of tailored requirements of the applications targeted in each vertical pilot, such

as the digital twin (DT), zero-defect manufacturing (ZDM) and drone fleet navigation applications (ADS). Similarly, 5G-DIVE impact on Eclipse fog05 as the OCS implementation is composed of two mains contributions, supporting a set of functional and non-functional requirements for an edge/fog virtual infrastructure manager and orchestration stack for the different deployment units (e.g. containers, binary applications, VMs) needed for the vertical pilots in the edge/fog environment. Both projects are under the umbrella of the Eclipse Edge Native Working Group[6].

According to the recently published 2021 IoT & Edge Computing Commercial Adoption Survey Report [12] , edge computing adoption is accelerating with 54% of surveyed organizations either utilizing or planning to utilize edge computing technologies within 12 months. In addition to that, 74% of organizations factor open source into their deployment plans. This demonstrates that the dominant IoT and Edge platform will be either open source or based on open source.

5.4.3. EAB

The developed PoC was demonstrated in Ericsson Research Day 2021, December 7-9, 2021, to promote the innovations and results inside Ericsson. After 5G-DIVE, we will also continue to promote the results and experiences obtained internally in Ericsson to create impacts on products and strategies. The PoC developed will be further developed for future research works in internal and external projects. The possible future works are listed as follows.

- Investigating more advanced autoscaling features, e.g. considering the tradeoff between resource utilization and latency.
- Investigating energy efficiency performance and optimizing energy consumption in the cloud environment.
- Continue to investigate data-driven approaches to enhance IoT security.
- Investigating more IoT features that would benefit from AI/ML and big data capabilities.

5.4.4. ULUND

The results and knowledge from 5G-DIVE are exploited both internally, as input to research and teaching, and externally as input to other projects and through knowledge transfer to other collaborative partners. In 5G-DIVE, Lund University performs the research work in close cooperation with Ericsson AB and RISE. After 5G-DIVE, we will continue to collaborate with Ericsson AB and RISE to further develop the testbed for future research works. We plan to contribute to demo events and scientific publications to promote the results to the public, also as part of a Ph.D. thesis work.

5.4.5. TID

Telefónica I+D (TID), as a part of the Telefónica Group, is in charge of the innovation and the strategic vision of emerging network technologies and solutions, with a focus on the application of new ideas, concepts and practices to the operations of the group as well as the development of advanced products

[6] https://edgenative.eclipse.org/

and services. TID is integrated into the Telefónica Global CTO Unit, then promoting the results and ideas inside the group strategic roadmap.

Telefónica is involved in a transformation of its networks, leveraging on new technologies and the deployment of 5G. Recent steps in that direction have been the creation of two new transversal affiliates, namely Telefónica TECH and Telefónica INFRA, complementing the operations in different countries (in Europe and Latam).

Different aspects of the Telefónica network, linked with 5G-DIVE activities, are subject of this transformation:

- Exposition of network capabilities that could be consumed by verticals through the generic concept of network slicing, as developed in 5G-DIVE WP2.
- Smooth integration of Non-Public Networks (i.e., vertical networks) with public networks from the operator side, with architectures compatible with the one from 5G-DIVE defined in WP1.
- Development of smart mechanisms for the operation of vertical networks, following the role of System and Service Provider, developed in 5G-DIVE WP1.
- Leverage the know-how acquired through the development of the different use cases in 5G-DIVE WP3.

5G-DIVE results will facilitate such evolution, impacting on one hand in the transversal technology companies of the group (TECH and INFRA) but also in the wholesale offerings of each particular operational company across the Telefonica global footprint. Especially, 5G-DIVE provides timely know-how to anticipate needs and requirements to be supported by the network assets. 5G-DIVE project is disseminated internally into the Telefonica group thanks to the key position of TID for the definitions of the technical guidelines of the company.

5.4.6. TELCA

Telcaria is an SME providing advanced services to network operators and equipment manufacturers worldwide. We partner with network operators to redesign their products towards NFV/SDN based network infrastructure and cloud-computing applications.

