



HORIZON 2020
ICT - Information and Communication Technologies

Deliverable D1.2
EMPOWER Strategy Document and
Collaboration Roadmap v1

Project Acronym: **EMPOWER**
Project Full Title: **EMpowering transatlantic PlatfOrms for advanced WirEless Research**
Grant Agreement: **824994**
Project Duration: **36 months (Nov. 2018 - Oct. 2021)**
Due Date: **31 October 2019 (M12)**
Submission Date: **21 November 2019 (M13)**
Revised version: **6 November 2020 (M25)**
Dissemination Level: **Public**

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Executive summary

This document presents the first update of the EMPOWER Strategy Document and Collaboration Roadmap. This document presents the results of the discussions reached so far, after the first year of the Project and includes the updated 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 advanced wireless communication platforms.

Following the experts' comments during the Project Review (10 July 2020), the partners revised the document, providing further information about the standardization and regulation aspects as well as the areas of collaboration, as requested.

The next update of the EMPOWER Strategy Document and Collaboration Roadmap is scheduled at M28, in February 2021.



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1. Introduction

Since its launch, on November 2018, 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. During this first year, EMPOWER has already laid the foundations towards the creation of a joint EU-US advanced wireless ecosystem whose aim is to (i) bridge the relevant EU-US Wireless communities and stakeholders, such as scientific researchers, platform engineers, standardization experts, regulators, and product incubators, (ii) develop a strategic EU-US collaboration agenda and (iii) support its execution based on common EU-US roadmaps spanning advances in scientific knowledge, platforms and testbeds, standards and regulations. EMPOWER is already collaborating with twin initiatives funded by the US NSF addressing the above-mentioned objectives, mainly thanks to the NSF Programme for Advanced Wireless Research (PAWR).

The objectives of the EMPOWER Strategy Document and Collaboration Roadmap are the following:

- Provide an analysis of the activities implemented during the first year of the project in order to assess their impact and the relevancy of their replication;
- 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. Nevertheless, since

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 proposes a review and an assessment of the actions already implemented during the first year. Section 4 resents an update of the Collaboration Roadmap, which includes the list of the actions planned for the next year. Section 5, focuses on dissemination and community building activities, presenting a summary of the achievements discussed in D4.1.

2. Key Challenges and open questions

Before entering into details of the key challenges and questions to be tackled, it is important to remind the following statement: “*Research Infrastructures are facilities, resources and services that are used by the research communities to conduct research and foster innovation in their fields*”¹.

The mission of the existing initiatives (i.e. OneLab/FIT², GENI³, Fed4Fire⁴, SLICES⁵, NSF/PAWR⁶, CENI⁷ or ICT-17⁸), though different in their approaches, is to provide the research and engineering community **with a fully controllable, programmable virtualized digital infrastructure test platform**. It aims to answer the fundamental questions regarding digital infrastructures in an evolving environment, enable new technologies to support ICT breakthrough discoveries with the use of both OTS and ad-hoc programmable technologies together with advanced design and execution cloud-based solutions.

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, under some policies, could be made available under the FAIR principle (Findable, Accessible, Interoperable, and Reusable) and initiatives such as EOSC⁹ (European Open Science Cloud) in Europe.

Benefits and objectives towards the experimenters, coming from the research and engineering communities:

- Equip researchers and practitioners with a wide range of scientific and experimental resources and tools by deploying and operating a large-scale platform providing access to cutting-edge technologies in wireless and wired networking, IoT, Cloud as well as end-to-end;
- Offer a wide variety of advanced computing and networking resources in order to respond to the needs of future dynamic and highly software-based systems;
- Provide advanced test tools to ensure reproducibility through an automated data repository and support an open data approach for these communities. A certification solution can be considered alike Cascad¹⁰ that warrants that the numerical results (tables and figures) reported in a scientific publication (working paper, published article, and report) are reproducible;
- Build the capacity by strongly contributing to the important education effort targeting both students and engineers, also boosting brain circulation of early career scientists and trainees.

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

- **Engaging the scientific community** primarily centered on digital sciences and the research domains involved in the design of large-scale digital infrastructures. It includes, but is not limited to, distributed systems, networking, wireless research, interoperability/testing, embedded systems, software engineering, system management, security, reliability, etc.;

¹ <https://www.esfri.eu/esfri-roadmap-2021>, visited on 7th October 2019.

² <https://onelab.eu/>

³ <https://www.geni.net/>

⁴ <https://www.fed4fire.eu/>

⁵ European initiative to build an ESFRI project

⁶ <https://advancedwireless.org/>

⁷ Chinese Experimental Network Initiative

⁸ <https://5g-ppp.eu/5g-ppp-phase-3-projects/>

⁹ <https://www.eosc-portal.eu/>, visited on 7th October 2019.

¹⁰ <https://www.cascad.tech>, visited on 7th October 2019.



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- **Involve stakeholders** from supply side to demand side, enabling the testing of new technologies but also accelerating the deployment of transformative services;
 - **Propose a coherent vision and roadmap to policy-makers** in research infrastructures in Europe and the USA;
 - **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...);
 - **Facilitate bi-(multi) lateral initiatives** leading to a better use and development of research infrastructures in this area.

In order to reach the five above-mentioned objectives, we consider necessary to brainstorm around a series of key questions or challenges. These questions, raised at the beginning of the project, have been evolving over the last months thanks to the lessons learned, especially during the joint events and the consultation. This strategic collaboration roadmap also focuses on how each question can be tackled, in order to foster collaboration in advanced wireless platforms on both sides of the Atlantic. Moreover, it is worthy to highlight that, in parallel, the partners have been working on the demand, such as the analysis of the trends, status and plans for advanced wireless that helped to define the first technology roadmap for advanced wireless. Most importantly, a strong trust relationship has been established with our peers in the US, including the funding agencies (like NSF).

2.1 Engaging the scientific community and involving stakeholders

The building of strong relations and a community around the development and research on advanced wireless platforms is one of the main outcomes of EMPOWER. Some of the key challenges to be addressed to engage the scientific community and involve, as much as possible, 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?

2.2 Areas of collaboration

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. Of course, it has a particular focus on wireless but not limited to the access and therefore the core and end-to-end issues are also part of the dialogue. After coordinating with our colleagues in the US, we decided to focus on three main areas of collaboration (reference architecture, reproducibility, AI). Those topics have been suggested as a starting to launch the discussions and engage the scientific community and the stakeholders on key challenges existing on both sides of the Atlantic. This initial list of topics will evolve during the project lifetime depending on the needs and expectations of the community, expressed during the joint activities (workshops, site visits, hackathons, mobilities, etc.).

