



H2020 5G-Coral Project

Grant No. 761586

D5.1 - Communication, dissemination, standardisation and exploitation achievements of Y1 and plans for Y2

Abstract

This deliverable (D5.1) reports on all the activities undertaken in WP5 in the first year of the project, i.e. from 1st of September 2017 to 31st of August 2018. It also provides an outline of the work plan for Year 2, building on the momentum reached in Year 1 and the technical developments anticipated in Year 2.

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Executive Summary

To maximize its impact, the 5G-CORAL project has invested significant efforts in Year 1 to communicate and disseminate the project vision, concept, technology and results, to all stakeholders in the wide international community. This deliverable provides a summary of the different activities on Dissemination, Communication and Exploitation performed during the first year of the project and the outline of the planned activities to be performed on the Second Year.

Amongst the key achievements in Year 1 are (summarised in Table 1):

- Active communication and dissemination of the project through 13 public presentations, 2 organized workshops, 4 videos at key events, 1 leaflet at the MWC'18 as part of 5G-PPP, and 1 leaflet in the European 5G Annual Journal.
- A good record of scientific peer-reviewed publications with 10 articles published or accepted for publication in reputed journals and conference/workshop proceedings such as IEEE Transactions, IEEE magazines, IEEE WCNC 2018, IEEE BMSB 2018, IEEE ICC 2018, and USENIX HotEdge 2018.
- A first showcase at EUCNC 2018 including 5 demonstrations as well as posters, videos and project elevating pitches and materials.
- Active promotion of the project concept and technologies in standardization forums such as European Telecommunications Standard Institute (ETSI), Internet Engineering Task Force (IETF) and Institute of Electronics and Electrical Engineering (IEEE). There have been 30 standardization materials delivered in Year 1.
- Active promotion of the project concept and technologies in open source foundations like the eclipse foundation and OpenFog consortium.
- Proactive identification of key innovations from the project with possible paths for commercial exploitation.

In addition to the above, an outline of the plan in Year 2 has been developed and presented in this deliverable.

TABLE 1: SUMMARY OF OVERALL ACHIEVEMENTS IN YEAR 1.

Activities		Achievements
Press and Media	Public Summary	1
	Leaflet	1
	Poster/Slides	2
	Press Release	5
	Videos	4
Public Presentations		13
Education and Training		1
Publication		10
Organized Events		2
Open Source Contributions		1
Co-organisation activities with other 5G-PPP projects		10

Exhibitions	Booth	2
	Demo	5
Standard Contributions (2 dissemination contributions, 28 standards contributions)		30

1 Introduction

This deliverable reports on the achievements of 5G-CORAL project in Year 1 for all communication, dissemination, standardization and exploitation activities. It also outlines a work plan for these activities in Year 2.

The deliverable is structured into four main chapters, namely, (1) communication and public activities, (2) dissemination and collaboration activities, (3) standardization and open source activities, and (4) exploitation activities.

Chapter 2 reports on the communication and public activities undertaken in Year 1 and outlines the corresponding work plan for Year 2. These activities are steered towards ensuring an up-to-date communication on the project to the large public through various channels including web portal, social networks, videos, and magazine articles.

Chapter 3 reports on the dissemination activities including talks, workshops, and peer-reviewed scientific articles. It also reports on related collaboration activities undertaken in the framework of the 5G-PPP including its projects and working groups. The goal of such activities is mainly to promote the project to the Research & Development (R&D) stakeholders and raise opportunities for collaboration or synergy with other projects and activities.

Chapter 4 reports on the standardization and open source activities undertaken and presents the standardization roadmap developed in the project. These activities are aimed at creating an influence from/to ongoing or future standardization activities so that the technology developed in the project can have an easier path for exploitation into future products.

Chapter 5 reports on the exploitation activities undertaken with the aim to identify innovations from the project that can find venues for exploitation in products, proof-of-concepts, and services.

The deliverable ends with conclusions summarizing the work done in Year 1, and insights on the next steps planned in Year 2.

2 Communication and Public Activities

Communication activities undertaken in Year 1 have been steered towards ensuring an up-to-date communication on the project concept and first results to the large public through various tools including web portal, social networks, videos, interviews, leaflets, posters and magazine articles. This chapter provides the Year 1 plan set for communication activities and reports the subsequent achievements. It then concludes with the next steps planned for Year 2 of the project.

2.1 Work Plan for Year 1

The focus in Year 1 has been put on raising and fostering awareness of the 5G-CORAL project vision, concept, objectives, and first initial results, amongst the various stakeholders (R&D community, market players, and the public). The following objectives were set:

- Deployment of the project web portal for an up-to-date communication on all events and milestones from the project to the wide community.
- Deployment of social networks accounts to complement with the project web portal.
- Delivery of video interviews and magazine articles for promoting the project vision, concept and initial results.
- Issuing of a press release announcing the project kick-off.
- Preparing a first project leaflet reflecting on the project concept and first results in time for communication at the Mobile World Congress 2018.

2.2 Report on Activities Undertaken and Achievements

Following the project kick-off on September 1, 2017, activities have been undertaken towards fulfilling the objectives set above. These are reported in

Table 2, Table 3, and Table 4, respectively for activities relating to (1) project portal and social networks, (2) press releases, blog articles and magazine articles, and (3) videos and leaflets. Additional activities prior to the project kick-off are reported in Table 5.

The leading partner for this task has been UC3M (the project coordinator) and the 5G-CORAL project has appointed a representative (NCTU, WP5 manager) for liaison with the 5G-PPP communication and dissemination working group, where news and events from 5G-CORAL are shared within the 5G-PPP.

TABLE 2: PROJECT PORTAL AND SOCIAL NETWORKS.

#	Month	Description	Lead partners
1	Sep '18	Release of 5G-CORAL project web portal http://5g-coral.eu/	UC3M
2	Sep '18	Set up of twitter @5G_CORAL and 5G-CORAL LinkedIn group	UC3M

3	Throughout Y1	Constant update of the project web portal with contents on the talks, workshops, demonstrations, and events undertaken and planned. It has been given free access to download public presentations and materials from the partners, subject to partner permission.	UC3M
4	Throughout Y1	Synchronicity between project web portal and the social media news shared on the project Twitter and LinkedIn accounts.	UC3M

TABLE 3: PRESS RELEASES, BLOG ARTICLES, AND MAGAZINE ARTICLES.

#	Month	Description	Lead Partners
1	Jul '18	Press release "Edge Robotics applied to industry verticals" published in: • IMDEA Networks • Blog Madri+d	UC3M
2	Jun '18	Public Summary to The European 5G Annual Journal 2018. (available at https://5g-ppp.eu/annual-journal/)	NCTU, UC3M
3	Apr '18	Samer Talat, Shahzoob Bilal Chundrigar. "5G 通訊網路之邊界與霧計算整合," <i>ITRI ICL Journal</i> , 2018.	ITRI
4	Apr '18	Ping-Heng Kuo, Alain Mourad. "Multi-RATs Convergence: A New Spin Through the Edge," <i>ITRI ICL Journal</i> , 2018.	IDCC
5	Apr '18	Press release "Converged Virtual 5G RAN – Concept or Reality?" published in: • Azcom Technology	AZCOM
6	Feb '18	Press release "UC3M and IMDEA Networks commit to 5G development at Mobile World Congress 2018" published in: • IMDEA Networks	UC3M
7	Jan '18	Press release: "InterDigital Joins European and Taiwanese Consortium to Deliver a 5G Converged Radio Access Network Living at the Edge" relayed by various media channels such as: • Globe Newswire • 4Internet • finanzen.net • newsquantified.com • Telecompaper • TelecomTV	IDCC

		• InterDigital.com	
8	Nov '17	Press release announcing the project kick-off, its vision, ambition, objectives and consortium, relayed in several media channels such as: • EurekAlert! Science News • AlphaGalileo News • NETCOM • 5TONIC • IMDEA Networks • Computerworld	UC3M
9	Sep '17	Magazine article in Computerworld: "Challenges in realizing the promises of the holistic edge"	IDCC

TABLE 4: LEAFLETS AND VIDEOS.

#	Month	Description	Lead partners
1	Feb'18	First project leaflet along with elevator pitch slides for MWC 2018. The leaflet is shown in Figure 1. (available at http://5g-coral.eu/wp-content/uploads/2018/04/Poster.pdf)	NCTU, UC3M, IDCC
2	Feb'18	Video of the MWC18 panel: "MWC18: Delivering the 5G Experience with Mobile Edge Services" https://www.interdigital.com/videos/mwc18-delivering-the-5g-experience-with-mobile-edge-services	IDCC
3	Feb'18	Video of the MWC' 18 panel: "Why 5G Business Cases Depend More on Edge Upgrades" https://www.interdigital.com/videos/alan-carlton-debates-why-5g-business-cases-depend-more-on-edge-upgrades	IDCC
4	Jun '18	5 videos on the demonstrations showcased at EuCNC 2018 http://5g-coral.eu/?page_id=156	ITRI, NCTU, UC3M, IDCC, AZCOM and TI

TABLE 5: ACTIVITIES PRIOR TO THE PROJECT KICK-OFF.

