H2020 5G-TRANSFORMER Project

Grant No. 761536

Communication, Dissemination, and Exploitation achievements through the project, exploitation plan after the end of the project and assessment of the contribution of 5G-TRANSFORMER in support of the 5G standard

Abstract

This document reports on the achievements of the project in accordance to the activities defined in its communication, dissemination, and exploitation (CoDEP) plan. The exploitation plan after the project ends and an assessment of the standardization contributions to 5G-related standards is also presented.

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Disclaimer

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List of Acronyms

Acronym	Description
3GPP	Third Generation Partnership Project
5G PPP	5G Public Private Partnership
API	Application Programming Interface
BTS	Base Transceiver Station
CDB	Common Dissemination Booster
CDN	Content Delivery Network
CoDEP	Communication, Dissemination, and Exploitation Plan
CPRI	Common Public Radio Interface
CSA	Coordination and Support Action
DoA	Description of the Action
E2E	End-to-end
EPC	Evolved Packet Core
ETSI	European Telecommunications Standards Institute
ICT	Information and Communication Technology
IEEE	Institute of Electronics and Electrical Engineering
IETF	Internet Engineering Task Force
IoT	Internet of Things
IP	Internet Protocol
IPR	Intellectual Property Rights
IRTF	Internet Research Task Force
ITU-T	International Telecommunications Union – Telecommunications standardization sector
LTE / -A	Long Term Evolution / -Advanced (3GPP)
MEC	Multi-Access Edge Computing
MPTCP	Multi-Path Transmission Control Protocol
MTP	Mobile Transport and Computing Platform
MVNO	Mobile Virtual Network Operator
NFV	Network Functions Virtualization
NFVRG	NFV Research Group (IRTF)
NGMN	Next Generation Mobile Networks
OBSAI	Open Base Station Architecture Initiative
ONF	Open Networking Foundation
OPNFV	Open Platform for NFV
QoS	Quality of Service
SAC	Standards Advisory Committee
SDN	Software Defined Networks
SDO	Standard Development Organization
SLA	Service Level Agreement
SO	Service Orchestrator
VNF	Virtual Network Function
VS	Vertical Slicer

Executive Summary and Key Contributions

This document reports on the achievements of the project in accordance with the activities planned in its communication, dissemination, and exploitation plan (CoDEP). It also explains the plans for exploitation after the project ends to guarantee its long-term impact.

Based on common practice at the EU level [1], *Communication* includes all the activities related with the promotion of the project and its results beyond the projects own community. This includes the interaction with other research projects (e.g., H2020 5G PPP) as well as communication of its research in a way that is understood by the non-specialist, e.g. the media and the public. *Dissemination* includes activities related with raising awareness of its results in a technical community working on the same research field. In general, this will be done through publications, and participation and organization of technical events. Finally, *exploitation* (in accordance with the European IPR Helpdesk) covers activities aiming at using the results in further research activities other than those covered by the project, or in developing, creating and marketing a products or processes, or in creating and providing a service, or in standardization activities.

In the last part of the project, and as part of the *Integrated Technology Demonstration* phase of CoDEP, the focus moved to showing the 5G-TRANSFORMER architecture in practice over real testbeds. A proof of that are the various integrated demonstrations showcasing various vertical services running on top of the full 5GT stack. An overview of the main achievements for the most relevant activities is provided below.

As for communication, project partners continuously presented the project in various events, participated in coordination calls with other 5G-PPP projects and generated content for the website and social media of the project. Since the project started, there has been a steady increase of the web and social media impact, for instance, reaching 33000 visits per year on the web or 109000 Twitter impressions (e.g. in the April-June 2019 quarter). Communication actions for society at large were also carried out.

Various events were also co-organised by 5G-TRANSFORMER with other H2020 projects (most of them 5G-PPP ones). More specifically, the joint work with other 5G-PPP projects was carried out in various forms. Some organized events are: “Workshop 2: From cloud ready to cloud native transformation, second edition” during EUCNC 2019, or the EM-5G workshop co-located with ACM Conext’18.

In addition to jointly organized events, the project is regularly participated in 5G-PPP working groups, and prepared joint papers. The project also regularly participated in 5G-PPP COMMS group, an activity organized by the To-Euro-5G CSA towards a joint dissemination strategy of all 5G-PPP projects, and so, regularly exploited these joint channels.

Several talks (technical and general public), publications, student supervision, etc. were also given.

As for dissemination and exploitation (task 6.2), several actions were also carried out. A number of papers (34 in Journals and 61 in conferences/workshops) were accepted and presented in international journals and conferences (e.g., IEEE Transactions on Mobile Computing, EUCNC, IEEE INFOCOM).

Furthermore, the participation of the project at the Mobile World Congress (MWC’18 and MWC’19) held in Barcelona is also relevant in this respect. In addition to other demos presented in the initial part of the project, let us highlight the four integrated

demonstrations presented at EUCNC'19, in a joint booth with 5G-CORAL. Other demos were presented in renowned international conferences, such as ACM Mobihoc'19, ACM Mobicom'19, IEEE SDN-NFV'19.

A number of results in terms of standardisation were also achieved in accordance with the roadmap set up by the standardization advisory committee (SAC). As part of these roadmap, a number of contributions, mostly to ETSI MEC, 3GPP SA2, and IETF working groups were submitted. Thirty five contributions to four different SDOs: 9 to IETF/IRTF, 10 to 3GPP, and 16 to ETSI NFV/MEC.

Exploitation achievements and plans after the project ends are also presented, by highlighting the impact on products and services of partner organizations that the concepts dealt with in this project are expected to have on each of them.

Furthermore, in other to maximize its impact and to disseminate the work to the community, the project released as open source code for each the building blocks of the 5G-TRANSFORMER architecture, in addition to contributing to other open source projects that were used.

Finally, let us also highlight that the project was granted all five services requested for the Common Dissemination Booster (CDB), jointly with other projects (5G-Crosshaul and 5G-Coral), which started its operation in May 2018 and whose actions were mostly undertaken during the last part of the project. In this context, a business- and SME-oriented exploitation workshop was co-organized with other projects and with the help of the CDB during EUCNC, whose title was "Emerging 5G Business Models: Opportunities for SMEs and large companies – lessons from 5G PPP (5G-EBM)".

1 Introduction

As shown in Figure 1, the last phase of the project was the *integrated experimental demonstrations* phase. As a consequence, dissemination and exploitation, including standardization, had high relevance.

The CoDEP of 5G-TRANSFORMER includes the following groups of activities:

- **Communication:** It includes all the activities related with the promotion of the project and its results beyond the project's own community. This includes the interaction with other research projects (e.g., H2020 5G PPP) as well as communication of its research in a way that is understood by the non-specialist, e.g., the media and the public.
- **Dissemination:** It includes activities related with presenting its results in a technical community working on the same research field. In general, this will be done through peer-reviewed publications in academic conferences and journals, and participation and organization of technical events.
- **Exploitation:** In accordance with the European IPR Helpdesk [1], it covers activities aiming at using the results in further research activities other than those covered by the project, which mostly imply 1) developing, creating and marketing products or processes, 2) creating and providing a service, or 3) standardization activities.

The original CoDEP has been periodically updated in the various WP6 deliverables during the project. As far as exploitation is concerned, the focus of the last part was on completing and consolidating all key innovations developed in the first two years of activities. Furthermore, this deliverable also explains the exploitation activities to maximize impact after the project ends. Standardization contribution outcomes, as a result of the roadmap defined (and periodically updated during the project) by the Standardization Advisory Committee (SAC) are also presented.

The document is structured into three parts: (1) 5G-TRANSFORMER CoDEP Achievements; (2) Exploitation plan after the project ends, and (3) Contribution of the project to 5G-related standards.

The first part of the document is structured into four sub-sections, namely communication, dissemination, exploitation, and standardization.

The second part presents the exploitation plan after the project ends. For those directly related with products and services, detailed explanations are provided.

Finally, in the third part, an assessment of the contributions of the project to 5G-related standards is provided.

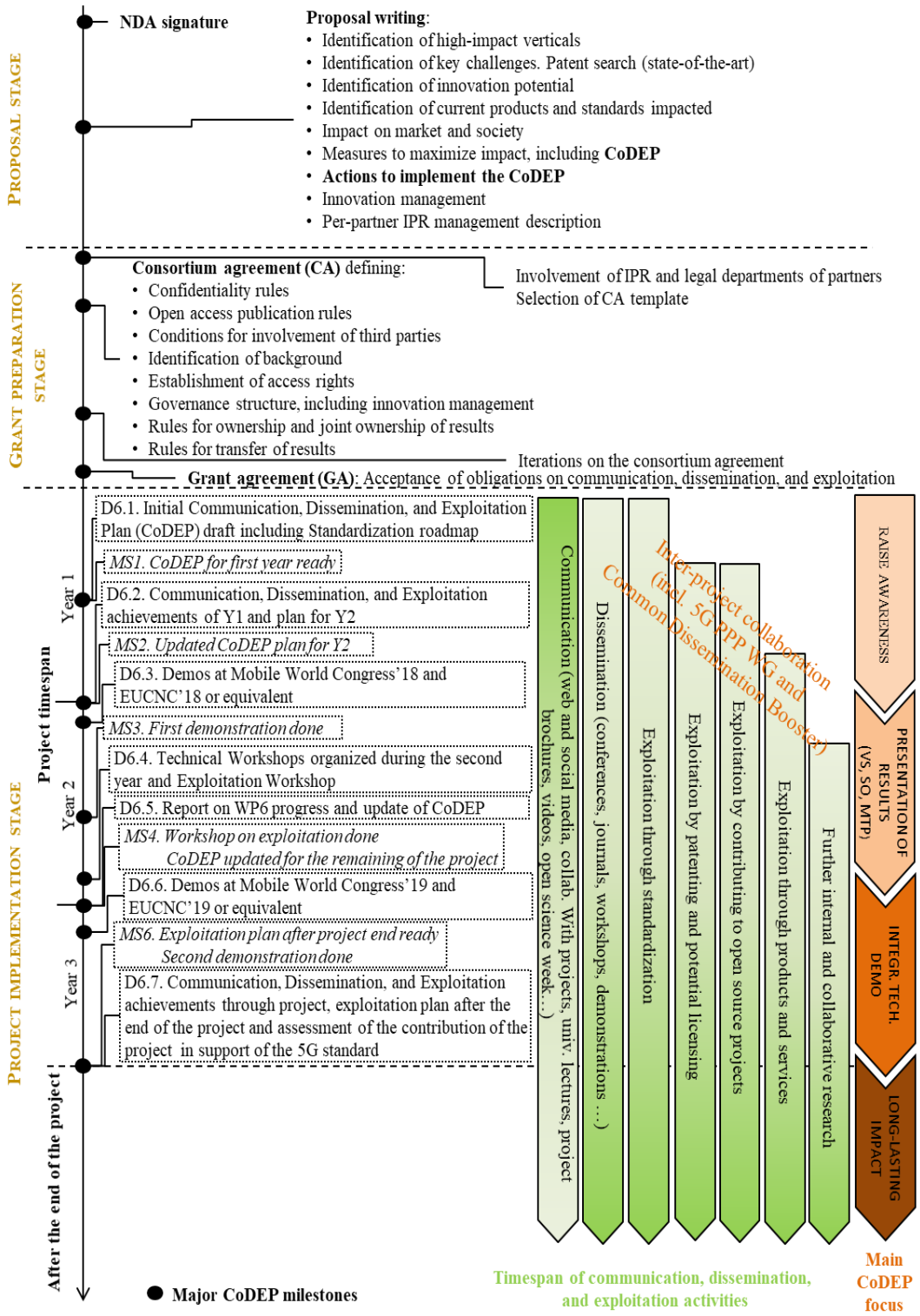


FIGURE 1: ILLUSTRATION OF THE COMMUNICATION, DISSEMINATION, AND EXPLOITATION (CODEP) PLAN OF 5G-TRANSFORMER

2 5G-TRANSFORMER CoDEP achievements

The first part of the document reports the WP6 progress during Y1 and Y2 of the project. Section 2.1 reports the communication activities, Section 2.2 describes the dissemination activities, and Section 2.3 reports the exploitation activities, including products and services, patents and licensing. Section 2.4 is dedicated to the standardization activities.

2.1 Communication

The 5G-TRANSFORMER communication plan is devoted to outreach activities to academia, industry, and society at large and to highlight the major achievements of the 5G-TRANSFORMER project, vision, concept, objectives, and results among the various stakeholders. All 5G-TRANSFORMER partners promote the 5G-TRANSFORMER project to the general public, and through different kinds of activities. In the following subsections, we will report all the activities, such as the Web, social media and project communication material, leaflet and poster, video, press releases and news, articles, presentation/lectures and collaboration with other projects for the whole project lifetime.

2.1.1 Web, social media, and project communication material

In order to achieve the objectives of the 5G-TRANSFORMER activities defined in D6.5, partners have continued contributing by issuing news about the project and utilizing their internal and external communication tools. In the last six months of the project, 5G-TRANSFORMER made a big effort on the generation of news around the presence of the project in demonstration-oriented events, showcasing the benefits of the technology developed, as shown in Section 2.1.4. More details can also be found on the project website (http://5g-transformer.eu/). Also, the statistics of 5G-TRANSFORMER social media are presented in Annex II. Throughout the project, the number of visits for various three-month periods ranged from 6000 to 12000 and the most popular page reaching more than 2000 visits in three months and always staying above 1000 visits. Furthermore, for one-year periods, the website had around 16000 visitors and 36000 visits. The number of downloads of posters and leaflets was also monitored. The most popular leaflet almost reached 1000 downloads.

The social media accounts of 5G-TRANSFORMER were also set up, and are the following:

- Twitter: https://twitter.com/5g_transformer
- LinkedIn: https://www.linkedin.com/in/5g-transformer
- Instagram: https://www.instagram.com/5g_transformer/
- YouTube: https://www.youtube.com/channel/UCIQXD0ICxTK9eh_mQzMweww

Again, in the last 6 months of the project, 5G-TRANSFORMER has kept the steady impact increment of the website and of social media according to the CoDEP execution phase of the project.

2.1.2 Communication leaflets and poster

In the last 6 months of the project, 5G-TRANSFORMER generated several communication materials, available on the web, for the promotion of the 5G-TRANSFORMER project. For example, demo-specific posters were used to aid in the presentation of the project outcomes during EuCNC 2019 (Figure 2 and Figure 3).

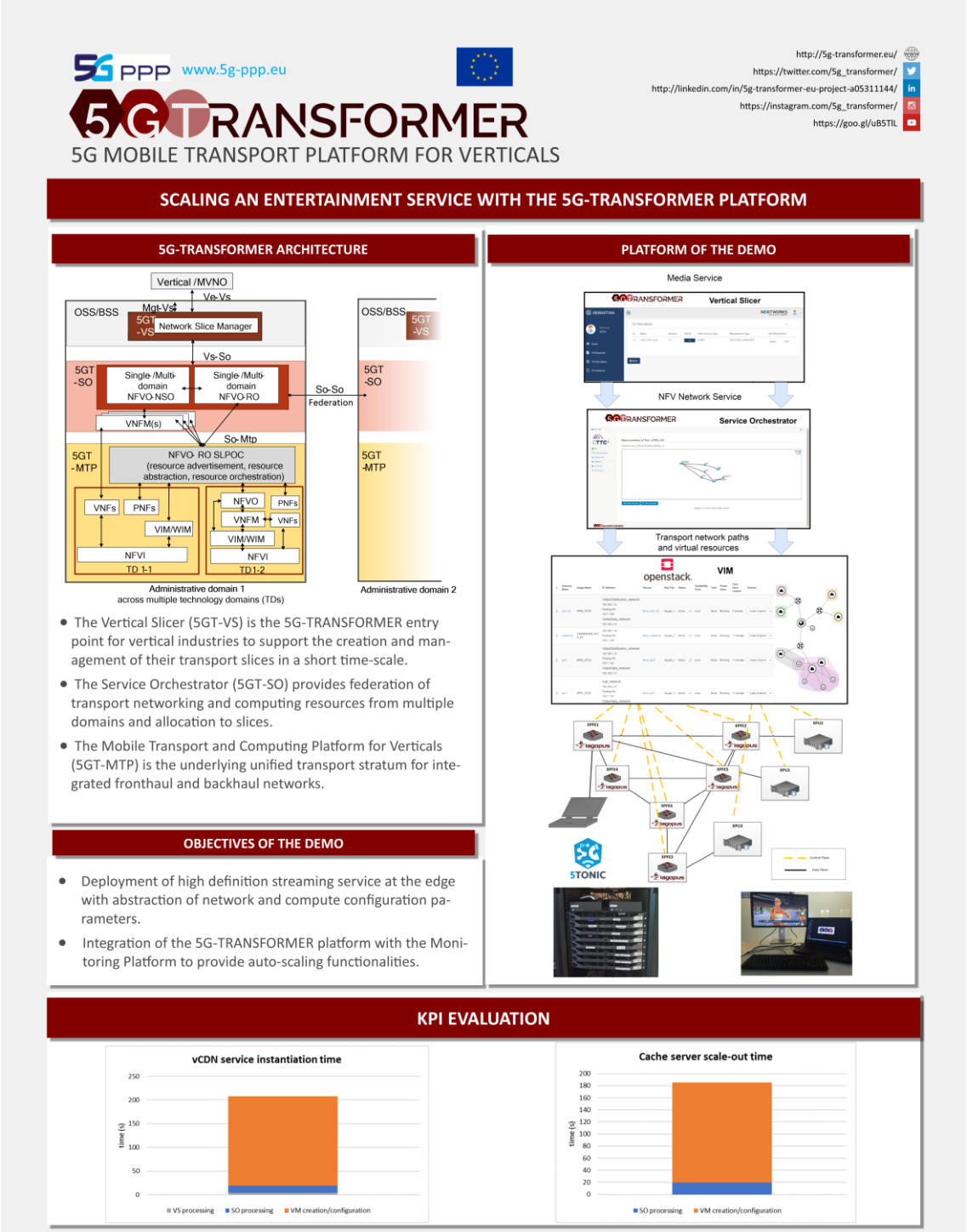


FIGURE 2: ENTERTAINMENT DEMO POSTER FOR EUCNC 2019

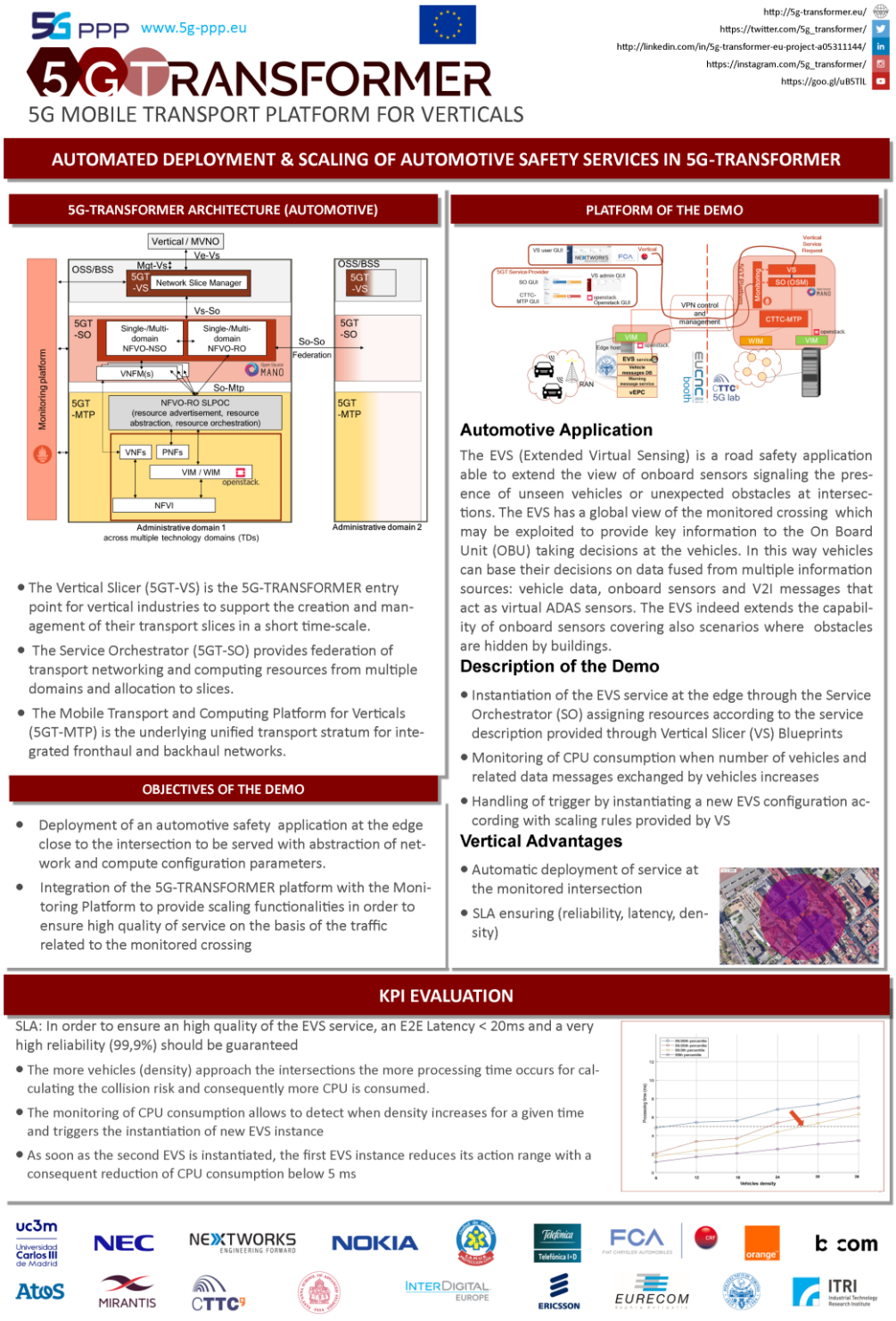


FIGURE 3: AUTOMOTIVE DEMO POSTER FOR EUCNC 2019

During these events (at the project booth), we also made available the 5G-TRANSFORMER leaflet. Besides, we also contributed to the generation of the SME workshop organized at EuCNC 2019, which was co-organized by 5G-TRANSFORMER (Figure 4).

FIGURE 4: LEAFLET OF THE EUCNC 2019 SME WORKSHOP

As reported in D6.5, we generated several leaflets and brochures during the first two years of the project, among which we can highlight the Netmgmt-WG Brochures and 5G-TRANSFORMER leaflet for MWC'19 (Y2) and the specific version generated and used in the 5G-Infrastructure Association booth and booths from partners during Mobile World Congress 2018 (Y1).

2.1.3 Communication videos and brochures

Table 1, Table 2 and Table 3 present the generated videos during Y1, Y2 and Y3 (the last 6 months of the project), respectively. During the last months of the project, most of the videos generated by 5G-TRANSFORMER have to do with demos performed in various events and have been uploaded to our YouTube channel. Since we are in the final part of the project lifetime, we expect to release several additional videos with the final demos and PoCs, which are being prepared at the time of writing of this deliverable. These videos will be made available on our YouTube channel and also accessible at the project web site.

TABLE 1: VIDEOS IN Y1

	Title	Link
1	5G-TRANSFORMER general video (presented, e.g., at Mobile World Congress in Barcelona, Spain, 2018, and EU "Showcase your project!" initiative)	https://www.youtube.com/watch?v=lZALdNBLWBQ

TABLE 2: VIDEOS IN Y2

	Title	Link
1	New general video of 5G-TRANSFORMER	https://www.youtube.com/watch?v=DfhWEoMc4bU
2	Interview with 5G TRANSFORMER project coordinator, Arturo Azcorra @ EUCNC'18	https://www.youtube.com/watch?v=Rkrmcn4FgFM
3	5G network slices for mobile communication services, demo @ EUCN'18	https://www.youtube.com/watch?v=0QxeZerDZKQ
4	5G network slices for media vertical services, demo @ EUCNC'18	https://www.youtube.com/watch?v=sRH4m_eQ6NM
5	Using cloudify and public & private clouds to deploy and entertainment, demo @ EUCNC'18	https://www.youtube.com/watch?v=MhxpLNuTOEE
6	Edge Robotics	https://www.youtube.com/watch?v=aNv6BwB-JRE
7	5TONIC Projects (incl. 5G-TRANSFORMER)	https://www.youtube.com/watch?v=QNq1YL_h4v0

TABLE 3: VIDEOS IN Y3

	Title	Link
1	EuCNC 2019: Booth 40 - Carlos J Bernardos (5G-TRANSFORMER) and Antonio de la Oliva (5G-CORAL)	https://www.youtube.com/watch?v=Ug9f3-Nzg_I
2	5G-TRANSFORMER Demo MobiHoc 2019	https://www.youtube.com/watch?v=QYe1iNZIh3E
3	5G-TRANSFORMER DEMO at NEM SUMMIT 2019	https://www.youtube.com/watch?v=90ZYURuTId4

Additionally, a number of communication brochures and posters presented at various venues (e.g., EUCNC, Mobile World Congress) were also generated. They are available for download at: http://5g-transformer.eu/index.php/communication/

2.1.4 Communication. Press releases and news

In the 5G-TRANSFORMER website, various press releases were posted as well as distributed through a variety of channels. Table 4, Table 5 and Table 6 present the summary of press releases and news during Y1, Y2 and Y3 (last 6 months of the project), respectively. It is important to highlight the impact of the news about different vertical oriented demos. Additional news, including impact on TV, is expected during the last months of the project and shortly after its finishes, related to the demonstration and validation of the main features of the 5G-TRANSFORMER platform.