This list of topics has been defined in the 2nd White Paper, published in June 2020¹¹:

¹¹ https://www.advancedwireless.eu/index.php/sdm_downloads/deliverable-white-paper-2/, visited on 5th October 2020.

1. **Reference architecture:** In order to offer a scientific instrument for providing experimentation services to researchers who are primarily involved in the design of digital infrastructures, a common reference architecture (RA) is desired. It includes three different levels: hardware architecture, software architecture, cloud and compute support infrastructure. This will serve as a blueprint for site maintainers and guarantee a certain level of homogeneity for distributed experimentation and reproducibility. This should benefit from the wealth of experience gained in EU research initiatives such as FIRE and more recently ICT-17 in addition to those from international initiatives such as PAWR. To this aim, the design of the overall architecture embraces cutting-edge hardware infrastructure, production-grade software solutions – similar to the frameworks used by big industry in Digital Sciences (e.g. Google, Facebook, etc.), and a supporting infrastructure for facilitating the Experimentation as a Service-provisioning paradigm.
2. **Reproducibility:** Repeated research is an important part of scientific methodology. Repeating or replicating research not only brings an independent perspective to the investigation, but also provides a basis for comparing different approaches and extending known results. The objective of EMPOWER initiative in this field is to create a forum that catalyzes such change, thanks to short and longer term complementary activities. The short-term activities include a series of workshops involving students and faculties in order to identify and develop a set of tools and best-practice-techniques for enabling reproducible research. 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.
3. **AI :** This area aims to discuss the place of AI in the test platforms and related research topics. As AI is paving its way into the networks on different layers, it opens some interesting research questions. AI can be seen as an automated tool for testing e.g. network functions and performance, as the complexity increases. Further, when AI methods are being integrated into the network, we need methods to test and compare different AI algorithms. The big question might be: Do we need AI to test AI?

2.3 Propose a coherent vision and roadmap to policy-makers

Building Advanced Wireless Platforms

Advanced wireless platforms development is essential 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?

Impacting Standards

Market is dominated by standards and this issue must be included into the roadmap proposed to the policy-makers and stakeholders. The collaboration between Europe and the 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 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?

At the very heart of the EMPOWER technology roadmap for the short and medium terms evolution of 5G lies the standardization roadmap from key wireless organizations such as the 3GPP and IEEE. The EMPOWER team has always been active in disseminating the alignment of the roadmap with standards roadmap noticeably in the 5G-PPP pre-standardization working group, with ETSI, and in the USA with ATIS in particular towards the ATIS next generation alliance for wireless standards. The future releases of the EMPOWER roadmap will continue to be primarily driven by and aligned with standards roadmap from 3GPP, IEEE, IETF, ETSI, ATIS.

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-23?
7. How can we influence spectrum regulations for the purpose of good conditions for research and experimentations?

The trends in spectrum regulations points almost unanimously towards higher frequency bands, up to 1 THz, as the analysis in D2.3 shows. In the wireless industry, spectrum is probably the single, most important commodity and spectrum regulations is highly commercialize. Policy makers are usually aware of the societal impact of having smart regulatory principles. Influencing, or impacting regulators does not seem to be a way forward for EMPOWER. Instead, we have chosen to monitor and analyze the trends.

2.4 Federate research communities and Facilitate bi-(multi) lateral initiatives

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:



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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?

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. Review and evaluation of the first year of the Strategy Document and Collaboration Roadmap

Based on the key questions, challenges and objectives defined at the beginning of the project, and stressed in the section 2, a set of community building tools was defined and the first activities were carried out during the first year. Those tools are essential for the proper and efficient implementation of the Collaboration Roadmap; this is the reason why the purpose of the section 3 is to review the work done, so far, and analyse the potential impact of those activities on the Collaboration Roadmap.

Considering EMPOWER’s ambition to accelerate the joint development between the EU and the US on advanced wireless platforms in 5G and beyond, the first activities mainly aimed to put together the key EU and US stakeholders and to launch the first bilateral discussions. Following these discussions, EMPOWER and PAWR decided to go further arranging a set of site visits for key researchers/stakeholders. Further information about the site visits is available in section 4.

3.1 EMPOWER Events

EMPOWER-PAWR joint meeting – Paris, 29th April 2019

Summary: This first joint meeting between the EMPOWER project and the US-based PAWR program took place in Paris, in parallel with IEEE International Conference on Computer Communications (IEEE INFOCOM).

The main objective of the joint meeting was liaised 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 (5G-EVE, 5G-VINNI, 5G-GENESIS) and the ongoing NSF PAWR projects (COSMOS, RENEW, POWDER) were presented. Each of these projects shortly highlighted the services provided by their projects, the infrastructure available at this stage and their roadmap.



Figure 1 - EMPOWER-PAWR joint meeting

Those presentations were followed by two sessions aim at exploring potential lines of joint activities. The first one, “Joint collaborative activities”, was focused on Software component store, Open Source Domain Analysis and Joint and Cross-Platform Experimentation; and the potential to use ICT-17/19/20 (and beyond) and PAWR nodes in order to bring forward the joint research and ideas via industry driven initiatives. The second one dedicated to EMPOWER Advanced Roadmap was the opportunity to exchange about future technical areas on the path of 5G evolution and the associated experimental challenges.



Figure 2 – EMPOWER-PAWR Panel – INFOCOM 2019

Extensive discussions followed, demonstrating joint interest, even if ICT17 and PAWR have different approaches and objectives. EMPOWER’s 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).

In addition to this joint meeting, EMPOWER and PAWR also chaired a panel during the INFOCOM conference, titled “Panel B: Experimentation Meets Platforms: A Survey of Macro Trends in Mobile Communication Research and Its Impact on Future Testbed Development”.

Outputs: This first joint meeting was the opportunity for the participants to know each other and to better understand the goals, the characteristics and the services provided by the different infrastructures. Among the lessons learnt, it came up that the PAWR and ICT-17 platforms have different targets and missions but they all shown some potential common interests. Indeed, PAWR focuses in pure research and the first PAWR nodes are oriented beyond 5G while ICT-17 platforms are demonstrating 5G and the focus is mostly deployment. ICT-19 addresses verticals landing on ICT17 infrastructures. Regarding the two new PAWR platforms (phase 2), they are driven by applications providing a big potential for deployment, which means that are closer to vertical sectors. In this context, the EMPOWER's role of catalyst is essential to promote joint experimentations, facilitating the exchange of detailed and practical information between both sides, and facilitate the exchange of knowledge in order to reinforce the commonalities between PAWR projects and ICT-17/19.