Telcaria foresees to exploit the components developed in the 5G-DIVE project, specifically the BASS and IESS, to bring automated and intelligent management features into its solution. On the one hand, the BASS can provide a unified interface for the deployment of VNFs over the heterogeneous edge and fog infrastructure. In the short term, Telcaria expects to exploit the BASS for the deployment and management of core functions for 4G and 5G private networks. The service descriptors and the automated life-cycle management offered by the BASS will allow for faster configuration and deployments in order to quickly adapt to the customer's specific scenario.

On the other hand, the IESS offers machine learning as a service, allowing for the easy implementation of intelligence engines and so automating business processes even further. Thanks to the experience in the integration of 5G-DIVE use-cases, Telcaria foresees to position itself as an intelligence service provider, bringing IESS features to other verticals. The goal is to provide an abstraction layer to

seamlessly introduce into the verticals use cases machine learning capabilities that help them integrate intelligence into their business.

5.4.7. III

III is the main maintainer and key contributor of the 5G NSA core network for ADS use cases in Taiwan demo site. The additional exploitation plan from III, includes deploying the III Core on KVM platform for integration and demo site. Also, support a PoC testbed in both internal and external demo events. One is in NCTU for drone fleet on the workshop in Taiwan to promote the results in public in 2020 and 2021, and this End-to-end demo scenario is also demonstrated in IEEE Globecom 2020 5G-DIVE project booth.

5.4.8. ITRI

In principle, the exploitation plans include technology transfer to large and small (SME) industrial partners, showcasing as part of testbeds, patents and engaging in standardization. Besides, ITRI organized a workshop in NCTU for Drone disaster relief based demonstrated 5G-DIVE platform and end-to-end system Field trials in 2020 and 2021. ITRI also joined the workshop with 5G-Growth project and presented the latest updates of ADS field trials results. It was also demonstrated in GlobeCom 2020 in Taiwan to promote the results in public. We will continue to use the developed PoC in both internal and external demo events especially for public safety agencies, which would help promote and transfer the research results internally and externally.

5.4.9. NCTU

In general, our exploitation plans include technology transfer of EagleEYE system and EagleStitch system to large and small (SME) industrial partners. Showcasing EagleEYE as one of the sub-systems for use in an end-to-end solution for aerial-based disaster relief response system. At this stage, we have also updated EagleEYE to have support for scalability, allowing for a single EagleEYE system instance to support handling multiple drone streams at once. Apart from that, the EagleStitch system also presents itself as a valuable addition to the disaster relief response team toolbox that can be used to perform 2D stitching to gather more information regarding the surrounding area.

5.4.10. RISE

RISE, Research Institutes of Sweden, as a government-owned research institute has the overall purpose to promote innovation and competitiveness of industry and society as a whole. In general, we exploit the results from research projects by knowledge transfer in close collaboration with partners, by publishing open-source software, by spin-offs and by scientific publications.

In 5G-DIVE, we exploit results in close collaboration with Ericsson as part of the work on the Massive MTC use case. Together with Ericsson we will look into the further exploitation of the developed softwarised IoT protocol stacks. The project work on edge orchestration using fog05 for mobile robotics

contributes to the iDrOS drone operating system which is also being published as open-source software.

5.4.11. IDCC

IDCC has already been actively following and contributing to 3GPP, IETF and ETSI MEC standards with a particular focus on features relevant to 5G-DIVE. Also, IDCC's I4.0 ZDM test bed platform has been used to showcase 5G-DIVE project. The test bed platform has been demonstrated in GlobeCom 2020 in Taiwan, in Mobile World Congress (MWC) 2021 in Barcelona, Spain and in different industrial partnership demos such as a pilot with Vodafone UK with computing edge resources from Amazon (telco-edge) to promote the results in public. The testbed platform and the above standardization activities have been and will be the pillars of IDCC exploitation plan after the project. The ZDM testbed platform will be exploited by further developments for future research works in internal and external projects.

5.4.12. AAU

As a public Finnish university, our exploitation of the project results is mainly through the technology transfer to the industrial players of the project. AAU exploits the 5G-Dive technology to primarily strengthen its research know-how and education offer. We plan to exploit the project results by creating new educational material for the thematic model Industrial Internet offered in our master's degree programmes.

We will exploit the developed architecture and software in close collaboration with IDCC in scientific publications and exploit the 5G-Dive concepts in transferring the built technology in the ongoing FUDGE-5G project and future joint research activities.

