HORIZON 2020
ICT - Information and Communication Technologies

Deliverable D1.1
EMPOWER Strategy Document and Collaboration Roadmap v0

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History

Version	Author	Date	Status
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1.0	Emilie Mespoulhes	31/05/2019	Final version submitted

Abstract

This document presents the initial version of the EMPOWER Strategy Document and Collaboration Roadmap. This initial version is the result of the discussion on the first six months of the Project and includes the initial strategy for collaboration and the planned roadmap/agenda of activities and collaboration opportunities for the short term. 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 advance wireless communication platforms.

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1. Introduction

The overarching aim of EMPOWER is to reinforce the cooperation between the EU and the US towards establishing a collaborative transatlantic community on the new connectivity frontiers beyond 5G. Our ambition is to create the conditions to accelerate the joint development of the associated advanced wireless platforms. EMPOWER follows and builds on the recurrent dialogue between the EU and the US regarding Advanced Networking Platforms as presented in the "Report from the EU/US Future Networks Workshop", dated November 11, 2017. EMPOWER targets the creation of a joint EU-US advanced wireless ecosystem for (i) bridging the relevant EU-US Wireless communities and stakeholders, such as scientific researchers, platform engineers, standardization experts, regulators, and product incubators, (ii) developing a strategic EU-US collaboration agenda and (iii) supporting its execution based on common EU-US roadmaps spanning advances in scientific knowledge, platforms and testbeds, standards and regulations. EMPOWER foresees twinning with initiatives funded by the US NSF addressing this objective, in particular entities participating in the NSF Programme for Advanced Wireless Research (PAWR).

The objectives of the EMPOWER Strategy Document are the following:

- Engage with 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 offer instruments for inducing collaboration targeting wireless and networks experimentation on both ends of the Atlantic, anticipating the future challenges in wireless networking and accelerating the related research agenda. This will be achieved (i) by stimulating interaction through transatlantic workshops conceived to raise awareness about technological advances, (ii) cataloguing and documenting software and deployment tools, (iii) stimulating joint developments and experimentations to address identified common challenges, and (iv) identifying standardization opportunities and dissemination/demonstration avenues to encourage industrial interest.

An important output of EMPOWER will be in the form of recommendations on technologies and experimentation methodologies and tools for future wireless experimentation objectives. EMPOWER will promote the use of test platforms and work with the community to make experiments simpler. This will assist in providing coordination between EU (Horizon Europe) and US NSF programmes for future individual and joint calls.

Worth noting that this document has been built considering other efforts from the 5G-PPP on cartographies and analysis of current research efforts for 5G and beyond 5G. Most notably the Platforms Cartography (https://5g-ppp.eu/5g-ppp-platforms-cartography/) developed by the Trials WG of the 5G-PPP.

The rest of this document is structured as follows. Section 2 presents the main challenges associated to the building of the transatlantic collaboration. Section 3 presents the Collaboration Roadmap, together with the list of already executed actions and the planned ones. Section 4, focuses on dissemination and community building activities, presenting a summary of the achievements discussed in D4.1. Finally, Annex I and II provide a comprehensive analysis of the actors involved in Advance Wireless research at both sides of the Atlantic.

2. Key Challenges and open questions

This section presents the different challenges identified to foster the collaboration in the research area of Advanced Wireless Platforms for 5G and Beyond. The challenges are structured in six key areas of collaboration:

- Foster collaboration through Dissemination and Community Building
- Building Advance Wireless Platforms
- Impacting Standards
- Impacting Radio Spectrum and Regulators
- Building common Software Toolboxes
- Performing Joint Experimentation

This initial version of the EMPOWER Strategy Document limits itself on the presentation of the key questions or challenges which need to be solved in order to foster collaboration on advance wireless platforms across the Atlantic. Future versions of this document will focus on how each question can be tackled.

2.1 Fostering collaboration through Dissemination and Community Building

The building of strong relations and community around the development and research on advance wireless platforms is a key outcome of EMPOWER. In the following we present some key challenges to be addressed in order to build such relationship:

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 at 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 higher presence of researchers from EU and USA on the Advanced Wireless communications topic?

2.2 Building Advanced Wireless Platforms

Advance wireless platforms development is key for reaching a predominant position in the next generation of wireless technologies. The level of complexity of wireless systems have reached a momentum where the testing and validation of key elements, confronting them with the requirements of their potential users is needed to understand their dynamics and to find possible bottlenecks. As such, we present next a list of challenges and potential questions to be developed further:

1. What kind of experimentation are researchers looking at?
2. What are the needs from researchers, is only PHY research look for or research in control approaches is also needed?
3. What kind of hardware is the best to build such a platform?
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?
6. Is there some way of connecting with industry, is pre-commercial hardware of any use?
7. Who are the users of the platforms? In Europe we are very focused on verticals, for Beyond 5G will it be the same?
8. What components should be available in the platforms? Only PHY, MAC? Complete end to end, Core?

2.3 Impacting Standards

Market is dominated by standards. The collaboration among Europe and USA surely will cover basic research but needs also to reach further into the development of joint standardization initiatives and efforts. Although we acknowledge the complexity of working in a world dominated by large companies, we think EMPOWER can help to foster collaboration in the standards framework:

1. How do we liaise with standardization bodies, considering international reach?
2. How we overcome the fact that companies will not consider join work or join licensing if they can avoid it
3. How do we set up a strategy for standards development?
4. What are the key standards for Beyond 5G research?