Based on the above-mentioned outputs, it has been agreed to explore two complementary activities:

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.
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.

The main topics of the following joint workshop (Radio OAI/O-RAN, ONF/OMEC Edge, NFV open framework) have been also defined at this occasion.

EuCNC workshop – Valencia, 18th June 2019

Title: Empowering Transatlantic Platforms for Advanced Wireless Research; a look at Pan-European end-to-end site facilities and vertical trials for 5G and their collaboration with NSF PAWR platforms.

Summary: Following the joint work started in the meeting, collocated with INFOCOM 2019, this workshop started by a session focused on exploring E2E system level, as agreed in Paris' meeting. The big question would be how to set-up an E2E open reference architecture, considering this might be a concern of mutual interest for Europe and the USA 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. In this context, the workshop participants brainstormed and exchanged on the role of Open Source for experimentation, production and infrastructures, paying special attention to radio platforms (use of OAI/O-RAN or other platform), core platforms (possible use of ONF/OMEC) and the need of a NFV open framework to provide a relevant test framework and toolset to perform tests. One of the round tables was dedicated to the challenges for Beyond 5G wireless Technologies, with the participation of representatives of ICT-17, NSF PAWR projects and other stakeholders, who discussed on the future of the platforms and their technology evolution. Followed by the presentation of several platforms, the workshop ended with an open discussion on how to best address the vertical experimentation and requirements. Here is the list of platforms and projects presented during this workshop: 5G-EVE, 5G-VINNI, 5GENESIS, 5Growth, 5G-Tours, 5G-Solutions, 5G-HEART, 5GINFIRE, 5G!Drones, 5G-VICTORI and EuWireless.



Figure 3 - EMPOWER-PAWR EuCNC workshop

Outputs: The discussions of this second EMPOWER workshop were fruitful and confirmed the common interest of both EU and US projects to collaborate in the field of Advanced Wireless Platforms in 5G and beyond 5G technologies. The main output of this workshop was the publication of a White Paper prepared by EMPOWER's partners and peer-review by the members of the Advisory Board. The aim of this document is to propose recommendations regarding the next phase and planning of activities.

3.2 White papers

As mentioned above, the first two workshops organised by EMPOWER consortium were the starting point for the creation of a joint EU-US advanced wireless ecosystem. They were a first step to organize the dialogue between the three ICT-17-2018 projects and their NSF PAWR counterpart. It was also extended to the ICT-19-2018 projects dealing with the verticals.

The discussions which took place in these workshops were fruitful and key for the update of this strategy document and collaboration roadmap. This is reason why many elements defined in the White Paper have been included in this document.

The aim of the first White Paper is to gather and summarise the conclusions and the lessons learned from both workshops¹². This document, available on the project website¹³, provides the reader with an analysis of the current situation and challenges faced by the digital infrastructures and also analyses the needs of the EU-US community based on the past and present lessons learned. As a conclusion, the white paper presents EMPOWER's mission and how the project can tackle all challenges, needs and barriers identified in the previous section.

The second White Paper, published in June 2020, focusses on important topics addressing both the demand and the need. It first analyses the driving forces and technology trends towards 5G. Then, it provides a first insight into an expert consultation analysis about the pivotal future wireless technologies. The reference architecture as a support for the interoperability of the future test platform is then introduced followed by future activities and solicitation on 1- reproducibility and 2-AI. Finally, the paper presents some important coordination activities between US and EU teams.

3.3 Events attended by EMPOWER consortium

EVENT NAME	RELATION TO EMPOWER	DATES	PLACE	OUTPUTS
PAST EVENTS				
IRACON Cost Action meeting	EMPOWER presentation by Per H. Lehne, Telenor Research.	16-18 Jan. 2019	Dublin, Ireland	<p>During this meeting, EMPOWER project was presented and the interest of the consortium to collaborate with IRACON was stressed. This collaboration would be particularly fruitful for the activities carried in WP2, about technology roadmap.</p> <p>The COST meeting was preceded by a joint workshop with the MSCA Action "WaveCombe", which focusses on mm-wave communications. In the WG-group sessions of IRACON, almost 90 presentations ("TD") were held.</p> <p>Two issues, of potential interest for EMPOWER, were discussed:</p> <ol style="list-style-type: none"> 1. Possible collaboration in order to create a vision "Beyond 5G", and address technology challenges in this domain. This would be particularly interesting for the research roadmap. 2. Organisation of a joint workshop between IRACON and EMPOWER.

¹² The White Paper corresponds to the milestone 3 (MS3), as defined in the annex I (part A) of the Grant Agreement.

¹³ <https://www.advancedwireless.eu/index.php/deliverable-white-paper/>, visited on 30th October 2019.

				The discussions around both issues are still ongoing and no decision has been taken so far.
MWC19 Barcelona	EMPOWER represented in 3 panels.	25-28 Feb. 2019	Barcelona, Spain	<p>Attended yearly by more than 100k attendees, the Mobile World Congress is the biggest worldwide mobile fair. During the last edition, EMPOWER project was represented by some of the project partners, in 3 panels titled:</p> <ol style="list-style-type: none"> 1. How Will Open Source Play a Role in the Evolving 5G Ecosystem? 2. Beyond 5G: What is Coming Next? 3. How Far Can Edge Computing Take Us to a New Network Architecture? <p>Abhimanyu Gosain, from PAWR office, also attended two of the panels mentioned above, demonstrating the common interest of EMPOWER and PAWR in taking part to international discussions on 5G and beyond 5G technologies.</p> <p>The potential impact of the participation of MWC19, in term of visibility for EMPOWER, is high.</p>
IEEE – 6G Wireless Summit	EMPOWER presentation by Alain Mourad, InterDigital.	24-26 Mar. 2019	Levi, Finland	<p>With around 300 attendees, from 29 different countries, <i>“the first 6G Wireless Summit launched the process of identifying the key drivers, research requirements, challenges and essential research questions related to 6G”</i>¹⁴. Alain Mourad’s 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.</p> <p>In addition to this presentation, Alain Mourad took this opportunity to do networking and tied a new link with the 6G community. For instance, the 6Genesis initiative is particularly interested in aligning its activities with EMPOWER roadmap: the first step to reach that was to invite them to the INFOCOM joint meeting and panel. In parallel, a contact was established with the joint TEKES-NSF programme Wireless Finland-US (Wi-FIUS), whose goals are similar and aligned with to EU-US EMPOWER’s one.</p> <p>Last but not least, Alain Mourad has also engaged in the work 6Genesis is planning on the 6G research agenda (due in 2019). This will provide EMPOWER with nice alignment opportunity and feed inputs into the WP2 activities.</p>
IEEE INFOCOM 2019	Joint meeting with PAWR and panel chair	1 May 2019	Paris, France	In addition to the above-mentioned joint meeting, EMPOWER and PAWR chaired a panel during the INFOCOM conference.