TABLE 4: PRESS RELEASES AND NEWS IN Y1

	Activity
1	News about 5G-T @ Mirantis blog https://www.mirantis.com/blog/network-slicing-and-5g-and-wireless-oh-my/
2	News about 5G-T @ CTTC website http://www.cttc.cat/european-industrial-and-academic-partners-join-to-develop-a-5g-mobile-transport-platform-for-verticals/
3	News about 5G-T @ Ericsson blog https://www.ericsson.com/research-blog/5g-transformer-eu-project-underway/
4	News about 5G-T in Mobile World Congress 2018 @ IMDEA Networks https://www.networks.imdea.org/whats-new/news/2018/investigadores-uc3m-presentan-sus-novedades-sobre-5g-mobile-world-congress-2018
5	News about 5G-T in MWC'18 @ CTTC website http://www.cttc.cat/cttc-contributes-to-the-future-5g-mobile-transport-platform-for-verticals-at-mwc18/
6	5G Forum in Malaga http://5g-xcast.eu/2018/04/26/prof-narcis-cardona-presentation-at-the-5g-forum-in-malaga/
7	News about 5G-T @ Portal web del Ayuntamiento de Madrid http://www.madrid.es/portales/munimadrid/es/Inicio/Emergencias-y-seguridad/SAMUR-Proteccion-Civil/?vgnextfmt=default&vgnextoid=c88fcdb1bfffa010VgnVCM100000d90ca8c0RCRD&vgnextchannel=f9cd31d3b28fe410VgnVCM1000000b205a0aRCRD&idCapitulo=6149819
8	News about opening 5G Lab 5TONIC http://s3platform.jrc.ec.europa.eu/digital-innovation-hubs-tool?p_p_id=%20digitalinnovationhub_WAR_digitalinnovationhubportlet&p_p_lifecycle=0&p_%20p_state=normal&p_p_mode=view&p_p_col_id=column-%201&p_p_col_count=1&formDate=1524592222123&freeSearch=5tonic&evolStages=3
9	News about 5G-T in collaboration with Samur-Proteccion Civil http://5g-transformer.eu/index.php/2018/04/20/5g-transformer-in-collaboration-with-samur-proteccion-civil/
10	News about 5G-T as 5G Mobile Transport Platform for Verticals @ globenewswire website http://www.globenewswire.com/news-release/2017/06/21/1027019/0/en/European-Industrial-and-Academic-Partners-Join-to-Develop-a-5G-Mobile-Transport-Platform-for-Verticals.html
11	News about 5G-T for Network Slicing and Industry Verticals @ sdxcentral website https://www.sdxcentral.com/articles/news/new-european-5g-group-will-focus-on-network-slicing-industry-verticals/2017/06/
12	News about 5G-T as part of 5G development @ sdxcentral website https://www-sdxcentral-com.cdn.ampproject.org/c/s/www.sdxcentral.com/%20articles/news/trials-use-cases-top-5g-developments-2017/2017/12/amp/%20Network%20Slicing%20Gets%20Traction
13	Press Release: European Industrial and Academic Partners Join to Develop a 5G Mobile Transport Platform for Verticals http://5g-transformer.eu/index.php/2017/06/20/5g-transformer-press-release/
14	Press Release: The 5G-TRANSFORMER project presents the future 5G mobile transport platform for verticals at MWC'18 http://5g-transformer.eu/index.php/2018/02/23/the-5g-transformer-project-presents-the-future-5g-mobile-transport-platform-for-verticals-at-mwc18/

TABLE 5: PRESS RELEASES AND NEWS IN Y2

	Activity
1	News about 5G-T Workshops at EUCNC http://5g-transformer.eu/index.php/2018/05/03/new-co-organized-workshop/
2	MEC Seminar at UC3M http://5g-transformer.eu/index.php/2018/05/09/multi-access-edge-computing-seminar/
3	Imagine Digital & Connect Europe, ICT2018 http://5g-transformer.eu/index.php/2018/05/18/5g-transformer-at-ict2018/
4	5GPPP Activities at EuCNC https://5g-ppp.eu/5g-ppp-at-eucnc-2018/
5	New Submitted Deliverables http://5g-transformer.eu/index.php/2018/06/02/new-submitted-deliverables/
6	News about CDB service http://5g-transformer.eu/index.php/2018/06/05/5g_in_cbd/
7	News in Linkedin about the participation of 5G-T in IEEE BMSB'18 conference 5GPPP group of Linkedin reports the participation of 5G-T in IEEE BMSB'18
8	5G-T activities at IEEE BMSB'18 http://5g-transformer.eu/index.php/2018/06/10/ieee-international-symposium-on-broadband-multimedia-systems-and-broadcasting/
9	News about 5G-PPP European Journal 2018 @ 5G-TRANSFORMER website http://5g-transformer.eu/index.php/news/
10	Press release: 5G-TRANSFORMER presence at EUCNC'18 http://5g-transformer.eu/index.php/news/
11	News about EC visit to 5GT booth @ EUCNC18 http://5g-transformer.eu/index.php/2018/06/22/the-european-commission-representatives-visited-the-5g-coral-5g-transformer-and-5g-ex-joint-booth-at-eucnc-2018/
12	New Submitted Deliverables http://5g-transformer.eu/index.php/2018/07/02/new-deliverables-available/
13	5GT in a tutorial at IEEE NetSoft2018 http://5g-transformer.eu/index.php/2018/07/05/5g-transformer-network-slicing-at-the-iee-netsoft-2018-conference/
14	News about a talk of 5GT at IEEE 5G Summit Tanger given by Xavier Costa (NEC), June 2018 http://5g-transformer.eu/index.php/2018/07/06/579/
15	News about Edge Robotics http://5g-transformer.eu/index.php/2018/07/13/edge-robotics/
16	News about 4th plenary meeting http://5g-transformer.eu/index.php/2018/07/23/4th-plenary-meeting/
17	News about 5GTONIC new projects http://5g-transformer.eu/index.php/2018/07/27/a-e50m-eu-sponsored-5g-programme-gives-5gtonic-a-key-role/
18	News about episodes of 5GCrosshaul http://5g-transformer.eu/index.php/2018/09/24/new-series-of-episodes-of-5g-crosshaul-integrated-backhaul-and-fronthaul-transport-network/
19	News about participation of 5G-TRANSFORMER in 2nd International Robotics Festival 2018

	http://5g-transformer.eu/index.php/2018/09/28/2o-international-robotics-festival-2018/
20	News about participation of 5G-TRANSFORMER in the EuMW2018 http://5g-transformer.eu/index.php/2018/09/27/940/
21	News European Researchers Night 2018 http://5g-transformer.eu/index.php/2018/10/01/5g-transformer-participated-at-european-researchers-night-2018/
22	News about 5GCrosshaul Success Story http://5g-transformer.eu/index.php/2018/10/04/taming-the-avalanche-of-mobile-data-the-5g-crosshaul-sucess-story/
23	News about presence of 5GT in Ran World 2018 http://5g-transformer.eu/index.php/2018/10/15/5g-transformer-in-ran-world-2018/
24	Press Release: "Towards the interactive digital fan experience" https://atos.net/content/mini-sites/look-out-2020/assets/pdf/ATOS_LOOK%20OUT_SPORTS.pdf ; Also available at: https://5g-transformer.eu/svn/5g-transformer/execution/WP6/T6.1-Communication_activities/Press%20Releases/181016_ATOS_LOOK%20OUT_SPORTS.pdf
25	News: The 5G PPP Newsflash October 2018 https://5g-ppp.eu/newsflash-october-2018/
26	News: 5G-TRANSFORMER project participates in the 23rd edition of the Science Week 2018 http://5g-transformer.eu/index.php/2018/11/26/5g-transformer-project-participates-in-the-23rd-edition-of-the-science-week-2018/
27	News: ETSI MEC meeting at UC3M http://5g-transformer.eu/index.php/2018/11/28/etsi-mec-meeting-in-uc3m/
28	Press release: Major milestone: Release 1 of 5G-TRANSFORMER software http://5g-transformer.eu/index.php/2018/12/02/1025/
29	News about Release 1 of 5G-TRANSFORMER software https://5g-ppp.eu/release-1-of-5g-transformer-software/
30	News about participation of 5GT in 10th Conference of Framework Program of the EU in Spain http://5g-transformer.eu/index.php/2018/12/06/1015/
31	News about using OSM MANO in 5GT http://5g-transformer.eu/index.php/2018/12/13/5g-transformer-using-osm-to-allow-service-providers-to-automatically-deploy-5g-network-services/
32	News about Plenary meeting Paris January 2019 http://5g-transformer.eu/index.php/2019/01/16/5g-transformer-plenary-meeting-in-paris/
33	News about 5G-TRANSFORMER presence at 5th OSM Hackfest http://5g-transformer.eu/index.php/2019/02/07/5g-transformer-in-the-5th-osm-hackfest/
34	Press release: 5G-TRANSFORMER presence in MWC19 http://5g-transformer.eu/index.php/2019/02/25/5g-transformer-presence-in-mwc2019/
35	News about 5G-TRANSFORMER presence in IEEE workshop Future Networks http://5g-transformer.eu/index.php/2019/03/01/5g-technology-workshop-during-mwc19-in-barcelona/
36	News: Arturo Azcorra: “How to deploy and run Connected Industry 4.0” (MWC19)

	http://5g-transformer.eu/index.php/2019/03/06/arturo-azcorra-how-to-deploy-and-run-connected-industry-4-0-mwc19/

TABLE 6: PRESS RELEASES AND NEWS IN Y3

	Activity
1	5G-TRANSFORMER's participation in IETF104 http://5g-transformer.eu/index.php/2019/04/11/5g-transformers-participation-in-ietf104/
2	FrontHaul & BackHaul Convergence for 5G Use Cases: http://5g-transformer.eu/index.php/2019/04/12/fronthaul-backhaul-convergence-for-5g-use-cases/
3	Visit of Juan Carlos García, from Telefonica GCTIO: http://5g-transformer.eu/index.php/2019/04/17/visit-of-juan-carlos-garcia-from-telefonica-gctio/
4	Special Issue "Beyond 5G Evolution": http://5g-transformer.eu/index.php/2019/04/25/special-issue-beyond-5g-evolution/
5	NEM Summit 2019: http://5g-transformer.eu/index.php/2019/05/24/nem-summit-2019/
6	White Paper "Validating 5G Technology Performance - Assessing 5G architecture and application scenarios: http://5g-transformer.eu/index.php/2019/06/07/white-paper-validating-5g-technology-performance-assessing-5g-architecture-and-application-scenarios/
7	5G-TRANSFORMER summary of participation at EuCNC 2019: http://5g-transformer.eu/index.php/2019/06/18/5g-transformer-summary-of-participation-at-eucnc-2019/
8	Ericsson activates 5G NSA technology at 5Tonic Open Innovation Lab: http://5g-transformer.eu/index.php/2019/06/21/ericsson-activates-5g-nsa-technology-at-5tonic-open-innovation-lab/
9	ACM MobiHoc Conference 2019 – Demo 1: http://5g-transformer.eu/index.php/2019/07/06/acm-mobihoc-conference-2019/
10	ACM MobiHoc Conference 2019 – Demo 2: http://5g-transformer.eu/index.php/2019/07/16/acm-mobihoc-conference-2019-demo-2/
11	Boletin Informativo Samur Julio 2019 (Spanish): http://5g-transformer.eu/index.php/2019/07/23/boletin-informativo-samur-julio-2019-spanish/
12	SAMUR, UC3M and Telefonica perform an eHealth use case demo: http://5g-transformer.eu/index.php/2019/07/30/samur-uc3m-and-telefonica-perform-an-ehealth-use-case-demo/
13	'Cloud-Native and Verticals' services – 5G-PPP projects analysis': http://5g-transformer.eu/index.php/2019/09/15/cloud-native-and-verticals-services-5g-ppp-projects-analysis/
14	5G-TRANSFORMER in Madrid Golf Open 2019: http://5g-transformer.eu/index.php/2019/10/15/5g-transformer-in-madrid-golf-open-2019/
15	SAMUR-Protección Civil colabora en el desarrollo de un dispositivo 5G de aviso automático de pacientes en parada cardiorrespiratoria: https://diario.madrid.es/blog/notas-de-prensa/samur-proteccion-civil-colabora-en-el-desarrollo-de-un-dispositivo-5g-de-aviso-automatico-de-pacientes-en-parada-cardiorrespiratoria/

2.1.5 Communication articles

Table 7, Table 8 and Table 9 show the activities related to communication articles during Y1, Y2 and Y3, respectively. The communication articles target a wider audience than that strictly specialized in the topics of the project.

TABLE 7: COMMUNICATION ARTICLES IN Y1

	Title	Published in
1	A Network Service Provider Perspective on Network Slicing	IEEE Softwarization, January 2018

TABLE 8: COMMUNICATION ARTICLES IN Y2

	Title	Published in
1	5G-TRANSFORMER. 5G Mobile Transport Platform for Verticals	5G-PPP European 5G Annual Journal 2018 https://bscw.5g-ppp.eu/pub/bscw.cgi/d257916/Euro%205G%20Annual%20Journal%202018-v1.1.pdf
2	5G-TRANSFORMER. 5G Mobile Transport Platform for Verticals	5G-PPP European 5G Annual Journal 2019 https://bscw.5g-ppp.eu/pub/bscw.cgi/d302069/Euro%205G%20PPP%20Annual%20Journal%202019-web.pdf

TABLE 9: COMMUNICATION ARTICLES IN Y3

	Title	Published in
1	Vertical Cartography published during EUCNC'19	Available at Global 5G website: https://www.global5g.org/5g-transformer-cloud-robotics-industrial-automation https://www.global5g.org/5g-transformer-intersection-collision-avoidance-ica https://www.global5g.org/5g-transformer-emergency-health-services https://www.global5g.org/5g-transformer-emergency-services https://www.global5g.org/5g-transformer-live-streaming-0
2	Think Big Blog- Innovation blog from Telefonica	https://blogthinkbig.com/5tonic-5g-telefonica

Table 10, Table 11 and Table 12 list the presentations and talks targeting a wide general audience during Y1, Y2 and Y3, respectively. They all describe the project general ideas and scope without entering too much into technical details.

TABLE 10: COMMUNICATION PRESENTATIONS IN Y1

	Activity
1	Talk entitled "5G Networks to realize Network society" at the "5G technology for automotive domain" workshop, 2017, including the 5G-TRANSFORMER approach.
2	A talk on 5G in general, and more specifically, on 5G-TRANSFORMER was given to high-school students and general public in the context of 22nd Open Science Week (Setmana de le Ciencia) in November 2017. It is organized by the Catalan Research and Innovation Foundation (FCRi). Information available at: http://www.cttc.cat/the-cttc-will-participate-in-the-22nd-edition-of-the-science-week-2017/
3	Organization of the Internet Festival (http://www.internetfestival.it/), the Robotics Festival 2017 (http://www.festivalinternazionaledellarobotica.it/en/)
4	Three-hour course taught at the National Chiao Tung University (NCTU) in Taiwan on topics related with 5G-TRANSFORMER
5	Master courses in UC3M on NFV and SDN for 5G networks
6	SSSA presents 5G-TRANSFORMER in 5G Summit in Trento
7	5G-TRANSFORMER presentation: 5G Mobile Transport Platform for Verticals in EuCNC workshop in 2017
8	POLITO presents 5G-TRANSFORMER in IEEE 5G Summit 2017 talk
9	SAMUR participation and presentation in 5G Forum in Malaga

TABLE 11: COMMUNICATION PRESENTATIONS AND LECTURES IN Y2

	Activity
1	Demo on Cloud Robotics at Festival Internazionale della Robotica (International Festival on Robotics).
2	Internet Festival Pisa 2018 Internet Festival 2018: Workshop "Internet in the Era of 5G, demo on "5G-Enabled Services"
3	Bright Researchers night 2018 Sant'Anna School celebrates the European "Bright" researchers' night 2018 in Pisa, Pontedera and Livorno
4	23rd edition of Science Week 2018 5G-TRANSFORMER project participates in the 23rd edition of the Science Week 2018
5	Nokia Discovery Day co-organized with IHK Industry and Commerce Chamber
6	5G-TRANSFORMER at the I Jornadas de investigación EPS

TABLE 12: COMMUNICATION PRESENTATIONS AND LECTURES IN Y3

	Activity
1	Proyecto 5G-TRANSFORMER "salvar vidas ahorrando tiempo", eHealth description use case at the Boletin Information Samur-Protección Civil (in Spanish), July 2019
2	"Diversity Drives Societal Change", 7th ACM Celebration of Women in Computing: https://womencourage.acm.org/2019/panels/
3	Panel about "5G, mobility and the automotive use case of 5G-TRANSFORMER", Tendencia Movilidad en Smart Cities (in Spanish): https://eventos.uc3m.es/38171/detail/movilidad-en-smart-cities.html

4	Sports & Technology Management Course of the Business & Engineering School of LaSalle Barcelona (Dec. 3, 2019)

2.1.6 Collaboration with other projects

A series of activities have been carried out together with 5GPPP projects in the framework of the various 5GPPP working groups. Table 13 lists the main activities within the 5G PPP CSA Working Groups (WGs) during Y1. Table 14 and Table 15 summarize the collaboration with other projects in these WGs as well as joint papers or joint organization of events in Y2 and Y3, respectively.

Furthermore, most meetings (face-to-face or through audioconferences) were attended by the project representatives. As an example, in the software networks working group, meetings took place at a pace of at least one per month, and often two. Among others, this resulted in various white papers, as reported below. The architecture working group meetings was also regularly attended, as well as all the rest of working groups, which makes a total of around 20 meetings attended per year.

TABLE 13: ACTIVITY WITHIN 5G PPP CSA WGS IN Y1

	Activity
1	Presentation to EC H2020 5G Infrastructure PPP Technical board on Performance KPIs and 5G-TRANSFORMER status in this respect. Active participation on this activity (periodic calls).
2	Inputs on 3GPP and 5G-TRANSFORMER to 5GPPP Pre-Standardization Working Group (WG). Various conference calls, including one with the WG Chair on including other non-3GPP activities.
3	Input on 5G-TRANSFORMER for preparation of a brochure for EUCNC. 5G PPP Network Management & QoS WG.
4	Participation to 5G PPP Trials WG and the roadmap (5G Pan-European trials roadmap 3.0.) generated by the group (https://5g-ppp.eu/5g-trials-roadmap/).
5	Participation to 5G PPP Architecture WG. The group organized a session at EuCNC 2018.
6	Active participation to the 5G PPP Software Networks WG. The 5G-TRANSFORMER project was presented in September 2017. 5G-TRANSFORMER contributed actively to the white paper 'From Webscale to Telco, the Cloud Native Journey''. The white paper will be presented at a EUCNC 2018 workshop, to which 5G-TRANSFORMER participates as well.

TABLE 14: ACTIVITY WITHIN 5G PPP WGS AND COLLABORATION WITH OTHER PROJECTS IN Y2

	Activity
1	5G-T Architecture Presentation for 5GPPP Arch WG
2	5G-PPP Software Networks WG white paper
3	WS3 Workshop @ EUCNC 18, joint with 5G-Exchange, 5G-CORAL, 5GCirty, 5G-Picture, Matilda, RECAP
4	Joint booth and Demos @ EUCNC18, with 5G-Exchange, 5G-CORAL
5	Netmgmt-WG Brochures
6	Special Session @ EUCNC'18
7	5G PPP PRE-STANDARDISATION WG - Mapping of Contributions to standards May 2018

8	Edge Robotics Demo in collaboration with 5G-Coral and 5G-Ex
9	Conext Workshop, joint with MONROE and 5G-CORAL
10	Joint paper with 5G-Monarch project for Mobicom'18 entitled "How Should I Slice My Network? A Multi-Service Empirical Evaluation of Resource Sharing Efficiency"
11	Joint paper with H2020-MSCA-ITN-20155G-Aura project @ ACM CONEXT'18 entitled “Overbooking Network Slices through Yield-driven End-to-End Orchestration”
12	PIMRC Workshop, joint with ITN H2020 5GAura
13	Joint paper with 5G-EVE project at IEEE Transaction on Big Data entitled: “From Megabits to CPU Ticks: Enriching a Demand Trace in the Age of MEC”
14	7th CLEEN workshop at WCNC19
15	Collaboration with NECOS project in the context of T1.3
16	Joint paper with 5G-EVE project at ACM/IEEE Transactions on Networking entitled: VNF Placement and Resource Allocation for the Support of Vertical Services in 5G Networks
17	Joint paper with 5G-Monarch project for INFOCOM'19 entitled: "A Utility-driven Multi-Queue Admission Control Solution for Network Slicing"
18	Joint paper with 5G-Monarch project for INFOCOM'19 entitled: “DeepCog: Cognitive Network Management in Sliced 5G Networks with Deep Learning”
19	Joint paper with 5G-Monarch project for IEEE Transactions on Mobile Computing entitled: "A Machine Learning approach to 5GInfrastructure Market optimization"
20	Presentation of an update of 5GT system architecture design to the 5G PPP Arch WG
21	Contribution to 5GIA Pre-Standardization WG
22	Contribution to 5GPPP Arch WG White Paper 3.0
23	Joint Demo with blueSPACE and 5G-Media projects for ACM MobiHoc 2019 Conference
24	Joint Demo with H2020-MSCA-ITN-2015 5G-AURA project
25	Joint Paper with 5G-Carmen project @ IEEE Communications Magazine (Telecom Software, Network Virtualization, and Software Defined Networks Series) entitled: “MANOaaS: A Multi-tenant NFV MANO for 5G Network Slices”
26	Joint Paper with 5G-MoNArch @ IEEE Wireless Communications Magazine entitled: “Artificial Intelligence for Elastic Management and Orchestration of 5G Networks”
27	Contribution to 5GPPP Arch WG White Paper 3.0

TABLE 15: ACTIVITY WITHIN 5G PPP WGS AND COLLABORATION WITH OTHER PROJECTS IN Y3

	Activity
1	Joint Paper with projects: 6Genesis, 5G!Pagoda, MATILDA @ IEEE Transactions on Mobile Computing, entitled ”CDN Slicing over a Multi-Domain Edge Cloud”
2	Joint Paper with project 5Growth @ IEEE Communications Magazine entitled "Service Shifting: a Paradigm for Service Resilience in 5G"
3	Contribution to White Paper “Validating 5G Technology Performance – Assessing 5G architecture and Application Scenarios” released by the 5G PPP Test, Measurement and KPIs Validation (TMV) Working Group

4	Joint paper with Spanish 5GCity project (TEC2016-76795-C6-3-R) @ IEEE Transactions on Networking entitled “Paper: RL-NSB: Reinforcement Learning-based 5G Network Slice Broker”"
5	Joint paper with 5G-Monarch project @IEEE Transactions on Network and Service Management entitled “Resource Sharing Efficiency in Network Slicing”
6	Contribution to 5GPPP Software Networks (SN) WG White Paper entitled “Cloud-Native and Verticals services”
7	Joint PhD with 5G-EVE, entitled “Network virtualization and 5G services” (ongoing)
8	Contribution to 5G PPP phase II KPIs - Annex to Programme Management Report
9	Contribution to Standard Impacts presentation at the 5GArch 2019: International Workshop on 5G Architecture by 5GPPP
10	Submission of a joint Paper with project 5GCoral @ IEEE Access entitled "Virtualization at the edge: exploiting NFV-MEC integration"
11	Participation in a published 5GPPP Software Networks (SN) WG White Paper entitled “Cloud-Native and Verticals services”
12	Joint Paper with project 5G!Drones @ Globecom19 entitled “Dynamic slicing of RAN resources for heterogeneous coexisting 5G services”
13	Joint Paper with projects: 5GROWTH, 5G-MoNArch, 5G-TOURS @ ACM Mobicom'19 entitled “vrAIn: A Deep Learning Approach Tailoring Computing and Radio Resources in Virtualized RANs”
14	Joint Demo with projects: 5GROWTH, 5G-MoNArch, 5G-TOURS entitled ”vrAIn Proof-of-Concept – A Deep Learning Approach for Virtualized RAN Resource Control”
15	Join Paper with project 5G-Coral @ IEEE CSCN 2019 entitled “5GEN: A tool to generate 5G infrastructure graphs”
16	Joint Demo with 5G-CORAL @ EUCNC'19: immersive robotic teleoperation

2.2 Dissemination

This section presents the outcomes of the project during the project lifetime, regarding the dissemination activities, which follow the plan described in D6.2 and D6.5. It reports activities for Y1, Y2, and Y3 on the publication of research results (Table 17, Table 18, and Table 19), technology demonstration (Table 20, Table 21, and Table 22), academic activities (Table 22, Table 24, and Table 25), organization of events (Table 25, Table 27, and Table 28) and participation to events (Table 29, Table 30, and Table 31). It also includes a sub-section on the Common Dissemination Booster activities, a service offered by the European Commission towards joint dissemination and exploitation with other projects, in this case 5G-Coral and 5G-Crosshaul.

