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**ICT - Information and Communication Technologies**

**Deliverable D1.3**  
**EMPOWER Strategy Document and**  
**Collaboration Roadmap v2**

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## Executive summary

This second update of the EMPOWER Strategy Document and Collaboration Roadmap presents the results of the discussions reached so far, after 28 months of project implementation. It includes both the updated strategy for collaboration and the planned roadmap/agenda of activities and collaboration opportunities for the medium term (by the end of the project). This document focuses on the definition of the key challenges to overcome for a fruitful collaboration and a deep analysis of the different actors involved in the research on advanced wireless communication platforms.

Considering the unexpected situation due to the outbreak of the COVID-19, early 2020, the consortium had to reshape a significant part of the strategy and activities initially planned in the previous versions of the EMPOWER Strategy Document and Collaboration Roadmap. The restrictions, especially in the field of travels and joint events, set up in most of the countries around the world and the uncertainty about the duration of these restrictions obliged EMPOWER partners to re-organize their activities to ensure the impact of the project.

Part of this document will focus on the updated strategy and the plan designed to guarantee the impact of EMPOWER on the community and its role as a catalyst between the EU and the US. This version will be the last one before the final update of this roadmap, due at the end of the project (April 2022).



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## 1. Introduction

Since 2018, the goal of EMPOWER is to establish a trust and sustainable relationship and thus reinforce the cooperation between the EU and the US on the new connectivity frontiers beyond 5G with a particular focus on advanced wireless platforms. EMPOWER has developed strong ties with the NSF Programme for Advanced Wireless Research (PAWR) as well as other projects such as NSF Fabric. We are also closely connected with the ecosystem of European and National projects in these domains.

The objectives of the EMPOWER Strategy Document and Collaboration Roadmap (D1.3) are the following:

- Provide an analysis of the activities implemented during the first period of the project;
- Organize the dialogue between the EU-US communities working on Advanced Wireless Platforms research and development, in particular the US NSF PAWR and the EU H2020/Horizon Europe;
- Develop and recommend a common EU-US strategic collaboration agenda on Advanced Wireless Platforms.

The main expected impact of this document is to show how we collect the demand, anticipating the future challenges in wireless networking and accelerating the related research agenda, and how we organize the dialogue to the benefit of the two parts.

Even if this document is aligned with the original plan, it has been significantly reshaped to cover the impact of the COVID-19 outbreak on EMPOWER's transatlantic activities. Because of the unpredictable situation and the fuzzy horizon that will certainly preclude all forms of physical interactions, we decided to reshape partly the organization of the dialogue.

We identified that what is necessary and missing, is a virtual place where the community will be able to meet and discuss topics of mutual interest. Of course, this should not overlap with all events (conferences) going virtual. A simple analysis shows that although online conferences allow a larger and more inclusive access, they lack the fora for discussion that is enabled by on site events. In addition, such a virtual place should be easily accessible and organized as a TV channel with interactions. Of course, we do not want to disseminate continuous content but provide an opportunity for the community to meet at regular times, even if the programs will also be recorded.

The main tool created for this purpose is *theNetworkingChannel*<sup>1</sup> whose aim is to propose to the community a regular *rendez-vous* to present and exchange on different topics of interest for the community. This concept of the channel was originally planned for the broadcasting of the EMPOWER/PAWR programs. However, during its design, it became so popular that we received several requests from other organizations to join and we finally decided to accept the sponsorship from ACM Sigcomm, the premium community dealing with our topics, a label of excellence and sign of recognition. As a consequence, the channel will be made even more inclusive. This will be further detailed in section 3.3.

The rest of this document is structured as follows. Section 2 presents the revised main challenges associated to the building of the transatlantic collaboration. Section 0 proposes a review and evolution of Strategy Document and Collaboration Roadmap, considering the current constraints. Section 4 presents an update of dissemination and community building activities. Last but not the least, the annexes I (6) and II (7) have also been revised and updated, with the new activities, especially in Europe.

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<sup>1</sup> <https://networkingchannel.eu>



## 2. Key Challenges for EMPOWER Collaboration Roadmap

Our mission and role are to promote the EU-US cooperation regarding research infrastructures as scientific instruments: *“Research Infrastructures are facilities, resources and services that are used by the research communities to conduct research and foster innovation in their fields”<sup>2</sup>*.

Existing initiatives are already providing the research and engineering community **with a fully controllable, programmable virtualized digital infrastructure test platform** and they should act as a **catalyst** to enable and foster the data-driven science and scientific data-sharing in this area.

Open research data should be considered together with the test platform and ultimately contribute to the deployment of a data repository where all data produced by the platform could be made available under the FAIR principle and initiatives such as EOSC<sup>3</sup> in Europe.

In this context, **EMPOWER aims to play this catalyst and coordination role between EU and US regarding Digital Research Infrastructures** in the domain of advance research platform, 5G and beyond:

1. **Engaging the scientific community** primarily centered in the design of large-scale digital infrastructures (e.g., distributed systems, networking, wireless research, interoperability/testing, embedded systems, software engineering, system management, security, reliability, etc.). This is the reason why anticipating the demand is instrumental in order to equip the test platform with the right components to answer the scientific research questions.
2. **Involve stakeholders** from supply side to demand side, enabling the testing of new technologies but also accelerating the deployment of transformative services;
3. **Inform the community** regarding various emerging initiatives that are or could be related; for instance, on the US side, PAWR does not have a direct role but as an ecosystem is following the following important initiatives: DoD [5G-to-NextG](#) (2.5B\$), DARPA [OPS-5G](#) and OPA-5G, [ATIS NextG alliance](#) and [MITRE Engenuity](#) (UAS experiments) and [MAGMA](#) Linux Foundation (Open Source 5G Core network and FCC O-RAN Forum. Likewise, in Europe, Horizon Europe SNS Partnership (The SNS JU Partnership Proposal document is available<sup>4</sup>).
4. **Propose a coherent vision and roadmap to policy-makers** in research infrastructures in Europe and the USA;
5. **Federate research communities** working on these subjects from software and computer system architects to transversal (vertical) applications. Articulate with other important relevant initiatives (O-RAN, OMEC, etc...);
6. **Facilitate bi-(multi) lateral initiatives** leading to a better use and development of research infrastructures in this area.

In order to reach the six above-mentioned objectives, we consider necessary to build our strategy around a series of key questions or challenges. These questions, raised at the beginning of the project and revised, have been evolving over the last months. Moreover, it is worthy to remind that the partners have been working on the demand and define the second technology roadmap for advanced wireless, prepared in parallel to this document. Most importantly, a strong trust relationship has been established with our peers in the US, including

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<sup>2</sup> <https://www.esfri.eu/esfri-roadmap-2021>

<sup>3</sup> <https://www.eosc-portal.eu/>

<sup>4</sup> [https://ec.europa.eu/info/files/european-partnership-smart-networks-and-services\\_en](https://ec.europa.eu/info/files/european-partnership-smart-networks-and-services_en)



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the funding agencies (like NSF). We will consolidate this collaboration thanks to the ties developed during the upcoming Networking Channel.

## **2.1 Evolution of the scientific community and stakeholders' involvement**

As mentioned in the previous version of this Strategy Document and Collaboration Roadmap, some of the key challenges to be addressed to engage the scientific community and involve the main stakeholders to build this community are the following:

1. What are the key actors that we need to involve in Europe and USA to foster collaboration between both regions in the topic of Advanced Wireless research?
2. How do we engage communities on both sides of the Atlantic to foster collaboration between them?
3. How can we support joint activities, how to mobilize the resources made available for that purpose?
4. What are the events with a higher presence of researchers from EU and USA on the Advanced Wireless communications topic?
5. How to engage the communities on both sides despite the restrictions due to the COVID-19 pandemic?

During the last period of EMPOWER, different activities have been developed to build this relation. EMPOWER has participated in different events (see section 3.1) to build such communities. In the remaining time of EMPOWER, we will also focus in the Networking Channel as the main venue to engage the community around key topics following the objectives described above.

## **2.2 Updated areas of collaboration**

As explained in the previous version of the Strategy Document, the consortium is developing a tight cooperation on the general topic of "Advanced Wireless Platforms", namely the instruments that should leverage the research and innovation in the general domain of digital infrastructures.

After coordinating with US colleagues, it has been decided to focus on three main areas of collaboration (reference architecture, reproducibility, AI). Those topics were suggested as a starting point to launch the discussions and engage the scientific community and the stakeholders on key challenges existing on both sides of the Atlantic. This list of topics will evolve during the project lifetime depending on the needs and expectations of the community, especially thanks the questions raised during the Networking Channel.

This list of the 3 topics was defined in the 2<sup>nd</sup> White Paper<sup>5</sup>, published in June 2020.

### **2.2.1 Reference architecture**

The design of an overall reference architecture is an important target in order to identify the main components that should be considered, their level of maturity as well as the global articulation. This objective is of utmost importance if we want to sustain the design and deployment as well as ease the interoperability at all levels and ensure the agility of platforms over several years. This is discussed in conjunction with various ongoing joint activities aiming at unifying experimental wireless platform architectures within Empower WP3.

### **2.2.2 Reproducibility**

Repeated research is a difficult challenge but a full part of the test platform best practices in all domains. The longer-term objective is to reach out to the main stakeholders, professional societies and conferences, with recommendations arguments and potential solutions for embedding reproducibility in the research life-cycle.

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<sup>5</sup> <https://www.advancedwireless.eu/index.php/2nd-empower-white-paper/>



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The first cycle is mostly about information and community engagement and will be integrated in the newly created [theNetworkingChannel](#).

In addition, a first panel about reproducibility were organised during INFOCOM 2020, as part of the CNERT session and confirms the motivation of the community.

### **2.2.3 AI**

The place of AI is growing up in the domain of Beyond 5G and 6G networks. There already exist different places where the topic is intensively discussed. Therefore, it is important to us to understand what the impact will be on the future test platforms and how we can embed the appropriate components upfront. We try to incentivize different actions dealing with this topic. As illustration AI research and innovation will be addressed in both EC Horizon Europe Programme (e.g., AI, Data and Robotics Partnerships and Smart Networks & Services Partnership) and Digital Europe Programme (European data spaces, Large Testing and Experimentation Facilities, scale up the European AI platform to access tested AI technologies). RThis topic is also going to be addressed in a spring session of The NetworkingChannel.

## **2.3 Proposed vision and roadmap to policy-makers**

### **2.3.1 Building Advanced Wireless Platforms**

Advanced wireless platforms development is essential for reaching a predominant position in the next generation of wireless technologies. As defined previously, the following challenges and potential questions to be developed further have been identified and updated based on the work carried out in EMPOWER:

#### *1. What kind of experimentation are researchers looking at?*

After the consultation and deep discussion with researchers in the area, we can conclude that there is a growing interest in testing end to end solutions, where different technological blocks may be swapped and provided by researchers. The lack of a full end to end platform is hindering the possibilities of researchers and may impose limitations in the future development of 6G research.

#### *2. What are the needs from researchers, is only PHY research look for or research in control approaches is also needed?*

PHY layer research has always required platforms to develop new physical layer solutions. Although typically when we thought about research platforms, we tend to think on expensive equipment mostly focused in physical layer research, there is a growing interest on testing control approaches, requiring end to end infrastructures as described above. Therefore, not only physical layer equipment is required, but the software components are gaining importance, requiring interactions between the control software and the actual boxes composing the network. This interaction must be based on common open standards to enable innovation. Currently there is a gap in the available infrastructures regarding this point.

#### *3. What kind of hardware is the best to build such a platform?*

We believe current trend is to combine SDR-capable hardware with white boxes for the software components. We can see this trend in O-RAN based experimental setups. Also, we cannot disregard that in parallel with this option, there are multiple innovation laboratories (specially for 5G research) that are opting for the adoption of a complete pre-commercial setup from a vendor. Although this allow these laboratories to develop near to



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market scenarios, it is very complex the innovation of specific components (vendor lock in) or of the control plane.

4. *Can we federate domains at both sides of the Atlantic to cover gaps in the deployment of the platforms?*
5. *What is the best way of connecting the platforms?*

We will cover items 4 and 5 above in this same paragraph as they are tightly coupled. There have been several attempts by partners of EMPOWER and USA entities to build examples of such a federated environment. We have found multiple issues which have yield towards a limitation in the nature of the experiments that can be tackled, specifically:

- Lack of high-speed, none-limited connections. Normal connections between USA and EU entities suffer from high delay (not only due to the distance) and jitter. Sub-optimal routing, and other problems are complicating the interconnection of the entities, resulting on a reduction of the possibilities of research, only allowing scenarios where a medium to high latency can be assumed.
- A possible solution to the above issue is the use of research networks such as GEANT, although they require strong investment in time in order to set them up.

These two main problems we have faced during the setup of experiments left us with the only choice of performing experiments in the roaming scenario, where the terminal is considered connected to a foreign network and control can be accessed in a home network.

6. *Is there some way of connecting with industry, is pre-commercial hardware of any use?*

There is a growing interest of industry on using this kind of platform, specifically of SMEs which see the testing platforms as a way of preparing their products and testing them over new technologies. Pre-commercial hardware is a very interesting approach towards enabling end to end solutions to test services, although they fall short as a mechanism to test or validate new technologies or control mechanisms since typically vendors do not allow any kind of modification.

7. *Who are the users of the platforms? In Europe, we are very focused on verticals, for Beyond 5G will it be the same?*

Currently platforms in Europe are focused on verticals since they were setup later in the process of 5G development. Due to the growing interest detected in the different stakeholders, we believe setting up a European infrastructure for networking research early in the process of 6G research will be good for the purpose of leading the research in this area.

8. *What components should be available in the platforms? Only PHY, MAC? Complete end to end, Core?*

We believe the platform should encompass a modular end to end network, composed of interchangeable blocks implementing each basic functionality.

### **2.3.2 Impacting Standard**

The year 2020 witnessed a significant momentum around B5G visions, research and standardization roadmaps in particular. At the same time the ITU-R WP5D issued its recommendations of the IMT-2020 radio interface technologies, it has started the work on a new report for future technology trends towards IMT-2030 and beyond. The NGMN has also recently launched its 6G vision working group. ETSI has also launched two groups, TREND and RISE, which encompass the technology areas with impact on ETSI standards in the years to come.



EMPOWER has been actively following the activities in standards around beyond 5G standards roadmap and issued its second technology roadmap recently (February 2021) by accounting of the trends in these standardization bodies. EMPOWER also provided into these standard bodies as an input to ETSI TREND and RISE groups. Moreover, EMPOWER through the technology roadmap activity in WP2 has also taken a key role in the 5G-IA pre-standardization working group in its mission to develop a pre-standardization roadmap. This is anticipated to lead to a guideline roadmap which will be circulated to EU research stakeholders, but also to international collaborating countries like the USA, South-Korea, Japan, China, India, and Brazil.

Furthermore, EMPOWER has assembled a session on the 6G standardization roadmap at the 6GSymposium Spring 2021 Edition Europe, May 4-6, 2021. The session includes representatives actively involved in the roadmap to 6G in organizations such as ITU-R, 3GPP, ETSI, IETF and IEEE, as well as opensource forums such as ONF, O-RAN, OAI, and others.

The project has also been actively monitoring cross-standards activities around experimental platforms for 5G and beyond, such as the ITU, ETSI and IEEE Joint SDOs Brainstorming Workshop on Testbeds Federations for 5G and Beyond: Interoperability, Standardization, Reference Model and APIs, 15-16 March 2021<sup>6</sup>.

### 2.3.3 Impacting Radio Spectrum and Regulators

Recognizing the high importance of spectrum issues for the EMPOWER strategy discussion, we defined the following questions in the previous version of the Strategy Document and Collaboration Roadmap (v1, D1.2) can be defined:

- Which new spectrum bands are being considered for the 5G evolution?
- Will new and relevant spectrum bands be available for research and experimentation in Europe and US before licensed to operational use?
- What are the spectrum regulation trends pointing forward?
- Will EU and US work towards a harmonization, both on specific frequency bands and conditions for usage?
- Will there be reserved bands for e.g. propagation studies?
- What will come out from WRC-19 related to spectrum beyond 5G and what will be the agenda for WRC-23?
- How can we influence spectrum regulations for the purpose of good conditions for research and experimentations?