¹⁴ Latva-aho, Matti and Leppänen, Kari, [Key drivers and research challenges for 6G ubiquitous wireless intelligence](#), Oulun yliopisto, September 2019.

				<p>Title: <i>“Panel B: Experimentation Meets Platforms: A Survey of Macro Trends in Mobile Communication Research and Its Impact on Future Testbed Development”</i>.</p> <p>“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 begun 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 platforms¹⁵.</p> <p>Moderated by Sorbonne University (EMPOWER coordinator) and Abhimanyu Gosain (PAWR office), the panelists were representatives of EMPOWER (Raymond Knopp from EURECOM and Alain Mourad (Interdigital, UK) and PAWR funded projects: Edward Knightly from Rice University ; Ivan Seskar from Rutgers University and Kobus Van der Merwe from University of Utah, who represented RENEW, COSMOS and POWDER.</p> <p>They gave a global view of efforts underway to implement platforms for experimenting on 5G and Beyond Technologies across radio, network and compute to be built on top of convergent RF/network/IT infrastructure to provide well defined abstractions and modularity to end users (e.g. researchers, developers and testers).</p>
Wireless World Research Forum Meeting 42	EMPOWER presentation by Alain Mourad, InterDigital.	15-16 May 2019	Tokyo, Japan	<p>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.</p> <p>During his presentation, Alain Mourad gave an overview of EMPOWER objectives, stressing the work currently implemented to define the B5G Technology Roadmap. The main objective of this presentation was not only to present EMPOWER but also to invite WWRF attendees to collaborate with our EU-US initiative.</p>
3rd Future Network Development Conference	EMPOWER presentation by Serge Fdida,	22-23 May 2019	Jiangning Nanjing (China)	<p>Prof. Serge Fdida was one the speakers of the 3rd Future Network Development Conference, organized on 22-23 May 2019 in China (number of attendees > 3,000). His presentation (title: The Disappearing Internet) was the opportunity to</p>

¹⁵ <https://infocom2019.ieee-infocom.org/panels>, visited on 7th October 2019.

	Sorbonne Université			<p>present to the community the current situation in Europe and EMPOWER, as one of the European initiatives taking part in the international dialogue for the future network, was included in his presentation.</p> <p>The main input for EMPOWER is the visibility provided by the attendance to this conference at international level.</p>
IEEE International Symposium on Local and Metropolitan Area Networks	EMPOWER has been invited to give a talk.	1-3 Jul. 2019	Paris, France	<p>The IEEE International Symposium on Local and Metropolitan Area Networks aims to present and discuss the latest technical advances in local and metropolitan area networking, bringing together researchers and practitioners in the field.</p> <p>Organised in 2019 in Paris, Prof. Serge Fdida, coordinator of the project, chaired the Keynote #1 related to “<i>The need for a research infrastructure in digital sciences</i>”. The presentation highlighted the main approaches and solutions currently being deployed and discussed the various challenges and concerns regarding the design and usage of research platforms. The talk will be illustrated with examples taken from various projects (EMPOWER was cited).</p> <p>This presentation gave visibility to EMPOWER initiative towards the community.</p>
IEEE World Forum	EMPOWER presentation by Alain Mourad, InterDigital.	1 Oct. 2019	Dresden, Germany	<p>Alain Mourad represented EMPOWER taking part to the panel titled “<i>Industry Panel: Industry Perspectives for AI Applications in Future Wireless Communication Systems</i>”. Organised in the framework of the IEEE 2nd 5G World Forum, the aim of this panel was to bring out the view from industry on AI/Machine Learning applications as a means to derive desired ‘intelligent’ outcomes based on the insights developed and address issues with the expected complexities in future wireless systems¹⁶.</p>
43rd Meeting of WWRF	Attendance of EMPOWER’s partners.	October 9-10, 2019	London, UK	<p>Charles Turyagyenda, from Interdigital, attended this event and represented EMPOWER project. The 43rd meeting of Wireless World Research Forum (WWRF) was dedicated to “Intelligent Applications for a 5G Connected World”. The main topics of the discussions were related to Smart Cities, Smart Connected Farming, Smart Mobile Health, Connected Vehicles, Smart Logistics.</p>

¹⁶ <https://iee-wf-5g.org/industry-panels-industry-perspectives-for-ai-applications-in-future-wireless-communication-systems/>, visited on 7th October 2019.

4. Update of the Collaboration Roadmap

The Figure 4 – Collaboration Roadmap shows all the activities, conferences, site visits, mobilities and meeting EMPOWER will organise and participate in the upcoming months with the aim to foster a networking collaboration related to 5G and beyond 5G, including the most important actors working in this field.

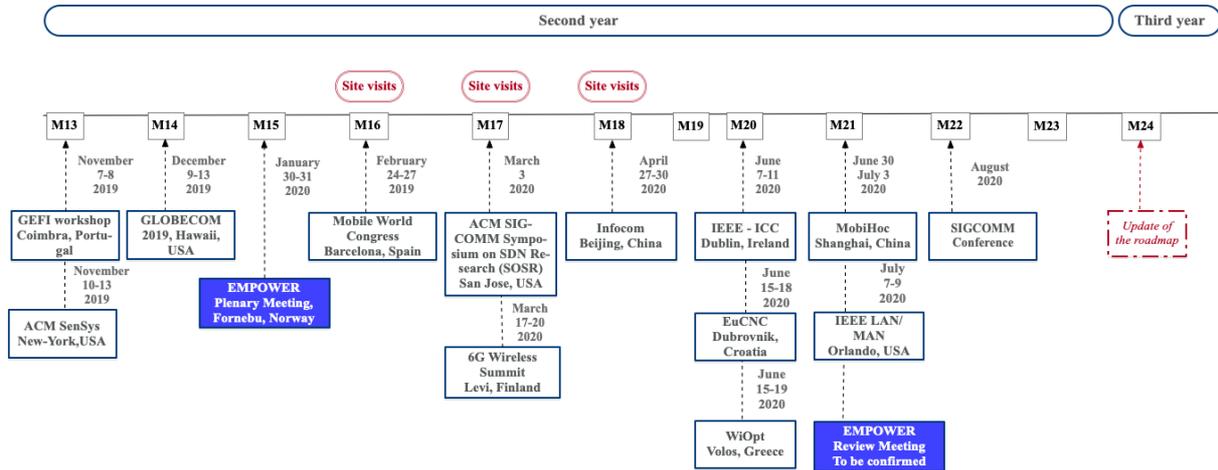


Figure 4 – Collaboration Roadmap

4.1 GEFI workshop

Following the two first workshops organised in Paris and Valencia, a third workshop took place on 7th and 8th November, 2019, in Coimbra (PT). This joint event was organised in collaboration with the PAWR office, in the framework on the Global Experimentation for Future Internet (GEFI).