Table 16 presents a comparison between the achieved metrics on the above-mentioned activities and the targeted metrics included in the DoA and updated in D6.2 and D6.5 (Publication and Participation to events). As observed in the tables for all the project lifetime, the consortium has achieved the objectives, exceeding all the targeted metrics. Regarding publication of research results, the 5G-TRANSFORMER partners have published 95 scientific papers in peer-reviewed journals (34), conferences and workshops (61), in very selective venues, such IEEE Transactions, and the IEEE INFOCOM conference. This also includes papers published in vertical-oriented venues (e.g., AEIT Automotive). The technology demonstration activity drastically increased during Y2 and the last 6 months of the project, as many 5G-TRANSFORMER concepts have gained maturity, and have been demonstrated via PoCs at well-known conferences,

such as EuCNC, ACM MobiHoc and IEEE INFOCOM. Several students have been enrolled on topics related to the project, at the PhD, master and Bachelor levels. 5G-TRANSFORMER has organized 15 events (Table 26, Table 27 and Table 28) collocated with international conferences, such as IEEE WCNC, IEEE EuCNC 2018 and 2019, IEEE PIMRC, and ACM CoNEXT. All events organized have achieved more than 70% of attendee satisfaction in terms of scientific and technical content (refer to Annex I). Moreover, an exploitation workshop dedicated to SMEs and large companies (Emerging 5G Business Models: Opportunities for SMEs and large companies-lessons from 5G PPP) has been organized in conjunction with EuCNC 2019. Finally, 5G-TRANSFORMER partners have given talks (invited) and keynotes, and participated to panels, on concepts related to the 5G-TRANSFORMER architecture and concepts, such as the Vertical Slicer, Network Slicing, Multi-access Edge Computing, etc., in several international events; this is without including the talks given at international conferences and workshops to present scientific papers.

TABLE 16: TARGETED METRICS VERSUS ACHIEVED METRICS

Activity	Targeted metric	Achieved metric
Publication of research results	8 during Y1, 10 during Y2 and 5 during Y3	95 publications
Technology Demonstration	At least 2 per year	20 different events (up to 4 demos in some events)
Academic activities	At least 2 master theses per academic partner over the course of the project	8 PhD, 12 Master and 2 Bachelor
Organization of events	One 50-people workshop co-located with a major conference with 70% satisfaction	17 events. All events with more than 70% of satisfaction (refer to Annex I)
	One 30-people workshop with 70% satisfaction	Exploitation workshop (Emerging 5G Business Models: Opportunities for SMEs and large companies -lessons from 5G PPP) collocated with EuCNC 2019 (refer to Annex I)
Participation to events	Not defined for Y1, average 10 talks during Y2, average 5 talks during Y3.	33 events (including Keynotes, Panels, Tutorials, and invited talks), and talks in conferences and workshops to present papers

TABLE 17: PUBLICATIONS IN Y1 (J: PEER REVIEW JOURNAL, B: BOOK CHAPTER, C: PEER-REVIEWED CONFERENCE, W: PEER-REVIEWED WORKSHOP)

	Title	Published in
J	WizHaul: On the Centralization Degree of Cloud RAN Next Generation Fronthaul	IEEE Transactions on Mobile Computing (TMC), February 2018
J	Efficient Caching through Stateful SDN in Named Data Networking	Transactions on Emerging Telecommunications Technologies, Jan. 2018
J	Virtualization-based evaluation of backhaul performance in vehicular applications	Computer Networks, April 2018

J	5G-TRANSFORMER: Slicing and Orchestrating Transport Networks for Industry Verticals	IEEE Communications Magazine, accepted in 2018
J	On Enabling 5G Automotive Systems Using Follow Me Edge Cloud Concept	IEEE Transactions on Vehicular Technology (TVT) 2018
J	Scheduling Advertisement Delivery in Vehicular Network	IEEE Transactions on Mobile Computing (TMC) in 2018
C	Sharing of Crosshaul Networks via a Multi-Domain Exchange Environment for 5G Services	IEEE NetSoft 2017
C	A Simulation-based Testbed for Vehicular Collision Detection	IEEE VNC 2017
C	Software Defined 5G Converged Mobile Access Networks: Energy Efficiency Considerations	Asia Communications and Photonics Conference, 10 - 13 November 2017, The Garden Hotel, Guangzhou, Guangdong China
C	SDN-enabled Latency-Guaranteed Dual Connectivity in 5G RAN	Asia Communications and Photonics Conference, 10 - 13 November 2017, The Garden Hotel, Guangzhou, Guangdong China
C	Network Orchestration in Reliable 5G/NFV/SDN infrastructures	19th International Conference on Transparent Optical Networks (ICTON) 2017, Girona, Spain
C	Requirements for 5G fronthaul	19th International Conference on Transparent Optical Networks (ICTON) 2017, Girona, Spain
C	Network Orchestration in Reliable 5G/NFV/SDN infrastructures	19th International Conference on Transparent Optical Networks (ICTON) 2017, Girona, Spain
C	Virtualized eNB latency limits	19th International Conference on Transparent Optical Networks (ICTON) 2017, Girona, Spain
C	Joint VNF Placement and CPU Allocation in 5G	IEEE International Conference on Computer Communications (INFOCOM) 15-19, April 2018, Honolulu, USA
C	FluidRAN: Optimal vRAN/MEC Orchestration	IEEE International Conference on Computer Communications (INFOCOM) 15-19, April 2018, Honolulu, USA
C	Present-day verticals and where to find them: A data-driven study on the transition to 5G	IEEE WONS 2018
C	Service migration versus Service replication in Multi-access Edge Computing (MEC)	IEEE IWCMC 2018, June 24-29, Cyprus
C	Orchestrating Lightpath Adaptation and Flexible Functional Split to Recover Virtualized RAN Connectivity	OFC 2018, March 11-15, 2018, San Diego, CA, USA
C	Software Defined 5G Converged Access as a viable Techno-Economic Solution	OFC 2018, March 11-15, 2018, San Diego, CA, USA

C	Enabling Flexible Functional Split through software 5G converged access	IEEE ICC 2018, Kansas City, MO, USA
C	Performance analysis of C-V2I-based Automotive Collision Avoidance	IEEE WoWMOM 2018, Chania, Greece
C	Optimization-in-the-Loop for Energy-Efficient 5G	IEEE WoWMOM 2018, Chania, Greece
C	Experimental SDN Control Solutions for Automatic Operations and Management of 5G Services in a Fixed Mobile Converged Packet-Optical Network	IEEE ONDM 2018
W	Orchestrating Lightpath Adaptation and Flexible Functional Split to Recover Virtualized RAN Connectivity (poster)	URLLC 2017
W	WizHaul: An Automated Solution for vRAN Deployments Optimization	WSA 2018 - ITG workshop on smart antennas, March 2018
W	Service Orchestration and Federation for Verticals	IEEE WCNC COMPASS workshop, April 2018, Barcelona, Spain
W	5G Mobile Transport and Computing Platform for Verticals	IEEE WCNC COMPASS workshop, April 2018, Barcelona, Spain
W	Network Slices For Vertical Industries	IEEE WCNC COMPASS workshop, April 2018, Barcelona, Spain
W	Impact of RAN Virtualization on Fronthaul Latency Budget: An Experimental Evaluation	International Workshop on 5G Test-Beds and Trials - Learnings from implementing 5G (5G--Testbed 2017) co-located with Globecom 2017, Singapore

TABLE 18: PUBLICATIONS IN Y2

	Title	Published in
J	Characterizing the Power Cost of Virtualization Environments	Transactions on Emerging Telecommunications Technologies, 2018
J	Optimization of an integrated fronthaul/backhaul network under path and delay constraints	Elsevier Adhoc Journal, February 2019
J	Orchestrating lightpath recovery and flexible functional split to preserve virtualized RAN connectivity	IEEE/OSA Journal of Optical Communications and Networking, Nov. 2018
J	z-TORCH: An Automated NFV Orchestration and Monitoring Solution	IEEE Transactions on Network and Service Management (TNSM), 2018.
J	From Megabits to CPU Ticks: Enriching a Demand Trace in the Age of MEC	IEEE Transactions on Big Data, 2018.
J	Joint Optimization of Edge Computing Architectures and Radio Access Networks	IEEE Journal on Selected Area in Communications (JSAC) SI on Emerging Technologies in Tactile

		Internet and Backhaul/Fronthaul Networks
J	Cost and availability aware resource allocation and virtual function placement for CDNaaS provision	IEEE Transactions on Network and Service Management (TNSM), 2018.
J	ORLA/OLAA: Orthogonal Coexistence of LAA and WiFi in Unlicensed Spectrum	ACM/IEEE Transactions on Networking (TON), 2018.
J	The RICH Prefetching in Edge Caches for In-Order Delivery to Connected Cars	IEEE Transactions on Vehicular Technology (TVT), Jan. 2019
J	Cellular access multi-tenancy through small-cell virtualization and common RF front-end sharing	Elsevier Computer Communications, 2018.
J	VNF Placement and Resource Allocation for the Support of Vertical Services in 5G Networks	ACM/IEEE Transactions on Networking (TON), 2019
J	A Machine Learning approach to 5G Infrastructure Market optimization	IEEE Transactions on Mobile Computing (TMC), 2019
J	Modeling Mobile Edge Computing Deployments for Low Latency Multimedia Services	IEEE Transactions on Broadcasting, accepted 2019
J	Impact of Virtualisation Technologies on Virtualised RAN Midhaul Latency Budget: A Quantitative Experimental Evaluation	IEEE Communications Letters, accepted 2019
J	Latency-aware Resource Orchestration in SDN-based Packet over Optical Flexi-Grid Transport Networks	IEEE/OSA Journal of Optical Communications and Networking, 2019
J	A Blockchain-Based Network Slice Broker for 5G Services	IEEE Networking Letters 2019
J	Artificial Intelligence for Elastic Management and Orchestration of 5G Networks	IEEE Wireless Communications Magazine
J	MANOaaS: A Multi-tenant NFV MANO for 5G	IEEE Communications Magazine
J	LaSR: A Supple Multi-Connectivity Scheduler for Multi-RAT OFDMA Systems	IEEE Transaction on Mobile Computing
B	Slicing challenges for Operators	Emerging Automation Techniques for the Future Internet, IGI Editor.
C	Enabling Vertical Industries Adoption of 5G Technologies: a Cartography of evolving solutions	European Conference on Networks and Communications (EUCNC 2018), June 2018, Ljubljana, Slovenia.
C	The Vertical Slicer: Verticals' Entry Point to 5G Networks'	European Conference on Networks and Communications (EUCNC 2018), June 2018, Ljubljana, Slovenia.
C	Experimental Evaluation of Orchestrating Inter-DC Quality-enabled VNFFG Services in Packet/Flexi-Grid Optical Networks	44th European Conference on Optical Communication (ECOC), September, Roma, Italy.

C	Latency-aware Network Service Orchestration over an SDN-controlled Multi-Layer Transport Infrastructure	20th International Conference on Transparent Optical Networks (ICTON), July 2018, Bucharest, Romania.
C	Encapsulation Techniques and Traffic Characterisation of an Ethernet-based 5G Fronthaul	19th International Conference on Transparent Optical Networks (ICTON) July 2018, Bucharest, Romania.
C	Support of Safety Services through Vehicular Communications: The Intersection Collision Avoidance Use Case	AEIT Automotive 2018
C	How Should I Slice My Network? A Multi-Service Empirical Evaluation of Resource Sharing Efficiency	ACM International Conference on Mobile Computing and Networking (MobiCom), October 2018, New Delhi, India.
C	On the Impact of IoT Traffic on the Cellular EPC	IEEE Global Communications Conference (Globecom) December 2018, Abu Dhabi, UAE
C	Latency and availability driven VNF placement in a MEC-NFV environment	IEEE Global Communications Conference (Globecom), December 2018, Abu Dhabi, UAE
C	Mobile Transport and Computing Platform for 5G Verticals: Resource Abstraction and Implementation	IEEE Conference on Network Function Virtualization and Software Defined Networks (NFV-SDN), November 2018, Verona, Italy
C	Overbooking Network Slices through Yield-driven End-to-End Orchestration	The 14th ACM International Conference on emerging Networking EXperiments and Technologies (Conext), December 2018, Heraklion/Crete, Greece
C	5G Traffic Forecasting: If Verticals and Mobile Operators Cooperate	15th IEEE Wireless On-demand Network systems and Services Conference (WONS), January 2019, Wengen, Switzerland
C	A Utility-Driven Multi-Queue Admission Control Solution for Network Slicing	IEEE International Conference on Computer Communications (INFOCOM) April 2019, Paris, France
C	DeepCog: Cognitive Network Management in Sliced 5G Networks with Deep Learning	IEEE International Conference on Computer Communications (INFOCOM) April 2019, Paris, France
C	Experimental Evaluation of Dynamic Resource Orchestration in Multi-Layer (Packet over Flexi-Grid Optical) Networks	23rd Conference On Optical Network Design And Modelling (ONDM), May 13-16, 2019, Athens, Greece
W	Understanding QoS applicability in 5G transport networks	WS3: Second Edition of the Workshop on Control and Management of Vertical Slicing including the Edge and Fog Systems, IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB), Valencia, June 2018
W	Multi-domain VNF mapping algorithms	WS3: Second Edition of the Workshop on Control and Management of Vertical Slicing including the Edge and Fog Systems, IEEE International

		Symposium on Broadband Multimedia Systems and Broadcasting (BMSB), Valencia, June 2018
W	Towards a resilient OpenFlow channel through MPTCP	WS3: Second Edition of the Workshop on Control and Management of Vertical Slicing including the Edge and Fog Systems, IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB), Valencia, June 2018
W	Orchestrating Inter-DC Quality-Enabled VNFFG Services in Packet / Flexi-Grid Optical Networks	5th International Workshop on Elastic Networks Design and Optimisation (ELASTICNETS 2018), 21-22 June 2018, Valencia (Spain).
W	Arbitration Among Vertical Services	IEEE PIMRC 2018 Workshop 5G Cell-Less Nets, September 2018, Bologna, Italy
W	Resource Orchestration of 5G Transport Networks for Vertical Industries	IEEE PIMRC 2018 Workshop 5G Cell-Less Nets, September 2018, Bologna, Italy
W	Wireless Interface Agent for SDN mmwave multi-hop networks: design and experimental evaluation	The 2nd ACM Workshop on Millimeter Wave Networks and Sensing Systems, October 2018, New Delhi, India
W	A Framework for Orchestration and Federation of 5G Services in a Multi-Domain Scenario	ACM CoNEXT workshop, EM-5G 2018, 1st International Workshop on Experimentation and Measurements in 5G, December 2018, Heraklion, Greece
W	Optimizing 5G networks	Informatica para todos
W	Experimental Demonstration of a Packet-based Protection for Seamlessly Recovering from a Multi-layer Metro Network Fronthaul Failure	The 5th IEEE INFOCOM Workshop on Computer and Networking Experimental Research using Testbeds 2019 (IEEE CNERT 2019), April 2019, Paris, France

TABLE 19: PUBLICATIONS IN Y3

	Title	Published in
J	CDN Slicing over a Multi-Domain Edge Cloud	IEEE Transactions on Mobile Computing (TMC)
J	Service Shifting: a Paradigm for Service Resilience in 5G	IEEE Communications Magazine
J	RL-NSB: Reinforcement Learning-based 5G Network Slice Broker	IEEE/ACM Transactions on Networking (ToN)
J	Resource Sharing Efficiency in Network Slicing	IEEE Transactions on Network and Service Management (TNSM)
J	A MEC-based Extended Virtual Sensing for Automotive Services	IEEE Transactions on Network and Service Management (TNSM)
J	Dynamic Latency-aware Resource Orchestration over Distributed Optical Telco Clouds in 5G Scenarios	Elsevier Computer Networks (COMNET)
J	Integrating Fronthaul and Backhaul Networks: Transport Challenges and Feasibility Results	IEEE Transactions on Mobile Computing

J	DeepCog: Optimizing Resource Provisioning in Network Slicing with AI-based Capacity Forecasting	IEEE Journal on Selected Areas in Communications (JSAC)
J	Exploiting flexible functional split in converged software defined access networks	IEEE/OSA Journal of Optical Communications and Networking
C	Exposing radio network information in a MEC-in-NFV environment: the RNISaaS concept	IEEE Conference on Network Softwarization (Netsoft), June 2019, Paris, France
C	On the Deployment of Large Scale NSaaS	European Conference on Networks and Communications (EUCNC 2019), June 2019, Valencia, Spain.
C	5G-TRANSFORMER Service Orchestrator: design, implementation, and evaluation	European Conference on Networks and Communications (EUCNC 2019), June 2019, Valencia, Spain.
C	Latency-driven Network Slices Orchestration	IEEE INFOCOM'19
C	A MEC-based Extended Virtual Sensing for Automotive Services	AEIT International Conference of Electrical and Electronic Technologies for Automotive (AEIT AUTOMOTIVE), July 2019, Turin, Italy.
C	Optical networking for 5G Xhaul and service convergence: transmission, switching and control enabling technologies	European Conference on Optical Communication (ECOC), September 2019, Dublin, Ireland.
C	Dynamic slicing of RAN resources for heterogeneous coexisting 5G services	IEEE Global conference on Communications (Globecom), December 2019, Hawaii, USA.
C	vrAIn: A Deep Learning Approach Tailoring Computing and Radio Resources in Virtualized RANs	The ACM Annual International Conference on Mobile Computing and Networking (Mobicom), October 2019, Los Cabos, Mexico
C	5GEN: A tool to generate 5G infrastructure graphs	IEEE Conference on Standards for Communications and Networking (CSCN), October 2019, Granada, Spain
C	iFUSION: Standards-based SDN Architecture for Carrier Transport Network	IEEE Conference on Standards for Communications and Networking (CSCN), October 2019, Granada, Spain
C	Towards the quest for 5G Network Slicing	IEEE CCNC2020 (accepted)
W	White paper on MANO chapter	5GArch 2019: International Workshop on 5G Architecture, held with EUCNC, June 2019, Valencia, Spain

TABLE 20: TECHNOLOGY DEMONSTRATIONS IN Y1

Title	Event
Demo of the initial heterogeneous network part of the MTP	Mobile World Congress'18
OVNES: Demonstrating 5G Network Slicing Overbooking on Real Deployments	IEEE INFOCOM 2018

TABLE 21: TECHNOLOGY DEMONSTRATIONS IN Y2

Title	Event
Robotic Control Leveraging a Radio Network Information Service (RNIS)	EuCNC 2018
Orchestrating entertainment network service deployment in a hybrid cloud with Cloudify	EuCNC 2018
Creating a media-oriented slice through the 5G-TRANSFORMER vertical slicer	EuCNC 2018
Overbooking Network Slices End-to-End: Implementation and Demonstration	ACM SIGCOMM 2018
Experimental Demonstration of a 5G Network Slice Deployment through the 5G-TRANSFORMER Architecture	ECOC 2018
Deploying a containerized ns-3/LENA-based LTE mobile Network Service through the 5G-TRANSFORMER platform	IEEE SDN-NFV 2018
Experimental Demonstration of a 5G Network Slice Deployment Exploiting Edge or Cloud Data-Centers	IEEE OFC 2019
Virtual CDN service deployment across multiple sites using 5G-TRANSFORMER architecture	ICT 2018
Latency-driven Network Slices Orchestration	IEEE INFOCOM 2019

TABLE 22: TECHNOLOGY DEMONSTRATION IN Y3

Title	Event
Demo of the entertainment use cases of the project	EuCNC 2019
Demos of the automotive use cases of the project	EuCNC 2019
Demos of the mvno use cases of the project	EuCNC 2019
Demos of the cloud robotics use cases of the project	EuCNC 2019
Demo of the robotic immersive teleoperation PoC (jointly with 5G-CORAL project)	EuCNC 2019
5G connected hospital use case, with radio access network and edge deployed locally and remote connection with core network hosted on BCOM NFVi central cloud	EuCNC 2019
Mobile Cloud Robotics Demonstration	Mobile Cloud Robotics Show'19 / Fronthaul & Backhaul Convergence for 5G Use Cases event
How 5G is transforming the business of Media & Entertainment	NEM 2019
5G connected hospital use case, with an on-site edge cloud as NFVi	MWC 2019
Use case in the media & entertainment vertical sector	IBC 2019
360 video service for fan engagement	PGA golf tour - Madrid
Provisioning and automated scaling of network slices for virtual Content Delivery Networks in 5G infrastructures	ACM Twentieth International Symposium on Mobile Ad Hoc Networking and Computing (Mobihoc), July, Catania, Italy.
Composing Services in 5G-TRANSFORMER	ACM Twentieth International Symposium on Mobile Ad Hoc Networking and Computing (Mobihoc), July, Catania, Italy.

Demonstration of Fault Localisation and Recovery of Optical Connectivity Supporting 5G vRAN	European Conference on Optical Communication (ECOC), September 2019, Dublin, Ireland.
Demo: vrAIn Proof-of-Concept – A Deep Learning Approach for Virtualized RAN Resource Control	The ACM Annual International Conference on Mobile Computing and Networking (Mobicom), October 2019, Los Cabos, Mexico
Experimental Demonstration of Live Migration Impact on Virtualized 5G Network using Federated Testbeds	IEEE Conference on Network Function Virtualization and Software Defined Networks (NFV-SDN), November 2019, Dallas, Texas, USA.
Automated deployment and scaling of automotive safety services in 5G-TRANSFORMER	IEEE Conference on Network Function Virtualization and Software Defined Networks (NFV-SDN), November 2019, Dallas, Texas, USA.
eHealth event in Madrid	Evento de demostración del Sistema Automático de Emergencias 5G, 27 November 2019

TABLE 23: ACADEMIC ACTIVITIES IN Y1

Title	Level	Status
eNB split functions (Distributed Unit --- DU --- and Central Unit --- CU) virtualization and its impact on fronthaul available latency budget.	PhD	Ongoing
Resource Orchestration in Virtualized Networks through SDN-enabled OpenStack	PhD	Ongoing
Software Defined Networking based mobility management in small cells	PhD	Ongoing
Mechanisms to integrate and enhance NFV and MEC	PhD	Ongoing
Design and optimization of solutions for discovery and federation for NFV in edge & fog scenarios	PhD	Ongoing
Multi-domain VNF mapping algorithms	Master	Defended
Development of a RNIS API based on Publish/subscribe using OAI	Master	Defended
Análisis de un orquestador NFV/SDN para redes de operador	Bachelor	Defended
Service Function Chaining en NFV: Evaluación práctica con OpenStack	Bachelor	Defended

TABLE 24: ACADEMIC ACTIVITIES IN Y2

Title	Level	Status
eNB split functions (Distributed Unit --- DU --- and Central Unit --- CU) virtualization and its impact on fronthaul available latency budget.	PhD	Ongoing
Resource Orchestration in Virtualized Networks through SDN-enabled OpenStack	PhD	Ongoing
Software Defined Networking based mobility management in small cells	PhD	Ongoing

Mechanisms to integrate and enhance NFV and MEC	PhD	Ongoing
Design and optimization of solutions for discovery and federation for NFV in edge & fog scenarios	PhD	Ongoing
Enhanced Connectivity in wireless mobile programmable networks	PhD	Defended
Development of an Orchestrator interface for OpenAirInterface5G (OAI)	Master	Defended
Development of a prototype 5G RAN orchestrator	Master	Defended
Graphical interface for an SDN monitoring platform	Master	Defended

TABLE 25: ACADEMIC ACTIVITIES IN Y3

Title	Level	Status
eNB split functions (Distributed Unit --- DU --- and Central Unit --- CU) virtualization and its impact on fronthaul available latency budget.	PhD	Ongoing
Resource Orchestration in Virtualized Networks through SDN-enabled OpenStack	PhD	Ongoing
Software Defined Networking based mobility management in small cells	PhD	Ongoing
Mechanisms to integrate and enhance NFV and MEC	PhD	Ongoing
Design and optimization of solutions for discovery and federation for NFV in edge & fog scenarios	PhD	Ongoing
NFV for automotive services in 5G	PhD	Ongoing
Network virtualization and 5G services	PhD	Ongoing
Design and Performance evaluation of Java based virtualized network resource Orchestrator	Master	Finished
5G for automotive applications	Master	Finished
Study of anti-congestion algorithms for autonomous and connected vehicles	Master	Finished
C-V2X Applications for a 5G network testbed exploiting OpenAirInterface framework and Multi-Access Edge Computing	Master	Finished
Connected cars and traffic flow control	Master	Ongoing
Kubernetes as a Virtual Infrastructure Manager (VIM) for MEC	Master	Ongoing

TABLE 26: ORGANIZATION OF EVENTS IN Y1

Title	Event
1st Workshop on Control and Management of Vertical Slicing including the Edge and Fog Systems (COMPASS).	Co-located with IEEE Wireless Communications and Networking Conference (WCNC) 2018, April, Barcelona. Jointly organized with 5G-CORAL project.
Organization of the "5G technology for automotive domain" workshop in Turin including industrial and academic presentations.	Industry-academia workshop organized in FCA, July 2017
Co-organization of a special session on 5G Mobile Transport Networks jointly with the 5G-Crosshaul project	Organized at Wireless World Research Forum (WWRF) 39 meeting in Barcelona, October 2017. More information available at: http://wwrf39.ch/WWRF.html
Organization of IEEE VNC 2017	2017 IEEE Vehicular Networking Conference (VNC), Nov. 2017, Torino

TABLE 27: ORGANIZATION OF EVENTS IN Y2

Title	Event
Workshop on Experimentation and Measurements in 5G, December 2018, Heraklion, Greece	Co-located with the 14th ACM International Conference on emerging Networking Experiments and Technologies (CoNext). Jointly organized with 5G-CORAL project.
2nd Multi-provider, multi-vendor, multi-player orchestration: from distributed cloud to edge and fog environments in 5G, June 2018, Ljubiana, Slovenia.	Co-located with European Conference on Networks and Communications (EUCNC 2018).
Workshop 'From cloud ready to cloud native transformation: What it means and Why it matters', June 2018, Ljubiana, Slovenia.	Co-located with European Conference on Networks and Communications (EUCNC 2018).
2nd Workshop on Control and Management of Vertical Slicing including the Edge and Fog Systems (COMPASS), June 2018, Valencia, Spain	Co-located with IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB)
Vertical-Oriented Service Programmability: Design and Optimization of 5G Cell-Less Networks, Bologna, Italy 2018.	Co-located with IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC)
Emerging 5G Business Models: Opportunities for SMEs and large companies - lessons from 5G PPP (5G-EBM) Workshop, June 2019, Valencia, Spain.	Co-located with European Conference on Networks and Communications (EUCNC 2019).
Seventh International Workshop on Cloud Technologies and Energy Efficiency in Mobile Communication Networks (CLEEN 2019), Marrakech, Morocco, 2019	Co-located with IEEE Wireless Communications and Networking Conference (WCNC).