#	Month	Description	Lead partners
1	Jan'17	"Enabling 5G through enhanced and converged RAN virtualization at the Edge" presented by Arturo Azcorra in 5G Mobile Edge and Fog Computing in Taiwan	UC3M
2	Jan'17	"From SDN-NF V and 5G-MEC to Their Modeling and Optimization" presented by Ying-Dar Lin in 5G Mobile Edge and Fog Computing in Taiwan	NCTU
3	Jun'17	"IoT and MEC: A marriage made in heaven" presented by Alain Mourad in EU-Taiwan 5G Workshop in Brussels	IDCC
4	Jun'17	"5G Crosshaul architecture" presented by Antonio de la Oliva in EU-Taiwan 5G Workshop in Brussels	UC3M

5G-CORAL: A 5G Convergent Virtualised Radio Access Network Living at the Edge



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Ericsson AB / InterDigital Europe /
Telecom Italia / Telcaria Ideas / RISE
SICS AB / Azcom Technology /
Industrial Technology Research
Institute Incorporated / ADLINK /
National Chiao Tung University

START DATE: 01/09/2017

END DATE: 31/08/2019

COST: 3,856,973.75€ including
2,497,223.75€ from EU H2020

MORE INFORMATION

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MAIN OBJECTIVES

5G-CORAL aims at delivering a converged 5G multi-RAT access through an integrated virtualised edge and fog solution that is flexible, scalable, and interoperable with other domains including transport (fronthaul, backhaul), core and clouds.

Main objectives:

- o Develop a system model including use cases, requirements, architecture, deployment scenarios, and business models to design and validate the 5G-CORAL solution.
- o Design virtualised Radio Access Network (RAN) functions for multiple RATs including Cellular, WiFi and IoT, data services, and users and third party low latency applications for hosting in the 5G-CORAL integrated Edge and Fog computing System (EFS).
- o Design an Orchestration and Control system (OCS) for dynamic integration and federation, and optimised allocation of 5G-CORAL EFS computing resources, including the interworking with other (non-EFS) domains such as the distant Cloud.
- o Integrate and demonstrate 5G-CORAL technologies in large-scale testbeds making use of facilities offered by Taiwan, and measure their Key Performance Indicators.
- o Disseminate and contribute 5G-CORAL results into international research and innovation venues to pave the way for their successful exploitation.

USE CASES

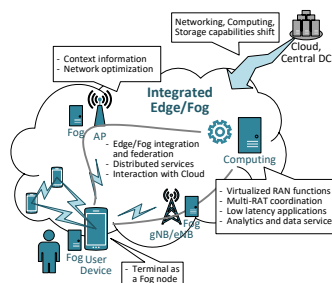
5G-CORAL project will be validated in three testbeds:

1. Shopping Mall with mixed reality (AR/VR) and robotic applications (Taiwan)
2. High-speed train (Taiwan)
3. Connected cars (Taiwan and Italy)

TECHNICAL AND RESEARCH CHALLENGES

5G-CORAL project leverages on the pervasiveness of edge and fog computing in the RAN to create a unique opportunity for access convergence. This is envisioned by means of an integrated and virtualised networking and computing solution where virtualised functions, context-aware services, and user and third-party applications are blended together to offer enhanced connectivity and better quality of experience.

The proposed solution contemplates two major building blocks, namely EFS and OCS. The EFS is a logical unified platform for hosting applications and functions in a distributed manner across the underlying edge and fog infrastructure. The EFS also offers a platform for distribution of the data services mainly from the multiple RATs in the RAN through publish/subscribe protocols (e.g. DDS, MQTT, etc.) to the functions and applications. The OCS is the entity in charge of creating the EFS and managing and controlling its operations. The OCS extends on the current NFV, SDN, and MEC frameworks to support automated and secure integration and federation of the distributed EFS resources which may be mobile, volatile, and owned by multiple owners including end users.



https://twitter.com/5g_coral/



<https://www.linkedin.com/in/5g-coral/>

FIGURE 1: ILLUSTRATION OF THE FIRST 5G-CORAL LEAFLET

2.3 Summary of Achievements over Year 1

Figure 2 shows that, in the period Jan. 2018 to Jul 2018, the project portal has attracted at least 500 visitors every month (~20 people per day on average), reflecting on a considerable attention globally.

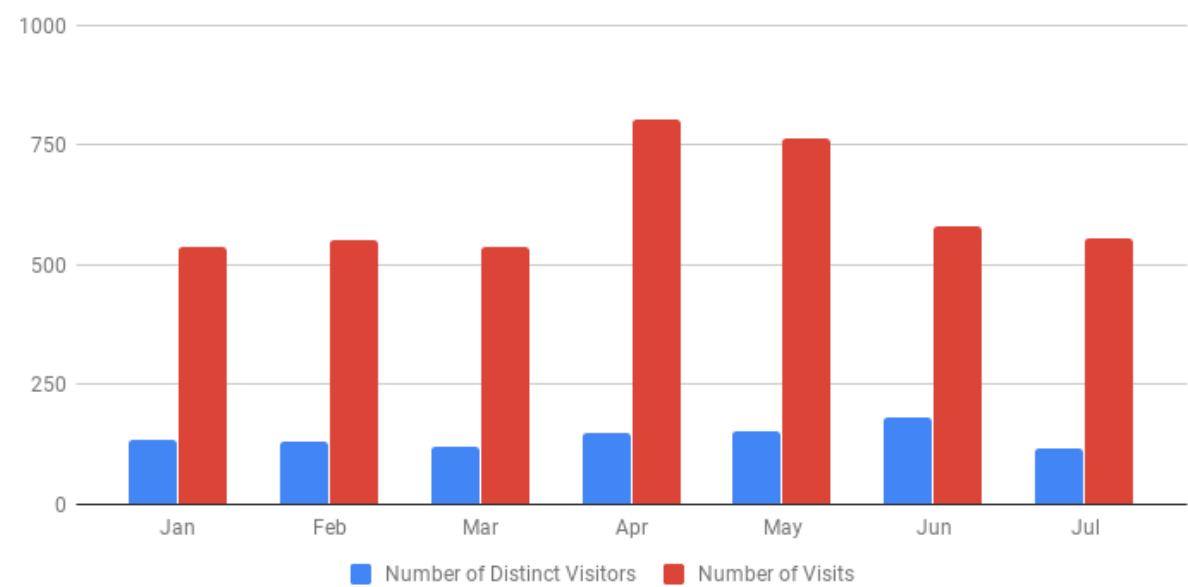


FIGURE 2: STATISTICS ON THE NUMBER OF VISITS TO THE 5G-CORAL PORTAL

Figure 3 shows the different communication activities performed during the first year to disseminate the key values of 5G-CORAL.

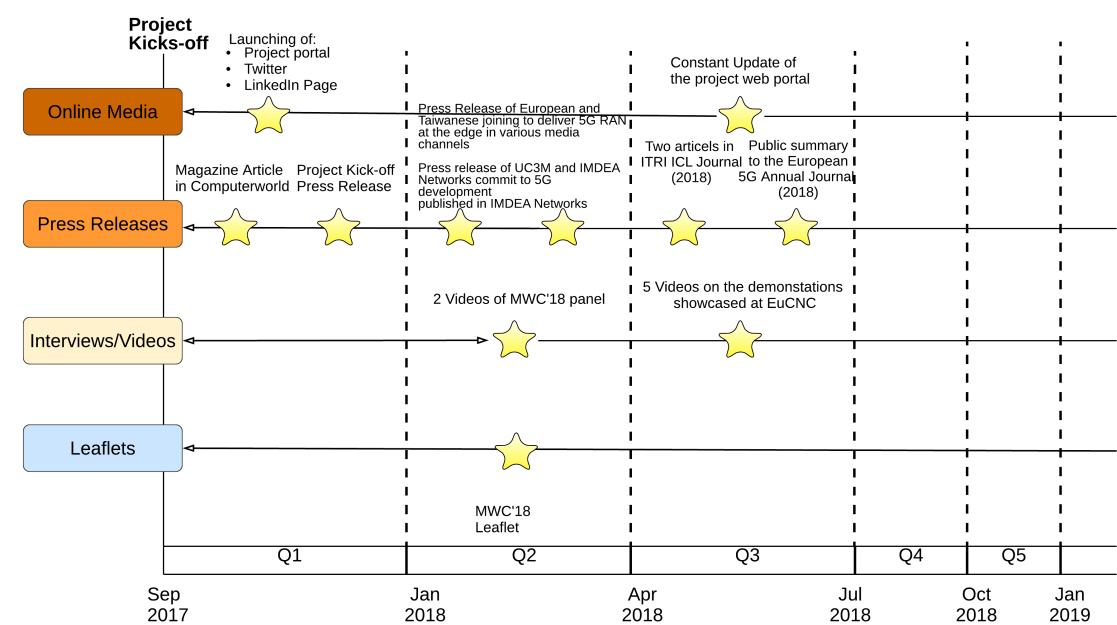


FIGURE 3: OVERVIEW OF THE COMMUNICATION ACTIVITIES OVER YEAR 1

2.4 Work Plan for Year 2

Building on the momentum reached in Year 1, and the anticipated technology development including trials in Year 2, the project plans to accompany these developments with the adequate communication activities including:

- Media coverage (press releases, videos) for the first trial scheduled in November 2018. Media coverage for subsequent trials in 2019 is also to be considered.
- Leaflets in time for MWC 2019 and COMPUTEX 2019.
- Additional blog more focused on the innovations outcome of the project as they happen in year 2.
- More activities for Taiwanese and Asian communities. For example, translation of the web page to Chinese, and a public event in Taiwan in November.
- Continuous communication through the project portal, the social networks, and the 5G-PPP communication and dissemination working group.