2.4   Impacting Radio Spectrum and Regulators

Platform based research on wireless technologies involves spectrum and frequencies in many ways. First, to perform experiments, platform owners and researchers depend on the access to vacant spectrum whether it is for propagation and channel studies, or for system development and performance studies. Second, for wireless research to be relevant, choosing the right frequency bands must be based on regulatory trends foreseen. Thus, global and regional spectrum policies should advice on the most likely frequency bands for future use. Third, spectrum management may be based on licensed or unlicensed approaches, and more advanced spectrum sharing methods are constantly being considered by the regulators, based on e.g. cognitive radio and AI-methods. Recognizing the high importance of spectrum issues for the EMPOWER strategy discussion, the following questions can be defined:

1. Which new spectrum bands are being considered for the 5G evolution?
2. Will new and relevant spectrum bands be available for research and experimentation in Europe and US before licensed to operational use?
3. What are the spectrum regulation trends pointing forward?
4. Will EU and US work towards a harmonization, both on specific frequency bands and conditions for usage?
5. Will there be reserved bands for e.g. propagation studies?
6. What will come out from WRC-19 related to spectrum beyond 5G and what will be the agenda for WRC-22?
7. How can we influence spectrum regulations for the purpose of good conditions for research and experimentations?

2.5   Building common Software Toolboxes

Researchers will highly benefit from the existence of a set of common tools and software toolboxes that can be used for 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. The following open questions try to put some light on the challenges:

1. What kind of tools are being used in the current platforms
2. What of them are OpenSource or can be used without licensing
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?

2.6   Performing Joint Experimentation

The objective of the collaboration between USA and EU geographical areas in the development of advanced wireless platforms make sense if a common set of joint technologies can be developed and validated across the different platforms. As such, the key question to be answered is what the common scenarios of interest across the two communities are and how can this scenario be validated. Currently the platforms developed across both regions, the ICT-17 projects in Europe and the PAWR platforms in USA are still not aligned in technologies. Therefore, careful planning of experiments, to exploit such heterogeneity and complementarities must be encouraged.

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. Identify the main target groups and communities.

3. Collaboration Roadmap

Figure 3-1 shows all the activities, conferences and meeting EMPOWER is organizing and participating during the first year of the project with the aim to foster a networking collaboration related to 5G including the most important actors working in this field.
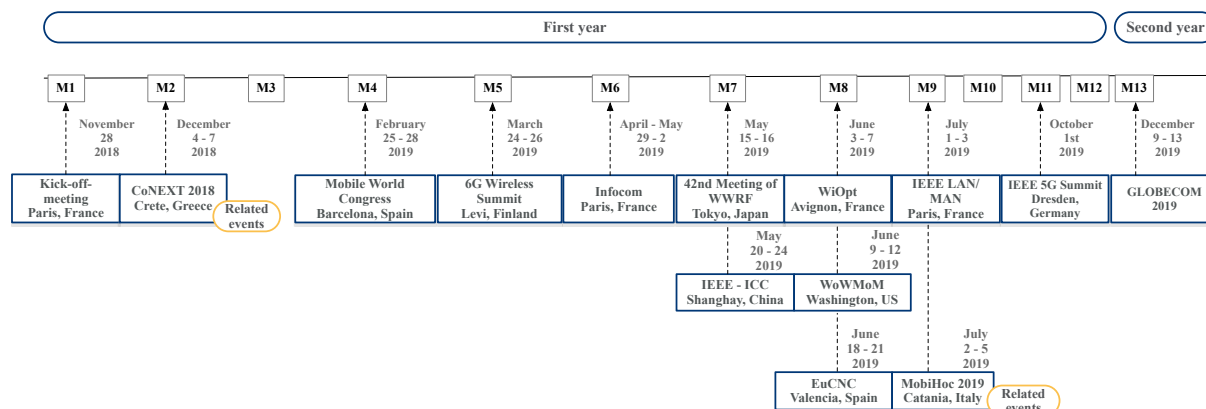

Figure 3-1: Collaboration Roadmap

Table 3-1 presents a detailed view of all the collaboration activities performed up to April 2019 and the future activities already planned for the near future.

Table 3-1: Detailed list of collaboration activities

EVENT	DATE AND LOCATION	EMPOWER PARTICIPATION
Kick off meeting	November 28th 2018 Paris, France	Consortium participants: SU, UC3M, UTH, EURECOM, IDG, NBLF, TELENOR and PAWR.
Mobile World Congress	February 25-28th 2019 Barcelona, Spain	Invited Panel February 25th, 2019 Moderator: Robert Gazda, VP of Interdigital Panelists: Rolf Schuster. Director, Open Edge Computing Initiative Laurent Depersin. Director Research and Innovation HOME Lab, Technicolor Arturo Azcorra. Director of IMDEA and VP and Co-Founder, 5TONIC Todd Spraggins Strategy Director, Communications Global Business Unit, Oracle Dirk Trossen Senior Principal Engineer, InterDigital and FLAME Technical Manager Invited Panel February 26th, 2019

		Moderator: Phil Kendall, Executive Director of the Service Provider Group Panelists: Arturo Azcorra, Vice President of 5TONIC Laboratory Heng Qiu, President of Global Marketing at Huawei Olof Henricsson, Teralytics, Global Head of Business Development More info at: https://www.mwcbarcelona.com/session/capitalising-on-operators-assets-for-the-industry-4-0-value-chain/
6G Wireless Summit	March 24-26th 2019 Levi, Finland	EMPOWER presentation by Dr. Alain Mourad, InterDigital. The presentation focused on showing the whole vision about EMPOWER. What the projects looks for and how could EMPOWER procure the purpose of broad relation collaborations from other entities and testbeds.
INFOCOM	April 29th May 2nd 2019 Paris, France	The fourteenth edition of this conference, IEEE proposes the exchange between researchers in the field of networking and closely areas. Raymond Knopp from EURECOM society and panelist at Infocom will participate in Panel B: Experimentation Meets Platforms: A Survey of Macro Trends in Mobile Communication Research and Its Impact on Future Testbed Development. Abstract: ""Softwarization" is often referred to as a general paradigm shift in telecom architecture from "boxes" to "functions", and from "protocols" to "APIs". This has profound impact on research testbed platform architecture and its components. The panel begins with exploration of such fundamental advances at all layers and by delving into investigations of the research infrastructures suitable for hosting at-scale experimentation in future mobile architectures, services, and applications, and use of such infrastructures for experimental research using practical examples. The distillation of the lessons learned above are laid out as requirements for future at-scale platforms."
42nd Meeting of WWRF	May 15-16th 2019 Tokyo, Japan	Wireless World Research Forum plan to foster an international discussion through 5G. Different countries from Europe, America, Africa and Asia participate in the effort to roll out 5G technologies, and an ongoing debate as to how to meet the requirements of the various vertical industries that will make use of 5G.
Future Network Summit	May 22-23th 2019 Nanjing, China	Large venue where main actors in China are present to discuss future trends. Demos and exhibitions are also presented. The inaugural session is hosting some international guest speakers.
IEEE – ICC	May 20-24th 2019 Shanghai, China	The International Conference on Communications (ICC) located in Shanghai, China in 2019 will discuss the main and current topics on communications field