TABLE 28: ORGANIZATION OF EVENTS IN Y3

Title	Event
Emerging 5G Business Models: Opportunities for SMEs and large companies - lessons from 5G PPP (5G-EBM) Workshop, June 2019, Valencia, Spain.	Co-located with European Conference on Networks and Communications (EUCNC 2019).
From cloud ready to cloud native transformation, Workshop	Co-located with European Conference on Networks and Communications (EUCNC 2019).
5GArch 2019: International Workshop on 5G Architecture, Workshop	Co-located with European Conference on Networks and Communications (EUCNC 2019).
ETSI MEC Meeting #17	One of the periodic ETSI MEC Industry Specification Group (ISG) took place in Madrid (#17).
eHealth event in Madrid	Evento de demostración del Sistema Automático de Emergencias 5G, 27 November 2019

eHealth workshop in Madrid	5G y la mejora de la atención a emergencias (tentative, final title to be defined), to be held in December 2019

TABLE 29: PARTICIPATION TO EVENTS AND TALKS IN Y1

Title	Type	Event
Connected Car and Digital Transformation	Keynote	IEEE Vehicular Networking Conference (VNC), Nov. 2017, Torino, Italy.
5G and Verticals: The Connected and Automated Driving (CAD) Case	Panel	IEEE Wireless Communications and Networking Conference (WCNC) April 2018, Barcelona, Spain.
RS-FCN: Resource Slicing for Future Clouds and Networks	Talk	IEEE International Conference on Computer Communications (INFOCOM), April 2018, Honolulu, USA
All conference and workshop publications have been presented in their corresponding venue	Talk	Several international conferences and workshops (see publications table)

TABLE 30: PARTICIPATION TO EVENTS AND TALKS IN Y2

Title	Type	Event
5G Networks for Industry Verticals	Keynote	IEEE 5G Summit Tanger
Mobile Edge Computing (MEC): a 5G Enabler	Keynote	IEEE 5G Summit Marrakech (http://www.5gsummit.org/marrakesh/)
Overbooking 5GNetworks	Keynote	IEEE CSCN'18
"5G Mobile Platforms for Industry Verticals"	Keynote	IEEE Globecom'2018 (Backnets workshop)
Panelist at RAN WORLD 2018 in the Network Slicing Panel, where 5G-TRANSFORMER's vertical slicer architecture was presented	Panel	RAN WORLD 2018 (http://www.ranworldevent.com/ran-world-2018-agenda)
Panelist at GLOBECOM'18 Industry Panel on "5G Network Slice Management"	Panel	IEEE Globecom 2018 (https://globecom2018.ieee-globecom.org/program/industry-program#ip04)
Network Slicing Landscape: A holistic architectural approach, orchestration and management with applicability in mobile and fixed networks and clouds	Tutorial	IEEE Netsoft 2018 (http://netsoft2018.ieee-netsoft.org/program/tutorials/)
Cloud Native for Vertical Services	Talk	EuCNC 2018
Entry point of verticals to 5G systems: the 5G-TRANSFORMER vertical slicer	Talk	Webinar in telecomsradar (https://telecomsradar.com/webinar/entry-point-of-verticals-to-5g-systems-the-5g-transformer-vertical-
Service Orchestration and Federation for Verticals in 5G	Talk	Webinar in telecomsradar.com (https://telecomsradar.com/webinar/service-

		orchestration-and-federation-for-verticals-in-5g/)
5GEx concepts and how they evolve together with 5G-Crosshaul into 5G-TRANSFORMER	Talk	Webinar in telecomsradar.com (https://telecomsradar.com/webinar/5gex-concepts-and-how-they-evolve-together-with-5g-crosshaul-into-5g-transformer/)
Presentation of the 5G-TRANSFORMER Project	Talk	10ª Conferencia del Programa Marco de Investigación e Innovación de la UE en España (10th Conference of the EU Research and Innovation Framework Program in Spain)
Presentation of 5G-TRANSFORMER	Talk	"5GDay: OSM & 5GResearch", colocated with 5th OSM MANO hackfest
An Experimental View on 5G Research Projects for Edge Cloud: From the Lab to the Field	Talk	IEEE Future Network Workshop
All conference and workshop publications have been presented in their corresponding venue	Talk	Several international conferences and workshops (see publications table)

TABLE 31: PARTICIPATION TO EVENTS AND TALKS IN Y3

Title	Type	Event
Panelist in the panel session of the workshop: "5GArch 2019: International Workshop on 5G Architecture", June 20th	Panel	5GArch 2019: International Workshop on 5G Architecture, hold with EUCNC 2019.
Panelist at IEEE ICC 2019 Workshop: 5G-Trials – From 5G Experiments to Business Validation called Challenges in 5G Trials	Panel	IEEE International Conference on Communications (ICC) 2019, Shanghai, China
5G new opportunities for verticals and technology providers: an SME viewpoint	Talk	"Workshop 5: Emerging 5G Business Models", Co-located with European Conference on Networks and Communications (EUCNC 2019).
5G & OpenSource can create Unlimited Opportunities	Talk	"Workshop 5: Emerging 5G Business Models", Co-located with European Conference on Networks and Communications (EUCNC 2019).
Exploiting Programmable and Reconfigurable Hardware in 5G	Talk	IEEE Summer Tropical Meetings Summer Series, July 2019, Florida, USA.
Cooperative Information Manager (CIM) (creation and purpose)	Talk	Presentation at 5GAA, WG MEC meeting
Description of 5GT-SO module	Talk	5Growth consortium
Description of 5GT-SO module	Talk	5GEVE consortium
"Overbooking 5G Networks for Industry Verticals"	Talk	IEEE 5G World Forum 2019 (Dresden).
"Overbooking 5G Networks"	Talk	2nd Annual World 5G Summit (Barcelona, 10-11 October)

"AI-based Overbooking of 5G Networks"	Talk	European Big Data Value Forum (Helsinki, 14-16 October)
All conference and workshop publications have been presented in their corresponding venue	Talk	Several international conferences and workshops (see publications table)

2.2.1 Common Dissemination Booster (CDB)

The Common Dissemination Booster (CDB) [9] is a service from the European Commission which encourages projects to come together to identify a common portfolio of results and shows them how best to disseminate to end-users, with an eye on exploitation opportunities. 5G-TRANSFORMER has formed a CDB group, named "CDB04-5G-Transformer", with 5G-Crosshaul and 5G-Coral: all projects deal with the orchestration and management of services, which may encompass different transport domains as well as services residing at the edge, the three projects also deal with federation of different administrative domains (or at least, combination of heterogeneous domains) and slicing with special focus on vertical applications. The application was approved for all the five services available in the CDB portfolio. The original timeline is reported in Figure 5 where the initial time "0" refers to the kick-off meeting held on May 14, 2018. However, it has been conveniently adapted, in particular service 5 to reach June 2019, during which EUCNC19 and the SME exploitation workshop is taking place.

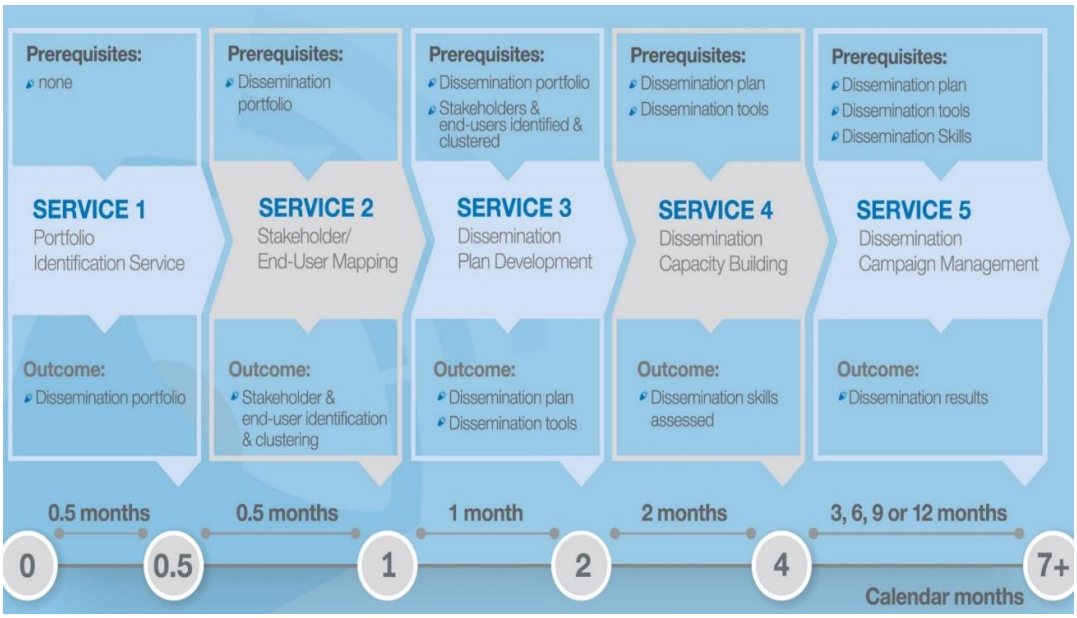


FIGURE 5: COMMON DISSEMINATION BOOSTER SERVICE RANGE AND TIMELINE

As part of the CDB, all services have been completed since CDB activities kick-off in May 2018 except for those related with Service 5, which is ongoing and will last until EUCNC 2019. The following paragraphs explain the undertaken activities in each of the services.

2.2.1.1 Service 1. Portfolio Identification

Service 1 consisted in identifying dissemination activities that can be done in common among all projects of the "CDB04-5G-Transformer", which is the name for the whole CDB including all projects. A series of discussions were set up to put in common a list of such services according to the following objectives:

- Objective 1: Communication outcomes of the three projects to the widest possible audience, including non-technical audiences.
- Objective 2: Ensure technical dissemination reaches the relevant industrial and academic communities.
- Objective 3: Maximize the impact of project outcomes through coordinated exploitation activities.
- Objective 4: Plan the activities for the dissemination and exploitation of results after the end of the funding lifecycle.

The main conclusions of Service 1 “Portfolio Identification” for the CDB04-5G-TRANSFORMER Group are:

- Capitalize on the ground-breaking results of 5G-Crosshaul by strengthening the links between the projects in communications messages and common dissemination actions. Highlight the key results for 5G and the EU 5G PPP with its focus on vertical industries. Leverage partner reputations and showcase the 5G PPP collaborative spirit.
- Produce a concise joint dissemination plan that can evolve with the projects. Identify events of mutual benefit and other actions where you can leverage commonalities. Focus initially on more technical events and subsequently reach out to vertical stakeholders.
- Be prepared to evolve our communications, websites and social media campaigns towards the ultimate end-users as the on-going projects reach greater maturity. Make sure you understand their information needs and knowledge of 5G so your messages and discussions are easily understood.
- Showcase the important work being done on standardization, including the involvement of partners from the verticals. Each project can have their own visual and “boost” it with a common image that can be promoted across the 5G PPP, standards groups and other industry networks.

In this direction, a self-assessment questionnaire filled in by each of the projects was used to identify the complementary research challenges among the projects in order to look for synergies in terms of dissemination as well as the differentiators of each of the projects, their positioning, and strengths and weaknesses. As a conclusion, some recommendations were generated.

2.2.1.2 Service 2. Stakeholder/End-User Mapping

The main task of Service 2 was stakeholders and dissemination network mapping (the specific title is CDB Service 2: Stakeholder User Mapping).

The main outcomes of this service for the CDB04-5G-TRANSFORMER group are:

- Identifying priority stakeholders and gauging current levels of engagement, interest and influence.
- Defining actions to improve and increase levels of engagement. Specific actions are matched against the barriers to engagement and dissemination.
- Providing practical dissemination networks for each priority stakeholder group, thus lowering barriers to engagement.
- Offering practical tips on the most effective dissemination channels for use by the Project Group based on an analysis of current practices and appeal to the stakeholder groups.

The main conclusions of Service 2 were:

STAKEHOLDER ENGAGEMENT (influential to very influential)

Industry engagement: Dedicate efforts on direct engagement with priority stakeholders and increase this over time. Common stakeholders include: large enterprise (supply side/value chain); Start-ups and SMEs (innovators/value chain); vertical industries (large and small businesses).

5G-Transformer also indicates mainstream press and media as a target group. Engagement with local/national media outlets will benefit the Project Group directly or indirectly.

Academia and Industrial Research: The main recommendation here is to increase buy-in within the Project Group academia/industrial research partners to increase visibility and engagement across the industry to increase awareness and build branding and reputation.

Standardisation and Open Source: The CDB-team also recommends showcasing contributions to the major standards organisations and open source communities for 5G.

They are also important building blocks towards the exploitation of results.

NEW DISSEMINATION ASSETS FOR CDB04-5G-TRANSFORMER

The dissemination networks are a core asset for facilitating and increasing engagement with the priority stakeholders, while boosting actions for strategic dissemination and exploitation of results.

The recommended dissemination channels will help the Project Group improve its approach to communicating project innovations, increase visibility and facilitate engagement with priority stakeholders outside the Project Group.

2.2.1.3 Service 3. Dissemination Plan Development

Service 3 developed a plan to increase dissemination based on the work done in previous services. The objective of this Plan is to help CDB04-5G-TRANSFORMER share results across wider geographies and variety of stakeholders detailed in the Service 2 report.

Specific objectives of the Plan are:

- Extending reach to stakeholders by leveraging the extensive network provided in CDB Service 2 and enabling the project group to boost exploitation potential. Actions include building up a community of stakeholders from relevant vertical industries and SMEs with a targeted engagement plan. Other actions seek to identify opportunities for increasing visibility with the press and media (telecommunications, national and local press). Identifying opportunities for joint demo presentations at large-scale industry events.
- Creating stronger dissemination and exploitation links between the ground-breaking research from 5G PPP phase 1 project, 5G-Crosshaul, and continued successful co-operation between industry and research experts in 5G-TRANSFORMER and 5G-CORAL.

Building on the skills development in CDB Service 4 and the implementation of the plan in CDB Service 5, this report will pave the way to increased impacts at:

- 5G events technical events, e.g. EuCNC 2019/7th Global 5G event.

- An SME workshop capturing benefits for this important stakeholder group in the 5G ecosystem.

2.2.1.4 Service 4. Dissemination Capacity Building

Service 4 consisted on providing the skills to the projects community to appropriately do dissemination. After a questionnaire was circulated to the key people involved in dissemination, an online course on the needed skills was prepared for them. The course consists of three modules:

- First, the strategy module consisted in learning to define objectives, the target stakeholders, the value proposition, the channels, timeline, and roles.
- Second, the implementation module focused on the tools to use, including social media, organization of events, or video preparation.
- Third, the monitoring module focused on measuring the impact.

2.2.1.5 Service 5. Dissemination Campaign Management

The goal of Service 5 is to ensure that the dissemination campaign is performed according to the dissemination plan in the targeted events, in this case, EUCNC 2019 and the SME workshop (i.e., the exploitation-oriented workshop of 5G-TRANSFORMER). As of the time of writing this deliverable, the final dissemination material is under preparation, including: a final video of the innovations of the CDB group, a joint logo for the final dissemination of results, and a social media guide to maximize communication and dissemination.

2.3 Exploitation

One of the objectives of WP6 is to identify the potential exploitation of the results, outcomes, and concepts developed in the project. The key innovations, commercial-grade products, services, solutions and patents are the aspects that are tracked, since the beginning of the project, to identify exploitation opportunities.

The exploitation direction for **vertical industries** partners has been mostly directed in the slicing capabilities of the system, based on the VS for the blueprint definition and for the access to the underlying lower layers. In particular, the system hides through APIs unnecessary details to the verticals, allowing them to focus on the definition of the services and to identifying the desired service levels. Exploitation is facilitated by the possibility to deploy their services over a common multi-domain infrastructure using virtual slices composed by VNFs running in the cloud or MEC on generic IT servers.

In this scenario, **operators** in the consortium, have gained from the project the opportunity to understand how to move from a conventional “bit pipe” business to a service business by exploiting the slicing concept for providing (virtual) infrastructure to vertical industries, as a service. Orchestration and federation have emerged as key elements for operators which are targeting deep levels of simplification, programmability, and automation in their networks. Federation has been identified by operators in the consortium as crucial to provide connectivity for vertical services that can expand across multiple operators, requiring to deploy capabilities outside the traditional footprint of the single telco. Moreover, the project has demonstrated as a shared infrastructure can support several vertical networking applications and services in parallel contributing to lowering cost of deployment and operation.

Equipment vendors in the project have been particularly involved in the design and development of system orchestration and in the evolution of mobile, transport, and

computing layers providing exploitation opportunities for their control planes, fronthaul/backhaul network portfolios, and MEC products. Exploitation have been boosted by two concurrent opportunities provided by the project. The first opportunity is the interaction with verticals, that have submitted their real needs, crucial to assess current products and to define future product directions. The second opportunity comes from interaction with operators, the "natural" customers of equipment vendors, that in the project provided an immediate feedback to equipment vendors on the real interest of the solutions under study for their in-field and planned network infrastructures.

The project had the benefits of the involvement of three **SMEs**, which have significantly gained value from the work in the project. In fact, exploitation opportunities for SMEs have been relevant and with large potential, especially in relation to the advent of SDN/NFV technologies where SME can deploy their innovative ideas in a common framework. 5GT-VS and 5GT-SO blocks are the main elements that SMEs can exploit from the project.

2.3.1 Vertical Services/Vertical Slicer (VS)

ATOS

Since 1989 ATOS has a global business unit which is dedicated exclusively to the provision of IT products and services to event owners, venue operators and rights holders. It is partner of Olympic & Paralympic Games, will mostly focus on the media distribution vertical industry. The expected increase of bandwidth requirements, coming from the advent of 4K/8K and High Dynamic Range (HDR) streams, has posed to ATOS the challenge of transporting more data in an extremely dense environment. In this scenario, ATOS has identified the need of the sport market to support massive content distribution within venues and stadiums, where in a relatively small area and for a limited number of hours during the week, there could be up to 50K viewers consuming hundreds of hours of media content [10]. These needs have been key inputs for 5G-TRANSFORMER.

Leveraging on the project, ATOS has delivered a successfully demo based on the streaming solution used in the Olympic Games which is for sure a TRL6, adapted to 5G-TRANSFORMER platform. The demo was delivered between the 3rd and 6th of October of 2019 in the “Mutuactivos Open de España” (the Golf Open in Spain). During the event, the ATOS team which included personnel from ATOS Research and Innovation and Major Events (the sport division) has deployed a local infrastructure running the entertainment sliced service orchestrated with the 5G-TRANSFORMER platform to capture 360 videos with up to 50 Mbit/s bandwidth and distributed the content in a local wireless network for visitors to consume either 360 video or an in service virtual reality experience using an immersive application developed by ATOS. Moreover, the event was also used to disseminate 5G-TRANSFORMER technology advances and how these technologies will impact such events.

SAMUR

SAMUR-Civil Protection, in close collaboration with the Subdirección General de Informática y Nuevas Tecnologías de la Dirección General de Emergencias y Protección Civil, in Spain, has defined and proposed in the project a concrete use case which consists of a "Smart T-Shirt/watch", designed to save lives in cases of a medical emergency thanks to 5G technology. The "Smart T-Shirt/watch" measures the heart rate by means of sensors that, in case of potentially lethal arrhythmia, generates an automatic alert to a nearby ambulance, through the mobile phone via Bluetooth. In turn, the mobile

phone, sends this alert to the nearest useful hospital for the patient, without having to go through a communications center, significantly reducing the response time to a life-threatening emergency. The system also locates, through an App, a volunteer near the incident to perform cardiopulmonary resuscitation (CPR) on the patient while waiting for the ambulance. The system will also automatically deploy/scale required servers and network capacity to aid the teams deployed in the emergency.

Centro Ricerche Fiat (CRF)

During the first stage of the project CRF explored several automotive services relevant for 5G which span from safety to entertainment and involves automated (partially or full) as well as autonomous vehicles. To better analyze the needs of the automotive domain versus the incoming communication technology, four main scenarios (urban, rural, highway, and transversal) and several use cases quite different for their peculiar features have been considered, outlining the key aspects that mostly impacts on 5G. This analysis allowed to collect the main automotive requirements and related KPIs to be kept into account by the novel 5G solution implemented by 5G-TRANSFORMER. Moreover, the results of this analysis have been presented at several conferences as well as at 5GPPP automotive WG and are the starting point for future exploitation in FCA projects aimed at implementing future 5G connected vehicles.

In a second stage, the focus has been on a relevant class of automotive services, namely, the Extended Virtual Sensing (EVS), which aim at enhancing the sensor measurements aboard vehicles with the information collected by the network infrastructure and exploit it to implement more robust safety as well as improved passengers/driver comfort. In particular, for the implementation of the PoC in 5G-TRANSFORMER, the EVS application for vehicle collision avoidance has been selected.

The PoC, implemented so far, is based on a MEC architecture that allows minimizing the latency and has been integrated with the 5G-TRANSFORMER functionalities aimed to support the automatic deployment of the EVS automotive application and the scalability of the service to ensure the SLA.

On June this EVS PoC has been successfully demonstrated at EUCNC 2019.

During the last stage of the project, the major effort consists in the integration of the services in the real vehicles and the preparation of a live demonstration.

The final PoC involves beyond the EVS, also a video streaming service offered on board.

The goal of the final demo is to show how the platform, thanks to the Arbitrator functionality, guarantees the EVS service balancing the available resources between all served services according to the respective priority, in the specific case the EVS with higher priority and the video streaming service with lower.

InterDigital (IDCC)

Since the project beginning, InterDigital has been constantly leveraging on the innovations, IPR and the outcomes of the development activity carried out in 5G-TRANSFORMER.

As initially planned, the Chordant™ platform was meant to benefit from the 5G-TRANSFORMER research activity on the Vertical Slicer. However, Chordant™ has been recently spun out of InterDigital, thus preventing any further involvement in the 5G-TRANSFORMER consortium. For this reason, the primal focus of the exploitation strategy has been devoted towards designing, validating and trialing a robotic prototype

based on the 5G-TRANSFORMER platform, with the goal of showcasing key features, such as network slicing and zero-touch deployment.

During the first year, InterDigital designed the MEC-enhanced robotic PoC demonstrating the benefits of processing network radio analytics supplied by the ETSI MEC platform. Next, the robotic platform was enhanced by incorporating a 360-degree panoramic camera and a more accurate control system to investigate typical industrial use cases. As a result, the system required the provision of two distinct network services, i.e., a high-data rate multimedia video streaming service and an ultra-reliable low-latency service to support the robotic controller, which were instantiated, maintained and operated through the 5G-TRANSFORMER Vertical Slicer. This PoC was showcased during the European Conference on Networks and Communications (EuCNC'19) in Valencia, Spain, where it sparked the interest of members of the 5G-VINNI consortium and set the stage for collaboration through the 5G-VINNI facility.

InterDigital also filed a patent entitled "Methods for advertising and selecting network slices dual-connectivity and multi-subscriber scenarios in 5G" (PCT/US18/46747) by investigating issues related to network slice operations in scenarios with dual connectivity and multiple subscribers.

BCOM

BCOM exploits the outcomes of 5G TRANSFORMER project to pursue evolution of its *Wireless Edge Factory* (see https://b-com.com/en/bcom-wireless-edge-factory) which integrates computing and networking capabilities in a single node. 5G-TRANSFORMER results had an impact on the functionalities by bringing both expertise and knowledge on the slice concept, architecture and development of slicing. BCOM developed a slice manager which performs the Live Cycle Management (LCM) for commission/decommission/activation/deactivation of network slices instances, to match with vertical needs and requirements. BCOM has led this expertise and share it to all partners when required at different stages of the project. BCOM is also able to exploit and follow up standard for ETSI NFV IFA005 interface and has developed plugin adaptor for VIM based on OpenStack, so that NFVO (Network Function Virtualized Orchestrator) can communicate directly with the VIM (Virtualized Infrastructure Management) whatever the type of technology is used to manage the infrastructure. 5G transformer allows BCOM to provide partner (Orange) with its *Wireless Edge Factory* embedding vEPC functions and services in order to contribute to the MVNO use case of the project. Finally, BCOM benefits of Network Slice Manager, with the NSaaS use case and the management of the network slices, is considered by BCOM as an enabler for the deployment of the BCOM *Wireless Edge Factory*, a core network solution for 4G/5G private mobile networks, which can be considered as a set of VNFs (VNFD and NSD for Open Source MANO have been initially built in the scope of H2020 5GinFIRE project).