As defined on the conference website¹⁷, “the Global Experimentation for Future Internet (GEFI) community connects researchers and research sponsors in the EU, US, Japan, Korea, and Brazil to advance international collaboration for experimental research in future networks. GEFI 2019 is the third workshop in the GEFI series, which expands on several previous bilateral and regional international collaborations. Potential participants in GEFI 2019 are invited to submit position statements and proposed session topics”.



Figure 5 – View of the workshop

¹⁷ <https://indico.rnp.br/event/1/>, visited on 10th October 2019.



Figure 6 – Abhimanyu Gosain (PAWR office) presenting PAWR initiative

Inviting stakeholders from the US and EU to GEFI, not only to the workshop itself but also to present a position statement, was a significant opportunity to go further into the discussions.

This event took place in a nice environment and was the perfect opportunity to present and discuss about the first results of the project (i.e. White Paper) not only the EU and US but also to participants from Brazil, Japan and Korea. Generally speaking, this workshop was a real success and its outputs are fruitful for EMPOWER project.

Moreover, GEFI conference was also the scenario for the ICE-T's meeting which took place in parallel to the EMPOWER's one. Promoted by the NSF and DG CONNECT, ICE-T¹⁸ project is another EU-US initiative which aims to enable US and EU researchers to collaborate to address compelling research challenges in NGI and

AWN. To do so, ICE-T program provides support to the researchers thanks to three types of awards: Research Collaboration; Research Collaboration Initiation; Research Fellowships.

4.2 Future dissemination events

The table below presents a detailed view of all the collaboration activities scheduled during the 2nd year of EMPOWER, that is to say up to October.

EVENT	DATE AND LOCATION	EMPOWER PARTICIPATION
GLOBECOM 2019	December 9-13 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. Members of EMPOWER will participate at the conference
Plenary meeting	30-31 January, 2020, TELENOR Fornebu, Norway	Consortium participants: SU, UC3M, UTH, EURECOM, IDG, NBLF and TELENOR. Discussions are currently on going in order to arrange a site visit of TELENOR's premises, in order for the partners to learn more about the ICT-17 (5G-VINNI) and ICT-19 (5G-HEART) projects in which TELENOR is involved in.
<u>Mobile World Congress</u>	February 24-27, 2020 Barcelona, Spain	The GSMA MWC series (formally known as Mobile World Congress) is the world's largest exhibition for the mobile industry, and incorporates a thought-leadership conference featuring prominent executives representing global mobile operators, device manufacturers, technology providers, vendors, and content owners. Members of EMPOWER will participate at the conference and will present/disseminate its results
<u>ACM SIGCOMM Symposium on SDN Research (SOSR)</u>	March 3, 2020 San Jose, USA	The ACM SIGCOMM Symposium on SDN Research (SOSR) is the premiere venue for research publications on SDN, building on past years' successful SOSR and HotSDN (Hot Topics in Software Defined Networking) workshops. New to this year, SOSR will be co-located with the Open Compute Project (OCP) Global Summit on March 3, 2020 in San Jose,

¹⁸ US-EU Internet Core & Edge Technologies (ICE-T), https://nsf.gov/funding/pgm_summ.jsp?pims_id=505516, visited on 7th November 2019.



		<p>CA to foster interaction between academic and industrial attendees.</p> <p>Members of EMPOWER will participate at the conference and will present/disseminate its results</p>
6G Wireless Summit	<p>March 17-20, 2020 Levi, Finland</p>	<p>The first 6G Wireless Summit attracted nearly 300 participants from 28 different countries and was deemed a great success. The 6G Wireless Summit is hosted by the national 6G Flagship Programme, that Finland started in spring 2018. The programme volume is 251M€ during the next eight years.</p> <p>Members of EMPOWER will participate at the conference and will present/disseminate its results</p>
INFOCOM	<p>April 27-30, 2020 Beijing, China</p>	<p>IEEE INFOCOM is a top ranked conference on networking in the research community. It is a major conference venue for 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 2020, the conference includes a main technical program, a number of workshops, a keynote speech, panels, a student poster session, and demo/poster sessions.</p> <p>Members of EMPOWER will participate at the conference and will present/disseminate its results</p>
IEEE – ICC	<p>June 7-11, 2020 Dublin, Ireland</p>	<p>The International Conference on Communications (ICC) located in Dublin, Ireland in 2020 will discuss the main and current topics on communication field through the different workshops, conferences, tutorial and technical symposia.</p> <p>Members of EMPOWER will participate at the conference and will present/disseminate its results</p>
EuCNC 2020	<p>June 15-18, 2020 Dubrovnik, Croatia</p>	<p>EuCNC 2020 is the 29th 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. This conference is one of the most prominent communications and networking conferences in Europe, which efficiently brings together cutting-edge research and world-renown industries and businesses.</p> <p>Members of EMPOWER will participate at the conference and will present/disseminate its results. In addition, other possibilities will be investigated.</p>
WiOpt	<p>June 15-19, 2020 Volos, Greece</p>	<p>The 18th International Symposium on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt 2020) will take place from June 15 to 19 , 2019 in Volos, Greece.</p> <p>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</p>