		through different workshops, conferences, tutorial and technical symposia.
WiOpt	June 3-7th 2019 Avignon, France	The 17th International Symposium on Modeling and Optimization in Mobile, Ad hoc, and Wireless Networks solicits high-quality contributions. It welcomes different perspectives, including performance analysis, protocol design, wireless communication, and optimization theory. Contributions to this symposium should improve the state-of-the-art in design, analysis, dimensioning and operations of wireless network by providing insights into theoretical aspects as well as providing practical methods and tools. All forms of wireless networks are of interest: from cellular wide-area and local-area networks to dense and sparse Ad Hoc networks; domain specific vehicular, public-transport and personal-area networks as well as application-specific sensor networks.
WoWMoM	June 29-12th 2019 Washington, US	IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM). The intellectual hub and melting pot of ideas from researchers and practitioners interested in all aspects of wireless, mobile, and multimedia pervasive communications.
5G Global Event/EuCNC	June 17-21th 2019 Valencia, Spain	EuCNC 2019 is the 28th edition of a successful series of a conference in the field of telecommunications, sponsored by the IEEE Communications Society and the European Association for Signal Processing, and supported by the European Commission. During five days, different panels, conferences and exhibition will take place in Valencia. EMPOWER consortium and their partners will participate to promote their project.
IEEE LAN/MAN	July 1-3rd 2019 Paris, France	IEEE LANMAN has an established tradition as a forum for presenting and discussing the latest technical advances in local and metropolitan area networking. Prof. Serge Fdida from Sorbonne University, LIP6 Laboratory & LINCS and Coordinator of EMPOWER will take part of the forum as keynote speaker.
MobiHoc 2019	July 2-5th 2019 Catania, Italy	International symposium dedicated to addressing challenges in dynamic networks and computing.
IEEE 5G Summit Dresden	October 1st 2019 Dresden, Germany	In order to engage industry members with innovative high-value technologies, IEEE Communications Society is holding a series of high-impact one day summits on emerging technologies, such as SDN/NFV, 5G, IoT, Big Data, and cyber security.
GLOBECOM 2019	December 9-13th 2019 Hawaii, US	Themed, Revolutionizing Communications, this flagship conference of the IEEE Communications society will feature a comprehensive high-quality technical program including technical tutorials and technical workshops.

3.1 Conclusions from the EMPOWER-PAWR joint meeting (29/04/2019, Paris)

A joint meeting between the European Union H2020 EMPOWER project and the US-based PAWR program was organized in Paris on 29/4/2019, in parallel with IEEE International Conference on Computer Communications (IEEE INFOCOM).

3.1.1 Main ideas of the meeting.

The main objective of the joint meeting was to establish liaisons between key persons in Europe and USA to share information and start discussing possible joint activities related to advanced wireless platforms at both sides of the Atlantic towards 5G and beyond 5G technologies. In addition, the ongoing work of the three ICT-17-2018 projects and the on-going NSF PAWR projects was presented. Each of these projects shortly highlighted the services provided by their projects, the infrastructure available at this stage and their roadmap.

First, participants discussed on potential joint experimentation between EU and US. The issues discussed were around Software component store, Open Source Domain Analysis and Joint and Cross-Platform Experimentation. The potential to use ICT-17/19/20 and the evolutions in Horizon Europe and PAWR nodes in order to bring forward the joint research and ideas via industry driven initiatives. There is a major opportunity for academic research to have more direct impact in pushing ideas to industry designs. There are several initiatives to be exploited such as Linux Foundation that federates software for Telecom Technology demonstrators; Telecom infrastructures projects, Small-cell forum and many others. There is a need for catalog of HW/SW tools and how to use them to build technology demonstrators and finally to promote 5G and beyond 5G technologies in industry driven venues and fora.

Second, a session was devoted to the "EMPOWER Advanced Roadmap", where participants assessed future technical areas on the path of 5G evolution and the associated experimental challenges. These research areas currently include enhancements to existing 5G specifications to support full-fledged operations in a wide range of vertical use cases, support of low-power low-cost devices, and support for spectrum above 50 GHz. Moving forward, research areas will include support of moving (including flying cells and relays), highly accurate positioning, machine learning-based advanced spectrum sharing, and fine integration of cellular and non-cellular technologies. Longer-term objectives include support for spectrum above 100 GHz, pervasive machine learning and artificial intelligence, integration of non-wireless communication technologies (sensing, radar, charging, imaging), and integration of massive High-Altitude Platforms (HAPs) and Very Low Earth Orbit (VLEO) satellites.

This joint meeting will be followed from other activities and opportunities for discussions, such as the EUCNC workshop (Valencia, June 2019) the GEFI (Portugal, November 2019) and others to be introduced at a later stage.