In 2019, the Network Slice Manager and the BCOM *Wireless Edge Factory* have been demonstrated three times with slicing live demos:

- BCOM booth at MWC 2019, illustrating a 5G connected hospital use case, with an on-site edge cloud as NFVi. See LinkedIn post (https://www.linkedin.com/posts/michel-corriou_b-com-on-twitter-activity-6506457042369282048-DyNv).
- 5G TRANSFORMER at EuCNC 2019, illustrating also the 5G connected hospital use case, with radio access network and edge deployed locally and remote connection with core network hosted on BCOM NFVi central cloud.

- BCOM booth at IBC 2019, illustrating a new use case in the media & entertainment vertical sector: news gathering for live broadcast and the need for differentiated QoS video streams.

Nextworks (NXW)

Since the beginning Nextworks has aimed at exploiting the project results to enhance its know-how in NFV, SDN and MEC areas and to apply it to consultancy services as 3rd party developer for ICT solutions and training courses on NFV products, cloud and MEC services.

In 5G-TRANSFORMER, Nextworks has developed SEBASTIAN, a 5GT-VS prototype released as open source software under the Apache 2.0 license. The 5GT-VS is a core component of the 5G-TRANSFORMER architecture that allows to bridge the gap between the vertical's perspective about service design and lifecycle management and the NFV modelling of the service combined with its infrastructure-dependent deployment and runtime management. The 5GT-VS concepts and prototype are an important asset for Nextworks, allowing the company to evolve and complete its NFV MANO portfolio. The stack of NFV MANO components developed by NXW includes, beyond SEBASTIAN, also an NFV Orchestrator, an OpenStack-based VIM, a control plane for network slices, a multi-NFVO catalogue and a Service Development Kit for designing services.

In this portfolio, SEBASTIAN has a central role since it is the key to enhance two fundamental aspects of service provisioning:

- It simplifies the modelling, automated deployment, and runtime operation of services. This can be directly applied to a range of Nextworks products for smart-home and smart-city management, to facilitate and further automate their provisioning in virtual environments, also exploiting MEC capabilities.
- It provides a complete tool for the intelligent management and sharing of network slices, a functionality that is gaining more and more attention from network operators to limit the Total Cost of Ownership of their infrastructures.

In this context, the development of the 5GT-VS prototype has provided Nextworks personnel with hands-on experience in the area of network slicing management and vertical services definition allowing significant improvements of the consultancy services in the NFV and network slicing area.

NECLE

NEC's Public, Enterprise and Network Services Business Units aim at addressing the 5G needs of industry verticals like construction, automotive, factories, health and public safety. For this purpose, proof-of-concepts are currently being conducted with such verticals to understand their requirements and develop a system that can be used to address their needs in an automated manner. In this context, the Vertical Slicer is a key novel building block to capture this new business opportunity by enabling the automated translation of industry verticals high-level requirements into network slicing requirements. NEC laboratories Europe has promoted towards multiple business units the 5GT-VS concept and open-source software implementation released in GitHub. Multiple demonstrations in Japan were conducted. The Network Service Business Unit has shown interest in testing it for "5G Private Networks" with industrial customers. NEC Industry Verticals PoCs:

https://www.nec.com/en/global/solutions/nsp/5g_vision/case.html

2.3.2 Service Orchestrator (SO)

NECLE

NEC/Netcracker's ETSI-compliant NFV Management & Orchestration offering fills the gaps in current solutions by automating operations and reducing time-to-market for new virtualized services. It aims at helping businesses move to the cloud by solving operational issues regarding network functions virtualization. It also provides vendor-agnostic VNF onboarding, interoperability, scalability, security, accounting and licensing. The advanced Service Orchestration solution developed by the 5G-TRANSFORMER project has been used to explore new features to be integrated in the product portfolio for network slicing and AI-based cost-efficient resource management. Results were presented at the Mobile World Congress in 2019 and shown to customers to gauge their interest.

Overbooking Network Slices:

https://www.nec.com/en/event/mwc2019/leaflet/pdf_2019/Overbooking_Network_Slices.pdf

MIRANTIS

Mirantis Cloud Platform (MCP) is a comprehensive multi-cloud software stack built with an operations-centric approach. It continuously delivers automated infrastructure updates and intelligent application delivery through a CI/CD pipeline toolchain while also providing proactive monitoring and analytics to ensure maximum availability. MCP can include OpenStack and/or Kubernetes to offer bare metal, VMs and containers, along with Ceph, OpenContrail and Calico for software-defined storage and networking. Having cutting-edge field experience in the NFV-related development, deployment and integration projects, in scope of the 5G-TRANSFORMER, Mirantis exploitation took place in both 5GT-SO and 5G-MTP (see next section for 5GT-MTP).

For 5GT-SO, considering Cloudify as foundation platform for the 5G-TRANSFORMER Service Orchestration layer, Mirantis has developed a set of plugins and extensions to enable Cloudify communication with the underlying infrastructure, like 5G-TRANSFORMER 5G-MTP component.

Additionally, Mirantis has performed integration of the 5G-TRANSFORMER Monitoring platform with the Service Orchestrator. As some project features like 5GT-SO federation were not available at the open source world yet, Mirantis jointly with partners have developed appropriate functionality and integrated it into the 5G-TRANSFORMER platform.

Considering numerous add-ons and functionality which were planned to be introduced during development phase of the 5GT-SO component, Mirantis has introduced Continuous Integration/Continuous Delivery (CI/CD) pipelines for development and deployment of the 5G-TRANSFORMER components.

2.3.3 Mobile Transport and Computing Platform (MTP)

Nokia (NOK-N)

Throughout the whole duration of the project, Nokia contributed to the conceptual work and architecture of the 5G-TRANSFORMER system. The concepts developed were used in the design of product features,for example, in the domain of network slicing for the AirScale Base Transceiver Station (BTS). Nokia gained better understanding of

deployment and integration scenarios of its products into operator and vertical environments.

Nokia evaluated the real-time behavior of different virtualization approaches and of different operating system configurations. These evaluations provide valuable insight on the design of virtualized BTSs and on platforms for MEC applications.

Nokia considered the project results on MEC integration to increase flexibility of its 5G-BTSs deployed as VNFs and of its MEC platform, allowing better resource utilization and supporting different slice and service types on the BTSs and of MEC applications. The MEC related extensions are relevant for the Airframe Open Edge Server. Nokia considers as well to extend its cloud platform with interfaces and functionality for the compute part of the MTP to ease use in regional data centers and for deployment of vertical services.

Additionally, Nokia filed two patents, one protects a technique to monitor reachability of VNFs in network slices, a second one protects a method to connect multiple VNF instances in different datacenters such that SLA requirements are satisfied.

NECLE

NEC is a vendor of solutions in the radio access network, transport and core domain. NEC's Integrated network management system MS5000 provides an end-to-end seamless view of entire network through state and configuration management, enabling a full range of fault and performance management functions. NEC's Traffic Management Solution helps carrier service providers to increase user's quality of experience, reduce CAPEX/OPEX and to generate new revenue streams for maximizing return on investment. The 5G-TRANSFORMER Mobile Transport Platform solution explored potential new features to be added to the current NEC integrated network operation and management system portfolio such as end-to-end network slicing and low-latency services through edge computing. NEC filed one patent in the MTP MEC area considered as a critical technical solution to enable low-latency services.

Ericsson (TEI)

As world leader in manufacturing of radio cellular networks, Ericsson has, since the beginning of the project, identified clear exploitation opportunities especially related to the smoothest possible integration of radio, transport, and cloud layers which is addressed in the 5GT-MTP building block.

The Ericsson team that has mainly contributed to the project belongs to Ericsson Research (ER). ER is an internal organization, dedicated to medium- and long-term research activities, in continuous interaction with the product lines which defines the product features and roadmaps and cooperating with the product development units that oversee implementations.

One important element has been the presence of vertical actors in the consortium: those have posed realistic and heterogeneous requirements to better assess the radio and transport architecture in terms of challenging values of the main performance parameters like availability, latency, throughput.

For Ericsson it's extremely valuable the synergy with telecom operators which are its traditional customers. A significant step in the direction of exploiting project result in a realistic environment has been done with the mobile cloud robotic demo (eIndustry use case), exhibited by Ericsson and Telefonica in the 5Tonic lab in Madrid. The demonstrator has addressed the topic of convergence of fronthaul and backhaul

exploiting the 5GT-MTP building block of 5G-TRANSFORMER to orchestrate radio, transport, and cloud and to enable the creation and operation of a real 5G-based service for industry verticals applications and, specifically, demonstrating cloud robotics in the industrial scenario.

In the transport segment, Ericsson has started to relate the 5G TRANSFORMER scenario with the Fronthaul 6000 platform which is a flexible wireless and (active and passive) fiber-based fronthaul solution for CPRI and eCPRI transmission. One important feature of Fronthaul 6000 is that it ensures high-capacity and low-latency transport to meet even the most stringent transport requirements of LTE and 5G.

In the cloud segment, Ericsson Cloud Infrastructure portfolio delivers proven, open and standards-based solutions to service providers. The foundation is the pre-integrated Ericsson NFVI solution following ETSI architectural principles. Main values for service providers include fast initial deployment, short time to market for new services and low total cost of ownership. Ericsson NFVI is evolved with edge computing and container management capabilities making it possible to deploy current and emerging IoT applications across centralized and distributed sites in a distributed cloud model.

InterDigital (IDCC)

InterDigital initial plan to exploit the 5GT-MTP was to primarily enhance the EdgeHaul platform. Nonetheless, EdgeHaul was later replaced with the EdgeLink platform, which no longer features the SDN mesh layer and became less relevant within the 5G-TRANSFORMER framework. For this reason, as already explained in Section 2.3.1 InterDigital decided to exploit 5GT outcomes by developing the robotic PoC, initially featuring a single IEEE 802.11ac radio access interface. As next step, InterDigital intends to further validate the robotic platform by adding a 5G NR interface, working together with partners involved in ongoing initiatives, including 5Growth and 5G-VINNI. Such interface will be managed and integrated through the 5GT-MTP facilities.

MIRANTIS

Mirantis has provided a platform for automatic 5G-TRANSFORMER 5GT-MTP layer deployment, which integrates and automatically provisions OpenStack and 5G-TRANSFORMER platform software components.

2.3.4 Exploitation Achievements for Service Providers/Operators

Orange and Telefonica (TID), the two operators in the consortium, have been involved in all facets of the project, including the definition of concepts, such as orchestration and federation of resources, and in the evolution of the radio/transport network. As a result, 5G-TRANSFORMER has presented exploitation opportunities for both.

ORANGE

Orange has developed expertise and research on slicing orchestration over several domains, starting from verticals use cases toward the necessary adaptation of the ETSI NFV model to support federation at different layers. The main results where shared with internal Orange researchers. It triggered internal technical discussion and consideration on the orchestration of network slices for different kinds of verticals. It helped identifying necessary evolution of ETSI standard, considered by Orange delegates when contributing on NFV working group features.

Orange contributed to the design and support for MVNO use case implementation, in strong cooperation with other partners who are delivering software building blocks. In particular, Orange support was helpful for the Network Slice as a Service and MVNO use

case implementations made with BCOM partner. The implementation was demonstrated at the EUCNC 2019 conference. Orange also strongly supports the final demonstration of the MVNO use case. The cost model developed is also presented.

Orange is also strongly involved in H2020 phase 3 projects where the 5G-TRANSFORMER architecture and achievements are used as background. One main example is the use of 5G-TRANSFORMER slicing architecture and core network building blocks in the trial platform being implemented in the H2020 5G-EVE project by Orange and other partners.

TELEFONICA I+D (TID)

Telefónica is involved on a transformation of its networks, in preparation to the broad deployment of 5G. Different aspects of the Telefónica networks are subject of this transformation:

- Simplification of the transport network, flattening the network and transitioning it into a full programmability transport substrate.
- Deployment of a common NFVI architecture in all the affiliates, named UNICA.

The results and knowledge obtained through the execution of 5G-TRANSFORMER have assisted Telefónica on the conceptual evolution of the residential and wholesale services in the 5G era in several ways:

- Insights on the future commercialization of UNICA NFV infrastructure by offering capabilities to federated third parties (e.g., other service providers) in 5G-TRANSFORMER-like environments, opening new opportunities of generating incomes.
- Support on the transition towards end-to-end programmable networks, including an essential aspect such as the interconnection with other providers.
- Exploration of new business cases.
- Experience in the definition of blueprints towards vertical customers.
- Identification of gaps in standard solutions such as ETSI MANO or ETSI OSM, essential for supporting multi-provider interworking with minimal integration costs.
- Enablement of automated service provision of services among Telefónica's affiliates.
- Know-how acquisition to anticipate needs and requirements to be supported by the network assets, assisting Telefónica at the time of elaborating product specifications released as commercial RFIs and RFQs.

In addition to all of that 5G-TRANSFORMER project has been disseminated internally into the Telefonica group thanks to the key position of TID for the definitions of the technological guidelines of the group.

2.3.5 Table of Commercial products and services

Table 32 summarizes the commercial products and services that are related to technologies in the scope of the project and that are possible receivers of the project outcomes. The process of exploiting project outcomes in such product and services has already started in some case while, for other, is planned beyond the project end as specified in Section 3.3.

TABLE 32: MAPPING BETWEEN BUILDING BLOCKS AND THE RELEVANT PARTNERS' PRODUCTS AND SERVICES

Block	PoC/Product/Service/Solution	Partner
Vertical Slicer/Vertical Services	Smart Platform/Smart Stadium/Fan Engagement Solution	ATOS
	Cloud Solutions	ATOS
	Smart T-Shirt	SAMUR
	FCA car models	CRF
	Wireless Edge Factory	BCOM
	Consultancy and training services	NXW
	Symphony	NXW
	Sealux	NXW
	NFV Mano Portfolio (Sebastian)	NXW
	Video Streaming Robotic Platform	IDCC
	Netcracker 12 (NFV Management & Orchestration)	NECLE
Service Orchestrator	Netcracker 12 (NFV Management & Orchestration)	NECLE
	TMS -Traffic Management System	NECLE
	MS5000- Integrated Network Management System	NECLE
	Mirantis Cloud Platform (MCP)	MIRANTIS
	Cloudify	MIRANTIS
	Ericsson Dynamic Orchestration	TEI
Mobile Transport and Computing Platform	Airscale 5G BTSs	NOK-N
	Airframe	NOK-N
	Airframe data center	NOK-N
	NFV-based packet core	NOK-N
	MEC Platform	NOK-N
	MS5000 - Integrated Network Management System	NECLE
	UNMS - Unified Network Management System	NECLE
	Fronthaul 6000	TEI
	Ericsson Cloud Infrastructure	TEI

2.3.6 Key Innovations

At the end of the second year, WP1/W2/WP3/WP4 have identified thirteen innovations presenting exploitation opportunities in and beyond the project lifetime. Table 33 reports said innovations, classified according to the WP where they emerged. The last column of the table reports the organizations that are, as single company or in cooperation with academia, interested in exploiting the innovations.

TABLE 33: KEY INNOVATIONS EMERGED AT THE END OF Y2

#	WP	Innovation	Leading Partners
1	WP1	**5G-TRANSFORMER Architecture** Novel architecture extending ETSI MANO based on two new functional building blocks, 5GT-VS and 5GT-SO, interworking with the 5GT-MTP extended from 5G-Crosshaul.	NECLE
2		**Slicing for Vertical Services** A system allowing the creation of vertical suited slices including integrated fronthaul/backhaul and computing resources (e.g. MEC/Cloud Services), using ETSI NFV NSDs as network slice templates.	NOK-N
3	WP2	**MTP Single Logical Point of Contact**	TEI, CTTC

		The MTP is a novel building block, in the ETSI architecture, that operates as a single logical point of contact and resources orchestrator to manage the combined complexity of transport, radio, and datacenters, and abstracting such resources towards the 5GT-SO. MTP manages multi-domain transport, multiple radio split options and multiple VIMs.	
4		**MTP platform for supporting MEC services** Integration and deployment of the MEP in an NFV environment at the MTP and abstraction of the MEC resources toward the 5GT- SO.	EURECOM
5		**Abstraction Module for MTP** Abstraction functions module allowing to keep scalability and stability of the solution, while guaranteeing the resources optimization, where the resource domains are heterogeneous in technology.	TEI, CTTC
6	WP3	**Arbitrator** The arbitrator has the role of prioritizing resources among vertical service instances and mapping them to multiple deployment options.	POLITO
7		**Translator** Usage of translation rules to bridge among the abstract view of verticals and the specific definition of network slices.	NXW
8		**Network Slice Manager** Network Slice Manager, with the use case NSaaS and the management of the network slices.	B-COM
9		**Vertical Slicer** Vertical slicer, allowing verticals to define their service based on a catalogue of blueprints defined by the service provider or infrastructure operator and mapping them to network slice instances according to SLA requirements.	NXW
10	WP4	**Service Monitoring Platform** Service monitoring platform for providing monitoring services including definition service-specific monitoring metrics and their provision to verticals and mobile network operators. Integration of this service as part of distributed cloud services/MEC.	NXW
11		**Enhanced Service Orchestrator for heterogeneous infrastructures**	MIRANTIS

		Enhanced service orchestrator platform able to support heterogeneous technologies like MEC, various cloud infrastructures, including both private and public clouds, integration of cloud and WAN transport technologies by development of the appropriate MEC/WIM/VIM plugins.	
12		**Federation** Federation mechanisms between 5G-TRANSFORMER platforms owned by different administrative domains and integration of vertical provided infrastructure through abstraction, advertising and interfaces.	TID

In addition to bringing project outcomes in specific commercial products, the demos and test-beds planned in the context of WP5 are expected to activate a fruitful ecosystem for experimentation where verticals, manufacturers, SMEs, operators, and academia can share requirements, constraints, feasibility of specific features and functionalities.

2.3.7 Patents and Licensing

The 5G-TRANSFORMER project addresses an area which provides significant opportunities for **patent** creation also leveraging on a strong background of over 40 patents, related to 5G-TRANSFORMER topics, filed by partners before joining the project.

As foreseen in Objective 8 of the project, partners have filed five patents, which list is reported in Table 34, that may lead to subsequent licensing opportunities, depending on the specific exploitation strategies of the relevant academic institutions and companies.

TABLE 34: LIST OF PATENT APPLICATIONS REPORTED AT THE END OF Y2

#	Patent Application Number and Title	Partner
1	PCT/IB2019/052094 - “Method for restoring the connection of a telecommunications network” (previously registered in Italy as “Metodo per il ripristino della connessione di una rete di telecomunicazioni”). Linked with: WO 2019/175835 A1 – “Modification of a Functional Split in case of Insufficient Availability of Resources”	SSSA
2	PCT/US18/46747 - “Methods for advertising and selecting network slices dual-connectivity and multi-subscriber scenarios in 5G”	IDCC
3	PCT/EP2018/066481 - "Multi-access edge computing, MEC, system and method for operating the same".	NEC
4	Patent in the area of ‘IP continuity checks’	NOK-N
5	Patent in the area of ‘Service instance discovery’	NOK-N

2.3.8 TRL6 demonstrations

In addition to the multiple demonstrations presented in the dissemination section, the technology developed in the project was demonstrated in real scenarios in two TRL6 events.

A demo was delivered between the 3rd and 6th of October of 2019 in the “Mutuactivos Open de España” (the Golf Open in Spain). During the event, the ATOS team which

included personnel from ATOS Research and Innovation and Major Events (the sport division) has deployed a local infrastructure running the entertainment sliced service orchestrated with the 5G-TRANSFORMER platform to capture 360 videos with up to 50 Mbit/s bandwidth and distributed the content in a local wireless network for visitors to consume either 360 video or an in service virtual reality experience using an immersive application developed by ATOS.

FIGURE 6: PICTURES OF THE ENTERTAINMENT TRL6 GOLF EVENT

As for the second event, a drill led by SAMUR and UC3M was organized to present the possibilities of 5G-TRANSFORMER-enabled 5G architectures to quickly react to emergency situations by deploying virtual functions at the edge right where the doctors need them and to speed up the reaction time of emergency health services in case of emergency. The demo took place on November 27th, 2019 and showed a 5G 100% automatic system that allows to reduce the time of action and minimize errors, which implies a higher percentage of survival in emergency situations. The system allows personalized attention to have the patient's medical data such as, among others, the pulse and blood test values. These values are shown in real time to the doctor in 5G augmented reality glasses to facilitate their flow of decisions when attending to the patient.

Among the attendees of the event we can highlight key people from the main companies of the project (Telefonica and Ericsson), high-ranked people from the regional government of Madrid, Guardia Civil, and Health companies. The meeting was also covered by different news media.

FIGURE 7: PICTURES OF THE TRL6 EHEALTH EVENT

2.4 Standardization

A detailed description of specific contributions that were brought to the SDOs relevant for 5G-TRANSFORMER is outlined in Table 35 and Table 36 below. The tables provide a description of how specific standardization contributions were prepared, discussed and ultimately presented in the relevant standards fora by 5G-TRANSFORMER partners, related to specific 5G-TRANSFORMER components.

To achieve this, we provide the specific contribution ID, e.g., 3GPP Technical Document (Tdoc) number, IETF draft or ETSI MEC contribution number. In addition, we specify how the content of such contribution relates to technology that is developed within 5G-TRANSFORMER. Finally, we indicate the status of these contributions, highlighting whether each contribution was “agreed/adopted/approved” or whether it was “rejected”/”presented”/”not yet adopted” or “noted”.

In addition, as highlighted in 3.3.1 the expertise acquired in NFV and MEC technologies has enabled further standardization activities within ETSI in several Specialist Task Force (STF) including ETSI NFV and MEC groups.