The general trend is a push towards higher frequencies, into sub-THz bands. ITU WRC-19 identified quite a few bands between 24 and 71 GHz for IMT-2020. It also includes bands specially identified for the use of HAPS (High Altitude Platforms), as we describe in D2.3. The agenda for WRC-23 was a bit disappointing with regards to spectrum for B5G. Some new bands for IMT below 10 GHz are to be discussed, which are the only agenda items pointing towards IMT.

There is no evidence of particular spectrum reservations for propagation studies, however, FCC has introduced 'Spectrum Horizon Licenses' between 95 GHz and 3 THz. Whether we can influence spectrum regulations for the benefit of wireless research is not easily answered. Direct influence is probably a direction which we cannot go, but we will aim to engage regulators in a discussion on this topic.

Regarding the general regulatory trends, traditional exclusive licensing is still being used for 5G, as we know from before. Another trend is that more and more bands are re-allocated from e.g., fixed, satellite and broadcast services to IMT.

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<sup>6</sup> <https://www.itu.int/en/ITU-T/Workshops-and-Seminars/20210316/Pages/default.aspx>.



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As we indicated in the previous report (D1.2), EMPOWER is not in the position of having a direct impact, but we will now seek to put different spectrum issues on the agenda for the 'Networking channel' (see section 3.3).

## 2.4 EMPOWER: a catalyst for research communities and bi-(multi) lateral initiatives

### 2.4.1 Building common Software Toolboxes

Researchers will highly benefit from the existence of a set of common tools in the form of software packages, development and deployment frameworks that can be used for reproducible experimentation in all the different platforms. The building of this common set of tools is very challenging due to the different nature of the platforms and the wide variety of experiments. It is hoped that this challenge can be met through open-source and community-based development methodologies. The following open questions try to shed some light on the challenges:

1. What kind of tools are being used in the current platforms and how will they evolve to address the needs of experimentation communities;
2. What of them are made available as open-source or can be used without or with experimentation-friendly licensing and of these which provide tools for community development;
3. How can we setup a common toolbox and common usage patterns so experiments can be replicated;
4. How do we manage the results obtained? Open Data? Will this be ok for industries or even academics? What kind of online support do we need for Open Data? What kind of access to the data do we support?

To address the above EMPOWER is engaging with several entities in the USA, in particular PAWR and Linux foundation MAGMA and OPNFV-VCO3) projects in order to

- a. Reduce fragmentation by producing common toolsets. A key step in this direction was taken to provide a single core network solution for the mobility-management entity (MME) between OpenAirInterface (OAI) and MAGMA. The MME is the key signaling entity in a 3GPP network allowing communication with commercial handsets and other user-equipment terminals. The MAGMA MME was forked from OAI in 2018 and both were developed independently. MAGMA developments were focused on production-ready deployment and OAI developed new features, e.g. Rel-15 signaling for 5G non-standalone operation. In 2020, after an agreement on relicensing the MME, OAI and MAGMA joined forces on producing a common design used for both communities and distributed by the Magma Foundation. Testing is done jointly by EURECOM/OAI and Magma Foundation partners both on EURECOM's 5G-EVE site and Magma Foundation resources at Facebook and FreedomFi.

A similar endeavor is now occurring between OAI and PAWR through the OpenAirX-Labs initiative<sup>7</sup> put forth by Northeastern University and other partners (North Carolina, Texas A&M, Rutgers, Mississippi, EURECOM). The main purpose of this initiative is to promote and help coordinate the development of OAI 5G software packages (5G radio-access network and core network) for academic use-cases in the USA. OpenAirX-Labs works in conjunction with the main development teams in Europe coordinated by the OAI Software Alliance.

- b. Harmonize software deployment methodologies This objective aims to provide common blueprints which can be used to deploy containerized versions of radio-access and core network software, including but not limited to OAI, Mosaic5G and Magma. To this end, EURECOM has been working since 2019 with RedHat and other partners in the context of the Linux Foundation OPNFV VCO (Virtual Central Office) project on providing multi-site testing of such deployment frameworks targeting Kubernetes / OpenShift clusters. The 5G-EVE site at EURECOM was the first to make use of this framework and similar sites in USA and Canada are using the VCO3 blueprints for deployment of telecom functions. The

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<sup>7</sup> <https://openairx-labs.northeastern.edu/>



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technologies are continually being extended to include support for orchestration and automation frameworks such as ONAP.

In a simpler vein, OAI also now provides fully open-source containerized deployment frameworks using docker-compose for both Ubuntu and RedHat based deployments of docker or podman containers. These are being used in conjunction PAWR for deployment on Colosseum, AERPAW and POWDER and R2LAB in France. OpenAirX-Labs now assists in maintaining the docker-compose based deployment framework on the sites it manages in the USA.

- c. Aggregate testing procedures across multiple platforms Testing is a key component for ensuring software-integrity, in particular for community-based development, when new features are added to a software package. Because of differences in infrastructure at different sites (different computing platforms and radio equipment) testing of common software packages should be firstly be automated by a continuous-integration (CI) and continuous-delivery (CD) system and secondly continuously adapted to the specific needs of the experimental sites. These needs are expressed in terms of features, deployment environments (static, highly-mobile, over-the-air or with test and measurement equipment) and require a high-level of coordination between the various parties. EURECOM, R2Lab and OpenAirX-Labs are working closely on defining and implementing a multi-site testing architecture for the OAI software packages using the various academic sites at its disposal. It is expected to be extended to the 5G-EVE Site at Orange Labs in 2021.

A similar effort is being implemented with the Magma Foundation and the Open Core Network (OCN) project. As mentioned above testing of the MAGMA MME currently occurs jointly at EURECOM 5G-EVE and Magma Foundation infrastructures and this will be extended to include 5G core network components from OAI and OCN.

#### **2.4.2 Performing Joint Experimentation**

In addition to a common set of joint technologies developed across the EU and the US, the alignment of experiments between the different platform will increase the cooperation and correlation between the use cases being tackled for next generation networks, which will help boosting the impact of the work at both sides of the Atlantic.

Following this line of thought, the key questions, which answer must be pursued in this domain are:

1. Are there interesting use cases that can be validated across the EU and USA domains?
2. What kind of remote access to the platforms can be supported?
3. How do we ensure replicability of experiments across sites?
4. How to identify the main target groups and communities?

To address the above questions, EMPOWER and PAWR are pushing together several experiments that will help understand the requirements and collaboration features that can be used and enhanced in the future. Currently the list of joint experiments is as follows:

1. Work on mmWave support implementation between IMDEA team and COSMOS platform. IMDEA as participant of one of the projects funded by the ORCA project (<https://www.orca-project.eu/>) is working towards the development of a mmWave research platform based on USRP. This project is based on the MISO<sup>8</sup> platform developed by IMDEA Networks. The proposal discussed within the COSMOS platform consists on a scale system able to transmit, capture and process the packet preamble of IEEE 802.11ad, scaling the OFDM inter-symbol time to enable their processing within the USRP bandwidth.
2. Ongoing discussion with Ivan Seskar from the COSMOS project on how to deploy such a platform within COSMOS.

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<sup>8</sup> <https://networks.imdea.org/projects/miso/>



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3. Connected IMDEA network lab and PAWR Project Office/Northeastern testbed for 5G/Cloud RAN experimentation between testbeds. The collaboration with the NSF “Platforms for Advanced Wireless Research” (PAWR) initiative, another activity with a potential notable impact, continued until the irruption of the pandemic. In fact, the visit of experts from the NSF was interrupted during COVID19, which prevented a proper visit of various 5G-EVE sites. Still, the 5TONIC infrastructure was interconnected with the Arena testbed at Northeastern University. Researchers from UC3M were able to access and interact with the remote testbed, and a probe reported a round-trip delay across the Atlantic of approx. 110 ms, which could support a number of interesting configurations for a 5G or beyond deployment. Unfortunately, a different interconnection is required for the testing of more advanced technologies, e.g., to be able to remotely deploy network slices or complete mobile network instantiations.
  4. Work with Eurecom/OAI to replicate OAI CI/CD (continuous integration /continuous development) testing framework to add reproduce results and contribute resources.



### 3. Review and evolution of Strategy Document and Collaboration Roadmap

Since the launch of EMPOWER and based on the inputs gathered from the different project activities (workshops, site visits, survey, etc.), a set of community building tools was defined and the first activities were carried out during the first two years. Those tools are essential for the proper and efficient implementation of the Collaboration Roadmap. However, due to the current situation caused by the COVID-19 pandemic, and its related uncertainty, the partners were obliged to brainstorm and define a new plan of action. Unfortunately, some of the activities, such as the mobilities and hackathons, which were key for the bridging the community will most probably not take place before the end of the project.

In order to cope with this situation and in order to guarantee that this will not affect the final outputs and impact of EMPOWER on the community, it has been decided to reshape the Collaboration Roadmap defined previously. The objective is to propose as much as possible virtual events instead of physical events and propose new activities if it is not possible to turn physical activities in online activities.

#### 3.1 Evaluation of the Strategy Document and Collaboration Roadmap

Until now, the Strategy Document and the Collaboration Roadmap followed the plan defined on the project description. However, in 2020, it became much more difficult to follow it and it forced the consortium to reconsider its plan on a short and medium term, especially regarding physical events.

Since the last version of the Strategy Document and the Collaboration Roadmap, the partners attended several events and had the opportunity to present the project in international conferences. Concerning the organization of the community building activities, the pace of implementing the activities was slower because of the pandemic outbreak but after a period of adoption and discussion, the partners decided to prepare an alternative, as described in the next sections.

Regarding the publications, until now, the partners have published 2 White Papers, both available on the project website and a 3<sup>rd</sup> one is scheduled by mid-2021.

The figure below shows all the activities, conferences, site visits, mobilities and meeting EMPOWER will organize and participate in the upcoming months with the aim to foster a networking collaboration related to 5G, beyond 5G and 6G, including the most important actors working in this field. In most of the cases, the meetings and events will be organized remotely.

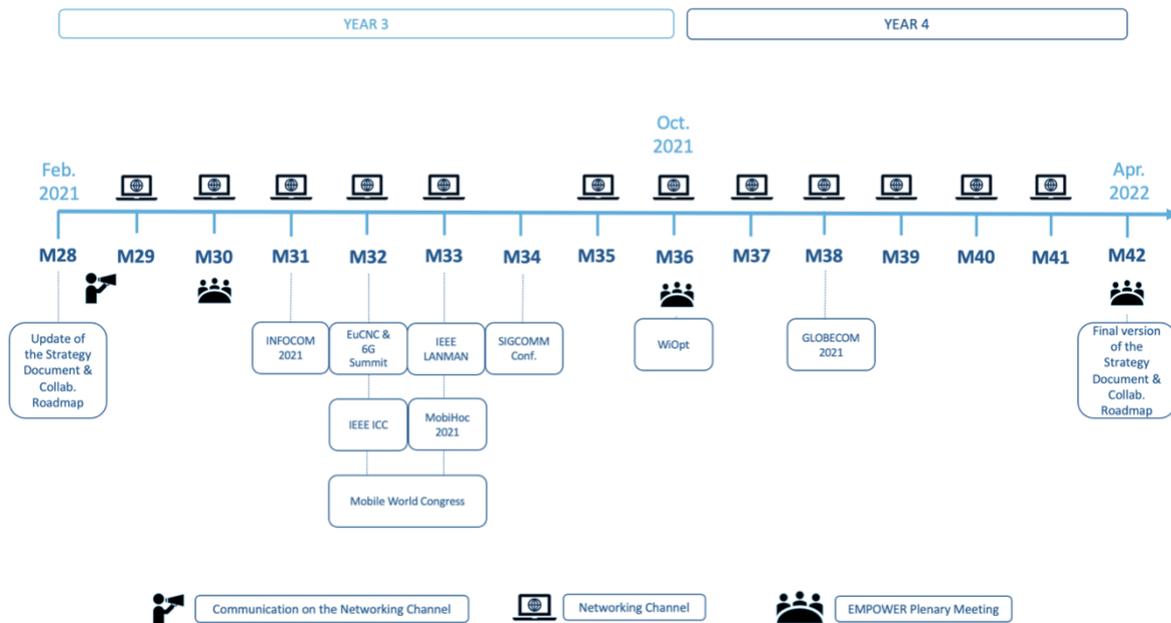


Figure 1 – Collaboration Roadmap

The table below presents the events, most of them virtual, attended by the partners since the last version of the Strategy Document and Collaboration Roadmap (October 2019). Those events were an opportunity to disseminate on EMPOWER project but also to gather information and outputs useful for the project outputs, such as the technology roadmap.

EVENT NAME	RELATION TO EMPOWER	DATES	PLACE	OUTPUTS
<a href="#">INFOCOM2020</a>	Participation of Serge Fdida (SU) in the Panel on Reproducibility (CNERT session)	6 July 2020	Virtual	Serge Fdida presented EMPOWER. Reproducibility is one of the identified areas of collaboration.
<a href="#">Forum on 5G Open Radio Access Networks</a>	Participation of Abhimanyu Gosain (Northeastern University/PAWR Office)	14 Sept. 2020	Virtual	Participation of the PAWR Office during the panel session about Technical Deep Dive.
<a href="#">MOBICOM 2020</a>	Participation and presentation of EMPOWER activities from Arturo Azcorra (UC3M) and Serge Fdida (SU)	21-25 Sept. 2020	Virtual	Participation and presentation of EMPOWER activities from Arturo Azcorra and Serge Fdida.
<a href="#">ACM Wintech 2020</a>	Events technically co-sponsored by the PAWR Project Office and by EMPOWER project	25 September 2020	Virtual	Raymond Knopp (EURECOM) was one of the keynote speakers.
<a href="#">6G Symposium</a>	Alain Mourad (IDG) presented EMPOWER	20-21 Oct. 2020	Virtual	Alain Mourad presented EMPOWER and its results to the 6G Symposium which aims to increase public awareness, excitement, and engagement around articulating a strong vision for 6G. The event was jointly organised by InterDigital and the Institute of Wireless Internet of Things (WIOT) at the Northeastern University aiming to the exploration of 6G.



<a href="#">Digital around the world</a>	Presentation of EMPOWER from Serge Fdida (SU)	20 Oct. 2020	Virtual	Serge Fdida presented EMPOWER and gave a presentation titled: International Research Infrastructures - Challenges and Perspectives. Manu Gosain from the PAWR Office also participated.
<a href="#">MoNeTec-2020</a>	Presentation of EMPOWER from Serge Fdida (SU)	28 Oct. 2020	Virtual	Serge Fdida presented EMPOWER.
<a href="#">WEBINAR: "Beyond 5G Evolution"</a>	Organisation by Antonio de la Oliva (UC3M) of a webinar	19 November 2020	Virtual	5GROWTH, 5G-DIVE and EMPOWER co-organize a webinar entitled "Beyond 5G Evolution"
<a href="#">GLOBECOM 2020</a>	Organisation by Antonio de la Oliva (UC3M) of a panel	7-11 Dec. 2020	Virtual	<i>Industry panel 5 (ip-05, on-demand): Advanced wireless research platforms towards 6G.</i> Participation of Antonio de la Oliva (UC3M), Alain Mourad (IDG), Serge Fdida (SU) and Abhimanyu Gosain (Northeastern University/PAWR Office).

It is important to highlight that the partners planned a series of events which were finally cancelled due to the COVID-19, such as:

- [Mobile World Congress 2020](#) (February 24-26, 2020 – Barcelona, Spain): InterDigital was organising two panels related with EMPOWER (1. What Do We Need to Do to Get 5G to Really Support AI and Machine Learning? / 2. Collaboration in the Open-Source Ecosystem). The EMPOWER technology roadmap and its consultation was planned to be presented.
- [EUCNC 2020](#) (June 16-17, 2020 - Dubrovnik, Croatia): EMPOWER was part of the workshop titled: Workshop on B5G key technology planning for EC collaboration with other geographical regions (B5G-COLAB). It was planned to present the technology roadmap but only the main conference was organised virtual and not the workshops.

### 3.2 Constraints and impact of the COVID-19 pandemic

Since early 2020, the COVID-19 pandemic had a significant impact not only on the project activities but on many events organized by the Community, worldwide. Several international conferences, such as the Mobile World Congress, have been cancelled and others were moved online, but with a reduced agenda. For instance, during EuCNC 2020, the main conference took place remotely but the workshops were cancelled.