3.1.2 Main conclusions of the meeting

Conclusions were focused on the discrepancies between the Europe and USA approaches:

- The PAWR and ICT-17 platforms have different target and missions but show some potential common interest.
- PAWR focuses in pure research and the first PAWR nodes are oriented beyond 5G.
- ICT-17 platforms are demonstrating 5G and the focus is mostly deployment, where ICT-19 will address verticals landing on ICT17 infrastructures.
- Differences existed in the past between FIRE and GENI however collaboration happened, so we need to further investigate the commonalities and the collaboration paths.
- The two new PAWR platforms (phase 2) are driven by applications providing a big potential for deployment, which means that are closer to vertical sectors.
- EMPOWER can act as the catalyst of the cooperation through the tools that we have:
    - Key technologies as described in the roadmap is important.
    - Benchmarking of usability.
- EMPOWER roadmap welcome contributions from European and US experts as discussed during the joint meeting.
- Joint experimentation is not easy to enable. It was mentioned more detailed and practical information about the respective platforms is necessary for both sides.

- EMPOWER can act as catalyst facilitating the exchange of knowledge through the use of the different tools (joint workshops, researchers visit/mobility, hackathons).
- Joint experimentation – maybe same verticals through ICT-17 and PAWR nodes or through KPI infrastructures for verticals.
- Commonalities between PAWR and ICT-17 – inventory of SW and HW components, tools used, etc. Details of each testbed.

The following action points have been agreed towards fostering the collaboration among USA and Europe in the advance wireless platforms area:

3.1.3 Actions points:

Based on the discussion that happened during the workshop, four complementary activities will be explored.

1. Sharing practices and solutions

EMPOWER/PAWR are willing to propose site visits to US and EU delegates with the objective to go into more details and therefore, be in a position to better identify potential opportunities for cooperation. Contacts will be taken to check interest and plan the visits. This concerns ICT17 and PAWR platforms.

2. Exploring E2E system level

This part aims at questioning how to set-up an E2E open reference architecture. This might be a concern of mutual interest as it goes beyond the wireless specific hardware components and target the issue related to the E2E architecture that should be encountered by most projects.

Three activities are envisaged and will be discussed further, inviting the relevant actors to take part to the debate. They will all be discussed at the next EUCNC EMPOWER/PAWR Workshop on June 18 2019, where the discussion will be focused on the role of Open Source for experimentation, production and infrastructures:

- Radio platforms: use of OAI/O-RAN or other platforms for the developing of the RAN in an open reference platform.

- Core platforms: possible use of ONF/OMEC or other platforms for the development of the Core part of the open reference platform.

- The need of an NFV open framework to provide a relevant test framework and toolset to perform tests.

3. EMPOWER Roadmap

As presented during the workshop, the roadmap first version will be developed, and all will be invited to contribute.

4. Data management and Reproducibility

All projects and platforms will have to propose a plan for the above. The idea is to explore the commonalities, invite other scientific domains to share with us their experience and solutions, talk to the research funding organizations and societies (ACM, EU FAIR, etc…).

The complete minutes of the workshop can be found in Annex III.

4. Dissemination and Community building

To guarantee the research network and mobility between both territories, EMPOWER will develop a communication and strategy plan, as it shows in D4.1 "Communication and Community Building Strategy and Plan". Through this planning, the consortium aims to define the communication and community building strategy and describe the activities EMPOWER partners will pursue so as to guarantee broad visibility, promotion and up-take.

EMPOWER proposes the following objectives and priorities for dissemination, communication and community building activities to obtain a successful collaboration between 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 trough 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 a entity such as Twitter, LinkedIn, YouTube, Slideshare, Vimeo and EMPOWER website.

To guarantee EMPOWER send a successful message and obtain UE-US collaborations is required to analyze the target audience.

The main target stakeholders identified EMPOWER preparation time are listed hereby.

- ***Related research wireless communities, stakeholders and initiatives***, with the objective to involve the best researchers and engineers who can have a leading role and a transformative effect. Addressing frameworks such as H2020 5G-PPP, ICT-17- 5G-end-to-end facilities, H2020 Beyond 5G, H2020 BigData-PPP, US PAWR, FIRE+ and other related advanced wireless platforms research communities.
- ***Application domains communities***, including Communities for Smart Cities, eHealth, Transport, Energy, Factories of the Future, Big Data, Cloud, High-Performance Computing etc., since they are potential users.
- ***Relevant initiatives*** in Europe and USA aiming at mutual exchange and communication, best practices and promotion of potential collaboration opportunities on research on advance wireless platforms, such as OSA, Linux Foundation, and O-RAN.
- ***Standardization bodies***, such as International standardization bodies in ICT, like ITU-R, ETSI, 3GPP, IEEE, as well as any other relevant standardization bodies.
- ***Policy makers***, at any level like the EC, PAWR office, NSF, Ministries, Governments, Regulatory agencies for the definition of the future research and innovation directions based on EMPOWER's acquired knowledge.

The communication tools that will be used to get all the objectives are based on four different actions:

- Support the community engagement and the capacity building considering the needs and priorities of the various stakeholders through the communication activities.
- EMPOWER's website will provide information about the project's objectives, methods and achievements. This action also be complemented by ***Social networking*** (project webpage, Facebook and Twitter). ***Newsletter production*** with the aim to describe the evolution of the project a bi-annual e-newsletter will be launch. ***Report publishing***, all public deliverables will be published on the project's website. ***Promotional material*** including flyers, posters, presentations, etc., and **Publications.**
- Workshops and events. EMPOWER takes care of organizing dedicated events, as well as coordinating participation to major ones in close collaboration with the EC and all ongoing relevant initiatives, which will contribute to increase the visibility and the impact, while attracting more newcomers.
- Mobility of researchers. Research mobility is particularly important in promoting knowledge flows and ensuring a diverse and highly skilled workforce that has the capacity to respond to opportunities and

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challenges in EU-USA in wireless research. The goal of this integration activity is to increase ties to transnational research in advanced wireless platforms and to promote the knowledge flows and collaboration between institutions promoting new interdisciplinary academic – industrial networks.