3 Dissemination and Collaboration Activities

Dissemination and Collaboration (primarily within the 5G-PPP) activities have been conducted in Year 1 in order to help promote the project concept and initial results to the International R&D community and raise opportunities for synergy with other projects and activities. This chapter presents the plan set in Year 1 and reports the related achievements for dissemination and collaboration activities respectively. An outline of the plan for Year 2 is then provided.

3.1 Work Plan for Year 1

The high-level objectives for dissemination and collaboration activities were defined as follows:

- To raise and foster awareness of the project vision, concept, objectives, and first initial results, amongst the R&D community. The dissemination activities will be steered towards generating impact through peer-reviewed publications, presentations, talks, demonstrations, panels, workshops, and events.
- To establish synergy links with other related projects, within the 5G- PPP programme, with the aim of promoting a coherent overall 5G architecture and developing consistent technology building blocks.

From the above -high-level objectives, the project has set specific and measurable goals for dissemination and collaboration activities in Year 1. These include:

- Delivery of at least six talks promoting the project vision, concept and initial results at selected R&D events and industry summits.
- Demonstration of project related prototypes or solutions at R&D events.
- Organization of at least one R&D event.
- Submission of at least six peer-reviewed scientific articles for publication at reputed conferences and journals.
- Co-organization of at least 10 activities with other 5G-PPP projects

3.2 Report on Activities Undertaken and Achievements

The dissemination and collaboration activities and achievements for Year 1, from September 2017 to August 2018, are reported in the following sub-sections.

3.2.1 Peer-reviewed Publications

Table 6 and Table 7 list all peer-reviewed publications in Year 1. Published or accepted for publication materials are reported. The project has published 4 peer-reviewed articles in journals and magazines, and 6 ones in conferences and workshops Year 1, with a few more already accepted for publication at the start of the Year 2.

**TABLE 6: PEER-REVIEWED PUBLICATIONS
IN CONFERENCES AND WORKSHOPS IN YEAR 1**

#	Type	Month	Description	Lead Partners
1	Workshop	Apr. 18	Ping-Heng Kuo, Alain Mourad, Chenguang Lu, Miguel Berg, Simon Duquennoy, Ying-Yu Chen, Yi-Huai Hsu, Aitor Zabala, Riccardo Ferrari, Sergio Gonzalez, Chi-Yu Li, Hsu-Tung Chien. "An Integrated Edge and Fog System for Future	IDCC

			Communication Networks,” <i>IEEE WCNC COMPASS, 2018.</i>	
2	Workshop	Apr. 18	Luca Cominardi, Osamah Ibrahim Abdullaziz, Kiril Antevski, Shahzoob Bilal Chundrigar, Robert Gdowski, Ping-Heng Kuo, Alain Mourad, Li-Hsing Yen, Aitor Zabala. “Opportunities and Challenges of Joint Edge and Fog Orchestration,” <i>IEEE WCNC COMPASS, 2018.</i>	UC3M
3	Workshop	Apr. 18	Damiano Rapone, Roberto Quasso, Shahzoob Bilal Chundrigar, Samer Talat, Luca Cominardi, Antonio De La Oliva, Ping-Heng Kuo, Alain Mourad, Alessandro Colazzo, Giacomo Parmeggiani, Aitor Zabala, Chenguang Lu, Chi-Yu Li. “An Integrated, Virtualized joint Edge and Fog computing system with multi-RAT convergence,” <i>BMSB, 2018.</i>	TIM
4	Conference	May 18	Chi-Yu Li, Giovanni Salinas, Po-Hao Huang, Guan-Hua Tu, Guo-Huang Hsu, Tien-Yuan Hsieh. “V2PSense: Enabling Cellular-based V2P Collision Warning Service Through Mobile Sensing,” <i>IEEE ICC, 2018.</i>	NCTU
5	Conference	Jun. 18	Chenguang Lu, Miguel Berg. “Analysis of Controlled Packet Departure to Support Ethernet Fronthaul Synchronization via PTP,” <i>ISPCS, 2018.</i>	EAB
6	Workshop	Jun. 18	Chi-Yu Li, Hsueh-Yang Liu, Po-Hao Huang, and Hsu-Tung Chien, Guan-Hua Tu, Pei-Yuan Hong and Ying-Dar Lin. “Mobile Edge Computing Platform Deployment in 4G LTE Networks: A Middlebox Approach,” <i>USENIX HotEdge, 2018.</i>	NCTU

**TABLE 7: PEER-REVIEWED PUBLICATIONS
IN JOURNALS AND MAGAZINES IN YEAR 1**

#	Type	Month	Description	Lead Partners
1	Journal	Jun. 18	Ying-Dar Lin, Yuan-Cheng Lai, Chien-Hsin Huang, and Hsu-Tung Chien. “Three-Tier Capacity and Traffic Allocation for Core, Edges, and Devices for Mobile Edge Computing,” <i>IEEE TNSM, 2018.</i>	NCTU
2	Magazine	Feb. 18	P.-H. Kuo and A. Mourad, “User-Centric Multi-RATs Coordination for 5G Heterogeneous Ultra-Dense Networks [Industry Perspectives],” <i>IEEE Wireless Communications Magazine, Feb. 2018.</i>	IDCC
3	Journal	Dec. 17	Atis Elsts, Xenofon Fafoutis, Simon Duquennoy, George Oikonomou, Robert Piechocki, and Ian Craddock, “Temperature-Resilient Time Synchronization for the Internet of Things,” <i>IEEE Transactions on Industrial Informatics, Dec. 2017.</i>	SICS

4	Journal	May 18	Nuria Molner, Antonio de la Oliva, Ioannis Stravakakis and Arturo Azcorra, "Optimization of an integrated fronthaul/backhaul network under path and delay constraints," Elsevier Ad-Hoc Networks, to appear.	UC3M
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3.2.2 Public Presentations

Table 8 lists all presentation activities delivered including talks and panels. As reported, 11 talks and 2 panels were delivered at nine different venues.

TABLE 8: TALKS AND PANELS DELIVERED IN YEAR 1

#	Type	Month	Venue	Description	Lead Partners
1	Talk	Sep. 17	2017 Taipei 5G Summit	5G CROSSHAUL ARCHITECTURE	UC3M
2	Talk	Sep. 17	Digital Catapult's 5G Workshop: Exploring the technical aspects of 5G	IoT & The Edge: 5G-CORAL Perspective	IDCC
3	Talk	Nov. 17	2017 3rd Asia Fog Computing and Networking Summit	Edge and Fog Integration towards 5G Communication with 5G-CORAL	ITRI
4	Talk	Nov. 17	2017 3rd Asia Fog Computing and Networking Summit	The making Of Fog Computing	ADLINK
5	Talk	Nov. 17	2017 3rd Asia Fog Computing and Networking Summit	Joint Edge and Fog Orchestration: Opportunities and Challenges	NCTU
6	Talk	Dec. 17	"Cambridge Wireless Radio SIG Event New developments in multiple access schemes"	Multi-RAT convergence – A new spin through the Edge!	IDCC
7	Talk	Jan. 18	"8th CommNet2 Challenge Workshop – Communications & Signal Processing for 5G++"	Multi-RAT convergence – A new spin through the Edge!	IDCC

8	Talk	Feb. 18	MONROE's Southern Stakeholders meeting	Thoughts on the problem of measuring KPIs in the 5G-PPP framework	UC3M
9	Panel	Feb. 18	MWC'18, Barcelona	"Delivering the 5G Experience with Mobile Edge Services"	IDCC
10	Panel	Feb. 18	MWC'18, Barcelona	"Why 5G Business Cases Depend More on Edge Upgrades"	IDCC
11	Talk	Mar. 18	IEEE 5G Summit	Edge and Fog in 5G	TI
12	Talk	Jun. 18	EuCNC Workshop 3	Chenguang Lu, "Virtualize IoT Multi-RAT Stacks at Edge"	EAB
13	Talk	Jun. 18	EuCNC Workshop 3	Alain Mourad, "FogRAN: A glimpse into the 5G-CORAL solution"	IDCC

3.2.3 Workshops

Table 9 lists the workshops organized in Year 1. Two workshops have been organized and an additional one proposed and accepted to take place in Year 2.