Another significant impact of the pandemic on the project is related to the community building activities, especially due to the travel restrictions and local constraints. The table summarizes the impact of the pandemic on the initially planned community building activities and a proposed alternative plan.

ACTIVITY INITIALLY PLAN	IMPACT OF COVID-19	PROPOSED SOLUTION
Mobility of Researchers, engineers and students (at least 19 short and 5 long mobilities)	<b>HIGH</b>	Due to travel restrictions, it is highly unlikely that the mobilities would be organized by the end of the project, especially the long ones. An alternative would be to allow researchers, engineers and

		students exchange but in a remote way.
Site visits (at least 2)	<b>HIGH</b>	On a short term, it will be difficult to arrange physical site visits. In order to compensate, online visits will be organized in the framework of the Networking Channel.
Workshops (e.g., for strategy definition, 1-day Networking, Engagement and Policy Workshop, etc.)	<b>LOW</b>	Considering that since a year, most of the events and workshops moved online, the impact of organizing them will be limited. The workshop planned in the DoA will be included in the Networking Channel programme.
On-line and face-to-face tutorials, training seminars	<b>MEDIUM</b>	The face-to-face tutorials will not be possible but the online ones will not be impacted by the COVID-19. The solution is to replace the face-to-face tutorials by online ones. They can be part of the Networking Channel.
Hackathons (at least 3)	<b>HIGH</b>	Due to travel restrictions, it is highly unlikely that hackathons would be organized. However, if the situation improves before the end of the project, EMPOWER consortium keeps this option. In the meantime, the hackathons would be replaced by technical session during the Networking Channel.
Travel grants (at least 10)	<b>HIGH</b>	Due to travel restrictions, it is highly unlikely that the travel grants would be allocated to the students before the end of the project. However, considering that it is very important for EMPOWER to involve student, specific sessions will be dedicated to them in the Networking Channel and they will be invited to follow and participate in the other sessions.
Webinars organised by EMPOWER (at least 3)	<b>LOW</b>	No impact on the webinars, initially organized online. The webinars planned in the DoA will be included in the Networking Channel programme.
Demonstrations and dedicated sessions for presentation of selected outcomes/initiatives at specific events	<b>HIGH</b>	On a short term, it will be difficult to organize demonstrations and dedicated sessions during physical events.

		The proposed solution is to include these sessions to the Networking Channel programme and to some of the event attended by the partners.
New tools developed and reported (at least 5)	LOW	Most of the development work can be done remotely. The impact will be limited.
Common transatlantic experiments and testbeds (at least 10)	LOW	Most of the transatlantic experiments and testbeds can be done remotely. The impact will be limited.
Interconnected platforms (at least 3)	LOW	Most of the work related of the interconnection of the platforms can be done remotely. The impact will be limited.
Twinning research projects (at least 5)	MEDIUM	The twinning research projects can be prepared remotely. The impact will be limited.
Videos recording during the platforms' visits and mobilities (at least 3)	MEDIUM	Due to the lack of physical events, it will be difficult to get inputs from. The platforms' visits and mobilities. The partners will consider the possibility to ask the platforms to provide videos. Another option is related to the Networking Channel since all the sessions will be recorded and make public.
Experts participated in the Technology roadmap (at least 50)	LOW	The experts involved in the Technology Roadmap will be contacted by email and during the events organized in the framework of the Networking Channel. As a consequence, the impact will be limited, even if we do not have the possibility to exchange directly with them as it can be done during the physical events.

Despite the difficulties and constraints, the partners are committed to move forward with the general objectives of EMPOWER, even if the initial plan has to be updated. The consortium considers that EMPOWER contributions to the EU and US Community are more than ever important and that despite the current context, small adjustments will allow to reach those objectives.

As announced previously, one of the proposed alternative plans is the creation of [theNetworkingChannel](#), organized in close collaboration with the PAWR Office and ACM SigComm. This channel will allow the partners to mitigate most of the risks raised by the pandemic. However, as stated in the above table, in some cases, it will be impossible or not relevant to organize remote events (e.g., hackathons). In this case, these events will be kept apart and organize if the situation improves before the end of EMPOWER.



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### 3.3 TheNetworkingChannel

Due to restrictions and the obligation to maintain physical distancing, the organization of in-person technical meetings/discussions became difficult or even impossible and obliged the organizers of these events to move to online solution.

One positive aspect of this change is that individuals who may not have been able to travel to in-person meetings, are now able to participate remotely in research activities, broadening the reach of our community. However, in this time of distancing, new vehicles are needed to maintain and build our research community, as we adapt our forms of scientific cooperation.

As consequence, and in order to reach its objectives, EMPOWER, together with the NSF PAWR Office, and in cooperation with ACM Sigcomm, acting as a catalyst between the global communities involved in future advanced networking activities, offers to continue the dialogue and build community organizing a Rendez-vous place as a “community channel” where the community will be able to share and meet.

The networking community channel will be organized as a regular event taking place every (second) Wednesday of each month, at 8am PST (11am EST, 5pm CET, 1am JST). Depending on the demand, the events may be scheduled more often. [TheNetworkingChannel](#) will offer a diversity of live and recorded events for the community.

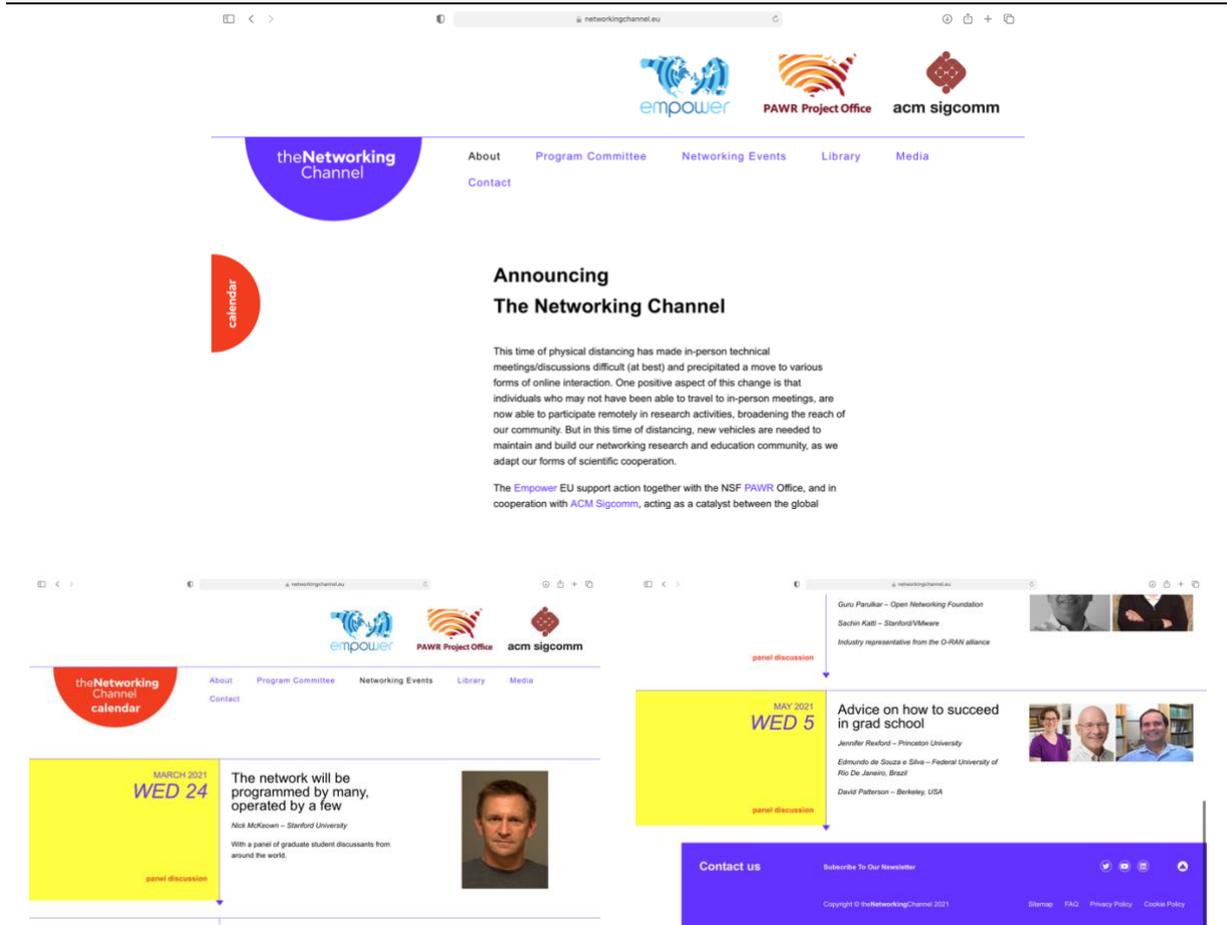
The consortium has already identified a series of topics, which will be broad and open ranging from research to experimentation and education. Students will be a target of the Channel since they will not have access to the travel grants and the mobility programme, due to the pandemic.

As a concrete example, here is the list of the topics scheduled by May 2021.

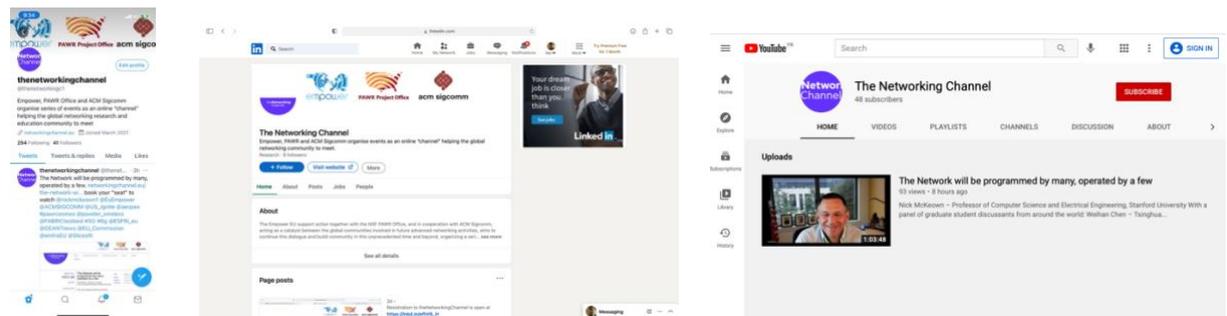
- The Network will be programmed by many, operated by a few (24 March 2021).
- A journey with mmWave research (7 April 2021).
- 5G and Next G Innovation Opportunities and Challenges: Enabled by Disaggregation, SDN and Open Source (21 April 2021).
- Advice on how to succeed in grad school (5 May 2021).

The channel will consist of attractive high-quality webinars, panels, tutorials, virtual site visits, keynotes and any other innovative forms. Moreover, a specific platform (Zoom - webinars) where previous streams can be downloaded and viewed asynchronously will be provided. The recordings and presentations or other material of the events will be available at the web site of [theNetworkingChannel](#) and on the [YouTube](#) channel of the event. The platform has been chosen after an extensive market research. In addition, a Slack channel has been created under ACM SigComm slack channel.

The web-site of [theNetworkingChannel](#) designed such as to be simple and powerful.



Social media have been created including [Twitter](#), [LinkedIn](#) and a [YouTube Channel](#), were all the recordings will be uploaded.



In order to propose the widest possible range of topics, an Editorial Board will be in charge of programming the channel topics, and will seek strong and active community input as to a broad and diverse set of topics. International experts, from both the EU and US but worldwide, will be members of the Programme Committee where EMPOWER members are well represented:

**Co-Chairs:**

- Matthew Caesar, University of Illinois at Urbana-Champaign, USA
- Serge Fdida, Sorbonne Université, France



- 
- Abhimanyu Gosain, Northeastern University, USA
  - Jim Kurose, University of Massachusetts, USA

**Members:**

- Arturo Azcorra, U. Carlos III and IMDEA, Spain
- Didier Bourse, Nokia, France
- Jiasi Chen, U. California Riverside, USA
- Jon Crowcroft, Cambridge U., UK
- Bruce Davie, VMware, Australia
- Edmundo de Souza e Silva, UFRJ, Brazil
- Bamba Gueye, U. Cheikh Anta Diop Dakar, Senegal
- Ping Ji, City U. of New York, USA
- Kanchana Kanchanasut, Asian Institute of Technology, Thailand
- Kate Keahey, U. Chicago, USA
- Raymond Knopp, Eurecom, France
- Z. Morley Mao, U. Michigan, USA
- Muriel Médard, MIT, USA
- Alain Mourad, Interdigital, UK
- Aki Nakao, U. Tokyo, Japan
- Ari Pouttu, U. Oulu, Finland
- Junaid Qadir, Information Technology U, Pakistan
- Jennifer Rexford, Princeton U., USA
- Gaogang Xie, Chinese Academy of Sciences, China
- Anita Nikolich, Univ of Illinois Urbana-Champaign, USA

Last but not least, the Networking Channel was launched 10<sup>th</sup> of March 2021 and the first event took place on 24 March 2021 with a keynote of Nick McKeown (Stanford University). The four first events announced and registration opened. The initial objective was to have a participation of 250-500 registrants with more than 50% active participation.

The outcomes of the first three events are the following:

- Event #1 – 24 March 2021 – *“The network will be programmed by many, operated by a few”*
  - Total registration: 480
  - Total attendees: 268
- Event #2 – 7 April 2021 – *“A Journey with mmWave research”*
  - Total registration: 256
  - Total attendees: 147
- Event #3 – 21 April 2021 – *“5G and Next G Innovation Opportunities and Challenges: Enabled by Disaggregation, SDN and Open Source”*
  - Total registration: 342
  - Total attendees: 174

The detailed statistics of the first three events, including the distribution of attendees per geographical area, are available in Annex III: First outcomes of the Networking Channel.

### 3.4 List of future related events

In addition to the events organized by EMPOWER, in the framework of the Networking Channel, the partners identified a series of international conferences of interest for EMPOWER project. The list below is indicative and will evolve in the next months.