- Hackathons. EMPOWER supports the organization of Hackathons on Advanced Wireless platforms. At least 2 hackathons are planned during the lifetime of the project.

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

PROGRAMME	CALLS
EUROPE **HORIZON 2020** 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. 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.	***ICT 08-2017 5G PPP Convergent Technologies.*** **5G-CITY.** Teaser: Delivering on the 5G promise of increased data rates, and ubiquitous coverages, poses stringent requirements on traditional vertically integrated operators. In particular, telecom operators are expected to massively roll out Small Cells, which requires finding appropriate urban spaces with both backhaul and energy availability. Network sharing becomes essential to unlock those commercial massive deployments. The open access model, or neutral host, will come to play a key role on the deployment of 5G networks, especially in urban scenarios where very dense Small Cell deployments are required. https://cordis.europa.eu/project/rcn/211066/factsheet/en **5-MEDIA** (Programmable edge-to-cloud virtualization fabric for the 5G Media industry). Teaser: The focus of 5G PPP H2020 remarkable research so far has been largely on the required advances in network architectures, technologies and infrastructures. Less attention has been put on the applications and services that will make use of and exploit advanced 5G network capabilities. 5G-MEDIA aims at innovating media-related applications by investigating how these applications and the underlying 5G network should be coupled and interwork to the benefit of both. https://cordis.europa.eu/project/rcn/211076/factsheet/en **5G MATILDA** (A Holistic, innovative framework for the design, development and orchestration of 5G-ready applications and network services over sliced programmable infrastructure). Teaser: The vision of MATILDA is to design and implement a holistic 5G end-to-end services operational framework tackling the lifecycle of design, development and orchestration of 5G-ready applications and 5G network services over programmable infrastructure, following a unified programmability model and a set of control abstractions. It aims to devise and realize a radical shift in the development of software for 5G-ready applications as well as virtual and physical network functions and network services, through the adoption of a unified programmability model, the definition of proper abstractions and the creation of an open development environment that may be used by application as well as network functions developers. Intelligent and unified orchestration mechanisms will be applied for the automated placement of the 5G-ready applications and the creation and maintenance of the required network slices.

ICT 09-2017 Network research beyond 5G. This topic is relevant because of the challenge it was proposed in the work-program, **"**The challenge is to support European scientific excellence notably in the DSP domain, and to bring the most promising long-term research coming from the labs closer to fruition."

Research projects

TERAPOD (Terahertz based Ultra High Bandwidth Wireless Access Networks). Teaser: The saturation of wireless spectrum access is leading to innovations in areas such as spectrum resource usage. It is widely thought however that the low hanging fruits of innovation for wireless communication are all but exploited with only marginal gains possible. For a real step change towards the coveted 1Tbps wireless transmission, new areas of the spectrum must be utilized. https://cordis.europa.eu/project/rcn/211071/factsheet/en

DREAM (D-Band Radio solution Enabling up to 100 Gdps reconfigurable Approach for Meshed beyond 5G networks). Teaser: Nowadays there is a shared vision among industry, operators and academy that beyond 5G wireless networks will have to provide wideband wireless access and ubiquitous computing anywhere and at any time. https://cordis.europa.eu/project/rcn/211059/factsheet/en

ULTRAWAVE (Ultra capacity wireless layer beyond 100 GHz based on millimeter wave Traveling Wave Tubes). Teaser: For the first time, smartphones and tablets data usage exceeds desktops. This is a wakeup call for manufacturers and operators to provide users with ubiquitous, high speed and high quality wireless coverage. https://cordis.europa.eu/project/rcn/211094/factsheet/en

TERRANOVA (Terabit/s Wireless Connectivity by TeraHertz innovative technologies to deliver Optical Network Quality of Experience in Systems beyond 5G). Teaser: To provide reliable connectivity of extremely high data rates in the Tbit/s regime and almost 'zero-latency' in networks beyond 5G, TERRANOVA proposes to extend the fiber-optic systems Quality of Experience and performance reliability to wireless. https://cordis.europa.eu/project/rcn/211078/factsheet/en

WORTECS (Wireless Optical/Radio TErabit Communications). Teaser: The first 5G release standard in 3GPP will be available by June 2018 with pre-commercial deployment in Korea soon after. Whilst 5G will meet current demand, the exponential rise in demand for wireless connectivity will ultimately require Tbps connectivity in indoor spaces. https://cordis.europa.eu/project/rcn/211056/factsheet/en

EPIC (Enabling Practical Wireless Tb/s Communications with Next Generation Channel Coding). Teaser: EPIC aims to develop a new generation of Forward-Error-Correction (FEC) codes to enable practical wireless Tb/s link technology— corresponding to a 10x–100x throughput improvement over the SoA.

NGPaaS (Next Generation Platform as a Service). Teaser: Cloud innovations have had a major impact on the IT industry but not yet on networks. The danger is that 5G will be a niche industry providing basic connectivity for the cloud applications and services boom. The NGPaaS project envisages 5G as: a build-to-order platform, with components, features and performance tailored to a particular use case; developed through a "Dev-for-Operations" model that extends the IT industry's DevOps approach to support a multi-sided platform between operators, vendors and verticals; and with revised Operational and Business Support Systems (OSS/BSS) to reflect the new parameters and highly dynamic environment. NGPaaS can enable 5G to become central to a cooperative future with cloud developers, by removing the technological silos between the telco and IT industries.

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). Teaser: 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.

5GENESIS (5th Generation End-to-end Network, Experimentation, System Integration, and Showcasing). Teaser: 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.

5G-EVE (5G European Validation platform for Extensive trials). Teaser: 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.