5.4.13. FET

In 5G-DIVE project, FET has to fulfill the previous agreement to provide an available radio spectrum (2600MHz) for the trials in the first year. FET will use the gained knowledge to shape the definition of 5G deployments and services in the next years, with a special focus on private networks tailored to vertical applications. Thus, FET aims to lead the development of the IoT industry in Taiwan while connecting with international trends.

6. Report from the exploitation workshop

As part of the project Communication, Dissemination, and Exploitation Plan, one of the dissemination goals of 5G-DIVE is to organize an exploitation workshop at the end of the project. The intention of the workshop is to maximize exploitation and to find new ways of exploiting the results produced by the project. This workshop was organized in collaboration with the 5GROWTH[7] project to allow open discussion on relevant exploitation aspects related to the outputs of the two projects.

The workshop invitation with the overall program is included in the next subsection. Then follows one subsection each for describing the content of the three workshop sessions. The section is concluded with the results of a participant satisfaction survey.

6.1. Workshop invitation and program

Driven by cellular technology, a rapid transformation of all industries is underway, with countless innovative solutions reshaping every sector for the better. Any sector can harness cellular technology to solve ongoing challenges and boost their agility, efficiency, safety, and profitability.

In this context, business and technical aspects are strictly related as the new 5G paradigm has the merit not only to allow a simple "cable replacement" but also to unlock important use cases (UC) which were not possible with legacy technologies.

FIGURE 6-1: AGENDA AND MS TEAMS WELCOME SESSION

Several actors or "stakeholders" are involved in this revolution: Verticals, Mobile Network Operators (MNO), Small and Medium Enterprises (SME), and vendors of communication systems.

5GROWTH and 5G-DIVE explored the concrete applicability of 5G technologies to real-world use-cases across various vertical sectors, by the realization of advanced 5G validation trials aimed at proving the technical merits and business value propositions of 5G technologies.

[7] https://5growth.eu/

This workshop aims at presenting the key aspects inferred by the projects' outputs from several perspectives: vertical operators, vendors, SME, with scope to highlight the opportunities, challenges, and critical aspects and to perform concrete exploitation.

The **Innovation Manager** of 5GROWTH, Paola Iovanna (Ericsson) has chaired the **Welcome and introduction** section of the workshop. Then, three sessions have been organized with the involvement of Verticals, MNOs, SMEs:

- Session 1: **Experience from Verticals** (Chair: Carlos J. Bernardos, UC3M).
- Session 2: **Experience from Operators & Vendors** (Chair: Josep Mangues-Bafalluy, CTTC).
- Session 3: **Experience from SMEs** (Chair: Antonio de la Oliva, UC3M).

The concluding panel with an open discussion has been chaired by Bengt Ahlgren (RISE).

6.2. Session 1 – Experience from Verticals

The session, chaired by Carlos J. Bernardos from UC3M, featured a presentation from Paulo Paixão (EFACEC_S), related to EFACEC Transportation pilot, and a presentation from Timothy William (NCTU) and Samer Talat (ITRI) entitled "E2E Deployment of 5G-enabled Edge Infrastructure to Support in Aerial Disaster Relief", the latter on behalf of the 5G-DIVE project.

6.2.1. Leveraging 5G Communications for Critical Transportation Systems

The presentation focused on the capability to use 5G technology to support railway signalling operations, in level crossing scenarios.

The more relevant outputs of the 5GROWTH project that will impact EFACEC refer the use of 5G technology to support the safety-critical communications between the train approaching detectors and the level-crossing controller. This allows to replace a cable communication to a wireless communication, and to obtain clear advantages in terms of reductions of : i) CapEx , ii) installation cost, iii) installation time, iv) cable cost, and v) maintenance cost.

FIGURE 6-2: SNAPSHOT OF THE PRESENTATION ABOUT TRANSPORTATION PILOT

6.2.2. E2E Deployment of 5G-enabled Edge Infrastructure to Support in Aerial Disaster Relief

The rising popularity of edge computing technology, as well as the advancement of fifth generation (5G) mobile networks have paved the way for revolution across vertical applications. Aerial disaster relief response application is one of the applications that can leverage the provisioning of high bandwidth, low latency, and reliable communication of 5G mobile network, as well as the high computing capability of edge computing technology. In this presentation, an End-to-End (E2E) deployment of 5G-enabled edge infrastructure to support the aerial disaster relief response system is of focus. An example of real-world disaster relief response scenarios to showcase the deployment are also presented.