EVENT NAME	DATES	PLACE	OUTPUTS
<a href="#">ITU-ETSI-IEEE Joint SDOs Brainstorming Workshop on Testbeds Federations for 5G and Beyond: Interoperability, Standardization, Reference Model and APIs</a>	17-26 March 2021	Virtual	The International Telecommunication Union (ITU), ETSI, and IEEE is organising a Joint SDOs Brainstorming Workshop on Testbeds Federations for 5G and Beyond: Interoperability, Standardization, Reference Model and APIs. This Workshop provides a platform for ETSI, ITU-T and IEEE to Brainstorm and share ideas on Testbeds Federation Challenges, including: 1) the Testbeds Federation Reference Model being jointly standardized by ETSI and ITU; 2) APIs Requirements for Testbeds Federations and what may have been achieved in this area with respect to existing API implementations by Research communities and the Industry; 3) how to use the Reference Model to guide Research and Industry to contribute to the development of the APIs being prescribed by the Reference Model; 4) how the SDOs can potentially share the burden on APIs Standardization and on Roadmaps in a harmonized and collaborative way; 5) Potential New Business Models for Testbeds Suppliers that derive from the Testbeds Federations Reference Model. Serge Fdida (SU) will attend the workshop together with the PAWR Office.
<a href="#">FABRIC Experimenters Workshop</a>	8-9 April 2021	Virtual	The goal of this workshop is to introduce FABRIC to experimenters and those considering experimenting. The consortium will share information about deployed sites, recent decisions that could affect your experiments, and demos of FABRIC's current capabilities. Additionally, the planned timeline will be shared, including future site deployment and testbed access. Some of the EMPOWER partners will attend the workshop together with the PAWR Office.
<a href="#">6GSYMPOSIUM</a>	4-6 May 2021	Virtual	By 2030 and the dawn of commercial 6G the world's climate aspirations, population, economy and work will have changed. If we are to deliver a smart, connected world that can meet the many demands on it, we need to start with all the stakeholders in the room and grow a complete set of viable solutions and business cases, not just a technology. The Spring edition of 6G Symposium, when leaders from across different industries, public and private sector and academia will meet to explore the key questions around what 6G offers industry and society and how to get there. Two panels are scheduled, directly related to EMPOWER: <ol style="list-style-type: none"> <li>1. The Standardization Roadmap: moderated by Alain Mourad (IDCC) and participation of Raydmon Knopp (EURECOM).</li> <li>2. The Spectrum Roadmap: participation of Prakash Moorut (NBLF).</li> </ol>
<a href="#">INFOCOM 2021</a>	10-13 May 2021	Virtual	IEEE INFOCOM is a top-ranked conference on networking in the research community. It is a major conference venue for

			<p>researchers to present and exchange significant and innovative contributions and ideas in the field of networking and closely related areas. IEEE INFOCOM covers both theoretical and systems research. For INFOCOM 2021, the conference includes a main technical program, a number of workshops, a keynote speech, panels, a student poster session, and demo/poster sessions.</p>
<a href="#">EuCNC &amp; 6G Summit</a>	8-11 June 2021	Porto & Virtual	<p>The 2021 Joint EuCNC &amp; 6G Summit, initiated this year, builds on putting together two successful conferences in the area of telecommunications: EuCNC, in its 30th edition of a series, supported by the European Commission; the 6G Summit, in its 3rd edition, originated from the 6G Flagship programme in Finland, one of the very first in its area. The conference is sponsored by the IEEE Communications Society and by the European Association for Signal Processing, and focuses on all aspects of telecommunications ranging from 5G deployment and mobile IoT to 6G exploration and future communications systems and networks, including experimentation and testbeds, and applications and services. It brings together cutting-edge research and world-renown industries and businesses, globally attracting in the last years more than 1 300 delegates from more than 40 countries all over the world, to present and discuss the latest results, and an exhibition with more than 70 exhibitors, for demonstrating the technology developed in the area, namely within research projects from EU R&amp;I programmes.</p>
<a href="#">IEEE ICC</a>	14-23 June 2021	Virtual & Montreal	<p>The IEEE International Conference on Communications (ICC) is one of the IEEE Communications Society's two flagship conferences dedicated to driving innovation in nearly every aspect of communications. Each year, around 3,000 researchers submit proposals for paper presentations and program sessions to be held at the annual conference.</p> <p>At the annual conference, thousands of participants gather to present research results, share visions and ideas, obtain updates on latest technologies and expand professional and social networking. These activities are realized through IEEE ICC's multiple diversified and exciting programs.</p> <p>This 5-day event includes several keynote speeches by distinguished speakers from industry, academia and government sectors; panels and forums; technical sessions featuring technical papers extensively reviewed by peers; workshops focusing on the latest trends in various technology; tutorials delivered by experts in respective disciplines; exhibits; an awards luncheon; and a relaxing and entertaining banquet.</p>
<a href="#">Mobile World Congress</a>	28 June – 01 July 2021	Barcelona	<p>MWC Barcelona is the world's most influential exhibition for the connectivity industry. In 2019, up to 2,400 exhibitors, 8,000 CEOs and 59% of the industries' most important decision makers gathered here.</p>
<a href="#">IEEE LANMAN</a>	12-14 July 2021	Boston & virtual (in needed)	<p>IEEE LANMAN has an established tradition as a forum for presenting and discussing the latest technical advances in local and metropolitan area networking. Continuing that tradition, IEEE LANMAN 2021 invites cutting-edge papers spanning both theory and experimentation.</p>
<a href="#">MobiHoc 2021</a>	Week of 26 July 2021	Virtual & Shanghai	<p>MobiHoc 2021, the International Symposium on Mobile Ad Hoc Networking and Computing will be held during the week of July 26, 2021. It will be held in Shanghai, China. MobiHoc is a premier international symposium dedicated to addressing challenges in dynamic networks and computing.</p>

			It will bring together researchers and practitioners from a broad spectrum of networking research to present the most up-to-date results and achievements in the field. MobiHoc 2021 will feature a highly selective technical program, multiple distinguished keynote addresses, and an exciting panel. In addition, it includes workshops that are focused on areas of emerging interest.
<a href="#">SIGCOMM Conference</a>	23–27 August 2021	Virtual	SIGCOMM is the flagship annual conference of the ACM Special Interest Group on Data Communication (SIGCOMM) on the applications, technologies, architectures, and protocols for computer communication.
<a href="#">WiOpt</a>	18-21 Oct. 2021	Philadelphia	The 19th International Symposium on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt 2021) will take place from June 18 to 21, 2021 in Philadelphia.
<a href="#">GLOBECOM 2021</a>	7-11 Dec. 2021	Madrid	The 2021 IEEE Global Communications Conference (GLOBECOM) will be held in Madrid, Spain, from 7 -11 December 2021. Themed “Connecting Cultures around the Globe,” this flagship conference of the IEEE Communications Society will feature a comprehensive high-quality technical program including 12 symposia, selected areas in communications track and a variety of tutorials and workshops. IEEE GLOBECOM 2021 will also include an attractive Industry program aimed at practitioners, with keynotes and panels from prominent research, industry and government leaders, business and industry panels, and vendor exhibits.

## 4. Dissemination and Community building tools

### 4.1 Overall strategy

EMPOWER proposes the following objectives and priorities for dissemination, communication and community building activities to obtain a successful collaboration between the US and Europe and create a long-term network:

- Expand the community by mobilizing the best researchers and engineers in the field;
- Engage new talent through the regular communication such international events, Community Outreach Seminars and policy events;
- Promote the value, benefit and usage of Advanced Wireless Platforms;
- Propose on-line and face-to-face tutorials to train people from industry and research audience;
- Create value-add synergies with media organizations and promote all the initiatives in all the distribution channels of EMPOWER;
- Convey the policy framework through interaction with EU and US policy bodies and key initiatives, including insight into governance models;
- Identify conferences and workshops across Europe and USA to increase EMPOWER visibility;
- Work on every on-line communication channel as an entity such as Twitter, LinkedIn, YouTube, Slideshare, Vimeo and EMPOWER website.



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## 4.2 Review and update of the overall strategy

Due to restrictions and the obligation to maintain physical distancing, the organization of face-to-face technical meetings/discussions became difficult or even impossible. It obliged the promoters of these events and tools to build and support the community have to move to online solution.

As consequence, and in order to reach its objectives, EMPOWER, together with the NSF PAWR Office, and in cooperation with ACM Sigcomm, acting as a catalyst between the global communities involved in future advanced networking activities organizes the already successful [theNetworkingChannel](#) as described in the previous section.

Nevertheless, if the situation improves in the next coming months, EMPOWER partners will implement the community building activities initially planned such as the mobilities or the organization of hackathons.



## 5. Conclusion

Since its launch, EMPOWER aims to act as a catalyst and reinforce the cooperation between the EU and the US on the new connectivity frontiers beyond 5G with a particular focus on advanced wireless platforms. The current situation caused by the outbreak of the COVID-19 pandemic highlighted the importance of the promotion of advanced wireless platforms and the need for deeper collaboration in this field. Unfortunately, the restrictions due to the pandemic had a significant impact on some of EMPOWER's activities but at the same time, they obliged the consortium to reinvent a new way to promote this cooperation between the EU and the US communities. [TheNetworkingChannel](#) is an innovative instrument that will allow EMPOWER in close collaboration with the PAWR Office to propose to the EU and US communities a meeting point where they will have the opportunity to exchange on topics of interest for both sides of the Atlantic, and beyond. The participation and support of ACM SigComm is an asset in order to reach a wider audience, not limited to the US and Europe.

Overall, EMPOWER is the main research liaison between the EU and US aiming at sharing information and roadmap as well as aligning the visions and components of the future platforms. Joint activities and events provide evidence about the strong dialogue and trust that has been developed between the two communities.

## 6. Annex I: Updated list of related European Activities (incl. ICT-52)

This annex presents a deep analysis of all the related European research programmes developing technologies for the advance wireless developing.

PROGRAMME	CALLS
<p><b>EUROPE</b></p> <p><b><u>HORIZON EUROPE</u></b> is the new EU research and innovation framework programme running from 2021 to 2027. It aims to:</p> <ul style="list-style-type: none"> <li>• to strengthen the EU's scientific and technological bases and the European Research Area (ERA)</li> <li>• to boost Europe's innovation capacity, competitiveness and jobs</li> <li>• to deliver on citizens' priorities and sustain our socioeconomic model and values</li> </ul> <p>The Commission proposes a budget of € 100 billion for Horizon Europe.</p>	<p><b><u>European Partnership for Smart Networks and Services</u></b></p> <p>The European communication networking and services sector is proposing the Smart Networks and Services (SNS) Partnership to secure European leadership in the development and deployment of next generation network technologies and services, while accelerating European industry digitization. It will position Europe as a lead market and positively impact the citizens' quality of life, while boosting the European data economy and contributing to ensure European sovereignty in critical supply chains.</p> <p>The SNS Partnership will be implemented as a Joint Undertaking (JU). EC officially released on 23.02.21 the Single Basic Act (SBA) for JUs Regulation (<a href="https://ec.europa.eu/commission/presscorner/detail/en/IP_21_702">https://ec.europa.eu/commission/presscorner/detail/en/IP_21_702</a>). EC also published the dedicated SNS webpage (<a href="https://ec.europa.eu/digital-single-market/en/news/europe-puts-forward-proposal-joint-undertaking-smart-networks-and-services-towards-6g">https://ec.europa.eu/digital-single-market/en/news/europe-puts-forward-proposal-joint-undertaking-smart-networks-and-services-towards-6g</a>). The SNS EC funded budget should be 900 ME.</p>
<p><b>HORIZON 2020</b> is an EU research and innovation program. Almost €77 billion of funding is available over seven years (2014-2020) distributed in different fields with the aim to foster a sustainable development related with all research and innovators European bodies.</p> <p>ICT topics in H2020 support core ICT industries through roadmap-based Public Private Partnerships (PPPs). The work in the last period will contribute to maintaining and developing the technology leading edge in key areas such as electronics, photonics, embedded systems, competing, robotics, etc.</p> <p><b>The projects listed here are some of the H2020 projects. A more detailed list is available on <a href="#">CORDIS website</a> and also on the <a href="#">5G PPP website</a>, with a list of projects per Strategic Objectives.</b></p>	<p><b><u>5G PPP PHASE 3, PART 5: 5G CORE TECHNOLOGIES INNOVATION AND 5G FOR CONNECTED AND AUTOMATED MOBILITY (CAM)</u></b></p> <p><b><i>ICT-42 – 5G PPP – 5G core technologies innovation</i></b></p> <p><b><u>COREect</u></b> – COREnect brings together the most prominent European industrial and academia players as well as industry associations in the network, microelectronics and verticals domains to jointly design a core technology roadmap. The goal is to establish a sustainable European technology sovereignty in 5G and beyond, promote innovation and business opportunities e.g., for small and medium-sized businesses (SMEs), pave the way for one or more future European champions in this area, and lay a solid foundation for the long-term success of both industries. A new COREnect community will emerge from the close collaboration between Smart Networks and Services (SNS) and Key Digital Technologies (KDT) communities as well as with other related communities, e.g., on High-Performance Computing (HPC), artificial intelligence (AI), Photonics, IoT and Cloud. Through outreach activities via its extensive industry and academia network, COREnect will have the potential to significantly impact the European R&amp;I and industry landscape of future connectivity systems over the next ten years.</p> <p><b><u>5G-RECORDS</u></b> 5G-RECORDS aims to explore the opportunities which new 5G technology components bring to the professional production of audiovisual content, including Programme Making and Special Events (PMSE). 5G-RECORDS targets the development, integration, validation and demonstration of 5G components for professional content production, as part of an overall ecosystem integrating a subset of 5G network functions.</p>

The challenge is to use 5G components from previous 5G-PPP projects and earlier R&D investments and further develop them. These components will be evaluated in three end-to-end 5G infrastructures provided by the project. These include the core network (5GC), radio access network (RAN) and end devices. The project aims to use of non-public networks (NPNs) as a way to bring these new components to emerging markets and new market actors. NPNs can be deployed as independent and standalone 5G networks or in conjunction with a public network. The project also aims to address recent emerging remote and distributed production workflows where cloud technologies cooperate with 5G. To ensure the successful demonstration of these use cases, the project brings together a set of experienced partners whose expertise covers both 5G and content production value chains. Most of the 5G components will be developed and implemented by specific key partners, being mostly innovative SMEs. The 5G-RECORDS implemented technologies will be based on existing 3GPP Rel-15 and Rel-16 specifications, while also prototyping some emerging Rel-17 capabilities. All technology components are expected to reach by the end of the project a minimum Technology Readiness Level (TRL) of 7. 5G-RECORDS has considered 3 use cases to embrace some of the most challenging scenarios in the framework of professional content production: live audio production, a multi-camera wireless studio and live immersive media production.

[AFFORDABLE5G](#) - Affordable5G aims at creating a 5G network that will deliver a complete and affordable solution covering the needs of private and enterprise networks through technical innovation that span across all parts of 5G network, leveraging cell densification, RU/DU/CU split, hardware acceleration, edge computing and core network virtualization, seamlessly combined with the adoption of open-source RAN, MEC and MANO solutions, for cloud-native, micro-service-based deployments. To achieve its innovative and ambitious goal, the consortium brings together ten European SMEs, supported by MVNOs, system integrators and research institutes, grasping the opportunity to enhance their products, according to each company's roadmap, while fostering collaboration among them. In this way, Affordable5G will offer a first-class opportunity to European companies to become frontrunners in the global 5G competition, facilitating them in their commercialization paths and strategies in niche market cases of neutral hosting, private networks and MVNOs with new entrant actors. The innovative solution will be evaluated and validated in two vertical pilots related to emergency communications and smart cities, which have been properly selected as being highly representative in terms of system performance, scalability, mobility patterns, slice types, deployment requirements and impact in the future 5G market.

## **5G PPP PHASE 3, PART 6: 5G INNOVATIONS FOR VERTICALS WITH THIRD PARTY SERVICES & SMART CONNECTIVITY BEYOND 5G**

### ***ICT-52 – 5G PPP – Smart Connectivity beyond 5G***

**6G BRAINS** (*Bringing Reinforcement learning Into Radio Light Network for Massive Connections*) – 6G BRAINS aims to bring AI-driven multi-agent Deep Reinforcement learning (DRL) to perform resource allocation over and beyond massive machine-type communications with new spectrum links including THz and optical wireless communications (OWC) to enhance the performance with regard to capacity, reliability and latency for future industrial networks. The project proposes a novel comprehensive cross-layer DRL driven resource allocation solution to support the massive connections over device-to-device (D2D) assisted highly dynamic cell-free network enabled by Sub-6 GHz/mmWave/THz/OWC and high-resolution 3D Simultaneous Localization and Mapping (SLAM) of up to 1 mm accuracy. The enabling technologies in 6G BRAINS focus on four major aspects including disruptive new spectral links, highly dynamic D2D cell-free network modelling, intelligent end-to-end network architecture integrating the multi-agent DRL scheme and AI-enhanced high-resolution 3D SLAM data fusion. The developed technologies will be widely applicable to various vertical sectors such as Industry 4.0, intelligent transportation, eHealth, etc.

**AI@EDGE** (*Bringing Reinforcement learning Into Radio Light Network for Massive Connections*) – Artificial Intelligence has become a major innovative force and it is one of the pillars of the fourth industrial revolution. This trend has been acknowledged also by the European Commission that has already pointed out how high-performance, intelligent, and secure networks are fundamental for the development and evolution of the multi-service Next Generation Internet (NGI). While great progress has been done during the last years with respect to the accuracy and performance of AI-enabled platforms, their integration in potentially autonomous decision-making systems or even critical infrastructures requires end-to-end quality assurance. AI@EDGE addresses the challenges harnessing the concept of “reusable, secure, and trustworthy AI for network automation”. In AI@EDGE European industries, academics and innovative SMEs commit to achieve an EU-wide impact on industry-relevant aspects of the AI-for-networks and networks-for-AI paradigms in beyond 5G systems. Cooperative perception for vehicular networks, secure, multi-stakeholder AI for IIoT, aerial infrastructure inspections, and in-flight entertainment are the uses cases targeted by AI@EDGE to maximise the commercial, societal, and environmental impact. To achieve the goal, AI@EDGE targets significant breakthroughs in two fields: (i) general-purpose frameworks for closed-loop network automation capable of supporting flexible and programmable pipelines for the creation, utilization, and adaptation of the secure, reusable, and trustworthy AI/ML models; and (ii) converged connect-compute platform for creating and managing resilient, elastic, and secure end-to-end slices capable of supporting a diverse range of AI-enabled network applications.