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 <u>cross border</u> 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). Teaser: 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). Teaser: 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). Teaser: 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

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). Teaser: 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). Teaser: 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). Teaser: 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). Teaser: 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). Teaser: 5G-Xcast will devise, assess and demonstrate large scale immersive media delivery by means of 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). Teaser: 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). Teaser: 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). Teaser: 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.

SaT5G (Satellite and Terrestrial Network for 5G). Teaser: 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).

BlueSpace (Building on the Use of Spatial Multiplexing 5G Networks Infrastructures and Showcasing Advanced technologies and Networking Capabilties). Teaser: 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.

5GCAR (Fifth Generation Communication Automotive Research and Innovation). Teaser: 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.

5G–TRANSFORMER (5G Mobile Transport Platform for Verticals). Teaser: 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.

5G-MoNArch (Mobile Network Architecture for diverse services, use cases, and applications in 5G and beyond). Teaser: 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.

5G-PICTURE (5G Programmable Infrastructure Converging disaggregated neTwork and compUte REsources). Teaser: 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.

COST Actions are funded over a four-year duration which requires the participation of at least seven different COST Full Members or Cooperating Members.

Next Open Call for new COST Actions is scheduled with a deadline of 5 September 2019

COST IRACON (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 also aims at training young researchers in the field of inclusive radio communications, via annual training schools and short term missions. COST IRACON started in 2016 and will end in 2020. http://www.iracon.org

HORIZON EUROPE is the following step of Horizon 2020 Program. The European Commission proposed €94.1 billion over seven years, starting in 2021 until 2027.
The main aims are to strengthen science and technology, to foster industrial competitiveness.

A potential candidate Partnership (2021-2027) on Smart Networks and Services (SN&S) is currently under definition (https://5g-ppp.eu/wp-content/uploads/2019/02/5G-IA-Position-Paper-Smart-Networks-and-Services_Horizon-Europe.pdf).

6GENESIS 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.
Research is organized into four strategic areas: Wireless Connectivity; Devices and Circuit Technology; Distributed Computing and Services and Applications.

The beginning of 6GENESIS is planned with the next European Framework Horizon Europe.

FIWARE, 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 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.
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

In Fiware website is published different events to promote collaboration between different organizations but there is no calls or proposals allowed.
https://www.fiware.org

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.

TRANSATLANTIC ICT FORUM Project co-funded by H2020 called "Discovery" Europe-North America Dialogues for ICT Cooperation. It finished in 2017 but the website is already active.

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.

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.
Website: http://discoveryproject.eu/transatlantic-ict-forum

In Transatlantic ICT Forum are published different events to promote collaboration between different organizations but there is no calls or proposals allowed.

FED4FIRE+ 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 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

Testbed they are working on this moment are,
CityLab, 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.
Exo Geni, is a GENI testbed that links GENI to two advances in virtual infrastructure services outside of GENI: open cloud computing (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 (NIaaS) 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.

6. Annex II: List of related USA Activities

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

INSTITUTION	PROGRAMMES AND PROJECTS
US	
NATIONAL SCIENCE FOUNDATION (NSF) 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 5G wireless data networks and beyond.	NSF INTEL PARTNERSHIP ON INFORMATION-CENTRIC NETWORKING IN WIRELESS EDGE NETWORKS 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.
NSF investments in the next generation of data networks spread across various research programs as well as infrastructure investments in advanced testbeds.	NETWORKING TECHNOLOGIES AND SYSTEMS (NeTS) 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.
Research in 5G spans a comprehensive array of areas from advanced physical layers to the support of emerging applications in 5G networks.	COMMUNICATION AND INFORMATION FOUNDATION (CIF) 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.
	COMMUNICATIONS CIRCUITS AND SENSING-CIRCUITS (CCSS) 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.

ENHANCING ACCES TO THE RADIO SPECTRUM (EARS)

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 program seeks to fund innovative collaborative research addressing large-scale challenges that transcend the traditional boundaries of existing programs.

FUTURE INTERNET ARCHITECTURES – NEXT PHASE (FIA-NP)

Continuing its long-standing commitment of supporting groundbreaking research in large-scale networking systems

INDUSTRY/UNIVERSITY COOPERATIVE RESEARCH CENTERS PROGRAM (I/UCRC)

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.

WIRELESS INNOVATION BETWEEN FINLAND AND US (WIFIUS)

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.

NSF SBIR/STTR PROGRAM

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.

PAWR

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,

US IGNITE, 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.

1. POWDER: 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 *Salt Lake City* and Utah, will create an advanced wireless research platform that will cover 2.3 square miles of the *University of Utah* 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 unique and specialized capabilities for dynamic spectrum sharing and advanced wireless antenna technologies.

2. COSMOS: Cloud Enhanced Open Software Defined Mobile Wireless Testbed for City-Scale Deployment.

COSMOS is partnering with *New York City, Silicon Harlem, City College of New York, University of Arizona* and *IBM,* 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.

SMART GIGABIT COMMUNITIES

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 stakeholders to support application deployment and sharing.

CLOUDLAB TECHNOLOGY

The software stack that manages CloudLab is based on Emulab, a testbed control suite that has been developed by the Flux Research Group at the University of Utah. 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.

→ **Geni:** 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.

DARPA. 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

COLOSSEUM

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.

- 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.
- 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,
- 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.
- Each channel's transmission and reception frequency is tunable between 10 MHz (as in broadcast FM radio) and 6 GHz (as in WiFi).
- 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.
- 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.

5G AMERICAS is an industry trade organization composed of leading telecommunications service

5G Americas publishes regularly white papers, some of their most recent publications are the following,

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.

Companies involved: at&t, Cable&Wireless, Cisco, Commscope, Ericsson, Intel, Kathrein, Mavenir, Nokia, Qualcomm, Samsung, Shaw), Sprint, Telefónica, T-Mobile, WOM.