The main aspects that will be considered for exploitation are:

- Integration of 5G-DIVE solution for public safety use (e.g., firefighter).
- Complete E2E deployment of 5G-enabled edge infrastructure to support for aerial disaster relief response system.
- 5G-DIVE DEEP platform (i.e., BASS, DASS, IESS) to enhance the overall performance of disaster relief response system.
- Deployment automation, to enable rapid response in a disaster relief mission.

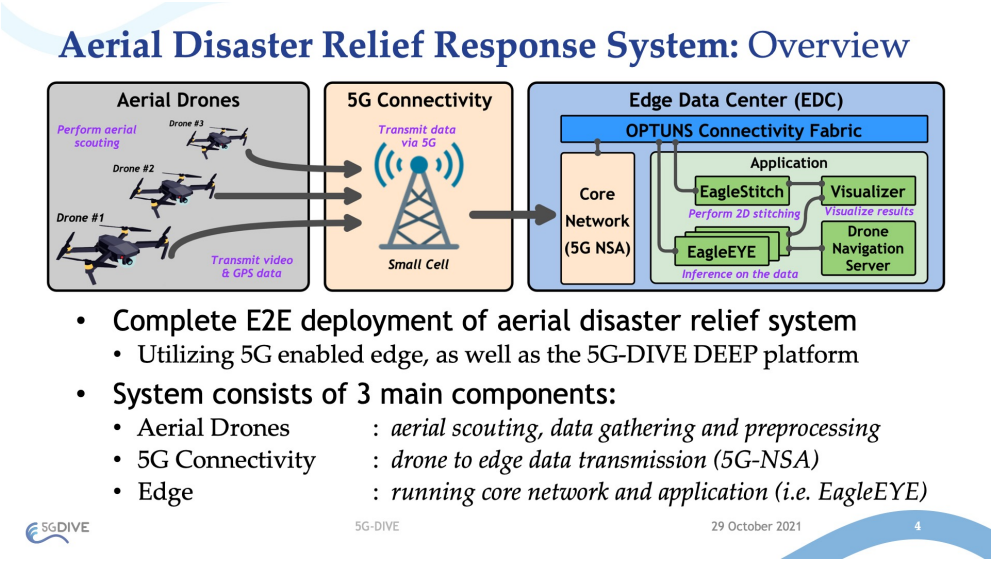

FIGURE 6-3: SNAPSHOT OF THE AERIAL DISASTER RELIEF RESPONSE SYSTEM PRESENTATION

6.3. Session 2 – Experience from Operators & Vendors

The session, chaired by Josep Mangues-Bafalluy, (CTTC) presented a talk by Koen De Schepper (Nokia Bell Labs), on behalf of the 5GROWTH project, and a talk from Chenguang Lu (Ericsson), on behalf of the 5G-DIVE project.

6.3.1. Mission Critical: Latency or Throughput?

The presentation was given by Koen De Schepper, Nokia Bell Labs, and dealt about how queuing latency and low packet loss for scalable congestion control (L4S) can provide an alternative plan (plan B) for remote control purposes, even under constrained available resources.

Remote interaction with a 360-degree camera at the port of Zeebrugge is demonstrated using a 5G-SA setup. When the SLA is kept at 25Mbps, the remote user can have full remote control and high definition video quality. However, when SLA degrades to be lower than 20Mbps, the remote user will have a delayed response or even totally lose control, at the same time the video quality slows down and skips fragments. With the introduction of L4S, the remote controllability can be fully maintained even with a lower video quality under 0.5Mbps throughput.

FIGURE 6-4: SNAPSHOT OF NOKIA PRESENTATION ABOUT CRITICAL REQUIREMENTS

6.3.2. Summary of 5G-DIVE Innovation and Exploitation

The presentation was given by Chenguang Lu (Ericsson). The presentation provided the summary about the innovation and exploitation activities in 5G-DIVE project, with focus on platform design and PoC testbeds.