**DAEMON** (*Network intelligence for aDaptive and sElf-Learning MOBILE Networks*) – The success of Beyond 5G (B5G) systems will largely depend on the quality of the Network Intelligence (NI) that will fully automate network management. Artificial Intelligence (AI) models are commonly regarded as the cornerstone for NI design; indeed, AI models have proven extremely successful at solving hard problems that require inferring complex relationships from entangled and massive (e.g., traffic) data. However, AI is not the best solution for every NI task; and, when it is, the dominating trend of plugging ‘vanilla’ AI into network controllers and orchestrators is not a sensible choice.

Departing from the current hype around AI, DAEMON will set forth a pragmatic approach to NI design. The project will carry out a systematic analysis of which NI tasks are appropriately solved with AI models, providing a solid set of guidelines for the use of machine learning in network functions. For those problems where AI is a suitable tool, DAEMON will design tailored AI models that respond to the specific needs of network functions, taking advantage of the most recent advances in machine learning. Building on these models, DAEMON will design an end-to-end NI-native architecture for B5G that fully coordinates NI-assisted functionalities.

**DEDICAT 6G** (*Dynamic coverage Extension and Distributed Intelligence for human Centric Applications with assured security, privacy, and Trust: from 5G to 6G*) – In future 6G wireless networks, it is imperative to support more dynamic resourcing and connectivity to improve adaptability, performance, and trustworthiness in the presence of emerging human-centric services with heterogeneous computation needs. DEDICAT6 aims to develop a smart connectivity platform using artificial intelligence and blockchain techniques that will enable 6G networks to combine the existing communication infrastructure with novel distribution of intelligence (data, computation, and storage) at the edge to allow not only flexible, but also energy efficient realisation of the envisaged real-time experience. DEDICAT 6G takes the next vital step beyond 5G by addressing techniques for achieving and maintaining an efficient dynamic connectivity and intelligent placement of computation in the mobile network. In addition, the project targets the design and development of mechanisms for dynamic coverage extension through the exploitation of novel terminals and mobile client nodes, e.g., smart connected cars, robots, and drones. DEDICAT also addresses security, privacy, and trust assurance especially for mobile edge services and enablers for novel interaction between humans and digital systems. The aim is to achieve (i) more efficient use of resources; (ii) reduction of latency, response time, and energy consumption; (iii) reduction of operational and capital expenditures; and (iv) reinforcement of security, privacy, and trust. DEDICAT 6G will focus on four use cases: Smart warehousing, Enhance experiences, Public Safety and Smart Highway. The use cases will pilot the developed solutions via simulations and demonstrations in laboratory environments, and larger field evaluations exploiting various assets and testing facilities. The results are expected to show significant

improvements in terms of intelligent network load balancing and resource allocation, extended connectivity, enhanced security, privacy and trust and human-machine interactions.

**Hexa-X** (*A flagship for B5G/6G vision and intelligent fabric of technology enablers connecting human, physical, and digital worlds*) – 2030 and beyond, Europe and the world will face opportunities and challenges of growth and sustainability of tremendous magnitude; proactively tackling the issues of green deal efficiency, digital inclusion and assurance of health and safety in a post-pandemic world will be key. A powerful vision is needed to connect the physical, digital, and human worlds, firmly anchored in future wireless technology and architectural research. The Hexa-X vision calls for an x-enabler fabric of connected intelligence, networks of networks, sustainability, global service coverage, extreme experience, and trustworthiness. Wireless technologies are of critical relevance for our society and economy today; their importance for growth will continue to steadily increase with 5G and its evolution, enabling new ecosystems and services motivated by strongly growing traffic and trillions of devices. The ambition of the Hexa-X project includes developing key technology enablers in the areas of: 1) fundamentally new radio access technologies at high frequencies and high-resolution localization and sensing; 2) connected intelligence through AI-driven air interface and governance for future networks, and 3) 6G architectural enablers for network disaggregation and dynamic dependability.

**MARSAL** (*Machine learning-based, networking and computing infrastructure resource management of 5G and beyond intelligent networks*) – MARSAL targets the development and evaluation of a complete framework for the management and orchestration of network resources in 5G and beyond, by utilizing a converged optical-wireless network infrastructure in the access and fronthaul/midhaul segments. At the network design domain, MARSAL targets the development of novel cell-free based solutions that allows a significant scaling up of the wireless APs in a cost-effective manner by exploiting the application of the distributed cell-free concept and of the serial fronthaul approach, while contributing innovative functionalities to the O-RAN project. In parallel, in the fronthaul/midhaul segments, MARSAL aims to radically increase the flexibility of optical access architectures for Beyond-5G Cell Site connectivity via different levels of fixed-mobile convergence. At the network and service management domain, the design philosophy of MARSAL is to provide a comprehensive framework for the management of the entire set of communication and computational network resources by exploiting novel ML-based algorithms of both edge and midhaul DCs, by incorporating the Virtual Elastic DataCenters/Infrastructures paradigm. Finally, at the network security domain, MARSAL aims to introduce mechanisms that provide privacy and security to application workload and data, targeting to allow applications and users to maintain control over their data when relying on the deployed shared infrastructures,

while AI and Blockchain technologies will be developed in order to guarantee a secured multi-tenant slicing environment.

**REINDEER** (*REsilient INteractive applications through hyper Diversity in Energy Efficient RadioWeaves technology*) – The REINDEER project will develop a new smart connect-compute platform with a capacity that is scalable to quasi-infinite, and that offers perceived zero latency and interaction with an extremely high number of embedded devices. It will thereto develop “RadioWeaves” technology, a new wireless access infrastructure consisting of a fabric of distributed radio, computing, and storage resources. RadioWeaves can be deployed as panels mounted on walls and ceilings. It brings a large number of antennas and intelligence close to devices offering consistently excellent service at minimal transmit power and making very efficient usage of network bandwidth and energy. Technologically, RadioWeaves advance the ideas of large-scale intelligent surfaces and cell-free wireless access, two theoretical concepts that bear great promise to offer capabilities far beyond 5G networks. We will characterize channels based on measurements and develop distributed platform architectures to realize the great potential in actual deployments. We will develop protocols and algorithms to establish novel resilient interactive applications that require ‘real-time’ and ‘real-space’ cooperation, for future robotized industrial environments, immersive entertainment, and intuitive care, we will co-design focusing algorithms and protocols for enhanced interaction with many energy-neutral devices. REINDEER will provide experimental proof-of-concept in versatile testbeds. The project runs for 42 months and receives funding from the European Union under grant agreement number 101013425.

**RISE-6G** (*Reconfigurable Intelligent Sustainable Environments for 6G Wireless Networks*) – The RISE-6G vision capitalises on the latest advances on Reconfigurable Intelligent Surfaces (RIS) technology for radio wave propagation control, in order to substantially improve them and, to conceive and implement intelligent, sustainable and dynamically programmable wireless environments that go well beyond the 5G capabilities developed under 3G PPP release 16. To this end, RISE-6G objectives are to (i) define novel network architectures and operation strategies incorporating multiple RISs; (ii) characterise its fundamental limits capitalizing on our proposed realistic and validated radio wave propagation models; (iii) design solutions to enable online trade between high-capacity connectivity, Energy Efficiency, EMF exposure, and localisation accuracy based on dynamically programmable wireless propagation environments, while accommodating specific legislation and regulation requirements on spectrum use, data protection, and EMF emission; and (iv) prototype-benchmark proposed innovation via two complementary trials with verticals. RISE-6G project is poised to actively participate in standardisation bodies and bring its technically advanced vision into the planned industrial exploitation. This will secure the European technology leadership, supporting the



creation of new European-conceived service and business opportunities in the B5G/6G global race.

**TeraFlow** (*Secured autonomic traffic management for a Tera of SDN flows*) – TeraFlow will create a new type of secure cloud-native SDN controller that will radically advance the state-of-the-art in beyond 5G networks. This new SDN controller shall be able to integrate with the current NFV and MEC frameworks as well as to provide revolutionary features for both flow management (service layer) and optical/microwave network equipment integration (infrastructure layer), while incorporating security using Machine Learning (ML) and forensic evidence for multi-tenancy based on Distributed Ledgers. The target pool of stakeholders expands beyond the traditional telecom operators towards edge and hyperscale cloud providers. These actors will be benefited from TeraFlow by a) exploiting a new type of secure SDN controller based on cloud-native solutions while, b) achieving substantial business agility with novel and highly dynamic network services with zero-touch automation features.

## **5G PPP PHASE 3, PART 1: INFRASTRUCTURE PROJECTS**

### ***ICT-19-2019 - Advanced 5G validation trials across multiple vertical industries***

**5G-SMART** – 5G-SMART is foreseen as key enabler for the future manufacturing ecosystem termed Industry 4.0. 5G-SMART unlocks the value of 5G for smart manufacturing through demonstrating, validating and evaluating its potential in real manufacturing environments. 5G-SMART trials will test the most advanced 5G integrated manufacturing applications such as digital twins, industrial robotics and machine vision based remote operations by bringing first ever 5G deployment in manufacturing setup.

<https://cordis.europa.eu/project/rcn/223885/factsheet/en>

**5G-TOURS** – The fundamental feature of the 5G-TOURS concept is the dynamic use of the network to seamlessly provide different types of services adapted to the specific needs of individual use cases. 5G-TOURS will enable different capabilities such as network slicing, virtualisation, orchestration or broadcasting as well as additional features developed by the project to bring more flexibility and improved performance. The ambition is to fully demonstrate pre-commercial 5G technologies at a large scale, showing the ability of the 5G network to meet extreme and conflicting KPIs while supporting very diverse requirements on the same infrastructure.

<https://cordis.europa.eu/project/rcn/223874/factsheet/en>

**5GROWTH** – The vision of the 5Growth project is to empower verticals industries such as Industry 4.0, Transportation, and Energy with an AI-driven Automated and Sharable 5G End-to-End Solution that will allow these industries to achieve simultaneously their respective key performance targets. Towards this vision, 5Growth will automate the process for supporting diverse industry verticals through (i) a vertical portal in charge of interfacing verticals with the 5G End-to-End platforms, receiving their service requests and building the respective network slices on top, (ii) closed-loop automation and SLA control for vertical services lifecycle management and (iii) AI-driven end-to-end network solutions to jointly optimize Access, Transport, Core and Cloud, Edge and Fog resources, across multiple technologies and domains.

<https://cordis.europa.eu/project/rcn/223873/factsheet/en>

**5G-SOLUTIONS** is a 5G-PPP project supporting the EC's 5G policy by

### ***ICT 17 2018: 5G End-to-End Facility***

“The challenges consist in providing an end-to-end facility that can i) demonstrate that the key 5G PPP network KPIs can be met; ii) be validated and accessed and used by vertical industries to set up research trials of innovative use cases to further validate core 5G KPIs in the context of concurrent usages by multiple users.”

### ***Research projects***

**5G-VINNI** (5G Verticals Innovation Infrastructure) – 5G-VINNI will accelerate the uptake of 5G in Europe by providing an end-to-end

(E2E) facility that validates the performance of new 5G technologies by operating trials of advanced vertical sector services.

<https://cordis.europa.eu/project/rcn/218529/factsheet/en>

**5GENESIS** (5<sup>th</sup> Generation End-to-end Network, Experimentation, System Integration, and Showcasing) – In the global race towards 5G, the establishment and implementation of the 5G-PPP programme in the EU has significantly strengthened the position of Europe, promoting both technological excellence and industrial leadership.

<https://cordis.europa.eu/project/rcn/218507/factsheet/en>

**5G-EVE** (5G European Validation platform for Extensive trials) – 5G-EVE supports this fundamental transition by offering to vertical industries and to all 5GPPP Phase3 projects facilities to validate their network KPIs and their services. Important representatives of these vertical industries are directly involved as partners of 5G-EVE exactly to influence the design of the end-to-end 5G services.

<https://cordis.europa.eu/project/rcn/217999/factsheet/en>

**ICT 18-2018: 5G for cooperative, connected and automated mobility (CCAM).** The challenge we considered interesting to focus on work-package is the following, “Validation of 5G in a broad CCAM context is realised through cross border trials along 5G corridors covering significant portions of roads and including the core technological innovation expected from 5G such as (but not limited to) New Radio new frequency bands[[35 Ghz band is the target option for V2N applications though other bands may be considered]] C-RAN Mobile Edge Computing network virtualisation new network architecture cross domains data flows.”

**Research projects**

**5G-CARMEN** (5G for Connected and Automated Road Mobility in the European Union) – European mobility is drastically changing: growing urbanisation, environmental aspects, and safety are only a few of the key indicators pointing in this direction. Road infrastructures and vehicles are blending with the digital world, becoming always-connected, automated and intelligent, delivering optimal experience to passengers, and addressing societal goals. In this respect, the European Union pushes for large-scale collaborative cross-border validation activities on cooperative, connected and automated mobility.

<https://cordis.europa.eu/project/rcn/219074/factsheet/en>

**5G-MOBIX** (5G for cooperative & connected automated MOBility on X-border corridors) – 5G-MOBIX will first define the critical scenarios needing advanced connectivity provided by 5G, and the required features to enable those advanced CCAM use cases. The matching between the advanced CCAM use cases and the expected benefit of 5G will be tested during trials on 5G corridors in different EU countries as well as China and Korea.

<https://cordis.europa.eu/project/rcn/219128/factsheet/en>

**5GCroCo** (Fifth Generation Cross-Border Control) – The possibility of providing connected, cooperative and autonomous mobility (CCAM) services along different countries when vehicles traverse various national borders has a huge innovative business potential. The situation is particularly challenging given the multi-country, multi-operator, multi-telco-vendor, and multi-vehicle-OEM scenario of any cross-border layout.

<https://cordis.europa.eu/project/rcn/219082/factsheet/en>

#### **5G PPP PHASE 2 PROJECTS**<sup>9</sup>

**ICT-07-2017- 5G PPP Research and validation of critical technologies and systems** “The vision is that in ten years from now, telecom and IT will be integrated in a common very high capacity and flexible 5G ubiquitous infrastructure, with seamless integration of heterogeneous wired and wireless capabilities.”

#### **Research projects**

**5G ESSENCE** (Embedded Network Services for 5G Experiences) – 5G ESSENCE addresses the paradigms of Edge Cloud computing and Small Cell as a Service by fueling the drivers and removing the barriers in the Small Cell market, forecasted to grow at an impressive pace up to 2020 and beyond and to play a key-role in the 5G ecosystem.

<https://cordis.europa.eu/project/rcn/211072/factsheet/en>

**METRO-HAUL** (METRO High bandwidth, 5G Application-aware optical network, with edge storage, compUte and low Latency) – METRO-HAUL is a project proposal addressing the Horizon 2020 ICT-07 5G PPP call; it is an RIA, focusing on strand 2 (high-capacity elastic – optical networks) and strand 3 (software networks). The central topic is cost-efficient optical metro networks for 5G backhaul.

<https://cordis.europa.eu/project/rcn/211077/factsheet/en>

**IoRL** (IoRL – Internet of Radio Light) – The Internet of Radio-Light (IoRL) project develops a safer, more secure, customizable and intelligent building network that reliably delivers increased throughput (greater than 10Gbps) from access points pervasively located within buildings.

<https://cordis.europa.eu/project/rcn/211086/factsheet/en>

**NRG-5** (Enabling Smart Energy as a Service via 5G Mobile Network advances) – Despite a number of software frameworks and reference architectures have made available for 5G enabling technologies, there is a clear gap to bridge towards 5G seamless application with a number of “vertical” sectors. Energy vertical represents undoubtedly one of the most significant “test cases” for 5G enabling technologies.

<https://cordis.europa.eu/project/rcn/211088/factsheet/en>

**5G-Xcast** (Broadcast and Multicast Communication Enablers for the Fifth-Generation of Wireless Systems) – 5G-Xcast will devise, assess and demonstrate large scale immersive media delivery by means of

<sup>9</sup> <https://5g-ppp.eu/wp-content/uploads/2017/11/5GPPP-brochure-phase2-final-web.pdf>

conceptually novel wireless technologies, contributing to the further definition of 5G and its standardization.

<https://cordis.europa.eu/project/rcn/211065/factsheet/en>

**SLICENET** (End-to-End Cognitive Network Slicing and Slice Management Framework in Virtualised Multi-Domain, Multi-Tenant 5G Networks) – 5G network providers are keen to offer “networks as a service” where logical network slices are created and allocated to use cases flexibly and efficiently in a multi-operator environment. SliceNet will create and demonstrate the tools and mechanisms to achieve this ambition.