Website: http://www.5gamericas.org/en/newsroom/press-releases/

- The Status of Open Source for 5G, February 2019
- 5G Spectrum Vision, February 2019
- 5G Communications for Automation in Vertical Domains, November 2018
- New Services & Applications with 5G Ultra-Reliable Low Latency Communications, November 2018
- Evolution of Security in 5G, October 2018

INTERNATIONAL CENTER FOR ADVANCED INTERNET RESEARCH (iCAIR), 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&D) projects in four key areas; 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.

Grid Networks: 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,

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 OMNInet testbed. OMNInet 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.

Multiple 10 Gbps Computational Clusters. 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.

EMPOWER-PAWR joint meeting

Notes and Action points

Paris, 29/4/2019

A joint meeting between the European Union H2020 EMPOWER project and the US-based PAWR program was organized in Paris on 29/4/2019, in parallel with IEEE International Conference on Computer Communications (IEEE INFOCOM).

EMPOWER is a European H2020 project with a mission to support collaboration and accelerate the joint development between the EU and the USA on advanced wireless experimental research, targeting the new connectivity frontiers beyond 5G.

PAWR (Platforms for Advanced Wireless Research) is a US-based 5G research consortium funded by the National Science Foundation and the PAWR Industry Consortium, which brings together 28 of the nation's leading companies and associations in wireless.

The main objective of the joint meeting was to liaise key persons in Europe and USA to share information and start discussing possible joint activities related to advanced wireless platforms at both sides of the Atlantic towards 5G and beyond 5G technologies. In addition, the ongoing work of the three ICT-17-2018 projects and the on-going NSF PAWR projects was presented. Each of these projects shortly highlighted the services provided by their projects, the infrastructure available at this stage and their roadmap.

Remy Bayou (EC DG Connect) and Monisha Gosh (NSF CISE) briefly presented the vision of the European Commission and NSF for the EU-US collaboration on advanced wireless platforms followed by the presentations of Serge Fdida, EMPOWER coordinator and Manu Gosain, PAWR director. It was emphasized that EMPOWER can act as the catalyst for such collaboration and it can provide different tools to foster joint activities, such as organization of joint workshops, mobility of researchers, hackathons, etc.

The 2 Phase 1 PAWR nodes were presented (see their respective web sites for more information).

- COSMOS by Ivan Seskar. COSMOS is partnering with New York City, Silicon Harlem, City College of New York, University of Arizona and IBM, to bring advanced wireless testbed to life in New York City. The testbed covers 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 pursues millimeter-wave radio communications and dynamic optical switching technologies, allowing experimentation at a scale that could not be achieved previously, thereby enabling new services and applications to benefit the entire community.

- POWDER by David Schruig, which is a Platform for Open Wireless Data-driven Experimental Research. It is a testbed in Salt Lake City (SLC) to enable mobile and wireless research in a "living lab" environment, enabling academia and industry to do research

- RENEW by Edward Knightly, which enables fundamental advances in wireless technologies by building an at scale massive MIMO research testbed and provides plug-n-play end-to-end experimentation observability and measurability, it is fully programmable open source design.

- POWDER integration will bring RENEW to others. POWDER-RENEW is the collaboration with municipal and state leadership from Salt Lake City and Utah, creates an advanced wireless research platform that covers 2.3 square miles of the University of Utah 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.

As mentioned from Manu Gosain, PAWR phase 2 projects are under selection and should be announced soon. They might most likely cover verticals rather than core wireless as for COSMOS and POWDER-RENEW.

5G-PPP phase 3 projects (ICT-17 platforms) were presented (likely precise information is found on their web sites):

- 5G-EVE, by Rodolphe Legouable. The 5G-EVE facility will enable experiments with: heterogeneous access, including NR, licensed/unlicensed spectrum, advanced spectrum management; Mobile Edge Computing, backhaul, core/service technologies; means for site-interworking and multi-site/domain/technology slicing/orchestration. The 5G-EVE end-to-end facility consists of the interconnection of four 5G-site-facilities (France, Spain, Italy, Greece), which have been selected because of their considerable previous work with vertical industries and standardization bodies, on top of their 5G technology competences. 5G-EVE aims at creating synergies between a significant number of facilities that will ensure sustainability and impact in terms of exploitation.

- 5G-VINNI by Per Hjalmar. The 5G-VINNI aims to: Design an advanced and accessible 5G end to end facility; Build several interworking sites of the 5G-VINNI end to end facility; Provide user friendly zero-touch orchestration, operations and management systems for the 5G-VINNI facility; Validate the 5G KPIs and support the execution of E2E trial of vertical use cases to prove the 5G-VINNI capabilities; Develop a viable business and ecosystem model to support the life of the 5G-VINNI facility during and beyond the span of the project; Demonstrate the value of 5G solutions to the 5G community particularly to relevant standards and open source communities with a view to securing widespread adoption of these solutions. The main facility sites are Norway (Oslo, Kongsberg), UK (Martlesham), Spain (Madrid), Greece (Patras)

- 5G-GENESIS by Jean-Michel Duquerrois. Its main goal is to validate 5G KPIs for various 5G use cases, in both controlled setups and largescale events in order to realize an integrated End-to-end 5G Facility. The five platforms of the 5GENESIS Facility, and their main features/orientation, are: The Athens Platform: An edge-computing-enabled shared radio infrastructure (gNBs and small cells), with different ranges and overlapping coverage that are supported by an SDN/NFV enabled core, to showcase secure content delivery and low latency applications in large public-events; The Málaga Platform: Automated orchestration and management of different network slices over multiple domains, on top of the 5G NR and fully virtualized core network to showcase mission critical services in the lab and in outdoor deployments; The Limassol Platform: Radio interfaces of different characteristics and capabilities, combining terrestrial and satellite communications, integrated to showcase service continuity and ubiquitous access in underserved areas; The Surrey Platform: Multiple radio access technologies that can support massive Machine Type Communications (mMTC), including 5G NR and NB-IoT, combined under a flexible Radio Resource Management (RRM) and spectrum sharing platform to showcase massive IoT services; The Berlin platform: Ultra dense areas covered by various network deployments, ranging from indoor nodes to nomadic outdoor clusters, coordinated via advanced backhauling technologies to showcase immersive service provisioning.