The main aspects considered in the presentation were to introduce the 5G-DIVE DEEP platform design, system integration with DEEP and 5 PoC testbeds developed by 5G-DIVE partners.

It was highlighted that open platforms and open source software are key aspects for the future development and the outputs of European projects, and in this sense, they provide a relevant contribution in such direction.

FIGURE 6-5: SNAPSHOT OF ERICSSON PRESENTATION ABOUT INNOVATION AND EXPLOITATION ASPECTS OF 5G-DIVE

6.4. Session 3 – Experience from SMEs

This session was chaired by Antonio De La Oliva, (UC3M) and it focused on the experiences of SME.

As output of 5GROWTH project, Giada Landi (Nextworks) provided a presentation about "SMEs' opportunities as technology providers for 5G solutions"; while from 5G-DIVE project, Matteo Pergolesi (Telcaria) presented "Easing the adoption of edge and AI technologies with 5G-DIVE DEEP: a vertical-oriented platform".

6.4.1. SMEs' Opportunities as Technology Providers for 5G Solutions

Research and collaborations in EU projects addressing 5G technologies bring strong opportunities for SMEs active in the ICT sector as technological solutions provider. The participation in 5G trials is key to build practical know-how and on-field experience, understand technical and business requirements from a variety of vertical industries and develop software assets for custom solutions to propose in the consultancy market.

From an exploitation point of view, the following points remark the relevant aspects for Nextworks that well highlight the opportunity for SMEs:

- Relevant role of research to build strong and practical know-how on 5G technologies, towards 6G.
- Opportunities for SMEs in 5G projects: development of custom 5G management and orchestration components and support to verticals in trials design and execution.
    - Key role of open-source contributions.

- Example of Vertical Slicer software, developed in 5GROWTH and other 5G PPP projects, as building block of a complete 5G management and orchestration suite, easy to customize with added-value features and vertical-oriented services.
- Collaboration with EU projects' consortia and participation in public demos, industrial events and standardization activities as opportunity to increase the company visibility and reach new potential customers.

- Business opportunities for SMEs.
  - Technology providers for 5G solutions, acting as 3rd party software providers, system integrators, etc., for vendors, small operators, vertical industries interested in stand-alone non-public networks.
  - Consultancy and system integration services for private 5G deployments targeting vertical industries.
  - Consultancy and 3rd party software development for 5G-enabled vertical services.