<https://cordis.europa.eu/project/rcn/211081/factsheet/en>

**To-Euro-5G** (Supporting the European 5G Initiative) – The To-Euro-5G project has a clear objective to support the activities of the European 5G Initiative as outlined in the 5G contractual Public Private Partnership (cPPP) during the second phase of the 5G-PPP from June 2017 to June 2019, with the intention of maximizing the return on this investment for Europe.

<https://cordis.europa.eu/project/rcn/211057/factsheet/en>

**ONE5G** (E2E-aware Optimizations and advancements for the Network Edge of 5G New Radio) – ONE5G commits to provide technical investigations and recommendations to evolve ‘5G’ towards ‘5G advanced’ as requested by the work program. Release 15 from 3GPP is about to set up a valuable initial specification for paving the way to reach the ultimate goals for 5G.

<https://cordis.europa.eu/project/rcn/211055/factsheet/en>

**SaT5G** (Satellite and Terrestrial Network for 5G) – The introduction and global roll out of eMBB service within 5G raises coverage and network dimensioning issues in underserved and unserved areas, especially in low ARPU regions of emerging markets, and on mobile platforms (e.g. vessels and aircraft).

<https://cordis.europa.eu/project/rcn/211060/factsheet/en>

**BlueSpace** (Building on the Use of Spatial Multiplexing 5G Networks Infrastructures and Showcasing Advanced technologies and Networking Capabilities) – The core concept of this project is exploiting the added value of Spatial Division Multiplexing (SDM) in the Radio Access Network (RAN) with efficient optical beamforming interface for the pragmatic Ka-band wireless transmission band.

<https://cordis.europa.eu/project/rcn/211090/factsheet/en>

**5GCAR** (Fifth Generation Communication Automotive Research and Innovation) – There are two ongoing industrial trends, one in the mobile communications industry and one in the automotive industry, which are becoming interwoven and will jointly provide new capabilities and functionality for upcoming intelligent transport systems and future driving.

<https://cordis.europa.eu/project/rcn/211068/factsheet/en>

	<p><b>5G–TRANSFORMER</b> (5G Mobile Transport Platform for Verticals) – The vision of the 5G-TRANSFORMER project is that Mobile Transport Networks shall transform from today’s rigid interconnection solutions into an SDN/NFV-based 5G Mobile Transport and Computing Platform (MTP) able of simultaneously supporting an extremely diverse range of networking and computing requirements to meet in particular the specific needs of vertical industries.  <a href="https://cordis.europa.eu/project/rcn/211067/factsheet/en">https://cordis.europa.eu/project/rcn/211067/factsheet/en</a></p> <p><b>5G-MoNArch</b> (Mobile Network Architecture for diverse services, use cases, and applications in 5G and beyond) – Motivation: The expected diversity of services and use cases in 5G requires a flexible, adaptable, and programmable architecture. While the design of such an architecture has been addressed by 5G-PPP Phase 1 at a conceptual level, it must be brought into practice in Phase 2. To this end, 5G-MoNArch will (i) evolve 5G-PPP Phase 1 concepts to a fully-fledged architecture, (ii) develop prototype implementations and (iii) apply these prototypes to representative use cases.  <a href="https://cordis.europa.eu/project/rcn/211061/factsheet/en">https://cordis.europa.eu/project/rcn/211061/factsheet/en</a></p> <p><b>5G-PICTURE</b> (5G Programmable Infrastructure Converging disaggregated neTwork and compUte REsources) – The explosive growth of mobile internet traffic introduces the need to transform traditional closed, static and inelastic network infrastructures into open, scalable and elastic ecosystems supporting new types of connectivity, high mobility and new mission-critical services for operators, vendors and vertical industries.  <a href="https://cordis.europa.eu/project/rcn/211091/factsheet/en">https://cordis.europa.eu/project/rcn/211091/factsheet/en</a></p>
<p><b>SLICES-RI</b> aims at the creation of a common space among the participating research infrastructures to construct and operate an effective and timely unified research Digital Infrastructure that will lead European research activities beyond. Leveraging the legacy of the previous research projects, SLICES-RI will adopt a new reference architecture and bring advanced functionalities on the experimental based research. Having a large-scale infrastructure based on state-of-the-art technologies in architectures and services will attract researchers at all career stages and will encourage partnerships in and across different fields. Being able to run experiments at every level of the software stack over a variety of hardware devices and clusters in a reproducible and controlled way, will allow researchers to develop and</p>	<p><b>SLICES-DS (H2020 – INFRADEV-01-2019-2020)</b> – The design, deployment and operation of complex and continuously evolving digital infrastructure is crucial to keeping our technologically advancing society humming. This is why the research community needs a test platform to address issues related to efficiency, reliability, availability, range, end-to-end latency, security and privacy. The EU-funded SLICES-DS will provide a Europe-wide test-platform designed to support large-scale, experimental research. It will provide advanced compute, storage and network components, interconnected by dedicated high-speed links. Pushing forward, the project’s main goal is to strengthen the research excellence and innovation capacity of European researchers and scientists in the design and operation of digital infrastructures.</p> <p><b>SLICES-SC (H2020 – INFRAIA-02-2020)</b> – SLICES-SC, we aspire to foster the community of researchers around SLICES-RI ecosystem, create and strengthen necessary links with relevant industrial stakeholders for the exploitation of the infrastructure, advance existing methods for research reproducibility and experiment repeatability, and design and deploy the necessary solutions for providing SLICES-RI with an easy to access scheme for users from different disciplines. A set of detailed research activities has been designed to materialize these efforts in tools for providing</p>



<p>experiment across the variety of DIs topics. Moreover, SLICES-RI will impact education, teaching and learning as students, engineers and researchers will be exposed to this broad set of technologies. The SLICES-RI will be used to design e-labs and MOOCs provisioned on demand where students can remotely learn, program, and practice with the technologies that they do not have in situ. There is obviously an economy of scale, a faster access to talents and an increased attractiveness. Therefore, SLICES-RI will provide a research infrastructure allowing academics and industry to experiment and test future, possibly long-term and disruptive DIs which is essential for the European research. European economic stakeholders will gain a competitive advantage at the early stage of the development cycle.</p>	<p>transnational (remote and physical) access to the facility, as well as virtual access to the data produced over the facilities. The respective networking activities of the project aspire in fostering the community around these infrastructures, as well as open up to new disciplines and industrial stakeholders.</p> <p>The SLICES community counts on 25 partners coming from 15 European countries. The consortium submitted an application to the ESFRI 2021 roadmap, on September 2020. The results are pending.</p>
<p><b>COST</b> Actions are funded over a four-year duration which requires the participation of at least seven different COST Full Members or Cooperating Members.</p>	<p><b>COST IRACON</b> (Inclusive Radio Communications for 5G and Beyond) defines technologies aimed to support Wireless connectivity at any rates, for any communicating units, and in any type of scenarios. Also aims to achieve scientific breakthroughs, by introducing novel design and analysis methods for 5G, and beyond-5G, radio communication networks. The Action was also training young researchers in the field of inclusive radio communications, via annual training schools and short-term missions. COST IRACON started in 2016 and ended in 2020. <a href="http://www.iracon.org">http://www.iracon.org</a>. A follow-up action proposal was submitted in October 2020 aiming for studying technologies for future intelligent networks beyond 5G.</p>
<p><b>6GENESIS</b> Flagship supported by the University of Oulu. The total volume will be approximately €250 million over eight years, consisting of the Academy of Finland and University of Oulu's own funding and estimated competitive external funding.</p> <p>Research is organized into four strategic areas: Wireless Connectivity; Devices and Circuit Technology; Distributed Computing and Services and Applications.</p>	<p>The beginning of 6GENESIS is planned with the next European Framework Horizon Europe.</p>
<p><b>FIWARE</b>, The FIWARE Community is an independent Open Community whose members are committed to materialize the FIWARE mission, that is: "to build an open sustainable ecosystem around public, royalty-free and implementation-driven software</p>	<p>In Fiware website is published different events to promote collaboration between different organizations but there is no calls or proposals allowed.</p> <p><a href="https://www.fiware.org">https://www.fiware.org</a></p>



<p>platform standards that will ease the development of new Smart Applications in multiple sectors”. The FIWARE Community is not only formed by contributors to the technology (the FIWARE platform) but also those who contribute in building the FIWARE ecosystem and making it sustainable over time.</p> <p>Interest in North America; Discussions are happening with USA in particular with US Ignite, and in Canada with a number of relevant organizations gathered by the University of Toronto, to investigate possible paths for cooperation and in particular for using FIWARE as one of the global platforms for Smart Cities worldwide.</p>	
<p><b>TRANSATLANTIC ICT FORUM</b> Project co-funded by H2020 called “Discovery” Europe-North America Dialogues for ICT Cooperation. It finished in 2017 but the website is already active.</p> <p>The purpose was to create the Transatlantic ICT Forum as a sustainable mechanism to support dialogues for EU-North America cooperation in the field of ICT.</p> <p>Partners of the Project: Inmark Europa, Life Supporting Technologies (LST)-Universidad Politecnica de Madrid (UPM), Waterford Institute of Technology-Telecommunications Software and Systems Group, NOrdforsk, Hewlett Packard Italiana srl, Georgia Institute of Technology and Emory University, European American Chamber of Commerce-New Jersey, Inclusive Design Research Centre-Ontario College of Art and Design University (OCAD University), The Governing Council of the University of Toronto.</p> <p>Website:  <a href="http://discoveryproject.eu/transatlantic-ict-forum">http://discoveryproject.eu/transatlantic-ict-forum</a></p>	<p>In Transatlantic ICT Forum are published different events to promote collaboration between different organizations but there is no calls or proposals allowed.</p>
<p><b>FED4FIRE+</b> Is a project under the European Union's programme Horizon 2020, offering the largest federation worldwide of next generation internet (NGI) testbeds, which provide open accessible and reliable facilities supporting a wide variety of different</p>	<p>Testbed they are working on this moment are, <b>CityLab</b>, is a smart cities FIRE testbed, operated by imec. It is intended for large-scale wireless networking experimentation at a city neighborhood level in the unlicensed spectrum. CityLab is located in the city center of Antwerp, Belgium.</p> <p><b>Exo Geni</b>, is a <a href="#">GENI testbed</a> that links GENI to two advances in virtual infrastructure services outside of GENI: open cloud computing</p>

research and innovation communities and initiatives.

It started in January 2017 and will run for 60 months, until the end of September 2021. The Fed4Fire+ project is the successor of the Fed4Fire project.

Fed4fire develops different testbed specialized in 5G, Big Data, Cloud, OpenFlow, IoT, Wired and Wireless

(OpenStack) and dynamic circuit fabrics. ExoGENI orchestrates a federation of independent cloud sites located across the US and rest of the world, of which UvA is one of them. ExoGENI is a widely distributed networked infrastructure-as-a-service (IaaS) platform geared towards experimentation and computational tasks.

**FIT** (Future <Internet of Things: <https://fit-equipex.fr/>) enables experimentation across a broad range of subject, greatly reduces the cost and time required to design, establish and monitor an experiment, and through testing, the robustness of the solutions is increased. FIT's mission is to provide a large-scale experimentation environment through the federation of testbeds that are competitive at the worldwide level, allowing to incubate advanced experiments and to stimulate of a large base of users coming from the research world as well as industry. FIT offers large-scale state-of-the-art wireless, sensing and mobility infrastructures for any builder of tomorrow's systems and services, who wish to try out, test and validate his/her solution before implementing it in real-life. FIT platforms are located across France: in Paris, Lille, Strasbourg, Lyon, Grenoble and Sophia Antipolis. They offer easy access, a library of tools and online support for wireless and wireless sensor networks including robots. You can even plug your own devices in our testbeds and run your tests there as well.

**FuSeCo**, Future Seamless Communication Playground – located in Berlin – is a pioneering reference facility, integrating various state of the art wireless broadband networks. Two of its most important components are the OpenIMS Playground and the 3GPP Evolved Packet Core prototype platform. Both are discussed in the next slides.

**Grid'5000**, is a large-scale and versatile testbed for Cloud, HPC, Big Data, networking, and deep learning. It is composed of 8 sites (located in France and Luxembourg), and more of 800 servers than can be reserved at the bare metal level. The sites are connected together with a 10-Gbps dedicated backbone.

**OFELIA i2CAT** Island provides an open facility to test and validate experimental research aligned with Future Internet technologies, specifically Software Defined Networking (SDN) and virtualization. The infrastructure is virtualized in order to offer logical isolated substrates to enable simultaneous disruptive research experiments in productive environments without interfering to parallel research users; following an IaaS (Infrastructure as a Service) mode.

**IRIS**, the reconfigurable radio testbed at Trinity College Dublin provides virtualized radio hardware to support the experimental investigation of the interplay between radio capabilities and networks. Our facility pairs underlying flexible radio and computations resources with various hypervisors in the form of software radio frameworks to realize various research and testing configurations.

**LOG-a-TEC** cognitive radio testbed is focused on spectrum sensing in TV whitespaces and cognitive radio applications in wireless sensor networks. A license from the local regulator allows for low-powered transmissions in TV whitespaces as well as frequency bands for unlicensed devices.

**NETMODE** testbed is a Wi-Fi testbed belonging to the National Technical University of Athens (NTUA). It consists of 20 x86 compatible nodes positioned indoors in an office environment.

**NITOS**, is comprised of 2 wireless testbeds for experimentation with heterogeneous technologies. An outdoor testbed, featuring Wi-Fi, WiMAX and LTE support and an indoor isolated testbed comprised of advanced powerful nodes.

**Perform LTE**, testbed follows a holistic approach combining different type of equipment, LTE radio access emulators equipment, Evolved Nodes B (eNBs), User Equipments (UEs) both commercial and engineered to provide measurements, and an Evolved Packet Core (EPC) emulation system. All these elements can be combined, and experimentation can be performed in all the components of a LTE network.

**PL-LAB** provides an access to distributed laboratory, spread around Poland and interconnecting major academia institutions and offering variety of equipment with different functionalities at a large scale. The major focus of experiments performed so far in PL-LAB was on how to enable Parallel Internet paradigms in future networks.

**Planetlab Europe**, Planetlab Europe is the European arm of the global PlanetLab system, the world's largest research networking facility, which gives experimenters access to Internet-connected Linux virtual machines on over 1000 networked servers located in the United States, Europe, Asia, and elsewhere.

**Portable Wireless Testbeds**, the WISHFUL project offers access to several wireless testbeds, such as TWIST (TUB), w-iLab.t (iMinds), IRIS (TCD), Orbit (Rutgers University) and a FIBRE Island at UFRJ. All of these testbeds are installed in either office environments or other dedicated testbed environments. Because some research requires doing measurement campaigns or actual testing in heterogeneous environments, the [WISHFUL project](#) also offers a portable testbed to the community.

**Smart Santander**, is a large-scale smart city deployment in the Spanish city of Santander. The testbed supports two types of experiments: Internet of Things native experimentation (wireless sensor network experiments) and service provision experiments (applications using real-time real-world generated sensor data).

**Tengu**, is a platform for big data experimentation, which allows for scalable streaming, analysis and storage of large amounts of heterogeneous data. Tengu offers access to heterogeneous storage technologies, supports both offline and real-time data analysis components and provides resource and data monitoring tools.

**Virtual Wall**, is an emulation environment that consists of 100 nodes (dual processor, dual core servers) interconnected via a non-blocking 1.5 Tb/s Ethernet switch, and a display wall (20 monitors) for experiment visualization. Each server is connected with 4 or 6 gigabit Ethernet links to the switch. The experimental setup is configurable through Emulab, allowing to create any network topology between the nodes, through VLANs on the switch. On each of these links, impairments (delay, packet loss, bandwidth limitations) can be configured.



**w-iLAB.t**, testbed is composed of two separate deployments, of which initially only the one called “w-iLab.t Zwijnaarde” will be available through the Fed4FIRE federation for the first round of open call experiments. This testbed is intended for Wi-Fi and sensor networking experimentation. It is located in Zwijnaarde, a district of Ghent, and belongs to iMinds.

## 7. Annex II: Updated list of related USA Activities

This annex presents an analysis of all the related research USA programmes developing technologies for the advance wireless developing.