TABLE 35: DETAILED DESCRIPTION OF STANDARDS DISSEMINATION ACHIEVEMENTS IN Y1, HIGHLIGHTING THE RELATIONSHIP BETWEEN CONTRIBUTIONS TO SPECIFIC SDOS AND 5G-TRANSFORMER COMPONENTS

SDO	Contribution ID	Contribution Summary	Outcome	Relation to 5G-T	Date
First Year of 5G TRANSFORMER					
IETF(DMM WG)	Proxy Mobile IPv6 extensions for Distributed Mobility Management https://tools.ietf.org/html/draft-ietf-dmm-pmipv6-dlif-04	A solution based on Proxy Mobile IPv6 is proposed in which mobility sessions are anchored at the last IP hop router, called Mobility Anchor and Access Router (MAAR). The MAAR is an enhanced access router, also able to operate as a local mobility anchor or mobility access gateway, on a per prefix basis.	Adopted	5G Mobile Transport and Computing Platform, deliverable D2.3 [5], implements a mechanism to provide Mobility support (clause 7.3.1.3) to aggregate resource base on virtual coverage. The virtual coverage encompasses radio and Core Network resources, including information on CN gateways. The cross-abstraction manager in the MTP considers the simultaneous anchoring of flows abstracting resources from a particular coverage area composed by ordered geographical points	10/05/2018
IRTF (NFVRG)	Network Virtualization Research Challenges https://tools.ietf.org/html/rfc8568	Survey of the different efforts taking place at IETF and IRTF with regards to network virtualization, automation and orchestration in contrast with efforts taken by other SDOs	Adopted	5G Mobile Transport and Computing Platform and Service Orchestrator, in conjunction with the Vertical Slicer leverage on the concepts of network slicing and network virtualization to provide slices tailored to needs (e.g., networking and computing requirements) of different vertical industries and to allow per-slice management of virtualized resources as described in deliverable D1.3 [6]. Furthermore, this RFC identifies multi-domain orchestration as one challenge that needs to be tackled by the IETF community. Multi-domain orchestration is one key contribution of the 5G	03/07/2017

				TRANSFORMER project, as seen not just in deliverables, e.g., D4.3 [8] but alson in other standardization contributions e.g., IETF Multi-domain Network Virtualization (https://tools.ietf.org/html/draft-bernardos-nmrg-multidomain-00).	
IETF (NMRG)	Multi-domain Network Virtualization https://tools.ietf.org/html/draft-bernardos-nmrg-multidomain-01	Analysis of the problem of multi-provider multi-domain orchestration, by first scoping the problem, then looking into potential architectural approaches	Not yet adopted	The 5GT Service Orchestrator addresses the problem of multi-provider/multi-domain orchestration by providing service scaling, network service composition, service federation, enhanced placement algorithms considering location constraint and MEC support, and enhanced service monitoring platform which provides monitoring data to the 5GT-SO for automated service scaling and SLA management, as described in deliverable D1.3 [6]	05/03/2018
IRTF (INTAREA)	IPv6-based discovery and association of Virtualization Infrastructure Manager (VIM) and Network Function Virtualization Orchestrator (NFVO) https://tools.ietf.org/html/draft-bernardos-intarea-vim-discovery-01	The contribution describes mechanisms allowing dynamic discovery of virtualization resources and orchestrators in IPv6-based networks. New IPv6 neighbor discovery options are defined	Not yet adopted	5G Mobile Transport and Computing Platform and in particular its Enhanced Placement feature, as described in deliverable D2.3 [5] addresses the issue of where to put VNF in multi-VIM domains	05/03/2018
IETF (COMS BoF)	COMS Architecture https://datatracker.ietf.org/doc/draft-geng-coms-architecture	The contribution defines the overall architecture of a COMS based network slicing system. COMS works on the	Not yet adopted	At its core, the 5G TRANSFORMER project, leverages on the concept of network slicing for providing slices tailored to needs (e.g., networking and computing	05/03/2018

		top level network slice orchestrator which directly communicates with the network slice provider and enables the technology-independent network slice management		requirements) of different vertical industries and to allow per-slice management of virtualized resources. Multiple enhancements and novelties have been included to satisfy the requirements to support heterogeneous network slicing as described in deliverable D1.3 [6]	
IETF (COMS BoF)	Problem Statement of Common Operation and Management of Network Slicing https://datatracker.ietf.org/doc/draft-geng-coms-problem-statement	This contribution discusses the general requirements and problem statement of supervised heterogeneous network slicing	Not yet adopted	The Vertical Slicer, through its Vertical Services Monitoring, supports monitoring of Vertical Service (VSI) their corresponding Network Slice Instances (NSI). The 5GT-VS interacts with the 5GT-SO to collect monitoring data about the established NFV network services and correlates or aggregates these data in order to produce metrics and KPIs for network slices and vertical services, as described in deliverable D3.3 [7]	05/03/2018
IETF (CCAMP WG)	A YANG Data Model for Microwave Topology https://datatracker.ietf.org/doc/draft-ietf-ccamp-mw-topo-yang/		Adopted	Definition of an information model and the related data model specified in deliverable D1.3 [6]	05/03/2018
IETF (CCAMP WG)	A framework for management and control of microwave and millimeter wave interface parameters https://datatracker.ietf.org/doc/draft-ietf-ccamp-microwave-framework	This contribution describes the required characteristics and use cases for control and management of radio link interface parameters using a YANG Data Model	Not yet adopted	5G Mobile Transport and Computing Platform, addresses the representation of network resources through Logical Links (LL) which define the link interconnecting two IP endpoints. The information model for a logical link, includes the IP address of terminating nodes and information related to the bandwidth and the latency induced by such connectivity.	05/01/2018

IETF (CCAMP WG)	A YANG Data Model for Microwave Radio Link https://datatracker.ietf.org/doc/draft-ietf-ccamp-mw-yang	This contribution defines a YANG data model to describe the topologies of microwave/millimeter	Adopted	5G Mobile Transport and Computing Platform has adopted YANG data models as information models defined to express relevant information parameters, thus enabling the exchange of this information through the adoption of a proper protocol, as described in deliverable D1.3 [6]	03/03/2018
3GPP SA2	(S2-183925-S2-183923)	New Key Issue: Identify scenarios when Network Slices cannot coexist within a single PLMN	Approved	Vertical Slicer, e.g., Verticals may impose requirements on what slices should be mutually exclusive (i.e., cannot be accessed simultaneously). The Vertical Slicer should be aware of this property. E.g., when managing policies per tenant, as specified in deliverable D3.3, in particular as part of the Policy Management and Arbitrator components.	16/04/2018

TABLE 36: DETAILED DESCRIPTION OF STANDARDS DISSEMINATION ACHIEVEMENTS IN Y2, HIGHLIGHTING THE RELATIONSHIP BETWEEN CONTRIBUTIONS TO SPECIFIC SDOS AND 5G-TRANSFORMER COMPONENTS

SDO	Contribution ID	Contribution Summary	Outcome	Relation to 5G-T	Date
Second Year of 5G TRANSFORMER					
ETSI NFV	IFA013	The contribution proposes a mechanism to associate specific policies to NFV NSIs	Accepted	The contribution allows the 5GT-VS to associate specific policies to NFV NSIs such that 5GT-SO could orchestrate different NSIs accordingly. Policies are needed to implement some of the SLA requirements, as described in deliverable D3.3 [7], and in particular as part of the Policy Management component	22/10/2018
ETSI NFV	IFA007ed321, IFA008ed321, IFA010ed321, IFA013ed321)	The contribution proposes a mechanism to associate specific policies to NFV NSIs	Accepted	The contribution allows the 5GT-VS to associate specific policies to NFV NSIs such that 5GT-SO could orchestrate different NSIs accordingly. Policies are needed to implement some of the SLA requirements. This is in line with deliverable D3.3 [7], and in particular as part of the Policy Management component	22/10/2018
3GPP SA2	Contribution to 3GPP SA2#127 meeting in Vilnius, LT. Technical Document (Tdoc): S2-187289	This contribution addresses KI1 "Mutually exclusive access to Network Slices" and in particular, identifying whether improvements to existing Release 15 System procedures are needed when controlling the access to mutually exclusive Network Slices, including aspects of both UE and network"	Noted	Verticals may impose requirements on what slices should be mutually exclusive (i.e., cannot be access simultaneously). The Vertical Slicer should be aware of this property. E.g., when managing policies per tenant, in line with deliverable D3.3 [7], and in particular as part of the Policy Management and Arbitrator components	02/07/2018

3GPP SA2	Contribution to 3GPP SA2#127 meeting in Vilnius, LT. Technical Document (Tdoc): S2-187248	This contribution proposes a new Kew Issue addressing system impacts when handling access to network slices, for UEs that have already been authenticated for PLMN access using 3GPP SUPI, but that require an additional level of authentication and authorization using User Identities and Credentials for specific slices	Approved	The arbitration features in the vertical slicer may need to consider slices that require Slice specific additional authentication, when selecting slices based on tenant policies as described in deliverable D3.3, [7]	02/07/2018
3GPP SA2	Contribution to 3GPP SA2#128bis meeting in Sophia Antipolis, FR. Technical Document (Tdoc): S2-188484	This contribution addresses KI1 (Key Issue) 1 “Mutually exclusive access to Network Slices” and in particular, identifying whether improvements to existing Release 15 System procedures are needed when controlling the access to mutually exclusive Network Slices, including aspects of both UE and network”	Approved	Verticals may impose requirements on what slices should be mutually exclusive (i.e., cannot be access simultaneously). The Vertical Slicer should be aware of this property. E.g., when managing policies per tenant, described in deliverable D3.3 [7], and in particular as part of the Policy Management and Arbitrator components	20/08/2018
3GPP SA2	Contribution to 3GPP SA2#129 meeting in Dongguan, China. Technical Document (Tdoc): S2-1811600	This contribution proposes and update to Solution 1.6 “Enabling access control to network slices that cannot be access simultaneously” in 3GPP. Solution 1.6 provides the evaluation of this solution	Approved	Verticals may impose requirements on what slices should be mutually exclusive (i.e., cannot be access simultaneously). The Vertical Slicer should be aware of this property. E.g., when managing policies per tenant, described in deliverable D3.3 [7], and in particular as part of the Policy Management and Arbitrator components	15/10/2018
3GPP SA2	Contribution to 3GPP SA2#129 meeting in Tenerife,	This Change Request (CR) proposes normative text to implement Slice-specific secondary	Postponed	The arbitration features in the vertical slicer may need to consider slices that require Slice specific additional	20/02/2019

	SP. Technical Document (Tdoc): S2-1901747	authencation, ensuring that the UE is first successfully registered to the Network before Slice Specific Authentication and Authorization is executed		authentication, when selecting slices based on tenant policies, as per SLA agreement, within section 2.1, in deliverable D3.3 [7]	
3GPP SA2	Contribution to 3GPP SA2#129 meeting in Tenerife, SP. Technical Document (Tdoc): S2-1901746	This Change Request (CR) proposes normative text to implement Slice-specific secondary authencation, ensuring that the UE is first successfully registered to the Network before Slice Specific Authentication and Authorization is executed	Postponed	The arbitration features in the vertical slicer may need to consider slices that require Slice specific additional authentication, when selecting slices based on tenant, as per SLA agreement, within section 2.1, in deliverable D3.3 [7]	20/02/2019
ETSI MEC	MEC(18)000298	MEC024 errata of use case 5.1 and exemplary figure	Accepted	The Vertical Slicer and Service Orchestrator should be aware what MEC resources are needed to be accessed when allocating resources to tenants when managing policies per tenant, as described in deliverable D3.3 [7]	24/07/2018
ETSI MEC	MEC(18)000299r1	MEC024 key issue on slice-awareness of the MEAO	Accepted	The Vertical Slicer and Service Orchestrator deliverables D3.3 and D4.3 [8] should be aware what MEC resources are needed to be access when allocating resources to tenants when managing policies per tenant, described in deliverable D3.3 [7], and in particular as part of the Policy Management component	24/07/2018
ETSI MEC	MEC(18)000300	MEC024 key issue on slice-awareness of the MEP	Accepted	The Vertical Slicer and Service Orchestrator deliverables D3.3 [7] and D4.3 [8] should be aware what MEC resources are needed to be access	24/07/2018

				when allocating resources to tenants when managing policies per tenant, described in deliverable D3.3 [7], and in particular as part of the Policy Management component	
ETSI MEC	MEC(18)000301	MEC024 key issue on slice-awareness of the MEPM-V	Presented	The Vertical Slicer and Service Orchestrator deliverables D3.3 [7] and D4.3 [8] should be aware what MEC resources are needed to be access when allocating resources to tenants when managing policies per tenant, described in deliverable D3.3 [7], and in particular as part of the Policy Management component	24/07/2018
ETSI MEC	MEC(18)000326	MEC024 - Some Clarifications for the use case 5.2	Accepted	The Vertical Slicer and Service Orchestrator deliverables D3.3 [7] and D4.3 [8] should be aware what MEC resources are needed to be access when allocating resources to tenants when managing policies per tenant, described in deliverable D3.3 [7], and in particular as part of the Policy Management component	31/07/2018
ETSI MEC	MEC(18)000329r1	MEC024 - Use case on dedicated instances of MEC components in a network slice	Accepted	The Vertical Slicer and Service Orchestrator deliverables D3.3 [7] and D4.3 [8] should be aware what MEC resources are needed to be access when allocating resources to tenants when managing policies per tenant, described in deliverable D3.3 [7], and in particular as part of the Policy Management component	31/07/2018

ETSI MEC	MEC(18)000339	MEC024 - Use case on multiple tenants in a single network slice	Accepted	The Vertical Slicer and Service Orchestrator deliverables D3.3 and D4.3 [8] should be aware what MEC resources are needed to be access when allocating resources to tenants when managing policies per tenant, described in deliverable D3.3 [7], and in particular as part of the Policy Management component	03/08/2018
ETSI MEC	MEC(18)000340	MEC024 - Use case on MEC applications shared among NSIs	Presented	The Vertical Slicer and Service Orchestrator deliverables D3.3 [7] and D4.3 [8] should be aware what MEC resources are needed to be access when allocating resources to tenants when managing policies per tenant, described in deliverable D3.3 [7], and in particular as part of the Policy Management component	02/08/2018
ETSI MEC	MEC(18)000430	MEC024 - Overview of Network Slicing Concept in ETSI NFV	Accepted	The Vertical Slicer and Service Orchestrator deliverables D3.3 [7] and D4.3 [8] should be aware what MEC resources are needed to be access when allocating resources to tenants when managing policies per tenant, described in deliverable D3.3 [7], and in particular as part of the Policy Management component	12/10/2018
ETSI MEC	MEC(19)000038	MEC024 - Draft v2.0.6 - Editorial Changes	Accepted	The Vertical Slicer and Service Orchestrator deliverables D3.3 [7] and D4.3 [8] should be aware what MEC resources are needed to be access when allocating resources to tenants when managing policies per tenant,	05/03/2019

				described in deliverable D3.3 [7], and in particular as part of the Policy Management component	
ETSI MEC	MEC(19)000039r2	MEC024 - Section 7 - Conclusions and recommendations	Accepted	The Vertical Slicer and Service Orchestrator deliverables D3.3 [7] and D4.3 [8] should be aware what MEC resources are needed to be access when allocating resources to tenants when managing policies per tenant, described in deliverable D3.3 [7], and in particular as part of the Policy Management component	05/03/2019
ETSI MEC	MEC(19)000067r1	MEC024 - Editorial changes and references formatting	Accepted	The Vertical Slicer and Service Orchestrator deliverables D3.3 [7] and D4.3 [8] should be aware what MEC resources are needed to be access when allocating resources to tenants when managing policies per tenant, described in deliverable D3.3 [7], and in particular as part of the Policy Management component	29/03/2019
ETSI MEC	MEC(19)000068	MEC024 - Scope text proposal (Section 1)	Accepted	The Vertical Slicer and Service Orchestrator deliverables D3.3 [7] and D4.3 [8] should be aware what MEC resources are needed to be access when allocating resources to tenants when managing policies per tenant, described in deliverable D3.3 [7], and in particular as part of the Policy Management component	29/03/2019
ETSI MEC	MEC(19)000122	MEC024 - Efficient E2E multi-slice support for MEC-enabled 5G deployments	Accepted	The Vertical Slicer and Service Orchestrator deliverables D3.3 [7] and D4.3 [8] should be aware what MEC	09/04/2019

				resources are needed to be access when allocating resources to tenants when managing policies per tenant, described in deliverable D3.3 [7], and, in particular, as part of the Policy Management component	
3GPP SA2	Contribution to 3GPP SA2#133 meeting in Reno, (NV) USA. Technical Document (Tdoc): S2-1905305, merged into S2-1906591	This Change Request (CR) proposes normative text to implement Slice-specific Authentication and Authorization, where the Network holds policies to indicated whether Slice Specific Authentication and Authorization should be run on more than one Access Network (e.g., 3GPP and Non-3GPP)	Agreed	The arbitration features in the vertical slicer may need to consider slices that require Slice specific additional authentication, when selecting slices based on tenant. In particular, whether Slice Specific Authentication should be run simultaneously for the same S-NSSAI when the UE access the system through 2 or more Access Networks. This is considered in the implementation of Service Level Agreements, described within section 2.1, in deliverable D3.3. [7]	17/05/2019
3GPP SA2	Contribution to 3GPP SA2#133 meeting in Reno, (NV) USA. Technical Document (Tdoc): S2-5306 merged into S2-1906592	This Change Request (CR) proposes normative text to implement Slice-specific Authentication and Authorization, where the Network holds policies to indicated whether Slice Specific Authentication and Authorization should be run on more than one Access Network (e.g., 3GPP and Non-3GPP)	Agreed	The arbitration features in the vertical slicer may need to consider slices that require Slice specific additional authentication, when selecting slices based on tenant. In particular whether Slice Specific Authentication should be run simultaneously for the same S-NSSAI when the UE access the system through 2 or more Access Networks. This is considered in the implementation of Service Level Agreements, described within section 2.1, in deliverable D3.3. [7]	17/05/2019

TABLE 37: DETAILED DESCRIPTION OF STANDARDS DISSEMINATION ACHIEVEMENTS IN Y3, HIGHLIGHTING THE RELATIONSHIP BETWEEN CONTRIBUTIONS TO SPECIFIC SDOS AND 5G-TRANSFORMER COMPONENTS

SDO	Contribution ID	Contribution Summary	Outcome	Relation to 5G-T	Date
Third Year of 5G TRANSFORMER					
3GPP SA2	Contribution to 3GPP SA2#136 meeting in Reno, (NV) USA. Technical Document (Tdoc): S2-1912735	The contribution proposes a New key issue to study what potential enhancements in the 5GS may be needed to provide event notification capabilities when quotas are reached, and the SLA cannot longer be met	Agreed	The contribution highlights the problem of how to monitor the enforcement of a Service Level Agreement outlining Slice Specific restrictions. This is considered in the implementation of Service Level Agreements, described within section 2.1, in deliverable D3.3. [7].	22/11/2019

3 Exploitation plan after the end of the project

3.1 Patents and licensing

As for role of patent for 5G development, it is not yet possible to reliably estimate the future 5G patent landscape based on patent analysis, as it takes years for a patent office to examine an application and issue a granted patent. At this point in time, a substantial portion of patent applications recently filed during 5G development are not yet granted, and many applications related to 5G are not yet even publicly available for analysis.

As foreseen in Objective 8 of the project, partners have filed (i.e. submitted to the European Patent Office to initiate the process for protection of the idea herein contained) five patents, which list is reported in Table 34. After submitting a patent application, it typically takes about one to three years to get a grant, sometimes significantly longer. It is also common to file additional divisional/continuing applications several years after the original filing. This means it can take several years before the final protection scope is known, and the time may vary significantly.

As for exploitation, protection of an invention with a patent may lead to subsequent licensing opportunities, depending on the specific exploitation strategies of the relevant academic institutions and companies. Manufacturer can also use patented systems or patented methods in products of their portfolio. In this case, the patent department inside the company typically activates a continuous monitoring of possible infringement typically targeting main competitors operated on the same market segment. Infringement detection and the relevant legal contention can also bring to additional revenues from the invention.

3.2 Open source code

To maximize the impact of the results, the project released open source code for each of the building blocks in the architecture. Most of the building blocks are released under the Apache 2.0 license, which substantially eases code reuse in other projects. Details are reported in the relevant 5G-TRANSFORMER deliverables: D3.4 for 5GT-VS, D4.4 for 5GT-SO, D2.4 for 5TG-MTP. Furthermore, the final release of the software is described in D5.5. The code is available for download at: https://github.com/5g-transformer

Moreover, the survivability of project results will also be ensured by exploiting the 5G-TRANSFORMER outcomes and its reference implementations in other projects. About this and how the code produced will be maintained in the future to achieve this goal, please refer to Section 3.4 for further details.

It is worth to notice that SME partners, in synergy with all the other project members, have had a crucial role in developing code in open source environments and to practically use such deployments in the demonstrators deployed under the coordination of WP5. For example, NXW has developed SEBASTIAN, a 5GT-VS prototype released as open source software under the Apache 2.0 license. Mirantis has empowered Virtlet and CRI Proxy upstream code development with 5G-TRANSFORMER specific focus and overall code stabilization. Mirantis has also contributed to the Cloudify AWSSDK plugin.

Academia has also fed the open source community. For example, SSSA has contributed with the extension to ONOS master code. More specifically, it contributed an extension of ONOS app exposing REST interface for establishing/retrieve/delete optical intents (when an intent is established a suggested path and optical channel can be

specified). The code has already been merged in master distribution of ONOS and used for implementing a demo at OFC2019. SSSA has also been the driver for using HP OpenFlow switches within ONOS.

From the operator point of view, Telefonica has declared that 5G TRANSFORMER facilitates the identification of gaps in standard solutions as ETSI Open Source MANO (OSM), which are essential for supporting multi-provider interworking with minimal integration costs, then reducing OPEX. OSM is one of the core MANO platforms that are integrated in the 5G-TRANSFORMER service orchestrator.

3.3 Products and services

3.3.1 Vertical Services/Vertical Slicer (VS)

ATOS

To answer the challenge of transporting more data in an extremely dense environment, outcomes of the project will be considered to improve ATOS Smart Platform, Smart Stadium offering and Fan Engagement solutions. In these solutions, the media and entertainment content could be distributed through a 5G-TRANSFORMER like infrastructure instead of through a traditional CDN specially for those consumers within the venue. This could enhance the service offered providing a flexible on-demand content distribution based on dynamic allocation of VNFs to support specific user needs. ATOS, which is also a Cloud Infrastructure Provider, has identified the opportunity to exploit technologies developed in the project to integrate its Cloud Infrastructure with the transport networks of operators [10].

After the success of the demo at the “Mutuactivos Open de España”, the PGA European Tour is interested in exploring the capabilities provided by 5G in general and 5G-TRANSFORMER in particular to exploit the business opportunities behind. The idea is to provide additional live content to the visitors of the match, adding more cameras and dynamically allocating more resources closer to the end users to enhance their experience. The expertise gained through the project and through the demo will be also used to add new added-value media services in the portfolio of the company, not only for golf tournaments but for all type of sport events, in closed and open venues.

SAMUR

The possibility of integrating T-shirts, bracelets and smart devices will be discussed with the health authorities, which by means of 5G the Emergency Services (SAMUR) would be alerted in case of a medical emergency.

The progressive implementation of 5G technology will be studied to meet the following SAMUR needs:

- Medical tele-supervision: high-quality videoconference between ambulances and the chief medical officer on duty to offer immediate remote medical advice in the event of a critical event.
- Improvement of the response time by incorporating automated emergency response via people remote monitoring and better-quality GPS positioning of the emergency resources (ambulances and first responders among the general population).
- Study the possibilities of using 5G for critical voice communications.

Centro Ricerche Fiat (CRF)

The final Automotive PoC integrated in the real vehicles will be a valuable tool for the internal exploitation.

In fact, the prototype will show the real benefits that the platform's features will provide to the future service ecosystem for the connected vehicles that FCA is going to build

On the other hand, the two implemented services, in particular, will be the starting point for the implementation of further flexible and dynamic connected services for safety and entertainment enabled by 5G-TRANSFORMER platform functionalities.

One of the main expected synergies is that toward the internal decoupled project Next Gen TCU aimed to define a new concept of connectivity for all FCA vehicle from CY22/23. The project will end in 2020 with the release of two new prototypes that will validate the concept and could be the base for future developments. FCA will provide dedicated engineering interfaces and will work with the selected supplier(s) to identify and collaborate with network operators who can facilitate connectivity to an operational (pre)commercial 5G network and related labs for testing.

All works done in 5GT from the definition of the 5G Use cases relevant for the Automotive Vertical and the elicited requirements to the final PoC are in fact a valid input for the design of the new connectivity solution, the setup of a validation methodology and the evaluation of the related PoC.

InterDigital (IDCC)

InterDigital intends to continue the robotic PoC development activity as well as to conduct trials in collaboration with on-going European research projects, such as 5Growth and 5G-VINNI. As for the former, InterDigital will take advantage of the knowledge and know-how gained within the 5G-TRANSFORMER project and will deploy and validate its technology at the vertical premises, by supporting the strict requirements dictated by manufacturers and ensuring adequate QoS and QoE.

On the other hand, InterDigital is quite keen to trial the robotic PoC through 5G NR connectivity, which will be provided by two different 5G-VINNI test-sites located in UK and Spain. Moreover, InterDigital will look to develop new IPR and will contribute in future standardization activities following up on the results obtained in 5G-TRANSFORMER.

BCOM

BCOM has not yet decided to adopt a Go-to-product strategy for the Network Slice Manager: the development of a proxy for ONAP has to be considered before to address market access. Nevertheless, an R&D license has been granted to partners in the scope of 5G-TRANSFORMER and it has also been proposed in the scope of ICT-17-2017 5G pilot project 5G EVE.

BCOM is definitively pushing the *Wireless Edge Factory* into a high TRL level (6-7) in order to maximize the chances to transfer this technology to BCOM partners, i.e., large industrial companies and SMEs, or other companies in a period of 3 years.

All works and research carried out within 5G-TRANSFORMER project are also used for different EU projects, such as previously mentioned 5G-EVE, but also ICT-19-2019 5G TOURS where BCOM is working on a 5G connected hospital use case (Wireless Operation Room).

Nextworks (NXW)

The knowledge acquired in 5G-TRANSFORMER on vertical requirements has been transferred to the product division of Nextworks to drive evolving company products for automation, A/V entertainment, and building management towards IoT-based and virtualized services exploiting cloud and MEC technologies. Target products are Symphony and Sealux: smart-home platforms where the re-engineering of product components towards NFV-based deployments can provide more efficient, flexible, and customizable IoT-based solutions that exploit cloud technologies for the delocalization of storage, control and backend functions.

The development and demonstration activities performed in 5G-TRANSFORMER around SEBASTIAN (in international conferences and exhibitions like EuCNC 2018, ECOC 2018, ICT 2018, EuCNC 2019, MobiHoc 2019) constitute an important reference to present the company expertise to potential customers, thus increasing competitiveness and differentiation from competitors. This will be particularly relevant to reach potential customers who are developing their own proprietary NFV MANO and network slicing solutions and, thus, may search for specialized skills to enhance their portfolio with innovative concepts. The demonstration in public exhibitions of Proof of Concepts around the NFV MANO and slicing solutions implemented by NXW, including also SEBASTIAN, have been and will be excellent opportunities to present the new ideas developed by the company, demonstrating their technical feasibility and potential benefits.

Moreover, the expertise acquired in NFV and MEC technologies is continuously feeding current consultancy activities with ETSI, where NXW is participating in several Specialist Task Force (STF) within ETSI NFV and MEC groups (e.g. for the 2018-2019 period: ETSI STF 551 on MEC Testing Framework; ETSI STF 569 on MEC API Conformance Test Specification; ETSI STF 557 on NFV API Conformance Test Specification and ETSI 563 on OpenAPI Specification for NFV).

Finally, the expertise acquired in the development of the 5GT-VS prototype will allow Nextworks to offer more effective consultancy services in the NFV and network slicing area, specifically targeting customers like service providers or small operators who are interested in delivering custom virtual infrastructure solutions providing simplified tools and interfaces towards a wide range of vertical industries.

NECLE

Although currently most of the proof-of-concepts with industry verticals are being setup as private networks, it is envisioned that in the near future such an approach will not be scalable enough to address the market needs. The Vertical Slicer will be promoted internally at NEC as a solution to fill this gap by introducing it within NEC/Netcracker NFV Management and Orchestration Solution portfolio.