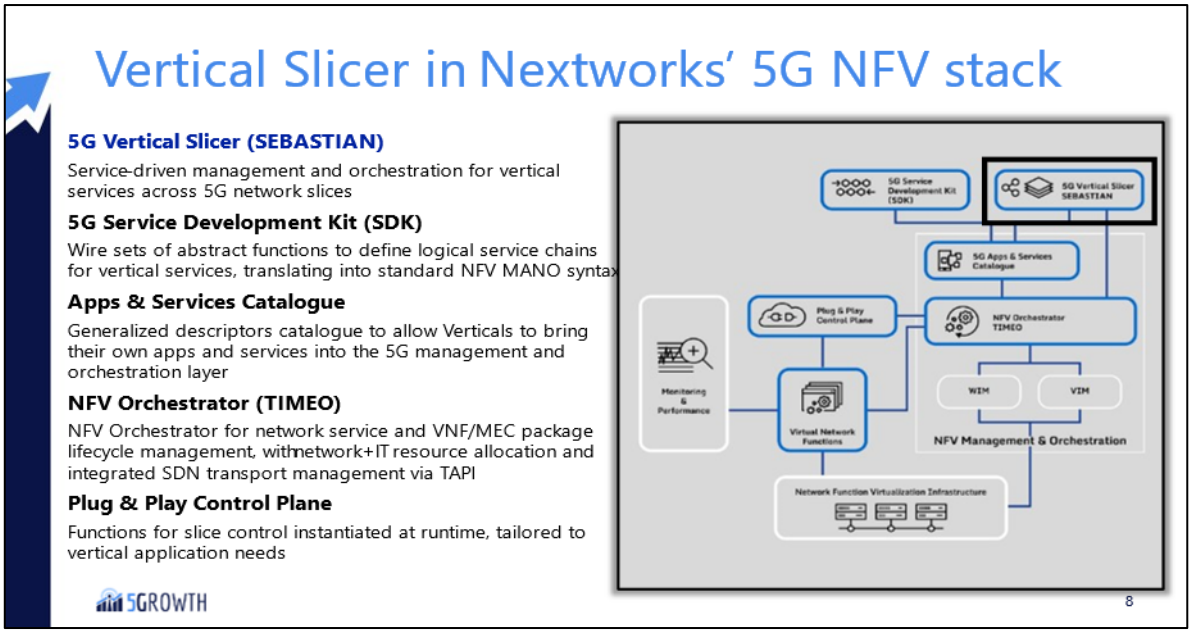

FIGURE 6-6: SNAPSHOT OF NEXTWORKS PRESENTATION ABOUT INNOVATION AND EXPLOITATION ASPECTS IN 5GROWTH

6.4.2. Easing the Adoption of Edge and AI Technologies with 5G-DIVE DEEP: a Vertical-Oriented Platform

In the fragmented world of cloud, edge, and AI platforms, there is a need for simplification and automation in order that verticals can exploit the full potential of new technologies. In 5G-DIVE, the DEEP platform was designed to unify the access to heterogeneous resources and provide advanced features, like monitoring, automatic scaling, and Machine Learning as a Service out-of-the-box.

This approach enables a new business model for SMEs that can propose themselves as platform providers to verticals. The model provides advantages for both parties, like efficiency in the integration and utilization of resources, optimized management, and last but not the least, data privacy.

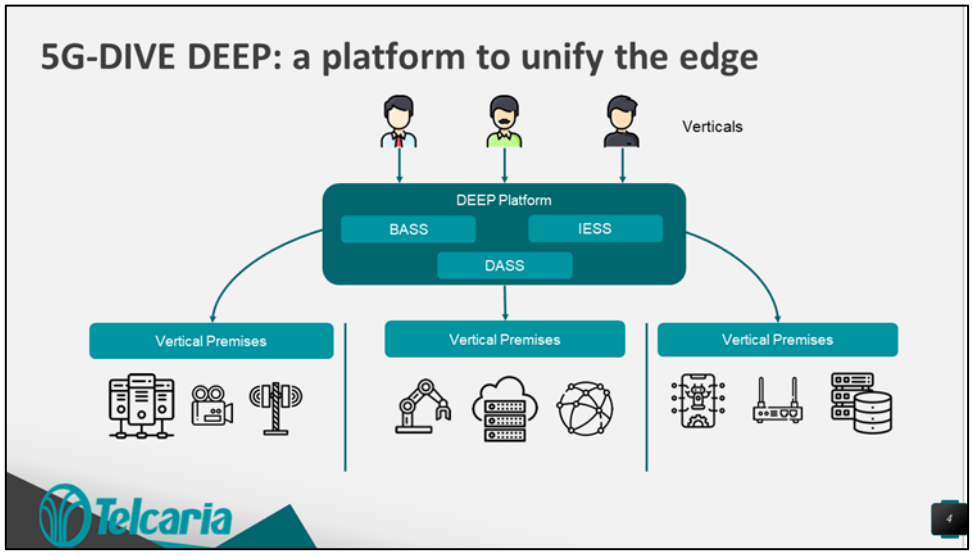

FIGURE 6-7: 5G-DIVE DEEP

6.5. Satisfaction Survey

As part of the regular quality control of the 5G-DIVE project when organizing events, attendees were requested to fill in a satisfaction survey. A satisfaction poll was prepared aiming at verifying the percentage of satisfied and very satisfied attendees (the target was 70%). The following charts report the poll's results obtained from 24 attendees. A percentage of 87.5% of the responders declared to be "very satisfied" with the workshop indicating the quality of presentations and the quality of speakers as the main strengths of the event.