TABLE 9: WORKSHOPS ORGANIZED IN YEAR 1.

#	Event	Month	Status	Workshop	Country
1	IEEE WCNC 2018	Apr.	Done	The First Workshop on Control and management of Vertical slicing including the Edge and Fog Systems (COMPASS) Note: 12 attendee surveys with 92% satisfaction	Spain
2	EuCNC 2018	Jun.	Done	2 nd Multi-provider, multi-vendor, multi-player orchestration: from distributed cloud to edge and fog environments in 5G Note: 40-50 attendees (7,25/8 satisfaction ratio)	Slovenia
3	ACM CoNEXT 2018	Jun.	Accepted	The First Workshop on Experimentation and Measurements in 5G (EM-5G)	Greece

3.2.4 Exhibitions and Demonstrations

Table 10 lists the exhibitions and demonstrations showcased in Year 1. A total of two posters and five demos have been delivered.

TABLE 10: EXHIBITIONS AND DEMOS IN YEAR 1.

#	Type	Month	Venue	Description	Lead partners
1	Poster	Jun. 18	EuCNC 2018	5G-CORAL in practice: from Low to High Mobility	ITRI
2	Poster	Jun. 18	EuCNC 2018	Fog-assisted Robotics	UC3M
3	Demo	Jun. 18	EuCNC 2018	AR Navigation in the Shopping Mall	ITRI NCTU
4	Demo	Jun. 18	EuCNC 2018	vMME in High-Speed Train	ITRI
5	Demo	Jun. 18	EuCNC 2018	Edge and Fog-assisted Robotics	UC3M

					IDCC ADLINK
6	Demo	Jun. 18	EuCNC 2018	Enhanced Safety in Connected Cars	TIM Azcom
7	Demo	Jun. 18	5TONIC	5G Fog Assisted Robotics Demo to the PSA group	UC3M

3.2.5 5G-PPP Cross-projects Collaboration Activities

During the first year, 5G-CORAL has put an effort towards the collaboration with other projects of the 5G-PPP shown in Table 11. This section presents a summary of all the different activities performed in Year 1:

TABLE 11: 5G-PPP CROSS-PROJECTS COLLABORATION ACTIVITIES IN YEAR1

#	Venue	Description
1	4th Taipei 5G Summit “The Power of New Radio & Edge Intelligence”	5G-CORAL representatives presented how the concepts developed in the H2020 5G-PPP Phase I 5G-Crosshaul extended to the phase-2 projects 5G-CORAL and 5G-Transformer. (More information: http://5g-coral.eu/?p=177)
2	Mobile World Congress 2018	Leaflet aligned with the 5G-PPP format and distributed at the 5G-PPP booth and consortium partners' booths, in addition to panels referring to 5G-PPP
3	1 st COMPASS workshop at WCNC'18	The 5G-CORAL project co-organized the <u>First Workshop on Control and management of Vertical slicing including the Edge and Fog Systems (COMPASS)</u> which took place in Barcelona, Spain on April 15, 2018 in conjunction with <u>IEEE Wireless Communications and Networking Conference (IEEE WCNC 2018)</u> . This COMPASS Workshop is a result of merging the First International Workshop on Edge and Fog Systems for 5G & Beyond (IWEF) with The Control and Management of network slices for VERTICALS (COMVERT) Workshop, creating this new COMPASS workshop, and is co-organized by the <u>5G-TRANSFORMER</u> and <u>5G-CORAL</u> projects. (More information: http://5g-coral.eu/?p=381)
4	2 nd COMPASS workshop on Control and management of Vertical slicing including the Edge and Fog Systems.	This workshop was organized by the Institute of Telecommunications and Multimedia Applications (<u>iTEAM</u>) of the Universitat Politècnica de València (<u>UPV</u>). 2018 is said to be the year of the first normative specifications of the fifth generation of wireless systems 5G, and IEEE BMSB 2018 was co-located with a one-day <u>tutorial</u> on emerging 5G broadcast technologies and applications by the 5G-PPP project <u>5G-Xcast</u> . IEEE BMSB 2018 counted also with a number of <u>workshops</u> on 5G organized by several 5G-PPP projects, such as 5G-CORAL and 5G-TRANSFORMER. On the first day, from 16:20-18:00 the 4B Session took place: 5G Transport (5G Transformer, 5G Coral, 5GEx Workshop). (More information: http://5g-coral.eu/?p=564)
5	EuCNC'18: 5G-CORAL	Several coordination activities with other H2020 5G-PPP projects during the EuCNC'18. 5G Coral, in collaboration with other 5G PPP projects, organized

		the Workshop 3 entitled: Multi-provider, multi-vendor, multi-player orchestration: from distributed cloud to edge and fog environments in 5G. This project was organized by 5G-Transformer, 5G-CORAL, 5G-Ex, 5G-City and RECAP. Presentations from a large list of H2020 projects were received: • 5G-Exchange: http://www.5g-ex.eu/ • 5G-TRANSFORMER: http://www.5g-transformer.eu/ • 5G-CORAL: http://www.5g-coral.eu/ • NECOS: https://intrig.dca.fee.unicamp.br/necos/ • 5G!Pagoda: https://5g-pagoda.aalto.fi/ • 5G-MONARCH: https://5g-monarch.eu/ • NG-PAAS: http://ngpaas.eu/ • SliceNet: https://slicenet.eu/ • 5GCity: https://www.5gcity.eu/ • 5G-PICTURE: http://www.5g-picture-project.eu/ • MATILDA: http://www.matilda-5g.eu/ • One5G: https://one5g.eu/ • 5GMEDIA: http://www.5gmedia.eu/ • RECAP: https://recap-project.eu/ In addition, 5G-CORAL together with 5G-Transformer and 5G-Ex organized a set of demonstrations in a common booth. (More information: http://5g-coral.eu/?p=585, http://5g-coral.eu/?p=617)
6	Demonstrations 5TONIC	5G-CORAL together with 5G-Transformer and 5G-Ex demonstrated the concepts of Edge Computing applied to the Robot scenario for the Manufacturing 4.0 use case, to representative of Telefonica I+D (Julio Linareas, CTO), on the 12th of July 2018.
7	Slicing on ETSI MEC WI	5G-TRANSFORMER and 5G-CORAL through their partners NEC, InterDigital, Telefonica, EURECOM, ITRI and with the support of UC3M, have contributed significantly to create a new ETSI MEC Work ITEM. The Work Item aims to study the support of network slices in MEC, fundamental aspect addressed by both projects. (More information, http://5g-coral.eu/?p=211)
8	First International Workshop on Experimentation and Measurements in 5G (EM-5G)	First International Workshop accepted for CONEXT-18: 5G-CORAL organizes together with 5G-Transformer and MONROE projects one of the two workshops accepted for CONEXT'18.
9	Dissemination Cluster Booster	5G-CORAL is participating actively on the Dissemination Cluster Booster created with 5G-Transformer and 5G-Crosshaul. (More information, http://5g-coral.eu/?p=557)
10	ETSI MEC implementation being developed in 5G-City	5G-CORAL is currently working together with the 5G-City project (common partner ADLINK), in order to leverage several innovations of both projects. 5G-City

		is analysing and working with 5G-CORAL partners to reuse the information model developed in WP3 for the OCS and possibly reusing the publish/subscribe mechanisms developed for information services. 5G-CORAL is looking at reusing parts of the ETSI MEC implementation being developed in 5G-City, although the specific parts are still under discussion.
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3.3 Work Plan for Year 2

The focus in Year 2 will be put on results and trials compared to Year 1 where the focus was on project concept and initial results. In particular, for some dissemination activities that can be measured, we aim to specify target numbers to achieve in Year 2 similar to what we have done in Year 1. These numbers in Year 2 account for the results achieved in Year 1 and for any scheduled activity in Year 2 that was prepared in Year 1 (e.g. submitted papers, scheduled talks, submitted workshop proposals, etc.). We therefore plan in Year 2 to boost the numbers targeted for talks, articles, demonstrations, and workshops such as:

- Demonstration of the project proof-of-concepts at least at three key events including at least two in Taiwan.
- Delivery of at least six talks at key R&D events.
- Publication (or acceptance for publication) of at least six peer-reviewed articles.
- Organization of at least one workshops.