		<p>specific vehicular, public-transport and personal-area networks as well as application-specific sensor networks¹⁹.</p> <p>UTH is the local organizer of the conference and will investigate the possibility to further disseminate the results of EMPOWER.</p>
EMPOWER project review	<p>Summer 2020 Brussels, Belgium</p>	<p>After the submission of the first project periodic report, the a review of EMPOWER will be carried by the European Commission with the support of external experts.</p>
<u>MobiHoc 2020</u>	<p>June 30 - July 3, 2020 Shanghai, China.</p>	<p>The International Symposium on Theory, Algorithmic Foundations, and Protocol Design for Mobile Networks and Mobile Computing will be held in Shanghai, China from June 30th to July 3rd, 2020. MobiHoc is a premier international symposium dedicated to addressing challenges in dynamic networks and computing. This Symposium brings together researchers and practitioners from a broad spectrum of networking research to present the most up-to-date results and achievements in the field.</p> <p>Mobihoc 2020 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.</p> <p>Members of EMPOWER will participate at the conference and will present/disseminate its results</p>
<u>IEEE LAN/MAN</u>	<p>July 7-9, 2020 Orlando, USA</p>	<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 2020 invites cutting-edge papers spanning both theory and experimentation. The organizing committee is delighted to invite you to the 26th IEEE LANMAN (LANMAN 2020) to be held in Orlando, Florida (USA) from July 7 to 9, 2020.</p> <p>Members of EMPOWER will participate at the conference and will present/disseminate its results</p>
<u>SIGCOMM Conference</u>	<p>August 2020</p>	<p>SIGCOMM is the flagship annual conference of the Special Interest Group on Data Communication (SIGCOMM). The annual SIGCOMM conference seeks papers describing significant research contributions to the field of computer and data communication networks.</p> <p>Members of EMPOWER will participate at the conference and will present/disseminate its results</p>

4.3 List of related US events

In addition to the dissemination and community building activities listed above, EMPOWER is paying special attention to the events organized and/or promoted by the PAWR office, as well as the tutorials and demos planned by the PAWR funded projects (COSMOS, POWDER, RENEW). Those events are of particular interest, especially for the tutorials, webinars, hackathons, etc. EMPOWER should organise. The events are the ones scheduled by the end of 2019.

¹⁹ Official presentation available on WiOpt website.

EVENT	DATE AND LOCATION	EVENT DESCRIPTION ²⁰
27th IEEE International Conference on Network Protocols	October 7-10, 2019 Chicago, USA	<p>ICNP 2019, the 27th annual edition of the IEEE International Conference on Network Protocols, is the premier conference covering all aspects of network protocol research, including design, analysis, specification, verification, implementation, and performance.</p> <p>The workshops will be on the 7th of October and the conference will be held from the 8th to the 10th.</p>
Mobile World Congress Los Angeles	October 22-24, 2019 Los Angeles, USA	<p>MWC Los Angeles 2019 is brings together leading companies and influential experts from all sectors within the mobile technology industry to advance Intelligent Connectivity – a fusion of 5G, IoT, AI and Big Data. MWC19 Los Angeles will offer the most dynamic technology exhibition and an inspiring conference program that consists of industry leaders, influencers and emerging innovators.</p> <p>The PAWR Project Office will be on site at Mobile World Congress LA and will participate to the Championship Event for DARPA’s Spectrum Collaboration Challenge (SC2). The wireless infrastructure used for SC2 will transfer to the PAWR program after the event.</p>
MobiCom 2019	October 21-25, 2019 Mexico, MX	<p>ACM MobiCom 2019 is dedicated to addressing the challenges in the areas of mobile computing and wireless and mobile networking. The MobiCom conference series serves as a highly selective, premier international forum addressing networks, systems, algorithms, and applications that support mobile computers and wireless networks.</p> <p>A COSMOS tutorial is scheduled on 21st October. This tutorial will introduce the PAWR COSMOS (“Cloud enhanced Open Software defined MOBILE wireless testbed for city-Scale deployment”) platform. COSMOS is a joint project involving Rutgers, Columbia, and NYU along with several partner organizations including New York City, City College of New York, University of Arizona, Silicon Harlem, and IBM.</p>
ACM SenSys 2019	November 10-13, New-York, USA	<p>The 17th ACM Conference on Embedded Networked Sensor Systems (SenSys 2019) introduces a highly selective, single-track forum for research on systems issues of sensors and sensor-enabled smart systems, broadly defined.</p> <p>A COSMOS tutorial is scheduled on 10th November. This tutorial will introduce the PAWR COSMOS (“Cloud enhanced Open Software defined MOBILE wireless testbed for city-Scale deployment”) platform. COSMOS is a joint project involving Rutgers, Columbia, and NYU along with several partner organizations including New York City, City College of New York, University of Arizona, Silicon Harlem, and IBM.</p>

4.4 Site visits

During the workshops’ discussions, it came out that it would be interesting for the community to organise site visits in both Europe and the USA. The aim of these visits is to give a first-hand view of the different approaches considered on both sides of the Atlantic, understanding the strong and weak points of the different strategies

²⁰ Official descriptions extracted from the different conferences’ web sites.



followed by the different sites. The visits will consider all the experimental facilities discussed in the 5G-PPP Trials WG, with a starting point on the 5G-PPP Experimental Facilities Cartography.

The planned visits will be bi-lateral, a delegation from PAWR and NSF will come to Europe to meet the selected facilities (mainly from ICT-17 and ICT-19 projects) and discuss experimentation with some of the scientists running them. In the same way, European scientists will travel to the USA to meet the PAWR facilities.

The precise schedule of the site visits is still under discussion but the provisory schedule consists in arranging site visits in Europe for US delegates, in February 2020, while the visits in the US for EU representatives would be scheduled in March/April. In both cases, the visits will last approximatively 5 days and will consist in visiting between 3 and 5 platforms.

Regarding the travel of the US delegation to the EU, EMPOWER partners are currently identifying 3-4 sites, whose characteristics correspond to US delegates' expectations, and which are willing to participate to EMPOWER site visits' programme. Concerning the EU delegation which will travel to the US, the idea would be to arrange a site visit in Utah (POWDER-RENEW facility) and/or in New-York (COSMOS). Once the facilities agree on that, EMPOWER partner will have to select a few delegates and then, propose them a date for those trips. Further information will be available soon on the project website.

Lastly, a first visit already took place on 6th November, in Aveiro (Portugal) for the US delegation. The idea was to take advantage of the GEFI workshop and the fact that many PAWR facilities' representatives were in Europe to arrange a tour at one of the 5G-VINNI experimentation facilities. This facility is hosted by Altice Labs (ALB) and Instituto de Telecomunicações (IT)²¹.

²¹ <https://www.5g-vinni.eu/portugal-experimentation-facility-site/>, visited on 7th October 2019.



5. Dissemination and Community building tools

The current communication and strategy plan, defined in the D4.1²², set up a series of activities and action plan in order to guarantee broad visibility, promotion and up-take.

5.1 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.

To guarantee EMPOWER send a successful message and obtain UE-US collaborations is required to analyse 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 currently 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, Twitter and

²² <https://www.advancedwireless.eu/index.php/deliverable4-1/>, visited on 10th October 2019.