NEC/Netcracker NFV Management and Orchestration Products:

https://www.netcracker.com/products/products/digital-operations-enablement/nfv-management-and-orchestration/

3.3.2 Service Orchestrator (SO)

NECLE

The advanced 5GT-SO technologies developed within the project will be considered by NEC's Netcracker to respond to future customer demands in terms of new features required for the NFV Management & Orchestration product. Special interest has been

raised by customers in automated solutions to improve the cost-efficiency of systems supporting network slicing.

NEC/Netcracker 12:

https://www.nec.com/en/event/mwc2019/leaflet/pdf_2019/netcracker_12_product_overview.pdf

Traffic Management system:

https://www.nec.com/en/global/solutions/nsp/tms/index.html

MIRANTIS

As reported in section 2.3.2 Mirantis has contributed with plugins, extensions, and components to the development of the 5GT-SO. The experience herein acquired pose to Mirantis the opportunity to exploit outcomes of the project in an enhanced service orchestrator platform able to support heterogeneous technologies like MEC, various cloud infrastructures, including both private and public clouds, integration of cloud and WAN transport technologies by development of the appropriate MEC/WIM/VIM.

Ericsson (TEI)

In February 2019 Ericsson has launched Ericsson Dynamic Orchestration, a multi-vendor, multi-domain, model-driven and open solution that is both ETSI compliant and aligned with ONAP. Dynamic Orchestration is a pre-integrated solution that enables Service Providers to launch “out of the box” business use cases that leverage both physical and virtual network functions. The use cases include mobile core related, like vEPC and vIMS as well as virtual Enterprise services, including vCPE or SD-WAN. The relation with 5G TRANSFORMER scenario is clear as the new Ericsson solution includes multi-vendor VNFs on the Service Provider environment and End-to-End Orchestration (to automate the instantiation and configuration of network services, including all intra-DC and inter-DC network services, across multiple domains and multi-vendor scenarios). Future evolutions of this new Ericsson solution could consider outcomes of 5G TRANSFORMER both in terms of system concepts and in terms of components.

3.3.3 Mobile Transport and Computing Platform (MTP)

Nokia (NOK-N)

Nokia will continue the development of IPR in areas related to the project, e.g. network slicing. Nokia plans to implement features for the AirScale BTS, such that the packet scheduler guarantees resource shares among network slices.

Nokia continues development of core network and radio access network functionality in a virtualized way for public and private networks, i.e. networks of verticals. This includes extensions of the Nokia MEC platform and the Airframe Open Edge Server and of the VNFs in the NFV based packet core.

NEC

The 5G-TRANSFORMER Mobile Transport Platform MEC extensions will be internally promoted for adding low-latency features to NEC’s unified network and traffic management systems.

MS5000 - Integrated Network Management Systems:

https://www.nec.com/en/global/solutions/nsp/nms/index.html

UNMS - Unified Network Management System:

https://www.nec.com/en/global/prod/nw/pasolink/products/unms.html

Ericsson (TEI)

The Ericsson Cloud Infrastructure solution has a modular architecture which facilitates capturing exploitation opportunities coming from the project. Ericsson Cloud Execution Environment module is the virtual infrastructure manager (VIM), based on OpenStack and OPNFV, in our market leading NFVI solution. This telecom grade VIM has been deployed with more than 50 operators around the world and provides efficient operations and optimized performance for virtual network functions while securing an always available cloud and NFVI environment.

The impact of 5G-TRANSFORMER outcomes on Ericsson product portfolio is also relevant for the Ericsson Fronthaul 6000 platform. This product comes in a passive version which provides transport of up to 24 CPRI services over a single fiber and in an active version which implements managed CPRI, eCPRI, OBSAI and Ethernet networking over WDM - when passive solution is not enough and management, demarcation and high availability through ring protection are important requirements. For the Fronthaul 6000 optical-based transport solution an evolution is possible to support the control plane envisioned by 5G-TRANSFORMER.

In this direction, 5G-TRANFORMER has defined an underlying 5G transport network able to provide an agnostic support of radio traffic transmission, in both fronthaul and backhaul segments, supporting current and future radio interfaces (CPRI, eCPRI, and beyond) while complying with broadband, critical, and massive communications needs.

InterDigital (IDCC)

As explained in Section 2.3.3, InterDigital will trial the robotic PoC through 5G NR connectivity, which will be provided by two different 5G-VINNI test sites located in the UK and Spain. To integrate the new RAT, InterDigital intends to use the 5GT-MTP as a mean to dynamically operate, maintain and manage the 5G NR interface.

MIRANTIS

Mirantis has provided a platform for automatic 5GT-MTP layer deployment, which integrates and automatically provisions OpenStack and 5G-TRANSFORMER platform software components. This scenario might also be enhanced with the Kubernetes container management platform for lightweight MEC applications. This will enable automatic 5GT-MTP and virtualization layer deployment across multiple locations

3.3.4 Exploitation Opportunities for Service Providers/Operators

ORANGE

Orange aims to leverage the project assets for Business to Business (B2B) opportunity in the 5G market, providing vertical actors with “ad-hoc” SLA in terms of bandwidth and connectivity but also IT resources (compute/storing). This is considered in Orange joint innovation 5G projects with companies that are market leaders in key sectors of the economy, such as the manufacturing industry, energy or transport, and that have an eye on the future.

The techno-economic achievements, such as the cost model for Network Slices will help in assessing future 5G deployment scenarios and infrastructure investments and to build the rolling plan according to related business.

Orange 5G trial platform will leverage on solution brought by the project to experiment network slicing orchestration and instantiation on real environments. This will be used and further developed in the context of both internal and collaborative projects, such as H2020 phase 3 ones.

Orange will also continue to use and promote research projects results in various standardization bodies, such as 3GPP and ETSI NFV as well as TM Forum for network management issues. Key positions handled by Orange delegates in those standardization bodies (e.g., Working Group Chair in ETSI NFV ISG) will help in promoting our approaches.

TELEFONICA I+D (TID)

From a business perspective, Telefónica will leverage on the experience obtained through 5G-TRANSFORMER to showcase the capabilities of dynamic orchestration of 5G services, in some cases spanning multiple providers as can be the case of the services involving multiple affiliates of the Telefónica group in Europe and Latin America.

From a technological perspective, Telefónica will leverage on the initial work initiated in 5G-TRANSFORMER for the overall slicing provision chain in order to align slicing procedures and operational aspects in 3GPP (e.g., generic slice template processing) and ETSI NFV (e.g., multi-site connectivity procedures) to be supported by a common transport substrate able to be consumed by very distinct customers (residential and vertical 5G, wholesale, etc. etc.), contributing results into standardization bodies and defining requirements for commercial RFQs.

3.4 Exploitation towards other projects and code maintenance

The survivability of project results will also be enforced by using results, like software components, for other projects. A clear short-term example of exploitation of the software in (and together with) other projects are the joint demonstrations carried out with these, in which these other projects could have a first-hand knowledge of the outcomes of 5G-TRANSFORMER, because there was an integration done with components coming from both projects. A list of collaboration activities with other projects (including joint demonstrations) can be found in section 2.1.6.

Additionally, there is also exploitation towards other projects in a mid-to-long-term timescale, by which other projects taking place after the end of 5G-TRANSFORMER take the components developed to adapt the design and code of the project to their respective needs. The most evident case of this is 5GPPP Phase 3 project **5Growth**. Its vision is to empower verticals industries, such as Industry 4.0, Transportation, and Energy with an AI-driven automated and sharable 5G E2E solution. Started in June 2019, 5Growth will leverage on the results of 5G-PPP Phase 2 projects where slicing, virtualization, and multi-domain solutions for the creation and provisioning of vertical services are being developed and validated. In this sense, 5Growth platform will be an evolution of the 5G-TRANSFORMER baseline architecture to provide improved support for verticals with enhanced vertical interfaces, enriched service descriptors and service-specific monitoring information, automated service creation, and service demand forecasting and dimensioning process. This tight link between both projects also implies that the code base of 5G-TRANSFORMER will be the basis on top of which modifications and new building blocks will be added.

Additionally, some components of 5G-TRANSFORMER, like the 5GT-VS reference implementation, has been already adopted as baseline for a network slicing solution in other 5G-PPP phase 2 projects **Slicenet** and **blueSPACE**.

Furthermore, the components related to VSB/VSD catalogues and to the translation between VSDs and NSDs will be extended and integrated into the platform under development in the 5G-PPP phase 3 **5G-EVE** project, one of the ICT 17 5G platform projects. In this case, experiment management information will be added to the regular vertical service management that was already present in 5G-TRANSFORMER. More details are available in D3.3, Section 5.8.

A remarkable part of the survivability of the code is its maintenance, the following section described the procedure followed in this direction.

3.4.1 Code maintenance

3.4.1.1 Vertical slicer

The 5GT-VS prototype SEBASTIAN is released as open source software under Apache 2.0 license and it constitutes the basis for the development of new or extended software modules in other EU projects or products in the NFV MANO stack developed by Nextworks. A custom version of SEBASTIAN is and will be maintained in the Nextworks Github (https://github.com/nextworks-it), at the following repository: https://github.com/nextworks-it/slicer . This custom version implements all the features and internal functionalities developed in the context of 5G-TRANSFORMER, but integrates a custom NFVO driver that enables the interaction between SEBASTIAN and TIMEO, an NFV Orchestrator developed by Nextworks. This particular version of SEBASTIAN is also adopted in the blueSPACE project[1].

In order to facilitate the re-usage of the SEBASTIAN code in other contexts, Nextworks is currently re-engineering the Vertical Slicer software, splitting its functional components in elementary software bundles. This approach will allow to extend the single functional elements of SEBASTIAN (e.g. the VS catalogue, the arbitrator, the Vertical Service Management Function (VSMF), the Network Slice Management Function (NSMF), the NFVO drivers, etc.), which will be re-used as stand-alone software modules or composed in a modular manner to build new software products. This re-engineering process involves the creation of new software repositories dedicated to “common elements” that will be integrated in multiple software prototypes and the organization of the original repository of the Vertical Slicer in multiple branches hosting its different releases.

At the moment, the following new repositories have been created:

- Slicer Identity Management (https://github.com/nextworks-it/slicer-identity-mgmt): this repository hosts the libraries and the software application for the management of users, groups, SLAs and policies.
- NFVO Drivers (https://github.com/nextworks-it/nfvo-drivers): this repository hosts the libraries and the software application to build a service that mediates the interaction with different kinds of NFV Orchestrators exposing a unified interface based on the NFV IFA information models.
- Slicer Catalogue (https://github.com/nextworks-it/slicer-catalogue): this repository hosts the libraries and the software applications of the Vertical Slicer catalogue (for vertical service blueprints and descriptors) and the vertical service

[1] https://www.bluespace-5gppp.eu/

to network slice translator. A branch of this repository (https://github.com/nextworks-it/slicer-catalogue/tree/5geve-release) hosts an extended version of the Slicer Catalogue, used in the portal of the 5G EVE[2] platform. This particular version implements an extended catalogue that stores not only blueprints and descriptors for vertical services, but also the ones related to 5G service experiments, test cases and execution contexts, as modelled in the 5G EVE platform.

The current plan [3] for the evolution of the original Vertical Slicer repository (https://github.com/nextworks-it/slicer) is based on the creation of the following future branches:

- *monolithic*: this branch will host the current monolithic version of SEBASTIAN and will be used mostly for maintenance and bug fixing.
- *split*: this branch will host the "master" of the new modular version of SEBASTIAN. This version will introduce the major functional split between the VSMF and the NSMF, with the option of instantiating each of these components as stand-alone applications and supporting different kinds of communications among them (e.g. via message bus or REST APIs). This split is the basis to evolve SEBASTIAN towards a multi-domain model, with the possibility to support a *1:N* relationship between a single VSMF and multiple NSMFs, as adopted in the EU Slicenet project[4].
- *multi-administrative-domain*: this branch, derived from the *split* branch and thus inheriting its multi-domain functionalities, will further extend this concept to address the service orchestration challenge in environments with multiple administrative domains, each of them implementing their own network slice management solution. The current plan is to adopt this version in the context of the Barcelona pilot in the EU 5G-CroCo project[5], focused on the deployment and validation of cross-border automotive services in 5G infrastructures. Since the changes to support multi-administrative-domain features will be mostly incremental, we will evaluate the possibility to merge this branch back into the *split* one.
- *RAN-management*: this branch, also derived from the *split* branch, will host the extensions needed to support the management of the RAN segment of the network slices. This feature may be adopted in the context of the 5GROWTH project[6]. As for the previous case, since the extensions will be incremental, at the end of the development process the branch will be merged back into the *split* one.

3.4.1.2 Service orchestrator

The 5GT-SO prototype is released as open source software under Apache 2.0 licence. It provides the basis for the development of new or extended software modules for the Network Service Orchestration within upcoming research projects (i.e., EU, national, industrial). A baseline version of the 5GT-SO prototype is available in the CTTC gitlab account (https://gitlab.cttc.es/cttc-cnd/MESCAL[7]) together with the 5G-TRANSFORMER

[2] https://www.5g-eve.eu/
[3] This is a rough plan still subject to changes.
[4] https://slicenet.eu/
[5] https://5gcroco.eu/
[6] http://5growth.eu/
[7] MESCAL stands for Multi-nfvo fEderated ServiCe orchestrAtion pLatform

github account. This version includes all the features and functionalities developed in the context of the EU Project 5G-TRANSFORMER by CTTC.

The current 5GT-SO prototype has been developed following a modular approach. This is to ease its reuse and to foster the inclusion of new features and algorithms. For instance, in the documentation folder, the user can find instructions to include new Placement algorithms (PAs) or to develop a new wrapper enabling the interaction with different available Management and Orchestration (MANO) platforms[8].

The current plan[9] for the evolution of the 5GT-SO prototype is mostly subject to cover future project's needs and/or specific scientific/innovation actions. The idea is to create a branch for each project requesting the modification to the 5GT-SO prototype. Then, once the project finalizes, and based on the scope of the added features and functionalities, these features will be eventually included in the "master" branch, i.e., the original one. In this regard, a new branch called "*5GT-SO-5Growth"* will be created to cover those new developments done within the context of the 5GROWTH project[10]. The emphasis in this project as far as the service orchestrator is concerned is on adding intelligence to the system. Therefore, it will evolve towards a closer interaction with artificial intelligence and machine learning modules for exchanging trained models and also with the monitoring platform as a source of inputs based on which these models are run to generate an orchestration action. Smart orchestration algorithms will also be evaluated. Furthermore, the service federation functionality will be further improved and adapted to the needs of the project.

3.4.1.3 Mobile transport and computing platform

The 5GT-MTP prototype is released as open source under GPL license. The software is available on GitHub and it is written using a modular approach that enables the reusability of single feature in different context. For example, the software can configure the RAN and Ericsson Radio commercial product; this feature will be reused in future Ericsson activities. The abstraction part is a separate Java package that can be easily reused. 5GT-MTP relies on a common framework that is the key component of Android application that make easy to include and extend the software adding new feature and support for different technology domains.

The current plan for the 5GT-MTP evolution is mostly done to cover the need of future projects. The idea is to create one branch for each project where the software will be used and then merge the modification when the code is stable and the its usage in the future project is finished. At the time of this deliverable the 5GT-MTP is planned to be used in two H2020 EU projects: 5GROWTH and 5G-EVE. In the former, the code baseline of 5G-TRANSFORMER will be extended to achieve the baseline 5G architecture to provide end-to-end network slicing, spanning RAN, transport and computing infrastructure. In the latter, the 5GT-MTP will be used to control the Italian site infrastructure in the intensive trial tests; in particular, in this context, 5GT-MTP will be extended by supporting a novel hierarchical orchestration approach of NFV.

Furthermore, the 5GT-CTTC-MTP is a custom implementation of the 5GT-MTP module to better address the particularities and characteristics of the multi-technology transport

[8] Current implementation includes wrappers for Open Source MANO (OSM) and Cloudify as MANO platforms
[9] This is a rough plan still subject to changes.
[10] http://5growth.eu/

network infrastructure available at CTTC. This prototype is released as open source software under Apache 2.0 licence. It constitutes the basis for the development of advanced software modules (bound to the network resource Orchestration within WAN transport networks) performed in upcoming research projects (i.e., EU, national, industrial). A baseline version of the 5GT-CTTC-MTP prototype is available in the CTTC gitlab account (https://gitlab.cttc.es/cttc-cnd/ELECTRA [11]) together with the 5G-TRANSFORMER github account. Such a version includes all the features and functionalities deployed in the context of the EU Project 5G-TRANSFORMER by CTTC.

The 5GT-CTTC-MTP prototype has been developed following a modular approach. This favours its reuse as well as the addition of new features and algorithms. For instance, in the documentation folder, the user can find instructions on how to include new Placement algorithms (PAs) for computing end-to-end paths over a WAN transport network.

The current plan[12] for the evolution of the initial 5GT-CTTC-MTP prototype is subject to future project's needs and/or specific scientific/innovation actions. The idea is to create a branch, for instance, for each project requiring the modification/enhancement to the 5GT-CTTC-MTP prototype. Then, upon project completion, relying on the scope of the added features and functionalities during the project period, such features are included in the "master" branch, i.e., the original one. For instance, a new branch called "*5GT-CTTC-MTP-5Growth"* will be created to support new developments done within the context of the 5GROWTH project[13]. The evolution of the CTTC-MTP to add artificial intelligence and machine learning to the decision process will also apply in this case.

[11] ELECTRA stands for mobilE tranport pLatform for multi-tEChnology neTwoRk infrAstructure
[12] This is a rough plan still subject to changes.
[13] http://5growth.eu/

4 Assessment of the contribution of 5G-TRANSFORMER in support of the 5G standard

As part of the communication, dissemination, standardization, and exploitation activities of 5G-TRANSFORMER, we have a commitment to producing and submitting at least 10 adopted contributions to key Standard Development Organizations (SDOs), such as 3GPP, IETF, or ETSI.

According to the Y2 and Y3 Standardization plan, meeting cycles from SDOs relevant to 5G-TRANSFORMER were to be analyzed to determine the best way to maximize 5G-TRANSFORMER input to overall Standardization activities, thereby improving our contribution rate into these forums.

As part of this analysis it was also made evident that our main inputs are generated primarily towards the following Standardization groups:

- ETSI NFV,
- ETSI MEC,
- IETF, and
- 3GPP SA2.

Our analysis also made evident something perhaps expected, although not necessarily obvious. The Study Phase and the Feasibility Phase of the project, when System Design and Architecture components are being defined, yields the best opportunities for dissemination, which explains the high output during Y1 and Y2. In addition, key SDO interrupted activities during the 2019 Summer months. For instance, 3GPP SA2 did not hold Standards meetings from the end of June to the beginning of October, however once Standards activities were resumed, 5G TRANSFORMER once again contributed to the industry submitting yet one more contribution to 3GPP Standards forums (SA2) during the 3GPP SA2 November meeting in Reno, NV. USA.

Nevertheless, given the maturity reached in the generation of relevant contributions to the main standardization bodies, 5G-TRANSFORMER has maintained a healthy and steady rate of relevant dissemination into key SDOs, allowing us not only to meet our goals but significantly exceeding them, and thus proving that our commitment toward dissemination into key SDOs, has been take from the beginning to the end of the project. This has been achieved by focusing the efforts of the SAC team in the writing and presentation of these contribution into the SDO groups as outlined above, while requiring minimum disruptions to the rest of the project activities, just as planned for Y2 and Y3.

Note that we include figures for the whole project (i.e., both Y1, Y2 and Y3 are shown in Table 35, Table 36 and Table 37), but we clearly specify what numbers belong to what reporting period.

To conclude, we want to emphasize the impact our project has had in the 5G Ecosystem. We would like to express this highlighting three main areas:

1. **Examples of key contributions adopted by two of the main 5G Industry Standards** (3GPP – TS23.501 and TS23.502 and IETF):

    a. ***Network Virtualization Research Challenges*** https://tools.ietf.org/html/rfc8568: This is an important contribution with significant impact in the industry. A testament of this fact is that this

contribution has become an RFC (as opposed to just a draft), which is a significant achievement.

Furthermore, this contribution provides a system wide view in the area of network virtualization, and in particular, the concept of multi-domain orchestration. The contribution is relevant to two of three architectural components of 5G-TRANSFORMER, namely 5GT-MTP and the 5GT Service Orchestrator.

b. *Slice-specific Authentication*
A second highlight that we want to set forth is a 3GPP WG SA2 Change Request (CR) proposing normative text to implement Slice-specific Authentication, Technical document S2-1905306.

This contribution has significant impact in the industry due to the fact that on top of been accepted, the proposal has already become part of the Key 5G 3GPP Architecture Specifications TS 23.501 and TS 23.502. Specification that are and will be used to design 5G Systems. The contribution is relevant to the Vertical Slicer and in particular to the aspect of implementing Service Level Agreements ad described within section 2.1, in deliverable D3.3.

c. *Introducing Network Slicing as a new Work Item (WI) in ETSI MEC*
A third highlight with significant impact is the successful introduction of slicing as a Work Item within ETSI MEC promoted by 5G TRANSFORMER as outlined in contribution ETSI MEC24 entitled “Multi-Access Edge Computing (MEC) Support for Network Slicing” summarizing how Network Slicing is being addressed in multiple Standards forums and it sets the basis for the identification of key issues and their solutions within ETSI MEC. The final standard document – ETSI GR MEC 024 V2.1.1 (2019-11) – has been published on November 2019.

2. Key Achievements:

a. *Outstanding Output*: We have achieved significant dissemination results in the area of Contribution to Key SDO. Not only have we met our Goals, but we have exceeded our Goals by two fold.

According to the DoA, Objective 8, we were expected to produce at least 10 adopted contributions to SDO, such as IETF, IEEE, ITU or 3GPP. We have already achieved 24 (adopted/accepted/agreed) contributions.

b. *Thorough System-Wide Coverage.* We have managed to bring contributions to Key SDO (including IETF, ETSI MEC and 3GPP) with content relevant to all the main architecture components of the project, including MTP, Service Orchestrator and Vertical Slicer, as a testament that we brought quality material, that has been scrutinized by industry experts and agreed to be adopted
By doing so, we effectively covered most 5G concepts, as described in section 3.3 where the main aspects of the system components are highlighted, including Edge Computing (e.g., Wireless Edge Factory), Multi-Domain Orchestration (e.g., Dynamic Orchestration) and Mobile Transport and Computing Platform (e.g., Mobile Transport and Computing Platform and in particular its Enhanced Placement feature).

Furthermore, a clear example of the impact that 5G-TRANSFORMER had is that in the NGMN E2E architecture white paper entitled “5G End-to-End Architecture Framework v3.0.8” released in September 2019, the 5G-TRANSFORMER overall vision, aligned with that of NGMN, is mentioned. Another example of that is the contribution to the 5GPPP white paper entitled “View on 5G Architecture v3.0“, release in June 2019.

5 References

[1]. IPR Helpdesk. “IPR glossary”. Available at: https://www.iprhelpdesk.eu/glossary

[2]. A. Ruete. “Communicating Horizon 2020 projects.” Available at: https://ec.europa.eu/easme/sites/easme-site/files/documents/6.Communication-AlexandraRuete.pdf

[3]. 5G-TRANSFORMER. “Communication, Dissemination, and Exploitation achievement of Y1 and plan for Y2”. Deliverable D6.2, June 2018.

[4]. 5G-TRANSFORMER. “Initial Communication, Dissemination, and Exploitation Plan (CoDEP) draft including Standardization roadmap”. Deliverable D6.1, November 2017.

[5]. 5G-TRANSFORMER. “Final design and implementation report on the MTP (including reference implementation)”. Deliverable D2.3, June 2019.

[6]. 5G-TRANSFORMER. “Refined architecture”, Deliverable D1.3, June 2019.

[7]. 5G-TRANSFORMER. “Final design and implementation report on Vertical Slicer (including reference implementation)”, Deliverable D3.3, June 2019.

[8]. 5G-TRANSFORMER. “Final design and implementation report on Service Orchestration, Federation and monitoring platform”, Deliverable D4.3, June 2019

[9]. European Commission. Common Dissemination Booster (CDB). Information available at: http://ec.europa.eu/research/participants/data/ref/h2020/other/comm/170927_cdb_en.pdf

[10]. 5G-TRANSFORMER. “Report on WP6 progress and update of CoDEP”, Deliverable D6.5, May 2019

6 Annex I. Survey of overall satisfaction of attendees to events (co-)organized by 5G-TRANSFORMER

The metric of the CoDEP related with event organization, is the degree of satisfaction of the attendees. In this section, we present the result of the polls gathered for all events organized by 5G-TRANSFORMER (Figure 8). We observe that a huge percentage of the attendees was satisfied with the technical content and organization of the event. The percentage of satisfied and very satisfied users is well above 70% (95%). The same happens in the case of the SME exploitation workshop.