4 Standardization and Open Source Activities

Maximizing the impact of the project innovations on present and future standardization and industry forums has been set as a key objective in order to help create opportunities for commercial exploitation of the project outcomes. This chapter presents first the plan set in Year 1 and reports next on the activities and achievements undertaken. An outline of the plan for Year 2 is then provided.

4.1 Work Plan for Year 1

The project has set the following three objectives for the standardization activities during the lifetime of the project:

- Create and maintain a project standardization activity roadmap. This roadmap will capture the standardization activities that may influence or get influenced by the project technological innovations. It will help (i) keep track of existing or upcoming industry specifications or recommendations that might affect the project technological choices; and (ii) identify opportunities for the project to contribute its proposed solutions to present and future standardization groups.
- Disseminate the project into the standardization forums to raise awareness and help create an opportunity for standardization exploitation.
- Contribute through the partners (individually or jointly) with project-related technology proposals into the relevant standardization forums.

With focus on Year 1, it is anticipated that the activities will first involve the creation of the project standardization activity roadmap (Objective 1). As the design of the project solutions progresses, we anticipate to see more efforts spent on standardization dissemination and contributions (Objectives 2 and 3). To create the project standardization activity roadmap, we have followed the two steps below:

- Identify the standardization activities that may be relevant to the Project.
- Map the project technology development areas onto the standardization activities from the above, by accounting of the timeline towards 2020.

The above two steps are presented in the following sub-sections.

4.2 Standardization Activities

4.2.1 3GPP

3GPP is the dominant SDO targeting at specifications of radio access networks (RAN) and core networks (CN) of cellular communication systems. The specifications of Rel-15 for Standalone 5G architecture has been completed recently (in June 2018), and the Phase-2 of 5G standardization (Release-16) has just started and it is anticipated to be completed in 2020.

Several study items (SI) and working items (WI) relating to 5G-CORAL have been identified by 3GPP in SA working groups, addressing aspects such as Management and Orchestration, Network Slicing, and Multi-RATs. Some SI/WI that are particularly relevant to 5G-CORAL include:

- Study on management aspects of virtualized network functions that are part of the 5G NR.
- Study on network policy management for mobile networks based on NFV scenarios.
- Study on management aspects of next generation network architecture and features.
- Study on Management and Orchestration Architecture of Next Generation Network and Service.
- Feasibility Study on LAN Support.

- Study on the Wireless and Wireline Convergence for the 5G system architecture.
- Study on Access Traffic Steering, Switch and Splitting support in the 5G system architecture.

4.2.2 IETF

The IETF SFC WG may broaden its current scope to allow terminals involve in the classification and decision process of service function chains. It is not in the charter, but some positive feedback was given to an individual joint submission made by UC3M and IDCC partners of 5G-CORAL.

The IRTF NFV RG is also a suitable venue to present topics related to virtualization resources discovery and dynamic association of orchestrators and controllers. 5G-CORAL partners have already submitted a joint contribution addressing some of these aspects.

The mobility of functions and resources are being considered by the IETF DMM WG. A document proposing these topics has been recently adopted as WG document. 5G-CORAL partners are amongst the editors of this document.

4.2.3 IEEE FOG - P1934

A working group called FOG (Fog Computing and Networking Architecture Framework) has been formed recently by the IEEE standard association to accelerate the creation and adoption of industry standards for fog computing and networking. Project 1934 was initiated in Nov. 2017, which has employed the reference architecture defined by OpenFog consortium as the baseline. The project has published the first draft standards in Feb. 2018.

Following on the architecture work done, it is expected (although not fully clear yet) that further specification activities would be launched by IEEE FOG in the near future (i.e. within the lifetime of 5G-CORAL) to address technology gaps that are being identified.

4.2.4 ETSI MEC

ETSI MEC is expected to start its Phase III in September 2018. A key topic in this phase III is addressing the challenges arising when the MEC host is mobile (e.g. in vehicles, trains, etc.), which is aligned with 5G-CORAL scope.

ETSI has also identified several gaps for the integration of MEC into NFV, as well as MEC-NFV deployment in 5G. Currently actions are being taken to address these gaps.

In addition, ETSI MEC has recently started a Working Item focused on the Slicing requirements of the ETSI MEC platform. Luca Cominardi (5G-CORAL WP3 leader) is the current rapporteur of this WI.

ETSI MEC is also defining a testing and certification framework for ETSI MEC-compliant products and solutions (MEC025), which is expected to be published by April 30th, 2019.

4.2.5 ETSI NFV

ETSI NFV ISG is the Industry Specification Group for NFV. This ISG group is 6 years old, and already completed its Release 1 and Release 2 specifications, and advanced significantly towards the completion of its final Release 3 specifications. Going forward, the ISG will maintain its published documents and address any future gaps that may be identified by the industry noticeably accounting for feedback on implementations and deployment.

4.3 Open Source Activities

4.3.1 OpenFog Consortium

The OpenFog Consortium is a consortium of industry interested in architectures related to Fog computing. The reference architecture design was released on February 2017 and it was also

taken as starting point from IEEE FOG for the P1934 as well as for a liaison between ETSI MEC and OpenFog in trying to merge the two different type of computing, that tries to solve a very similar problem, but they come from two different industries.

The definition of Fog Computing that has agreed in OpenFog is the following:

“A horizontal, system-level architecture that distributes computing, storage, control and networking functions closer to the users along a cloud-to-thing continuum.”

This definition is also agreed in 5G-CORAL in the OCS definition which can orchestrate resource that comes from different tiers allowing users to have a unified view of all the computing, networking and storage fabric.

4.3.2 Eclipse Foundation

Eclipse Foundation is one of the biggest OpenSource community for the IoT, allowing users to find projects that cover all the spectrum of IoT solutions. As Fog Computing is one of the key technologies for enabling and efficient IoT and IIoT deployment, some of the key technologies used in 5G-CORAL has been accepted as Eclipse IoT projects, in particular these technologies are fog05¹ and Cyclone DDS², which respectively provide end-to-end infrastructure virtualization and end-to-end publisher/subscriber communication fabric, Cyclone DDS is also the only OpenSource DDS implementation currently available. Publishing these outcomes of the project in the Eclipse Foundation project to grow in popularity in the developer's community as well as provide a very good testbed for the solutions found.

4.4 Standardization Roadmap

In order to draw the standardization roadmap, we first attempt a classification of what 5G-CORAL relevant technology development areas are addressed by which standardization projects. This is presented in Table 12 below.

TABLE 12: CLASSIFICATION OF STANDARDIZATION ACTIVITIES FOR 5G-CORAL.

No.	Technology Development Area of the Project	Standard Bodies
1	Initial Requirements, Gaps Identifications, Use Cases, Architecture	3GPP SA, IEEE FOG, ETSI MEC, OFC
2	Orchestration and Management of virtualization resources and computing tasks deployment	3GPP SA, IEEE FOG, ETSI MEC, ETSI NFV, IETF NFVRG
3	Mobility and Volatility Management	3GPP SA, IETF DMM
4	Service function chaining (SFC) and Slicing	3GPP SA, IEEE FOG, IETF SFC, ETSI NFV
5	Multiple access technologies	3GPP SA, ETSI MEC

Based on the above classification, we draw an initial standardization roadmap in Figure 2 including an indicative timeline towards the year 2020 (i.e. one year following the end of 5G-CORAL project).

As shown in Figure 4, the 2017-2018 timeframe will see the finalization of the gaps identification, requirements setting and architectures definition for Fog and Edge, noticeably in areas relating to

¹ <https://projects.eclipse.org/projects/iot.fog05>

² <https://projects.eclipse.org/projects/iot.cyclonedds>

the mobile, volatile and constrained hosts. The key SDOs involved here are: 3GPP, IEEE FOG, OFC, IRTF NFVRG and ETSI MEC.

The 2019-2020 is anticipated to focus on the specifications activities to address the gaps and requirements being identified. This includes several specifications from several SDOs such as 3GPP (Release 16), IEEE FOG, IETF SFC, IETF DMM, and ETSI MEC.

From 2020 onwards, maintenance of specifications, amendments and extensions accounting for implementations and deployment are anticipated. Open source projects like ECLIPSE will contribute in particular to identifying gaps based on implementations and deployment feedback.