LinkedIn). **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 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.

5.2 Dissemination and community building activities

External actions to engage the community	Duration	Expected N. of persons	N. of events	Implemented	Planned	Comments
Workshops EU	2 days	50	2	2 ²³	1 ²⁴	More concrete plans on future Workshops will be announced shortly.
Workshops US	2 days	50	2	0	0	Concrete plans of the organization of Workshops in US will be finalised shortly.
Short mobility	2-3 weeks	15	15	0	0	Short mobility will be organised either through internal matching of needs and offer from US partners or through publication and open call process. Concrete plan will be available early Y2020
Medium mobility	2-3 months	9	9	0	0	Medium mobility will be organised either through internal matching of needs and offer from US partners or through publication and open call process. Concrete plan will be available early Y2020

²³ EMPOWER-PAWR meeting at INFOCOM, 29/4/2019 and EMPOWER-PAWR workshop at EUCNC, 18/6/2019.

²⁴ GEFI workshop, CloudNet 2019, 07/11/2019.



Tutorials	0.5 day	30	3	0	0	Tutorials are linked with the results of WP3 and joint experimentation. Concrete plan will be available early Y2020
Hackathons	1 day	30	3	0	0	Hackathons agreed to be organised when WP3 will have concrete plans on experimentation. Three hackathons are foreseen, starting in Y2020. Concrete plan will be available early Y2020
Newsletter			Twice per year	0	2	One to be send within October 2019. 2nd just after the organisation of GEFI.

In addition to the communication carried out by the consortium, the partners are also doing an effort and promote EMPOWER towards their respective community. For instance:

- InterDigital already published several press releases which reach a very broad readership;
- UC3M invited a researcher from the USA, Roger Marks (IEEE 802.16 chair) to give some talks and discuss about future research collaboration.

6. Conclusion

EMPOWER's mission is to mobilize the various Forum dealing with Research Infrastructures addressing future Internet, communication and services. It aims to provide strategic guidance but should also be very practical, providing tools to support a tight collaboration at all levels of the various communities and initiatives. This framework is open and welcome all those who would like to contribute. Its ambition is also to help understanding how to transform current generations of test platforms and provide guideline about a common reference design.

7. Annex I: List of related European Activities

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

PROGRAMME	CALLS
<p>EUROPE</p> <p>HORIZON 2020 is an EU research and innovation program. Almost 77 billions 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>ICT-19-2019 - Advanced 5G validation trials across multiple vertical industries</p> <p>NEW. 5G-SMART 5G 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</p> <p>NEW. 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</p> <p>NEW. 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</p>

NEW. 5G-SOLUTIONS is a 5G-PPP project supporting the EC's 5G policy by implementing the last phase of the 5G cPPP roadmap. It aims to prove and validate that 5G provides prominent industry verticals with ubiquitous access to a wide range of forward-looking services with orders of magnitude of improvement over 4G, thus bringing the 5G vision closer to realisation. This will be achieved through conducting advanced field-trials of innovative use cases, directly involving end-users across five significant industry vertical domains: Factories of the Future, Smart Energy, Smart Cities, Smart Ports, Media & Entertainment. In particular, 5G-SOLUTIONS will provide: (a) validation of more than 140 KPIs for 20 innovative and heterogeneous use cases that require 5G performance capabilities and that are expected to have a high future commercialisation potential. These use cases will be field trialled separately as well as concurrently with real end-user actors through ICT-17's 5G-EVE and 5G-VINNI facilities.

<https://cordis.europa.eu/project/rcn/223669/factsheet/en>

NEW. 5G!Drones aim is to trial several UAV use-cases covering eMBB, URLLC, and mMTC 5G services, and to validate 5G KPIs for supporting such challenging use-cases. The project will drive the UAV verticals and 5G networks to a win-win position, on one hand by showing that 5G is able to guarantee UAV vertical KPIs, and on the other hand by demonstrating that 5G can support challenging use-cases that put pressure on network resources, such as low-latency and reliable communication, massive number of connections and high bandwidth requirements, simultaneously. 5G!Drones will build on top of the 5G facilities provided by the ICT-17 projects and a number of support sites, while identifying and developing the missing components to trial UAV use-cases.

<https://cordis.europa.eu/project/rcn/223672/factsheet/en>

NEW. 5G-HEART (validation trials) will focus on these vital vertical use-cases of healthcare, transport and aquaculture. In the health area, 5G-HEART will validate pillcams for automatic detection in screening of colon cancer and vital-sign patches with advanced geo-localization as well as 5G AR/VR paramedic services. In the transport area, 5G-HEART will validate autonomous/assisted/remote driving and vehicle data services. Regarding food, focus will be on 5G-based transformation of aquaculture sector (worldwide importance for Norway, Greece, Ireland).

<https://cordis.europa.eu/project/rcn/223673/factsheet/en>

NEW. Full5G project will assess the achievements of the 5G PPP and impact these results have had on the evolution of 5G in Europe over the period of life of the 5G PPP. This work will also look to the future and consider what additional actions are necessary to maintain the European momentum and leadership in 5G and facilitate the uptake of 5G by the European vertical sectors.

<https://cordis.europa.eu/project/rcn/223010/factsheet/en>

NEW. 5G-VICTORI will conduct large scale trials for advanced vertical use case verification focusing on Transportation, Energy, Media and Factories of the Future and cross-vertical use cases. It leverages 5G network technologies developed in 5G-PPP Phase-1 and Phase-2 projects 5G-XHaul and 5G-PICTURE and exploits extensively existing facilities interconnecting main sites of all ICT-17 infrastructures i.e. 5G-VINNI, 5GENESIS and 5G-EVE and the 5G UK test-bed in a Pan-European Infrastructure.

<https://cordis.europa.eu/project/rcn/223637/factsheet/en>

ICT-23-2019 - EU-Taiwan 5G collaboration

NEW. 5G CONNI Building on the premise of Private 5G Networks, the 5G CONNI project aims at providing an integrated end-to-end 5G test and demonstration network for industrial applications, leveraging current results from standardization and related research projects. Major contributions of the project consist in the definition of new Private 5G Network architectures and operator models, measurements and tools for application specific network planning, tuning and monitoring and the development of innovative new technologies and enabling components in the context of URLLC radio communication, mobile edge computing, core network design and joint optimization of these components. The project will set up two interconnected industrial trial sites in manufacturing facilities in both, Europe and Taiwan.