Two sessions followed in order to explore potential lines of joint activities.

Raymond Knopp introduced the discussion on potential joint experimentation between EU and US. The issues discussed were around Software component store, Open Source Domain Analysis and Joint and Cross-Platform Experimentation. The potential to use ICT-17/19/20 and the evolutions in Horizon Europe and PAWR nodes in order to bring forward the joint research and ideas via industry driven initiatives. There is a major opportunity for academic research to have more direct impact in pushing ideas to industry designs. There are several initiatives to be exploited such as Linux Foundation that federates software for Telecom Technology demonstrators; Telecom infrastructures projects, Small-cell forum and many others. There is a need for catalog of HW/SW tools and how to use them to build technology demonstrators and finally to promote 5G and beyond 5G technologies in industry driven venues and fora.

Alain Mourad hosted a session entitled "EMPOWER Advanced Roadmap", where he assessed future technical areas on the path of 5G evolution and the associated experimental challenges. These research areas currently include enhancements to existing 5G specifications to support full-fledged operations in a wide range of vertical use cases, support of low-power low-cost devices, and support for spectrum above 50 GHz. Moving forward, research areas will include support of moving and flying cells and relays, highly accurate positioning, machine learning-based advanced spectrum sharing, and fine integration of cellular and non-cellular technologies. Longer-term objectives include support for spectrum above 100 GHz, pervasive machine learning and artificial

intelligence, integration of non-wireless communication technologies (sensing, radar, charging, imaging), and integration of massive High-Altitude Platforms (HAPs) and Very Low Earth Orbit (VLEO) satellites.

Extensive discussions followed, demonstrating joint interest, even if ICT17 and PAWR have different approaches and objectives. However, our mission is also to liaise US and EU on advanced wireless platforms reaching out to a broader community (e.g., not restricted to ICT17 and PAWR invited to this first event).

This joint meeting will be followed from other activities and opportunities for discussions, such as the EUCNC workshop (Valencia, June 2019) the GEFI (Portugal, November 2019) and others to be introduced at a later stage.

Highlights from the discussion:

There are differences in Europe and USA:
- The PAWR and ICT-17 platforms have different target and missions but show some potential common interest.
- The road mapping activity (is minimal in PAWR).
- PAWR focuses in pure research and the first PAWR nodes are oriented beyond 5G.
- ICT-17 platforms are demonstrating 5G and the focus is mostly deployment, where ICT-19 will address verticals landing on ICT17 infrastructures.
- There exist some commonalities is different areas
- Differences existed in the past between FIRE and GENI however collaboration happened, so we need to further investigate the commonalities and the collaboration paths.
- The two new PAWR platforms (phase 2) are driven by applications providing a big potential for deployment, which means that are closer to vertical sectors.
- EMPOWER can act as the catalyst of the cooperation through the tools that we have:
    - Key technologies as described in the roadmap is important,
    - Benchmarking of usability,
- EMPOWER roadmap welcome contributions from European and US experts as discussed during the joint meeting.
- Joint experimentation is not easy to enable. It was mentioned more detailed and practical information about the respective platforms is necessary for both sides.
- EMPOWER can act as catalyst facilitating the exchange of knowledge through the use of the different tools (joint workshops, researchers visit/mobility, hackathons),
- Joint experimentation – maybe same verticals through ICT-17 and PAWR nodes or through KPI infrastructures for verticals.
- Commonalities between PAWR and ICT-17 – inventory of SW and HW components, tools used, etc. Details of each testbed.

Actions points:
Based on the discussion that happened during the workshop, four complementary activities will be explored:

1. Sharing practices and solutions
EMPOWER/PAWR are willing to propose site visits to US and EU delegates with the objective to go into more details and therefore, be in a position to better identify potential opportunities for cooperation. Contacts will be taken to check interest and plan the visits. This concerns ICT17 and PAWR platforms.

2. Exploring E2E system level
This part aims at questioning how to set-up and E2E open reference architecture. This might be a concern of mutual interest as it goes beyond the wireless specific hardware components and target the issue related to the E2E architecture that should be encountered by most projects.

Three activities are envisaged and will be discussed further, inviting the relevant actors to take part to the debate. They will all be discussed at the next EUCNC EMPOWER/PAWR Workshop on June 18 2019.

        2.a) Radio OAI/O-RAN

This activity will involve those interested by the future development of OAI and O-RAN. It will be animated by Raymond Knopp (Eurecom) on the EU side.

        2.b) ONF/OMEC Edge

The ONF/OMEC framework has the potential to offer some interesting tools and solutions for the purpose future platforms. A first presentation of this initiative will be done at EUCNC and raise awareness and if positive, further joint activities will be organized.

        2.c) NFV open framework

This topic is concerned about providing a relevant test framework related to NFV and appropriate experiments. There has been several projects and communities dealing with this topic. They will be contacted and invited to take part to the discussion.

EMPOWER Roadmap

As presented during the workshop, the roadmap first version will be developed, and all will be invited to contribute. Alain Mourad (InterDigital) is taking the lead.

Data management and Reproducibility

All projects and platforms will have to propose a plan for the above. The idea is to explore the commonalities, invite other scientific domains to share with us their experience and solutions, talk to the research funding organizations and societies (ACM, EU FAIR, etc…).

Next steps:

The action points above will be developed.
In addition, the next opportunity for discussion is provided by the ENCNC joint workshop.
The program planned will be slightly modified to take into account the outcomes of the first workshop.
As a consequence, the morning session following the introduction will be organized according to the 3 topics below:
a) Radio / OAI/ORAN
b) ONF/OMEC Edge
c) NFV open framework