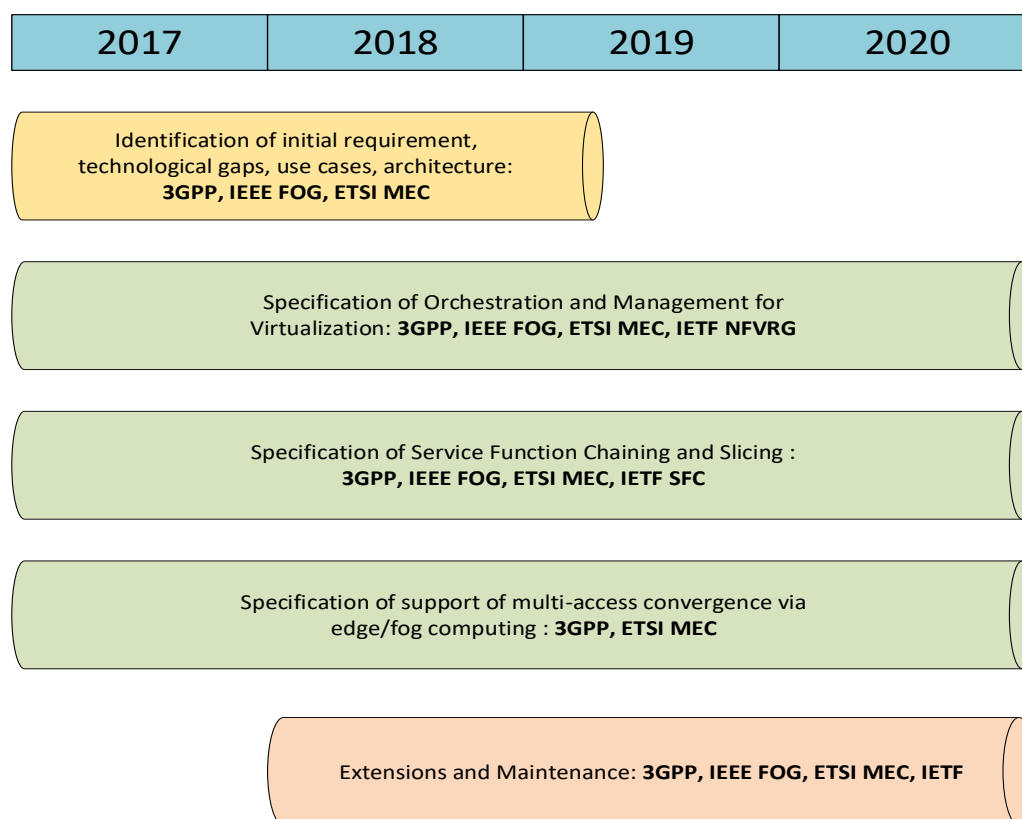


FIGURE 4: INITIAL STANDARDIZATION ACTIVITY ROADMAP TOWARDS 2020.

4.5 Standardization Activities

Following on the above standardization roadmap, the 5G-CORAL partners have undertaken several standardization activities, mostly focusing on ETSI MEC and IETF. Table 13 reports on these standardization activities in Year 1.

TABLE 13: STANDARDIZATION DISSEMINATION IN YEAR 1.

#	Month	Standardization Item	Leading Partners
1	Aug '18	Contribution to ETSI MEC: "MEC(18)000339 MEC024 Use case on multiple tenants in a single network slice"	UC3M

2	Aug '18	Contribution to ETSI MEC: "MEC(18)000340 MEC024 Use case on MEC applications shared among NSIs"	UC3M
3	Jul '18	Contribution to IETF: "Distributed Mobility Anchoring"	UC3M
4	Jul '18	Contribution to IETF: "Cooperating Layered Architecture for SDN"	UC3M, Ericsson
5	Jul '18	Contribution to IETF 6TiSCH WG: "6TiSCH Minimal Scheduling Function (MSF)"	SICS
6	Jul '18	Contribution to IETF 6TiSCH WG: "Robust scheduling against selective jamming in 6TiSCH networks"	SICS
7	Jul '18	Contribution to ETSI MEC: "MEC(18)000298r1 MEC024 errata of use case 5.1 and exemplary figure"	UC3M
8	Jul '18	Contribution to ETSI MEC: "MEC(18)000299r1 MEC024 key issue on slice-awareness of the MEAO"	UC3M
8	Jul '18	Contribution to ETSI MEC: "MEC(18)000301r1 MEC024 key issue on slice-awareness of the MEPM-V"	UC3M
9	Jul '18	Contribution to ETSI MEC: "MEC(18)000300r1 MEC024 key issue on slice-awareness of the MEP"	UC3M
10	Jul '18	Contribution to ETSI MEC: "MEC(18)000326 Some Clarifications for the use case 5.2"	UC3M
11	Jul '18	Contribution to ETSI MEC: "MEC(18)000329r1 Use case on dedicated instances of MEC components in a network slice"	UC3M
12	May '18	Contribution to ETSI MEC: "MEC(18)000171r2 MEC024 Instantiating a network slice integrating MEC app"	UC3M
13	May '18	Contribution to ETSI MEC: "MEC(18)000185r1 MEC024 Use case on creation and termination of a slice"	UC3M
14	Apr '18	Contribution to ETSI MEC: "MEC(18)000170 Need for a configuration framework for WNIS"	UC3M

15	Apr '18	Contribution to ETSI MEC: "MEC(18)000172 Managing traffic redirection from the mobile edge platform: approaches to address issue #9 of ETSI MEC017"	UC3M
16	Mar '18	Contribution to IETF: "Proxy Mobile IPv6 extensions for Distributed Mobility Management"	UC3M, IDCC
17	Mar '18	Contribution to IETF: "Service Function Chaining Use Cases in Fog RAN"	UC3M, IDCC
18	Mar '18	Contribution to IETF: "IPv6-based discovery and association of Virtualization Infrastructure Manager (VIM) and Network Function Virtualization Orchestrator (NFVO)"	UC3M, IDCC
19	Mar '18	Contribution to IETF: "Service Function discovery in fog environments"	UC3M, IDCC
20	Feb '18	Contribution to ETSI MEC: "MEC(18)000055 MEC024 Overview of network slicing in 3GPP"	UC3M
21	Feb '18	Contribution to ETSI MEC: "MEC(18)000056 MEC024 Overview of network slicing in NGMN"	UC3M
22	Feb '18	Contribution to ETSI MEC: "MEC(18)000057 MEC024 Overview of network slicing in ONF"	UC3M
23	Jan '18	Contribution to ETSI MEC White Paper: "MEC Deployments in 4G and Evolution Towards 5G" (Dissemination contribution)	UC3M
24	Feb '18	Contribution to IETF: "Network Virtualization Research Challenges"	UC3M, IDCC
25	Dec '17	Contribution to ETSI MEC: IOT and Edge Computing: What can be done in ETSI MEC?	UC3M, IDCC
26	Nov '17	Contribution to IETF 6TiSCH WG, "6TiSCH Autonomous Scheduling Function (ASF)".	SICS
27	Nov '17	Contributions to IETF: https://tools.ietf.org/html/draftbernardos-dmm-pmipv6-dlif-00 https://tools.ietf.org/html/draftbernardos-sfc-fog-ran-02	UC3M, IDCC
28	Oct '17	Contribution to ETSI MEC: "MEC(17)000494 Initial Skeleton for ETSI MEC024 draft"	UC3M

29	Sep '17	Contribution to ETSI MEC White Paper: "Developing Software for Multi-Access Edge Computing" (Dissemination contribution)	UC3M
30	Sep '17	ETSI MEC Working item on MEC Slicing approved (UC3M as rapporteur)	UC3M

4.6 Work Plan for Year 2

In Year 2 (September 2018 to August 2019), as the project solution matures, we see more and more potential for contributions into the relevant SDOs identified in the standardization roadmap. The plan therefore for Year 2 includes the following:

- For the standardization roadmap, the focus in Year 2 will be on maintaining this roadmap with updates as new groups emerge and others end. In addition, the 5G-CORAL project will continue to closely follow the relevant standardization activities, so that it can account for new requirements, architectures, and technologies as they emerge from the standardization forums, in the development of the 5G-CORAL solution.
- For the standardization activities, we will continue in Year 2 to contribute the project technology, and at the same time, receive feedback from the standardization community on our technology development plan and how best we can steer it towards successful transfer into standards.
- Regarding OperSource contribution to the Eclipse Foundation, during Year 2 will be consolidating what was already published (in particular fog05) and will start focusing more on performance targeting devices smaller than the one targeted today, as well as exploit the Eclipse community for disseminating the results of the project.

5 Exploitation Activities

It is the project's ultimate goal to achieve tangible exploitation of its findings and results during the course of the project and afterwards. Various forms of exploitation are targeted including pre-commercial proof-of-concepts (PoCs) and commercial products, innovations and new features adopted into standards, and new services. Whilst Chapter 4 presented on the standardization activities, this chapter sets focus on the proof-of-concepts and products as well as potential new services which might get influenced by innovations from the project. This chapter presents first the work plan set for exploitation activities in Year 1. It moves next to describe proof-of-concepts and products as well as new services which are identified with potential impact from/to the project. The key innovations identified in Year 1 are then summarized, followed by an insight on the activities foreseen in Year 2.

5.1 Work Plan for Year 1

The work plan for Year 1 included activities relating to all aspects of the exploitation strategy envisioned as follows:

- Identify the opportunities in the PoCs, technology transfer, products and services which might bear a potential impact from/to the innovations targeted by the project;
- Identify innovations as they emerge from the technology development undertaken by the technical work packages (WP1/2/3/4);
- Map these innovations onto identified products and services of industrial stakeholders, and;
- Promote the exploitation of these innovations by the various stakeholders.