INSTITUTION	PROGRAMMES AND PROJECTS
<p><b>US</b></p> <p><b>Department of Defense</b></p>	<p><a href="#">5G-to-NextG</a></p> <p>The United States Department of Defense is at the forefront of cutting edge 5G testing and experimentation which will be transformative to the Nation’s warfighting capabilities.</p> <p>In 2020, the Department announced \$600 million for 5G testbeds across five U.S. military sites, representing the largest full-scale 5G tests for dual-use applications in the world. Through this effort, the Department partners with industry to test 5G operations such as augmented and virtual reality training, smart warehousing, and distributed command and control.</p> <p>In 2021, the Department will be announcing a second tranche of awards at seven more test sites. The requests for proposals will open soon.</p>
<p><a href="#">Linux Foundation</a></p>	<p><a href="#">MAGMA CORE PROJECT</a></p> <p>Magma connects 100 to 1,000,000 servers using the same fully distributed network architecture. Designed to be access network (cellular or wifi) and 3GPP release agnostic, it can flexibly support a radio access network with minimal development and deployment effort.</p> <ul style="list-style-type: none"> <li>▪ Allows operators to offer cellular service without vendor lock-in with a modern, open-source core network.</li> <li>▪ Enables operators to manage their networks more efficiently with more automation, less downtime, better predictability, and more agility to add new services and applications.</li> <li>▪ Federate between existing MNOS and new infrastructure providers for expanding rural infrastructure allows operators who are constrained with licensed spectrum to add capacity and reach by using wi-fi and CBRS.</li> <li>▪ All parts of the network are stateless except the access gateway, providing greater scale, resiliency, and simplicity. The distributed deployment model limits fault domains and allows more frequent and seamless upgrades.</li> </ul> <p>Founding Organizations: arm, Deutsche Telekom, Facebook, FreedomFi, Northeastern University, Open Infrastructure Foundation, OpenAir Interface, Qualcomm.</p>
<p><a href="#">ATIS NextG alliance</a></p>	<p>The Next G Alliance is a bold new initiative to advance North American mobile technology leadership over the next decade through private sector-led efforts. With a</p>



	<p>strong emphasis on technology commercialization, the work will encompass the full lifecycle of research and development, manufacturing, standardization and market readiness.</p> <p>Mobile technology underpins the advancement of several important industries. These include Aerospace, Agriculture, Defense, Education, Healthcare, Manufacturing, Media, Energy and Transportation, all of which are vital to U.S. interests and increasingly dependent on mobile technology. Ensuring North American leadership in mobile technology across these key sectors will strengthen and promote the region's economic interests globally.</p> <p>The goals of Next G Alliance are:</p> <ul style="list-style-type: none"> <li>▪ Advance North American global leadership over the 5G evolutionary path and 6G early development.</li> <li>▪ Create a Next G development roadmap that will promote a vibrant marketplace for 6G introduction, adoption and commercialization with North American innovation in mind.</li> <li>▪ Develop a set of national priorities that will influence government applied research funding and promote incentivized government actions.</li> <li>▪ Progress a North American model that promotes development across the full lifecycle of research to realization, aligned with commercialization outcomes.</li> </ul>
<p><a href="#">MITRE Engenuity</a></p>	<p>MITRE Engenuity is a trusted tech foundation that brings industry together to apply state of the art MITRE innovation for the public good.</p> <p>MITRE Engenuity targets 4 main areas: cyber, health, 5G and transportation.</p>
<p><b>NATIONAL SCIENCE FOUNDATION (NSF)</b> supports fundamental research in wireless communications and wireless data networks, from the early days of the Internet. NSF has already been paving the way for <a href="#">5G wireless data networks and beyond</a>.</p>	<p>NSF INTEL PARTNERSHIP ON INFORMATION-CENTRIC NETWORKING IN WIRELESS EDGE NETWORKS</p> <p>Next-generation wireless networks, utilizing a wide swath of wireless spectrum and an array of novel technologies in the wired and wireless domains, are on the cusp of unleashing a broadband revolution with promised peak bit rates of tens of gigabits per second and latencies of less than a millisecond.</p>
<p>The Computer and Network Systems is one of the Research Areas of the NSF which manages programmes such as Research Infrastructure-1 (Mid-scale RI-1) (Division Of Computer and Network Systems Mid-scale).</p>	<p>FABRIC (Adaptive Programmable Research Infrastructure for Computer Science and Science Applications) is a unique national research infrastructure to enable cutting-edge and exploratory research at-scale in networking, cybersecurity, distributed computing and storage systems, machine learning, and science applications.</p> <p>It is an everywhere programmable nationwide instrument comprised of novel extensible network elements equipped with large amounts of compute and storage, interconnected by high speed, dedicated optical links. It will connect a number of specialized testbeds</p>



	<p>(5G/IoT PAWR, NSF Clouds) and high-performance computing facilities to create a rich fabric for a wide variety of experimental activities.</p> <p><a href="https://fabric-testbed.net/">https://fabric-testbed.net/</a></p>
<p>NSF investments in the next generation of data networks spread across various research programs as well as infrastructure investments in advanced testbeds.</p>	<p><b>NETWORKING TECHNOLOGIES AND SYSTEMS (NeTS)</b>          Computer and communication networks need to be available anytime and anywhere, and be accessible from any device. Networks need to evolve over time to incorporate new technologies, support new classes of applications and services, and meet new requirements and challenges; networks need to scale and adapt to unforeseen events and uncertainties across multiple dimensions, including types of applications, size and topology, mobility patterns, and heterogeneity of devices and networking technologies.</p>
<p>Research in 5G spans a comprehensive array of areas from advanced physical layers to the support of emerging applications in 5G networks.</p>	<p><b>COMMUNICATION AND INFORMATION FOUNDATION (CIF)</b>          CIF program supports potentially transformative research that addresses the theoretical underpinnings of information acquisition, transmission, and processing in communications and information processing systems. As a result, CIF projects strengthen the intellectual foundations of communications, information theory, signal processing, and statistical learning in a variety of network types such as wireless and multimedia networks, sensor networks, social networks, and biological and quantum networks.</p>
	<p><b>COMMUNICATIONS CIRCUITS AND SENSING-CIRCUITS (CCSS)</b>          The CCSS Program is intended to spur visionary systems-oriented activities in collaborative, multidisciplinary, and integrative research. CCSS supports systems research in hardware, signal processing techniques, and architectures to enable the next generation of cyber-physical systems (CPS) that leverage computation, communication, and algorithms integrated with physical domains. CCSS supports innovative research and integrated educational activities in micro- and nano-electromechanical systems (MEMS/NEMS), communications and sensing systems, and cyber-physical systems.</p>
	<p><b>ENHANCING ACCES TO THE RADIO SPECTRUM (EARS)</b>          The National Science Foundation's Directorates for Computer and Information Science and Engineering (CISE), Engineering (ENG), and Mathematical and Physical Sciences (MPS) are coordinating efforts to identify bold new concepts with the potential to contribute towards significant improvements in the efficiency of radio spectrum utilization, protection of passive sensing services, and the ability for traditionally underserved Americans to benefit from current and future wireless-enabled goods and services. This EARS</p>



	<p>program seeks to fund innovative collaborative research addressing large-scale challenges that transcend the traditional boundaries of existing programs.</p>
	<p><b>FUTURE INTERNET ARCHITECTURES – NEXT PHASE (FIANP)</b> Continuing its long-standing commitment of supporting groundbreaking research in large-scale networking systems</p>
	<p><b>INDUSTRY/UNIVERSITY COOPERATIVE RESEARCH CENTERS PROGRAM (I/UCRC)</b> The Industry-University Cooperative Research Centers (IUCRC) program develops long-term partnerships among industry, academe, and government. The Centers are catalyzed by an investment from the National Science Foundation (NSF) and are primarily supported by industry Center members, with NSF taking a supporting role in the development and evolution of the Center.</p>
	<p><b>WIRELESS INNOVATION BETWEEN FINLAND AND US (WIFIUS)</b> The US National Science Foundation (NSF) and the Academy of Finland have signed a Memorandum of Understanding (MOU) on research cooperation in the area of wireless networking. This MOU provides an overarching framework to encourage collaboration between the US and Finland research communities and sets out the principles by which jointly supported activities may be developed.</p>
	<p><b>NSF SBIR/STTR PROGRAM</b> This program helps startups and small businesses transform their ideas into marketable products and services. It is focused on high-risk and high-impact technologies.</p>
<p><b>US IGNITE</b>, spurs the creation of next-generation applications and services that leverage advanced networking technologies to build the foundation for smart communities, including cities, rural areas, regions, and states. The nonprofit organization helps to accelerate new wired and wireless networking advances from research to prototype to full-scale smart community and interconnected national deployments.</p>	<p><b>PAWR</b> The Platform for Advanced Wireless Research Project Office (PPO) manages the \$100 million public-private partnership and oversees the research platforms. Funded by CISE research resources from NSF Programs. It was started in April 2018 and will end in March 2023. There are two different research platforms in PAWR,</p> <ol style="list-style-type: none"> <li>1. <b>POWDER</b>: Platform for Open Wireless Data-driven Experimental Research, in partnership with RENEW, Reconfigurable Ecosystem for Next-gen End-to-end Wireless. POWDER-RENEW consists in creating a collaboration with municipal and state leadership from <b>Salt Lake City</b> and Utah, will create an advanced wireless research platform that will cover 2.3 square miles of the <b>University of Utah</b> campus, 1.2 square miles of downtown Salt Lake City and a two-mile corridor in between, reaching a potential population of 40,000 people. While it will enable wireless research across many technical areas, the research platform will offer</li> </ol>

	<p>unique and specialized capabilities for dynamic spectrum sharing and advanced wireless antenna technologies.  <a href="https://powderwireless.net/">https://powderwireless.net/</a></p> <p>2. COSMOS: Cloud Enhanced Open Software Defined Mobile Wireless Testbed for City-Scale Deployment. COSMOS is partnering with <b>New York City, Silicon Harlem, City College of New York, University of Arizona</b> and <b>IBM</b>, to bring this advanced wireless test bed to life in New York City. The test bed will cover 1 square mile in a vibrant, densely-populated neighborhood in West Harlem. The technical focus of the COSMOS platform is on ultra-high-bandwidth and low-latency wireless communications, with tightly coupled edge computing, a type of cloud computing enabling data processing at the edge of the network. COSMOS will pursue millimeter-wave radio communications and dynamic optical switching technologies. This new wireless research platform will allow for experimentation at a scale that could not be achieved previously, thereby enabling new services and applications to benefit the entire community.  <a href="https://cosmos-lab.org/">https://cosmos-lab.org/</a></p> <p>3. AERPAW: AERPAW is led by <b>North Carolina State University</b> (NC State) in partnership with <b>Wireless Research Center of North Carolina, Mississippi State University, RENCI, Town of Cary, City of Raleigh, North Carolina Department of Transportation, Purdue University, University of South Carolina</b>, and many other academic, industry and municipal partners. AERPAW will be a first-of-its-kind aerial wireless experimentation platform with the goal to accelerate the integration of UAS into the national air-space, and to enable new advanced wireless features for UAS platforms, such as flying base stations for hot spot wireless connectivity. As part of this effort, AERPAW will develop a software-defined, reproducible, and open-access advanced wireless platform with experimentation features spanning 5G technologies and beyond.  <a href="https://aerpaw.org/">https://aerpaw.org/</a></p>
	<p><b>SMART GIGABIT COMMUNITIES</b></p> <p>US Ignite’s Smart Gigabit Communities (SGC) program is a network of more than 25 communities, each committed to the goal of accelerating the development, deployment and sharing of smart community/ Internet of Things (IoT) applications as an important element of their efforts to drive local innovation economies. Participating SGC communities leverage local resources including high-speed networks, local university researchers and innovation steering committee of local</p>

	<p>stakeholders to support application deployment and sharing.</p>
	<p><b>CLOUDLAB TECHNOLOGY</b></p> <p>The software stack that manages CloudLab is based on <a href="#">Emulab</a>, a testbed control suite that has been developed by the <a href="#">Flux Research Group</a> at the <a href="#">University of Utah</a>. Emulab’s primary strength lies in provisioning an ensemble of resources at the physical level, giving experimenters “raw” access to compute, network, and storage resources. The description of an ensemble includes a full description of the network, enabling Emulab to tightly control network topologies and to do network-aware resource placement.</p> <p>→ <b>Geni</b>: is a distributed infrastructure built by the National Science Foundation to support research in networks and distributed systems. CloudLab uses many technologies that were originally developed for GENI.</p>
<p><b>DARPA.</b> Defense Advanced Research Projects Agency. Its main mission is to make pivotal investments in breakthrough technologies for national security. The ultimate results have included not only game-changing military capabilities, but also such icons of modern civilian society such as the Internet, automated voice recognition and language translation</p>	<p><b><a href="#">Open, Programmable, Secure 5G (OPS-5G)</a></b></p> <p>DARPA’s Open, Programmable, Secure 5G (OPS-5G) aims to address this risk by pursuing research leading to the development of a portable standards-compliant network stack for 5G mobile that is open source and secure by design. OPS-5G seeks to create open-source software and systems that enable secure 5G and subsequent mobile networks such as 6G. The signature security advantage of open-source software is increased code visibility, meaning that code can be examined, analyzed, and audited, either manually or with automated tools. In addition, the portability of open-source serves, as a desired side-effect, to decouple the hardware and software ecosystems. This significantly raises the difficulty of a supply-chain attack and eases the introduction of innovative hardware into the market. The program seeks to enable a “plug-and-play” approach to various software components which reduces reliance on untrusted technology sources.</p> <p><b>COLOSSEUM</b></p> <p>Is an electronic arena funded under the Grand Challenge called the Spectrum Collaboration Challenge. The Colosseum testbed can emulate tens of thousands of possible interactions among hundreds of wireless communication devices—including cell phones, military radios, Internet-of-Things devices, and a litany of others—operating simultaneously in a square-kilometer expanse. That’s an area some 40 times that of the Roman Colosseum’s six acres.</p> <ul style="list-style-type: none"> <li>• The Colosseum testbed is a 256-by-256-channel RF channel emulator, which means it can calculate and simulate in real-time more than 65,000 channel interactions among 256 wireless devices.</li> </ul>

	<ul style="list-style-type: none"> <li>• it resides in a mere 30-foot by 20-foot server room on the campus of the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, MD,</li> <li>• Each simulated channel behaves as though it has a bandwidth (information content) of 100 MHz the testbed supports 25.6 GHz of bandwidth in any instant.</li> <li>• Each channel's transmission and reception frequency is tunable between 10 MHz (as in broadcast FM radio) and 6 GHz (as in WiFi).</li> <li>• The amount of digital RF data coursing through the Colosseum each second, more than 52 terabytes, exceeds the estimated amount of information contained in the entire print collection of the Library of Congress.</li> <li>• Engineers at APL assembled the Colosseum with 128, two-antenna, software defined radio (SDR) units built by National Instruments (NI). Emulating electromagnetic waves from these radios traversing the physical world is no small task. To tackle this, APL partnered with NI to put 64 field programmable gate arrays (FPGAs) to the task. The FPGAs enable the Colosseum to make the SDRs behave as though they are operating in any of countless environments, each designed like an electromagnetic movie set.</li> </ul>
<p><b>5G AMERICAS</b> is an industry trade organization composed of leading telecommunications service providers and manufacturers. The organization's mission is to advocate for and foster the advancement and full capabilities of LTE Wireless technologies and their evolution to 5G Americas is invested in developing a connected Wireless community while leading 5G development for all the Americas. 5G Americas is headquartered in Bellevue, Washington.</p> <p>Companies involved: at&amp;t, Cable&amp;Wireless, Cisco, Commscope, Ericsson, Intel, Kathrein, Mavenir, Nokia, Qualcomm, Samsung, Shaw), Sprint, Telefónica, T-Mobile, WOM.</p> <p>Website:  <a href="http://www.5gamericas.org/en/newsroom/press-releases/">http://www.5gamericas.org/en/newsroom/press-releases/</a></p>	<p>5G Americas publishes regularly white papers, some of their most recent publications are the following,</p> <ul style="list-style-type: none"> <li>• <a href="#">The Status of Open Source for 5G, February 2019</a></li> <li>• <a href="#">5G Spectrum Vision, February 2019</a></li> <li>• <a href="#">5G Communications for Automation in Vertical Domains, November 2018</a></li> <li>• <a href="#">New Services &amp; Applications with 5G Ultra-Reliable Low Latency Communications, November 2018</a></li> <li>• <a href="#">Evolution of Security in 5G, October 2018</a></li> </ul>
<p><b>INTERNATIONAL CENTER FOR ADVANCED INTERNET RESEARCH (iCAIR)</b>, The mission of iCAIR is to Accelerate Leading-Edge Innovation and Enhanced Digital Global Communications through Advanced Internet Technologies, in Partnership with the International Community. The Center accomplishes its mission by undertaking research and development (R&amp;D) projects in four key areas;</p>	<p><b>Grid Networks:</b> Next Generation Networks and Computational Grids, the development of new types of information technology continues to progress rapidly. It has often been noted that one way to view the future is to visit an advanced technology research lab where innovative developers are creating powerful new architecture, protocols, integrated systems. Optical Network Architecture and DWDM,</p>



[Advanced Applications](#), [Advanced Network Middleware](#), [Advanced Infrastructure](#), and [Public Policy Initiatives](#).