<https://cordis.europa.eu/project/rcn/224157/factsheet/en>

NEW. 5G-DIVE targets end-to-end 5G trials aimed at proving the technical merits and business value proposition of 5G technologies in two vertical pilots, namely (i) Industry 4.0 and (ii) Autonomous Drone Scout. These trials will put in action a bespoke end-to-end 5G design tailored to the requirements of the applications targeted in each vertical pilot, such as digital twinning and drone fleet navigation applications. 5G-DIVE's bespoke design is built around two main pillars, namely (1) end-to-end 5G connectivity including 5G New Radio, Crosshaul transport and 5G Core, and (2) distributed edge and fog computing integrating intelligence located closely to the user.

<https://cordis.europa.eu/project/rcn/224158/factsheet/en>

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.

<https://cordis.europa.eu/project/rcn/211083/factsheet/en>

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 Gbps 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.

<https://cordis.europa.eu/project/rcn/211052/factsheet/en>

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

	<p>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.</p> <p>https://cordis.europa.eu/project/rcn/211070/factsheet/en</p>
	<p>ICT 17 2018: 5G End-to-End Facility</p> <p>“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.”</p> <p>Research projects</p> <p>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.</p> <p>https://cordis.europa.eu/project/rcn/218529/factsheet/en</p> <p>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.</p> <p>https://cordis.europa.eu/project/rcn/218507/factsheet/en</p> <p>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.</p> <p>https://cordis.europa.eu/project/rcn/217999/factsheet/en</p>
	<p>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.”</p>

	<p>Research projects</p> <p>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</p> <p>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</p> <p>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</p>
	<p>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.”</p> <p>Research projects</p> <p>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</p> <p>METRO-HAUL (METRO High bandwidth, 5G Application-aware optical network, with edge storage, compUte and low Latency). Teaser: METRO-HAUL is a project proposal</p>

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.

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

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).

<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). 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.

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

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.

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

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.

<https://cordis.europa.eu/project/rcn/211067/factsheet/en>

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.

<https://cordis.europa.eu/project/rcn/211061/factsheet/en>

	<p>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.</p> <p>https://cordis.europa.eu/project/rcn/211091/factsheet/en</p>
<p>COST 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>Next Open Call for new COST Actions is scheduled with a deadline of 5 September 2019</p> <p>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</p>
<p>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.</p>	<p>A potential candidate Partnership (2021-2027) on Smart Networks and Services (SN&S) is currently under definition.</p> <p>https://5g-ppp.eu/wp-content/uploads/2019/02/5G-IA-Position-Paper-Smart-Networks-and-Services_Horizon-Europe.pdf</p>
<p>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.</p>	<p>The beginning of 6GENESIS is planned with the next European Framework Horizon Europe.</p>
<p>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</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>https://www.fiware.org</p>

<p>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>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.</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: http://discoveryproject.eu/transatlantic-ict-forum</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>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.</p> <p>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.</p> <p>Fed4fire develops different testbed specialized in 5G, Big Data, Cloud, OpenFlow, IoT, Wired and Wireless</p>	<p>Testbed they are working on this moment are,</p> <p>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.</p> <p>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 (IaaS) platform geared towards experimentation and computational tasks.</p> <p>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</p>

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



	<p>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.</p>
	<p>NEW. SLICES. Currently under preparation, SLICES initiative is a scientific instrument for research in distributed computing and networks, which will enable to tackle new scientific challenges combining aspects from the Internet of Things, data centers, 5G and beyond. This test platform will enable SLICES community to investigate the design of future and emerging infrastructures which is key to its mission. The first step of this initiative is the Design Study, through SLICES-DS project (GA 951850), launched on September 2020. www.SLICES-RI.eu</p>

8. 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.

Since the first version of the roadmap, a new initiative, FABRIC, has been added to the table below. Others will be added to the upcoming versions of this roadmap since the deadline for the PAWR Round III Request for Proposals (RFP) is scheduled on 13th December 2019. This will be the third and final RFP of the PAWR Program. It will offer up to \$8 million in cash from NSF and up to \$8 million of in-kind contributions from the PAWR Industry Consortium for the creation of a wireless testbed focused on research in rural broadband technology²⁵.

INSTITUTION	PROGRAMMES AND PROJECTS
US	
<p>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.</p>	<p>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.</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>NEW. 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. 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 (5G/IoT PAWR, NSF Clouds) and high-performance computing facilities to create a rich fabric for a wide variety of experimental activities. https://fabric-testbed.net/</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>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.</p>

²⁵ PAWR Round III RFP. <https://advancedwireless.org/apply/>, visited on 10th October 2019.



<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>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.</p>
	<p>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.</p>
	<p>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.</p>
	<p>FUTURE INTERNET ARCHITECTURES – NEXT PHASE (FIANP) Continuing its long-standing commitment of supporting groundbreaking research in large-scale networking systems</p>
	<p>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</p>



	<p>industry Center members, with NSF taking a supporting role in the development and evolution of the Center.</p>
	<p>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.</p>
	<p>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.</p>
<p>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.</p>	<p>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,</p> <ol style="list-style-type: none"> 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. https://powderwireless.net/ 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,

	<p>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.</p> <p>https://cosmos-lab.org/</p> <p>3. AERPAW: AERPAW is led by North Carolina State University (NC State) in partnership with 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, 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.</p> <p>https://aerpaw.org/</p>
	<p>SMART GIGABIT COMMUNITIES</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 stakeholders to support application deployment and sharing.</p>
	<p>CLOUDLAB TECHNOLOGY</p> <p>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.</p> <p>→ Geni: is a distributed infrastructure built by the National Science Foundation to support</p>



	<p>research in networks and distributed systems. CloudLab uses many technologies that were originally developed for GENI.</p>
<p>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</p>	<p>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.</p> <ul style="list-style-type: none"> • 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.
<p>5G AMERICAS 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</p>	<p>5G Americas publishes regularly white papers, some of their most recent publications are the following,</p> <ul style="list-style-type: none"> • The Status of Open Source for 5G, February 2019 • 5G Spectrum Vision, February 2019



<p>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&t, Cable&Wireless, Cisco, Commscope, Ericsson, Intel, Kathrein, Mavenir, Nokia, Qualcomm, Samsung, Shaw), Sprint, Telefónica, T-Mobile, WOM.</p> <p>Website: http://www.5gamericas.org/en/newsroom/press-releases/</p>	<ul style="list-style-type: none"> • 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
<p>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.</p> <p>This organization is working on different research projects to promote international relations based on its four keys areas.</p>	<p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p>

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.