In view of the high importance given by the project to the exploitation activities, the project has appointed an Innovation Manager (Dr. Chenguang Lu from Ericsson) to lead the work and ensure successful exploitation of the innovations from the project.

5.2 Activities Related to Commercial Exploitation

A first step in the exploitation strategy is to identify the pre-commercial PoCs, commercial products, and services, from the project partners, which might have an impact from/to the innovations targeted by the project. This is done in this section with focus on the PoCs, products and services the project has identified in Year 1.

5.2.1 Proof-of-Concepts

5.2.1.1 IoT Multi-RAT PoC

In this PoC, we design an IoT Multi-RAT access system which is IoT technology-agnostic and provides future-proof IoT support. It follows the Cloud-RAN approach, centralizing baseband processing at the Edge in EFS. The idea is to have one radio infrastructure to support several IoT radio technologies. This would avoid the need to deploy parallel systems for supporting different technologies. It would significantly reduce the cost and increase flexibility and future-proofness, because baseband processing is softwareized and cloudified in an edge cloud infrastructure. The system comprises of three parts: radio heads, a fronthaul network (e.g. Ethernet) and edge cloud. The radio heads are in charge of transmitting and receiving radio signals. It is connected to a (or several) communication stack, running on the EFS in an Edge cloud. Each communication stack is in charge of modulating/demodulating the radio signals for one RAT, as well as of handling all upper layers. Particularly, the PoC prototype under development will support IEEE 802.15.4 and NB-IoT.

The PoC is tightly related to 5G-CORAL. It is designed to support 5G-CORAL architecture with EFS and OCS. The communication stacks will be virtualized (e.g. using Docker) as EFS functions and some orchestration features will be implemented with OCS (e.g. using Kubernetes).

5.2.1.2 Fog-based AR PoC

ITRI's Fog-based Augmented Reality Proof of Concept system is a technology that uses Edge Computing device to offload a computational heavy indoor localization and image recognition (IR) algorithm in an efficient manner. The proposed solution reduces the need for the video frame and localization information to travel from the end user's phone to the remote data centre and taking the advantages of Location Based (LB) information and service to provide proximity services. Fog-based AR PoC is also further enhanced by adding beacon-based system to reduce the time needed for the IR engine to process the incoming images. Indeed, beacon signalling gives feed-back about the approximate location of the user and hence allows to optimize the process by preselection of the image datasets.

The PoC is aimed to provide low-latency experience for the user AR Indoor Navigation solution for Shopping Mall through densely deployed Fog-devices. The localization system that enables seamless navigation and shopping experience are combined of two elements: an IR engine and a Localization module. Both components interact with each other while residing in the shopping mall's Fog Node. IR engine is responsible for detecting the precise location of the user and infer information about his surroundings. In order to do so, IR engine receives video frames from the AR Navigation application residing on the UE's of the mall's clients. The frame is compared against pictures stored in the local database. In order to reduce computational burden coming from the need of searching through the big database, IR engine is collaborating with the Localization module. The AR Navigation App on the UE receives BLE (Bluetooth Low Energy) beacon signals which are sent for localization purpose by the beacon devices (with unique beacon ID each) deployed within the shopping mall. By analysing beacon signalling signature received from multiple beacon devices, Localization module is able to roughly estimate area within the shopping mall where UE is located. Later, the area is sent to the IR engine to which selects only those pictures that are relevant to a particular area.

ITRI Fog-based AR Navigation System will take part in the demonstration scenarios and trials planned in 5G-Coral. A first joint demonstration is planned with partners and in NanGang Shopping Mall Q4'2018. The deployment in such demonstration obeys the initial 5G-CORAL EFS and OCS architecture design.

5.2.1.3 Cleaning/Delivery by Robot PoC

This use case addresses the use of the edge and fog in order to control robots in a certain geographical area. The idea is to move the intelligence for a certain application from the robot itself to the Edge (Fog+MEC). The logical centralization of the robot intelligence provides gains on the joint control of multiple robots simultaneously, while the use of multi-RAT permits the robots to communicate locally in a D2D fashion so as to provide a link for the feedback control loop required for the synchronized movement of the robots, which is independent of the channel between the robots and the edge/fog.

This use case will allow us to show multiple functionalities of the 5G-CORAL platform (EFS and OCS) such as the movement of EFS functions, the support of orchestration algorithms, use of Edge computation for offloading very intensive functions (Lidar mapping), localization services of different granularity, etc.

This use case has been already presented to Telefonica I+D and PSA group to gather their views on the possible business models and technological perspectives. The use case has been received very positively by both companies, which agreed on the importance of moving the intelligence to the Edge in order to increase the flexibility and reduce the cost of current robotic manufacturing.

5.2.1.4 VR PoC

The Virtual Reality PoC showcases a 360° video live streaming service delivered by a couple of 360° cameras located in specific points of interest inside the Taiwan shopping mall. The main

motivation for using this technology lie in offering an ultimate experience to users attending a live event, such as celebrity appearances, contests and sporting events, as well as helping relieve overcrowded situations that may occur when a significant number of people gather in a limited space. In such cases, a 360° video live cast can offer the opportunity for everyone inside a shopping mall to watch the live event panoramically and reduce the crowd management cost. However, the 360° video delivery entails high bandwidth consumption and low latency requirements which are hard to fulfil in conventional wireless networks. One of the solutions to overcome this issue consists of employing a viewport adaptive streaming technology. This technique relies on the clients' viewing orientation and aims to deliver the portion of the 360° video (e.g., viewport) being watched by the user in high quality/resolution, whereas the rest is delivered in low quality/resolution. Furthermore, viewport adaptive streaming is currently supported by the latest MPEG VR standard, Omnidirectional Application Format (OMAF), and MPEG video streaming standard DASH.

The distributed and multi-RAT nature of 5G-Coral is key to enhancing the viewport adaptive streaming solution by allocating different tasks to different computing devices. More specifically, a crucial component in the demo architecture is the orientation service, which provides the DASH streaming server with the client viewing orientation, with the aim of delivering the viewport in high quality and the rest of the video in low quality. In addition, the distributed fog computing platform will consist of multiple fog nodes capable of offloading computing load from the mobile devices. Specifically, the fog nodes host the orientation service, which is in charge of retrieving the viewing orientation from the VR client and forwarding this information to the remote data centre, which will optimise the transmission quality based on this. Finally, the possibility of migrating EFS services, applications and functions from one fog node to another will play a key role in this use case, given the low-latency requirement of VR.

5.2.1.5 Connected Cars

Azcom and Telecom Italia Proof of concept prototype focuses on “Road Safety” use cases, specifically on a delay sensitive warning service and which design exploits the resources of the EFS available not only at the edge but even at the vehicles. The demonstration aims to show how 5G CORAL technologies can satisfy the requirements of this scenario in terms of improved latency and system reliability. In the proposed PoC the 5G CORAL technologies such as EFS Applications, EFS Services and EFS Functions are configured to run also on the vehicles (On Board Units that act as Fog CD). Moreover, this PoC will demonstrate also that some of the 5G CORAL innovations could be integrated in a legacy network with a reasonable effort enabling new use cases.

5.2.2 Existing or New Products and Solutions

This subsection includes products from the partners that will be impacted by 5G-CORAL technology.

5.2.2.1 Radio Dot System

Ericsson Radio Dot system (RDS) is an innovative indoor radio solution to meet high capacity traffic demand indoors, such as in shopping malls, office buildings, airports etc. It improves the cost-effectiveness via using Ethernet cables to distribute radio signals and also the power remotely, and the sleek design of the Radio Dot for easier installation. It also provides feature parity to Macro cells, which enables both indoor and outdoor deployments share the same software feature and future-proofness.

The multi-RAT IoT use case investigated in 5G-CORAL can be used to extend RDS. Radio Dots can act as the radio head infrastructure to serve both mobile broadband (MBB) and IoT services. The MBB services can be processed by the traditional base stations (i.e. BBUs), while the IoT services are processed at an edge cloud. The benefit of this approach is that the high performance of MBB services is kept while the costs of IoT services are reduced.

5.2.2.2 Fog05

Eclipse fog05 aims to provide IaaS for managing the Fog Computing environment, as well as the compatibility to ETSI MEC. It allows users to unify the three fabrics which present in today's computing, storage and networking infrastructures, providing an End-to-End abstraction over different infrastructures. This allows the possibility to deploy applications closest possible to the users and allow to harvest computing power also in factories, as well as the possibility to deploy heterogeneous types of deployable unit (such as Containers, Native applications, ROS2 applications, VMs and so on). So, users are not limited to VMs or Containers, in a very heterogeneous infrastructure that can comprise from servers in a data-centre to robots in a factory plant.