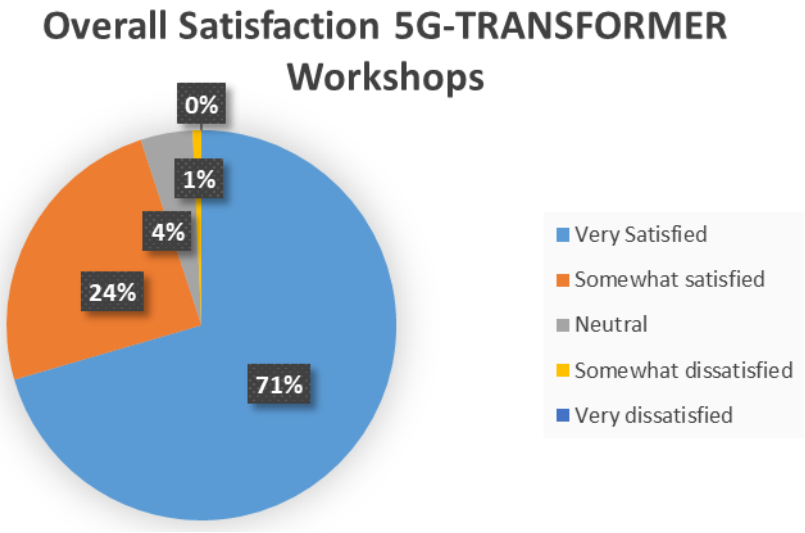


FIGURE 8: SURVEY ON OVERALL SATISFACTION FOR ALL EVENTS ORGANIZED BY 5G-TRANSFORMER

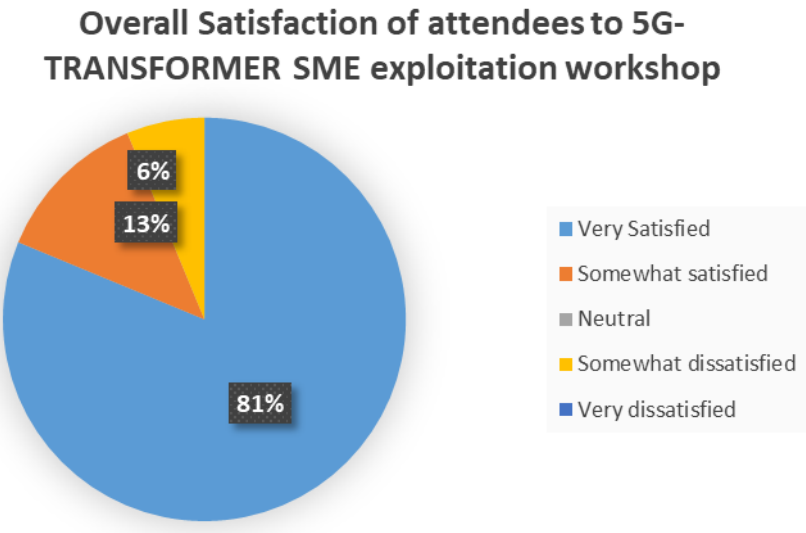


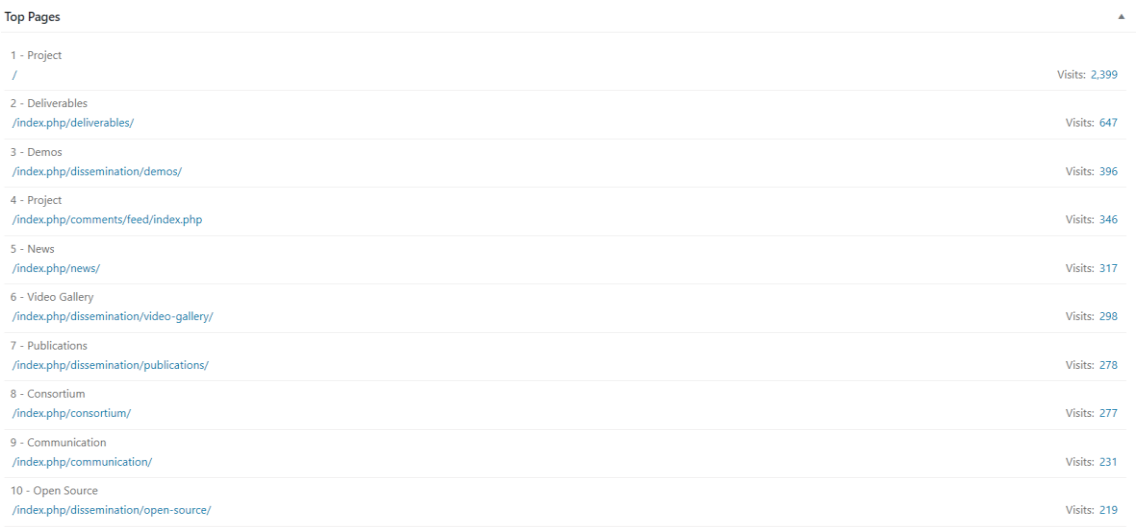
FIGURE 9: SURVEY ON OVERALL SATISFACTION OF THE SME EXPLOITATION WORKSHOP AT EUCNC'19

7 Annex II. Statistics of Web and Social Media

In this annex, sample metrics obtained for the website and the social media of the project are presented. Overall, the visits/hits and other social media metrics (impressions, retweets, etc.) kept increasing throughout the project lifespan, which resulted in an increased awareness of the community of the 5G-TRANSFORMER results.

7.1 Statistics of the 5G-TRANSFORMER website

In this section, we provide some examples of the statistics that were gathered during the project lifetime to show the evolution of this metrics. In particular, Figure 10 shows the Top 10 most visited pages of the 5G-TRANSFORMER website in two different periods. The first period is from September to December 2018. The second period is from April to June 2019. One can observe that the more specific technical content (e.g., deliverables, papers) is the one attracting more attention, though the rest of the content also receives remarkable visits. Additionally, as example, in period from September to December 2018, the observed visits are around 12000, while in the April to June 2019 period they are 6500, and in the July to September 2019 one they are 9300.



(a) September to December 2018

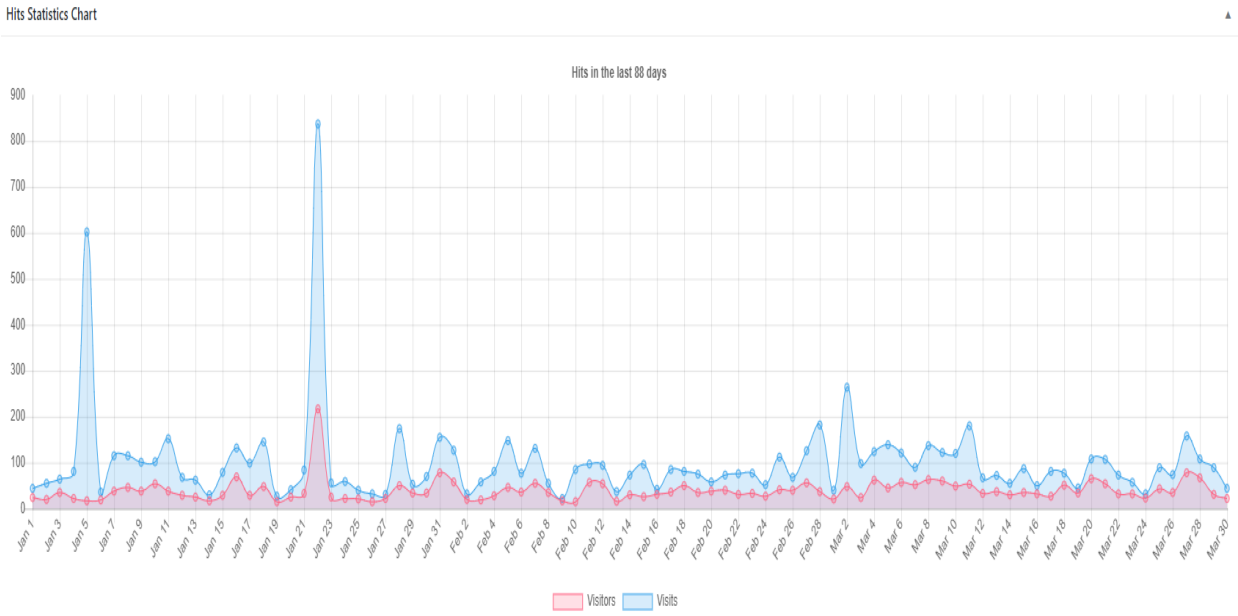
Top Pages

ID	Title	Link	Visits
1	Project	/	1,013
2	Journals and Magazines	/index.php/dissemination/publications/journals-and-magazines/	611
3	Deliverables	/index.php/deliverables/	598
4	Publications	/index.php/dissemination/publications/	253
5	Communication	/index.php/communication/	252
6	Visit of Juan Carlos García, from Telefonica GCTIO	/index.php/2019/04/17/visit-of-juan-carlos-garcia-from-telefonica-gctio/	226
7	Consortium	/index.php/consortium/	199
8	FrontHaul & BackHaul Convergence for 5G Use Cases	/index.php/2019/04/12/fronthaul-backhaul-convergence-for-5g-use-cases/	196
9	Contacts	/index.php/contacto/	184
10	Project	/index.php/communication/index.php	180

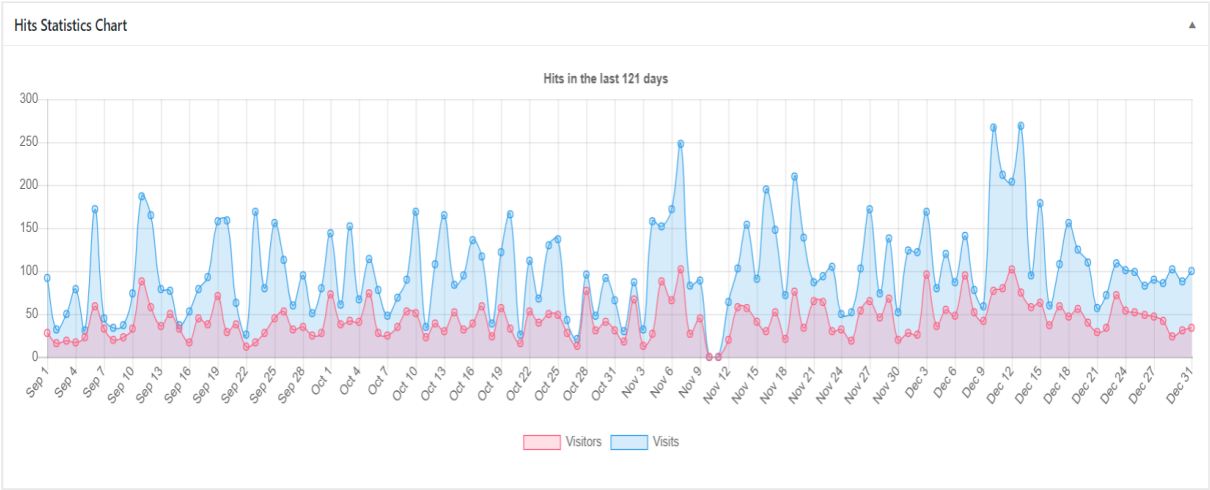
(b) April to June 2019

FIGURE 10: TOP VISITED PAGES OF THE 5G-TRANSFORMER WEBSITE

Figure 11 shows a sample hit statistics chart. In particular, the hit statistics from January to March of 2019 are presented in Figure 11(a). While Figure 11 (b) shows the hit statistics from September to December 2018. Figure 12 illustrates a summary of the last 365 days, where the visitors are more than 16000 with around 36000 visits, which are the usual numbers throughout the project.



(a) January to March 2019



(b) September to December 2018

FIGURE 11: HIT STATISTICS CHART

Summary

Online Users: 2

	Visitors	Visits
Today:	20	47
Yesterday:	49	131
Last 7 Days:	332	653
Last 30 Days:	1,424	2,592
Last 365 Days:	16,094	35,933
Total:	25,910	57,797

FIGURE 12: SUMMARY OF WEB STATISTICS FOR THE LAST 365 DAYS

The number of downloads of posters and leaflets was also monitored. The most popular leaflet almost reached 1000 downloads.

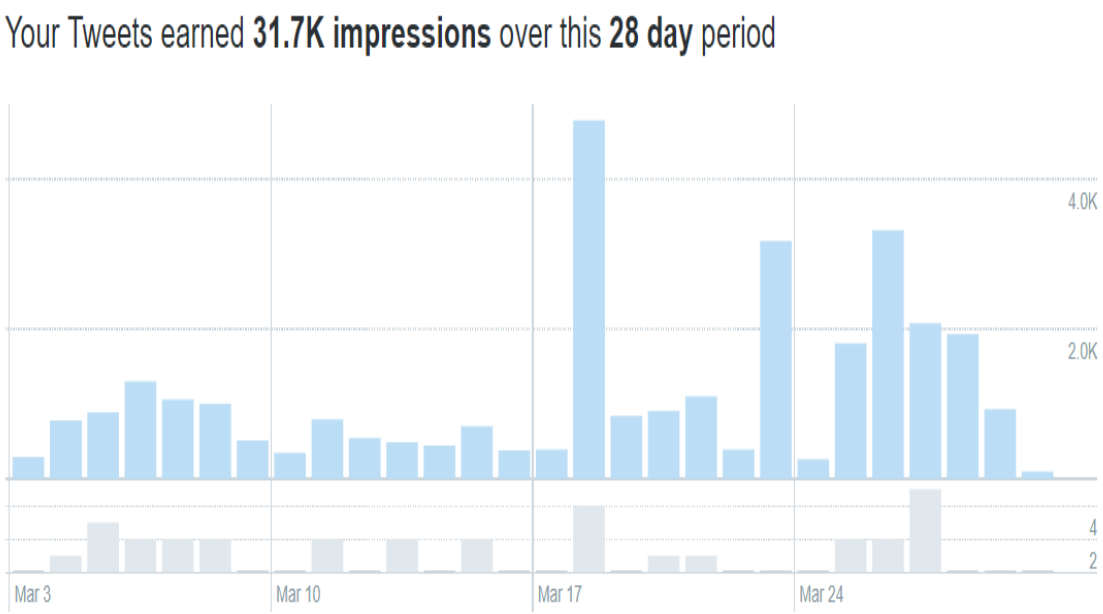
	ID	FILE			DOWNLOADS
Leaflet	1059	http://5g-transformer.eu/wp-content/uploads/2017/08/Transformer_leaflet-1.pdf	—	—	963
Poster	1058	http://5g-transformer.eu/wp-content/uploads/2017/08/5G-Transformer-poster-1.pdf	—	—	762
Project Factsheet Edit | Quick Edit | Trash | View | Clone	1052	http://5g-transformer.eu/wp-content/uploads/2018/09/5GPPP_Project_Factsheet_5G_TRANSFORMER_v03-1.pdf	—	—	875
5G TRANSFORMER Brochure MWC2018	1064	http://5g-transformer.eu/wp-content/uploads/2019/01/5GTransformer-brochure-MWC18.pdf	—	—	144
5G TRANSFORMER Brochure EUCNC18	1062	http://5g-transformer.eu/wp-content/uploads/2019/01/5GTransformer-brochure-EUCNC18_euflag.pdf	—	—	161

FIGURE 13: NUMBER OF DOWNLOADS OF LEAFLETS AND POSTER DURING 2019

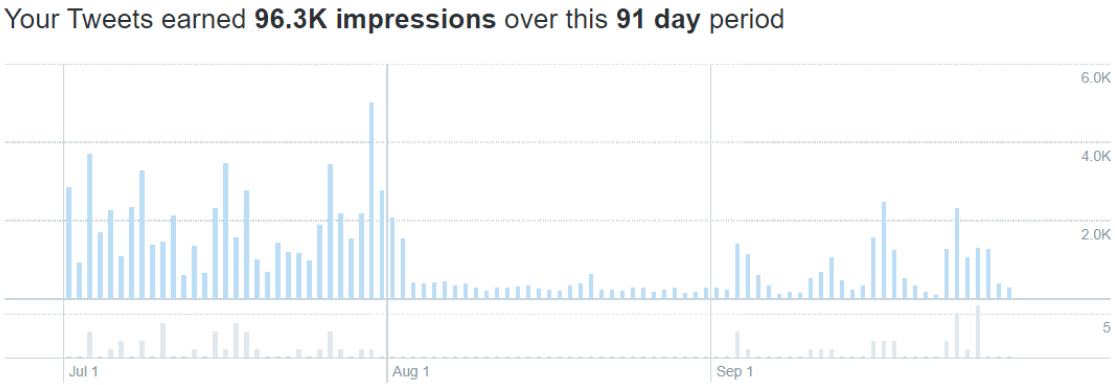
7.2 The statistics of 5G-TRANSFORMER Twitter

In this section, the Twitter impact statistics are presented, especially the impact from monitored information of published content as shown in Figure 14. Figure 15 (a) to (d) present some samples of statistics of published content. They reflect the common behavior during the corresponding period durations (i.e., 1 month, and 3 months) as well as interests of Twitter users interacting with the content of the project and a sample of various other statistics that have been periodically gathered (e.g., engagement rate, retweets). As can be observed below, 96000 impressions were reached despite the summer holiday period in three months. Furthermore, the number of followers and the interactions with the tweets steadily increased throughout the project, reaching 934 followers towards the end of the project.

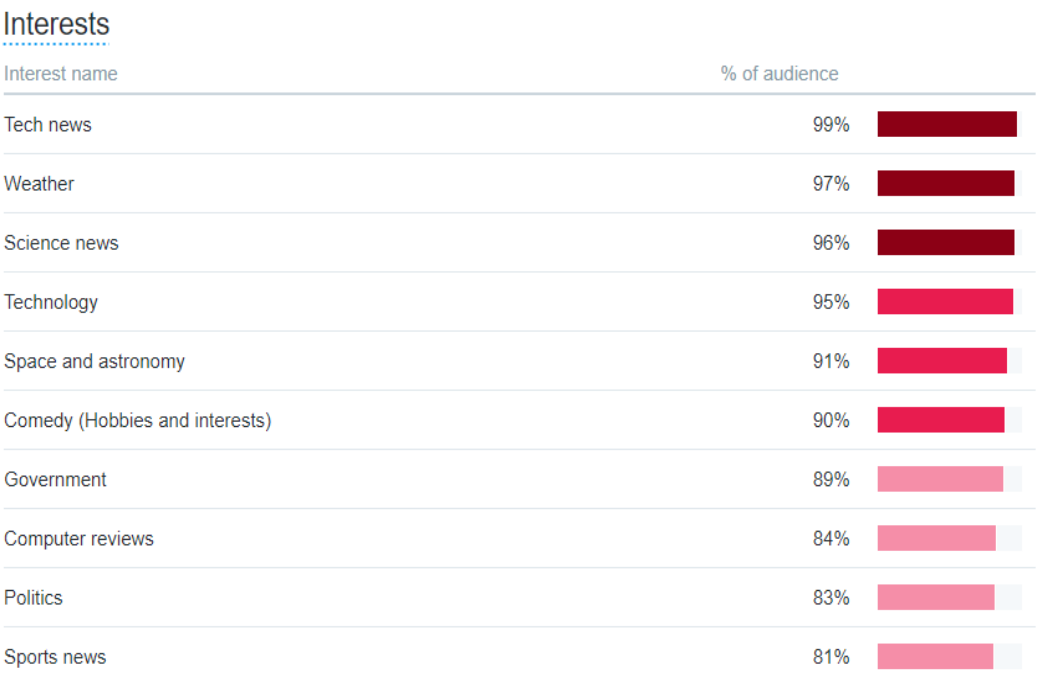
FIGURE 14: SAMPLE 5G-TRANSFORMER TWITTER ACCOUNT ACTIVITY (IN MID JUNE 2019)



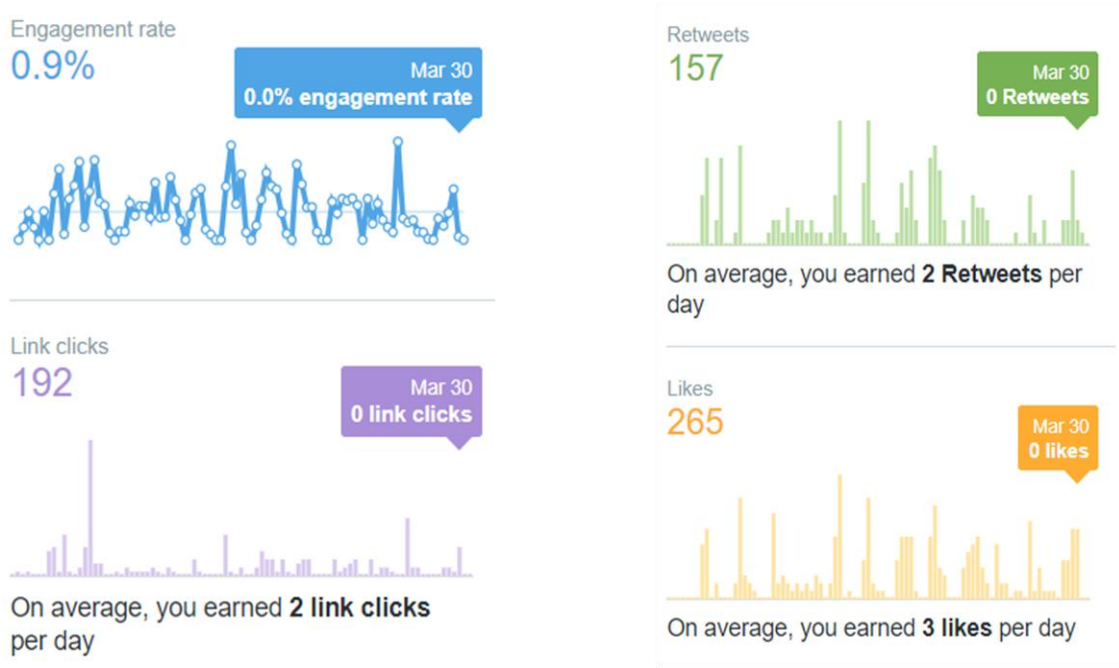
(a) Sample Twitter account activity (impressions): March 2019



(b) Overall view of Twitter impressions between July to September 2019



(c) Sample Twitter information: Top interests



(d) Sample Twitter activity statistics during January and March 2019

FIGURE 15: SAMPLE TWITTER STATISTICS JANUARY-MARCH 2019

7.3 Instagram, Youtube, LinkedIn

In the course of 5G-TRANSFORMER, the aforementioned materials in 5G-TRANSFORMER have posts in other social media (Instagram, LinkedIn and YouTube). The same trend as in Twitter is observed in the rest of social media, though with a lower intensity. For instance, in Instagram, as of September 2019, the project has 98 publications with 57 followers and 1267 LinkedIn followers. As an example, the 5G-TRANSFORMER high-level video had more than 261 visualizations between January and March 2019 and the watch time is more than 460 minutes (in addition to those during the events in which it was played, such a Mobile World Congress 2019). Technical videos were recorded and published on the YouTube channel for some of the demonstrations of the project (e.g., EUCNC 2019). In total, the project videos reached 2100 visualizations. More statistics of top most visited videos of YouTube are shown in Figure 16 and Figure 17 for two different periods.

Video	Impressions	Impressions click-through rate	Views	Average view duration	Watch time (minutes)
Total	2,480	2.8%	261 100.0%	1:46	464 100.0%
5G-TRANSFORMER: 5G Mobile Transport Platform for V...	598	2.8%	86 33.0%	2:09	186 40.1%
5G network slices for media vertical services	199	3.5%	31 11.9%	2:22	74 15.9%
Using cloudify and public & private clouds to deploy and...	41	2.4%	19 7.3%	3:17	63 13.5%
5G network slices for mobile communication services	291	6.9%	49 18.8%	1:00	49 10.6%
5G TRANSFORMER, 5G Mobile TRANSport platFORM fo...	708	1.0%	24 9.2%	1:18	31 6.8%
Cloud Robotics	469	2.6%	27 10.3%	0:52	24 5.1%
nxw_atos_instantiation	0	n/a	3 1.1%	4:15	13 2.8%
Edge Robotics- Courtesy of Imdea Networks	31	6.5%	10 3.8%	0:56	9 2.0%
nextworks_atos_v1-3	0	n/a	2 0.8%	4:03	8 1.7%

FIGURE 16: SAMPLE YOUTUBE FROM JANUARY TO MARCH 2019

Video	Impressions ↓	Impressions click-through rate	Views	Watch time (minutes)	Unique viewers
Total	**1,047**	**3.1%**	**152** 100.0%	**263** 100.0%	**0** 100%
5G-TRANSFORMER: 5G Mobile Transport Platform for Verticals	249	2.8%	51 33.6%	112 42.5%	– –
5G TRANSFORMER, 5G Mobile TRANSport platFORM for vERticals	196	1.5%	11 7.2%	13 4.9%	– –
Cloud Robotics	173	1.2%	10 6.6%	11 4.1%	– –
5G-TRANSFORMER Demo MobiHoc 2019	93	8.6%	32 21.1%	50 18.9%	– –
5G network slices for mobile communication services	88	3.4%	11 7.2%	15 5.7%	– –
5G network slices for media vertical services	65	3.1%	11 7.2%	23 8.7%	– –
5G-TRANSFORMER DEMO at NEM SUMMIT 2019	51	7.8%	6 3.9%	10 3.8%	– –
Interview with 5G TRANSFORMER project coordinator, Arturo Azcor...	31	6.5%	8 5.3%	6 2.3%	– –
5TONIC Projects	27	0.0%	– 0.0%	– 0.0%	– –
Edge Robotics- Courtesy of Imdea Networks	27	0.0%	5 3.3%	6 2.2%	– –

FIGURE 17: SAMPLE YOUTUBE FROM JULY TO SEPTEMBER 2019