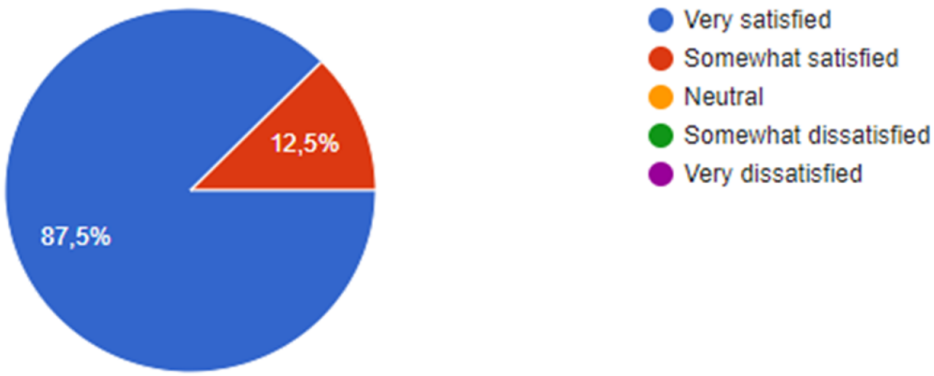

FIGURE 6-8: OVERALL SATISFACTION

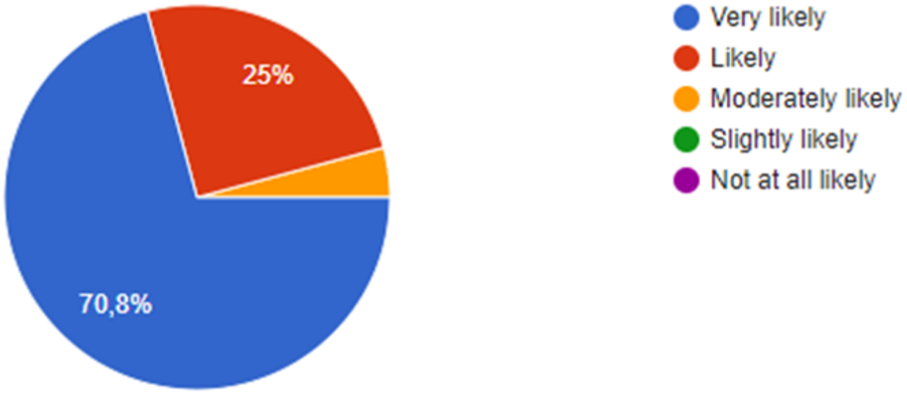

FIGURE 6-9: INTENTION TO RECOMMEND THE WORKSHOP TO A COLLEAGUE

FIGURE 6-10: EVALUATION OF THE DIFFERENT ASPECTS OF THE WORKSHOP

7. Conclusions

This deliverable reported on the execution and overall achievements of the project's communication, dissemination, and exploitation plan (CoDEP) that was defined in project Deliverable 4.1 [5] and updated in Deliverables 4.2 [7] and 4.2b [13]. The Covid-19 crisis made it more difficult and required the adaptation of the plans for more online presentations. Despite this, the dissemination targets have been met or exceeded.

The project has been active during its lifetime with communication and public activities. The Covid-19 re-planning meant that we put effort into producing videos of presentations and demos. The statistics show that the project has a quite active website where the consortium events and deliverables are the most popular content.

The project partners have published many scientific papers during the project's lifetime. Some additional publications are anticipated after the formal completion of the project. The plans for participating in exhibitions have not been completely fulfilled due to cancelled events, but some have been replaced with online substitutes. The project has engaged in several cross-project collaboration activities, not least for organising workshops and other events. Several of these activities have been subject to re-planning due to Covid-19, but despite some difficulty, have largely been following plan.

The standardisation activities of the project cover the standardisation bodies 3GPP, IETF, ETSI, IEEE and ORAN Alliance. Several contributions have been made to 3GPP, IETF and ETSI, clearly exceeding the targets. Releasing and contributing to open-source software are very important means of disseminating the project results. Project partners are driving two such projects, and some of the software developed for the use-case trials have additionally been made available as open source.

An exploitation workshop was arranged in October in collaboration with the 5GROWTH project covering experience from verticals, from operators and vendors, and from SMEs. The exploitation activities are described relating to the developed proof-of-concept prototypes, to partner's products and services, as well as, to additional partner activities. Key innovations from the 5G-DIVE architecture platform and from the proof-of-concepts were identified.

8. References

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