In the 5G-CORAL architecture fog05 will be used as the reference implementation for the OCS, providing abstraction over the different resources, and enabling use cases that need the ability to instantiate different types of deployable unit over the fog environment as well as provide the network virtualization and slicing on fog devices.

Eclipse fog05 provides a virtualised infrastructure that allows to distribute computing, storage, control and networking functions closer to the users along a cloud-to-thing continuum. fog05 can leverage cloud infrastructure or equally function without it. Starting from 16 May 2018 the fog05 project has become part of the Eclipse IoT ecosystem (approved as an Eclipse Foundation project) and published as open-source under Eclipse Public License 2.0. We are also working with the OpenFog Consortium to have fog05 as one of the reference implementations for a Fog Computing IaaS.

5.2.2.3 Connected Cars Framework

Azcom, as an SME specialised in small cells and automotive appliances, is studying the applications of the 5G-CORAL project concepts to the automotive scenario. Azcom already provides hardware platforms and software products that can be used to develop, augment and enhance the current connected vehicle applications³ (telemetry and on-board infotainment) but still using only a legacy approach where the applications run in a distant central cloud. The connected cars use case investigated in 5G-CORAL can be used to extend these products to be the key components of an edge and fog infrastructure tailored to specific new use cases (e.g., enabling low latency for car to car communication for vehicles safety, using the resources available not only at the edge but even at the vehicles). V2X standards have emerged to facilitate vehicle and infrastructure communications but they have been poorly adopted due to the massive capital investment required for creating a dedicated network, such as Dedicated Short-Range Communication (DSRC). 5G-CORAL overcomes this by delivering low latency and proximity services through the edge and fog infrastructure. This enables the creation of solutions like optimised congestion-based routing and speed management, cooperative adaptive cruise control, collision avoidance, emergency vehicle prioritisation, that are no longer tied to a specific infrastructure, but rather can be quickly and cost-effectively deployed at large-scale over a multitude of computing nodes at the edge. A partial implementation of this concept by 5G-CORAL would be of great benefit for Azcom products and will serve as a basis for future new implementations and whenever applicable, Azcom will consider offering commercial versions of the products targeting the connected vehicles market segments. Moreover, all the above potential developments and applications of 5G-CORAL fit Azcom's business strategy, which focuses on the continuous improvement of the existing automotive platforms and software products. These platforms and software products will potentially incorporate several of the technologies involved in 5G-CORAL and by integrating such innovative concepts earlier, Azcom will be able to foresee the future difficulties and challenges in automotive solution implementation domain.

³ <http://www.azcom.it/index.php/innovations/connected-car/>

5.2.2.4 Contiki-NG

SICS is co-maintainer of the Contiki-NG project, an open-source Operating System for constrained IoT systems. Contiki-NG focuses primarily on low-power multi-hop communication, where hundreds of nodes connect together and form a mesh, with end-to-end Internet connectivity. The nodes embed an IPv6 stack, more specifically with the protocols 6LoWPAN, RPL, CoAP, 6TiSCH and more. Contiki-NG is one of the leading OSeS in the field, both for Industry and Academia.

In 5G-CORAL, we use Contiki-NG in the Multi-RAT IoT Gateway Use Case. The IEEE 802.15.4 access point, which is an EFS Function, runs a virtualized Contiki-NG node. Outside of the EFS domain, constrained IoT devices run Contiki-NG directly on their microcontroller. We contribute to Contiki-NG any new feature, enhancement, stability fix done for 5G-CORAL. One major new feature under development is the port of Contiki-NG for GNU Radio SDRs, which enables running the full low-power IPv6 stack of Contiki-NG in virtualized radio environments.

5.2.2.5 SDN/NFV Services

Telcaria is designing and implementing an SD-WAN solution which leverages 5G-CORAL features for enhancement. The aim is to deploy and manage Wide Area Networks (WANs) using SDN for network control and NFV to develop virtualized network functions (VNF), e.g. QoS, Firewall. The inclusion of SDN and NFV technologies to deploy Wide Area Networks brings the benefits of both trends to companies, who can reduce operation costs. Although SD-WAN (software defined WAN) increases the flexibility compare with legacy WAN networks, the flexibility can be further increased in future fog environments where many volatile resources can be found. Dynamic orchestration, multi-RAT and edge and fog resources, which are not considered in current solutions, will be the path to follow.

Some inherited benefits are that the company utilizing the SD-WAN network does not have to own the infrastructure. Dynamic orchestration will deploy the branch function where it better fits after discovering feasible resources. Also, the radio access technologies are not fixed to WiFi access points. Multi-RAT support increments the accessibility to deploy a new access point of a different technology. In the scope of a facility like a shopping mall, these features add more benefits to current SD-WAN solutions.

5.3 Key Innovations Identified in Year 1

The innovations are main in the areas of EFS and OCS.

- 1) EFS: the innovations are mainly about EFS functions and EFS applications designed for different 5G-CORAL use cases, as well as the EFS service platform related innovations.
- 2) OCS: the innovations are mainly about the OCS software components with particular focus on VIM and EFS Manager.

TABLE 14: MAPPING BETWEEN PROJECT INNOVATIONS AND RELEVANT PARTNERS' POCS, PRODUCTS, SERVICES AND APPLICATIONS

Innovation area	PoC, Product, Service, Tech Transfer or software components/features	Partner
EFS	IoT Multi-RAT PoC - Virtualized multi-RAT communication stacks - IQ sample service	Ericsson/SICS
	VR PoC: Virtual Reality Orientation Service	IDCC
	Fog-based AR PoC	ITRI

	- iBeacon Localisation Service - low latency distribution (neural-network based) solution for real-time coordinated processing across neighbouring Fog nodes for IR	
	Cleaning/Delivery by Robot PoC - Virtual Wi-Fi access point - LTE Radio Network Information Service (RNIS) - WiFi Network Information Service	UC3M/IDCC
	Enhanced safety in connected cars	AZCOM
OCS (VIM and EFS Manager components)	Information model for unification of ETSI NFV, ETSI MEC, and TOSCA descriptors	UC3M/ADLINK
	Information model for common resource discovery across multiple radio access technologies	UC3M/ TELCA/ ITRI/IDCC
	Control and management of resource-constrained and heterogeneous devices	ADLINK/UC3M
	Dynamic migration of virtualized applications and functions in distributed environment	ITRI/ADLINK
	Federation of edge and fog systems	NCTU
	fog05 PoC IaaS for managing the Fog Computing environment	ADLINK

5.4 Patent Applications

Patent applications are in process by consortium partners. Detailed information has not been available to be public. We will update the related patent information, once any is available.

5.5 Work Plan for Year 2

The exploitation strategy developed and executed upon in Year 1 remains valid for Year 2, with potential refinement as new innovations, PoCs, products, services, and applications emerge. In particular, in Year 2, it is anticipated that more innovations will come out of the project and get validated through a number of testbeds and trials planned in WP4. This will help to better address and motivate the uptake of these innovations into products and services by not only the project partners but also industrial stakeholders outside the project. We therefore intend to devote our efforts in Year 2 to:

- Identify further innovations from the project as they emerge and get validated through test beds and trials.
- Leverage on the test beds and trials to build a compelling story to promote these innovations to industrial stakeholders inside and outside the project consortium.

6 Conclusions

This document reported the progress on communication, dissemination, collaboration, standardization and exploitation activities, for the first year of 5G-CORAL project, i.e. September 2017 to August 2018. According to the reported progress for dissemination activities, it is clear that the consortium has achieved significantly more than the targets set in Work Plan of Year 1. Specially, 12 scientific journal or conference papers have been published (compared to 6 scientific publications as planned), while 12 talks have been delivered by the consortium partners (compared to the planned target of 10 talks). On the other hand, the partners have managed to hold 7 workshops and conducted 6 demonstrations throughout Year 1. Moreover, the dissemination plans for Year 2 are presented, which puts emphasis on proof-of-concept demonstrations and trials.

In order to bring impacts of this project to the specifications of new standards, various standard activities have been carried out to serve such purposes. The report has updated the status of several standardization bodies relating to 5G-CORAL project, as well as the standardization dissemination and contribution activities that have been undertaken by the consortium partners during Year 1.

Exploitation of the innovations is also a key pillar to the activities. This report highlights the pre-commercial proof-of-concepts, commercial products and services from the project partners that might have an impact from/to the project. It also summarizes the key innovations identified from the project in year 1 and attempts a mapping of these innovations on relevant PoCs, products, services and applications from the project partners. Insights into the exploitation for Year 2 have also been provided.

In general, this report summarises the achievements of WP5 in Year 1 and showcases a remarkable milestone for dissemination activities of this project. Meanwhile, the vision of standard activities and exploitation plans is also elaborated and offers a guideline for WP5 work of 5G-CORAL project in the following year.