This organization is working on different research projects to promote international relations based on its four keys areas.

**Optical Metro Network Initiative (OMNI)** is developing a reference model for multiple next generation large scale communication services, based on optical technologies that allow for lightpath-based services supported by advanced photonic technologies. One of the key projects of this initiative is the OMNI-net testbed. OMNI-net is an inter-organizational cooperative research partnership, which includes iCAIR, Nortel, SBC (now AT&T), the Electronic Visualization Lab at the University of Illinois at Chicago, the MCS Division of Argonne National Lab, CANARIE (the Canadian Advanced Network for Advanced Research, Industry, and Educations. Experiments on the testbed have been extended via NetherLight to SurfNet in the Netherlands.

**Optical Dynamic Intelligent Network (ODIN)**, experimental architecture is being developed by iCAIR to explore new techniques for lightpath provisioning, in particular as a mechanism for bringing directly into applications capabilities that traditionally are placed deep within the core of networks.

**Simple Path Control (SPC) Protocol**, is a signaling mechanism that allows for edge processes, including applications, to communicate requirements for specific paths through a network by signaling to a server capable of establishing such paths using core network resources.

**OptIPuter** is a national and international distributed facility that closely relates multiple IT components, including optical networking, Internet Protocol (IP), high performance computational clusters, computer storage, and visualization technologies. It is an infrastructure envisioned as one that will tightly couple computational resources over parallel optical networks using the IP communication mechanism.

**Distributed Optical Testbed (DOT)**. DOT is being designed and implemented by an inter-organizational cooperative research partnership to facilitate the research and development of innovative techniques that require the efficient execution of distributed applications.

**Global Lambda Integrated Facility (GLIF)**, iCAIR is a founding member of the Global Lambda Integrated Facility ([GLIF](#)) is an international organization that is advancing new concepts, architecture and services related to dynamically provisioned lightpath (lambda) networking.

**National Lambda Rail**, One such initiative, the National Lambda Rail ([NLR](#)), has created a distributed fiber facility across the US. Half of that fiber can be used for research projects. iCAIR is participating in several projects that are using the NLR for experimental projects. The connection point for these research projects is the StarLight facility. Several of these projects use the CaveWave, a 10 Gbps research circuit between UIC and UCSD managed by EVL.



	<p><b>Multiple 10 Gbps Computational Clusters.</b> Traditionally, iCAIR computational clusters have been based on racks of compute nodes with I/O for each node provided by a GE link to a high performance L2 switch, aggregate the single GE flows to 10 GE. Currently, iCAIR is designing computational clusters that will have 10 G NICs as part of each node. iCAIR is evaluating and experimenting the various components required, high performance backplanes, NICs based on various protocols, Linux stacks, protocols, off-load technologies, writable processors, and others.</p>
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## 8. Annex III: First outcomes of the Networking Channel

### 8.1 Registrations / attendees per region

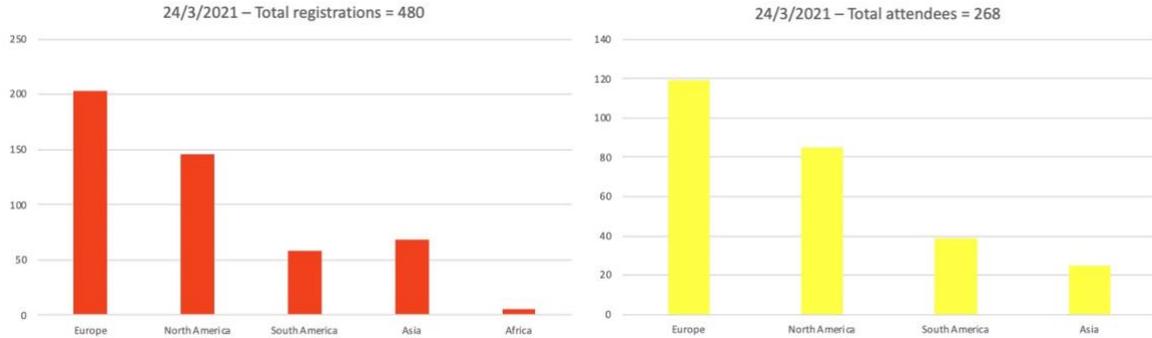


Figure 2 – Registration/attendees for the 1<sup>st</sup> event, 24 March 2021

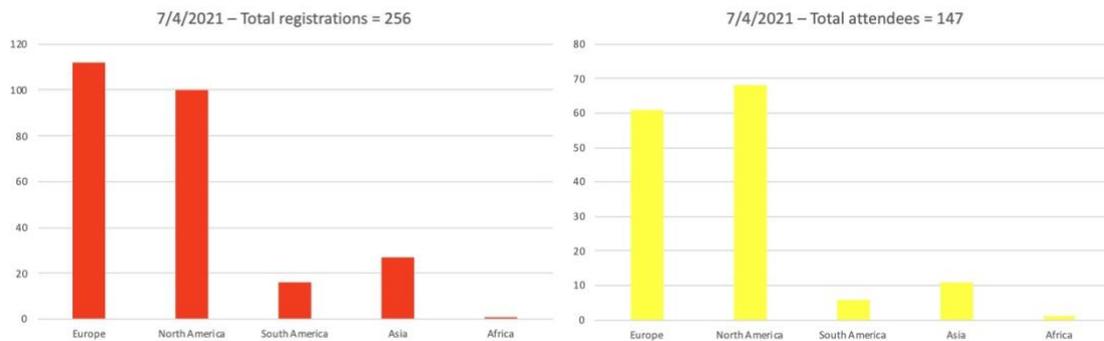


Figure 3 – Registration/attendees for the 2<sup>nd</sup> event, 7 April 2021

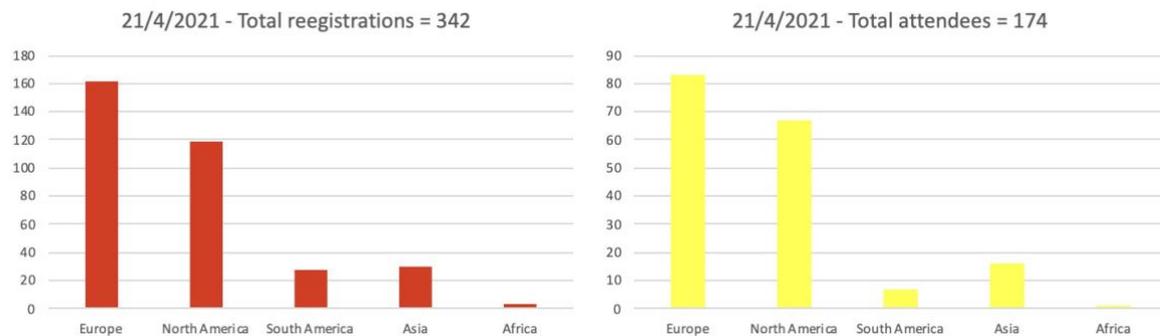


Figure 4 – Registration/attendees for the 3<sup>rd</sup> event, 21 April 2021

## 8.2 Website and social media impact

- 84 subscribers at our YouTube Channel
- Number of views of the recording:
  - Event #1: 352
  - Event #2: 117
  - Event #3: 13 (a few hours after the event).

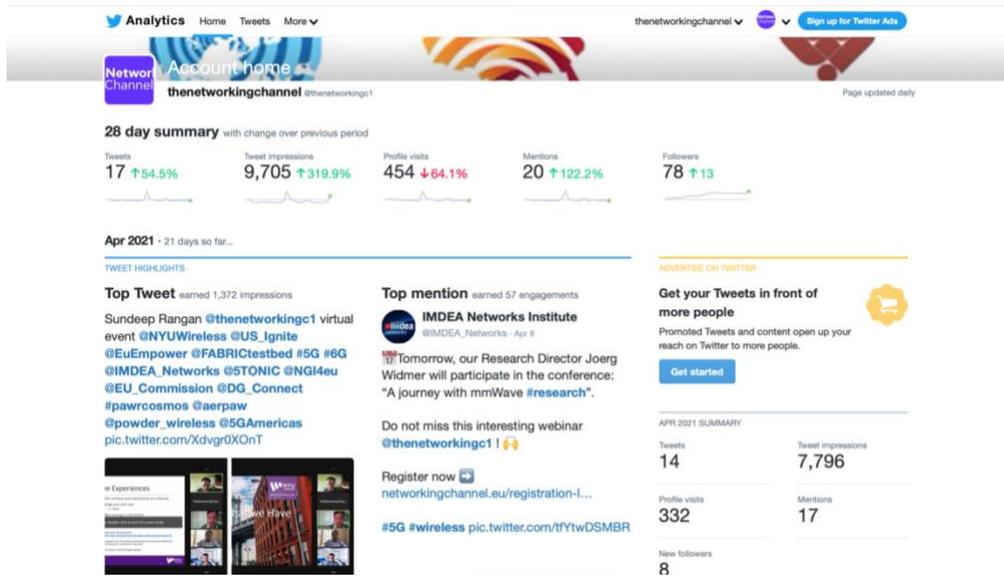
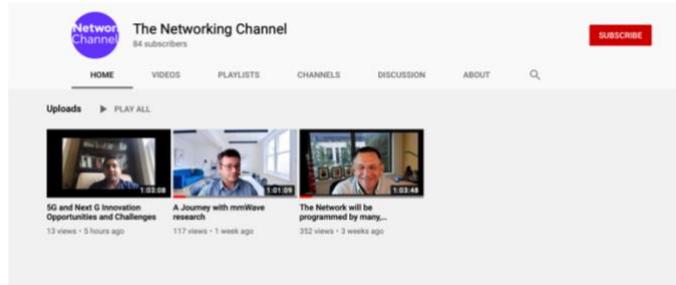


Figure 5 – Social Media statistics (Twitter)

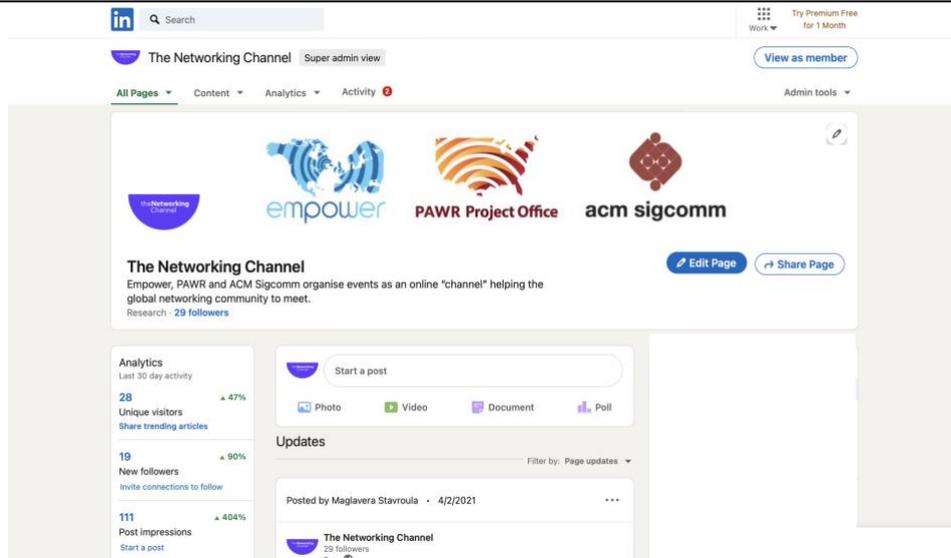


Figure 6 - Social Media statistics (LinkedIn)

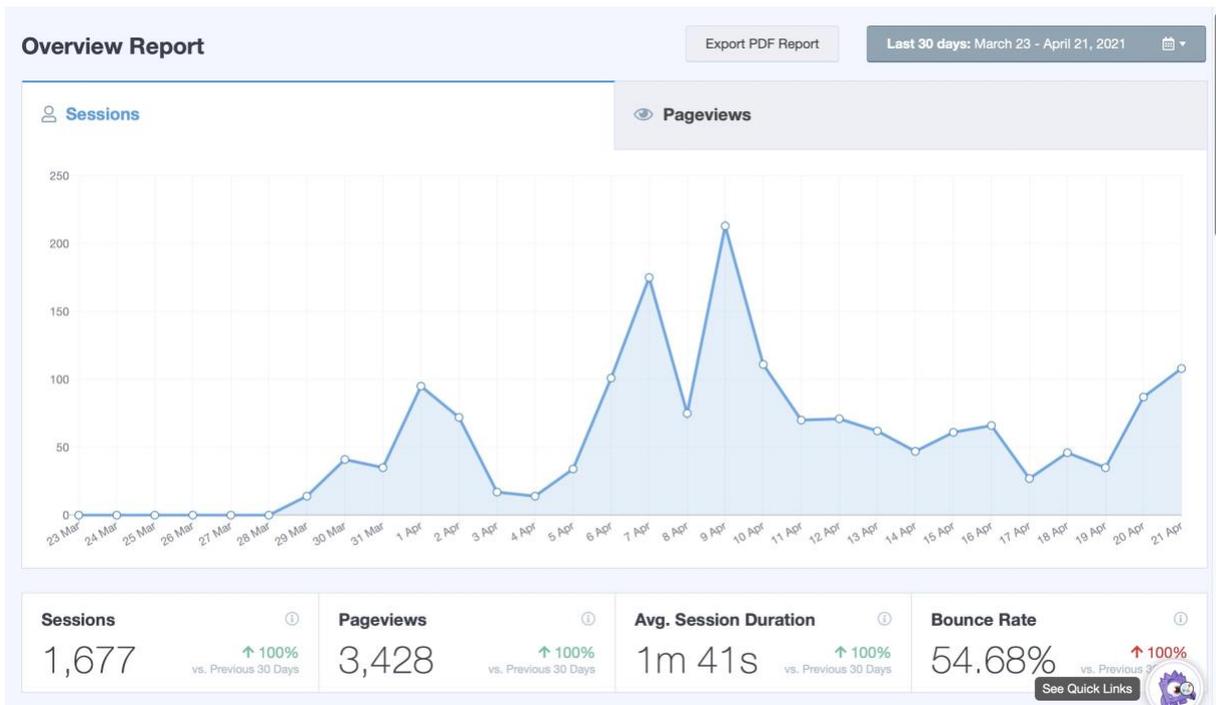


Figure 7 – Web-site visits

<b>Top 10 Countries</b>		①
1.	 United States	556
2.	 France	105
3.	 Brazil	104
4.	 Germany	101
5.	 India	82
6.	 Spain	76
7.	 Greece	73
8.	 Italy	63
9.	 United Kingdom	57
10.	 Thailand	53

Figure 8 - Website statistics (Top 10 countries)

<b>Top Posts/Pages</b>		①
1.	The Networking Channel	675
2.	Networking Events – The Networking Channel	579
3.	A Journey with mmWave research – The Networking Channel	384
4.	5G and Next G Innovation Opportunities and Challenges – The Networking Channel	287
5.	mmwave-research-downloads – The Networking Channel	272
6.	Open RAN as a novel paradigm to disaggregate and democratize the RAN – The Networking Channel	188
7.	Registration List – The Networking Channel	138
8.	Library – The Networking Channel	132
9.	network-downloads – The Networking Channel	119
10.	Committees – The Networking Channel	115

Figure 9 – Website statistics (Top posts/pages)