HORIZON 2020

ICT - Information and Communication Technologies

List of related European Activities (incl. ICT-52) and list of related USA Activities

Project Acronym:	**EMPOWER**
Project Full Title:	**EMpowering transatlantic PlatfOrms for advanced WirEless Research**
Grant Agreement:	**824994**
Project Duration:	**42 months (Nov. 2018 - Apr. 2022)**
Due Date:	**30 April 2022 (M42)**
Submission Date:	**30 April 2022 (M42)**
Dissemination Level:	**Public**

Disclaimer

The information, documentation, and figures available in this deliverable, is written by the EMPOWER project consortium under EC grant agreement 824994 and does not necessarily reflect the views of the European Commission. The European Commission is not liable for any use that may be made of the information contained herein.

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

This annex presents a deep analysis of all the related European research programmes developing technologies for the advance wireless developing. This Annex includes all the information on European activities from the start of the project for it to be a complete reference.

PROGRAMME	CALLS
EUROPE	
HORIZON EUROPE is the new EU research and innovation framework programme running from 2021 to 2027. It aims to: • to strengthen the EU's scientific and technological bases and the European Research Area (ERA) • to boost Europe's innovation capacity, competitiveness and jobs • to deliver on citizens' priorities and sustain our socioeconomic model and values The Commission proposes a budget of € 100 billion for Horizon Europe.	**European Partnership for Smart Networks and Services** The European communication networking and services sector is proposing the Smart Networks and Services (SNS) Partnership to secure European leadership in the development and deployment of next generation network technologies and services, while accelerating European industry digitization. It will position Europe as a lead market and positively impact the citizens' quality of life, while boosting the European data economy and contributing to ensure European sovereignty in critical supply chains. The SNS Partnership will be implemented as a Joint Undertaking (JU). EC officially released on 23.02.21 the Single Basic Act (SBA) for JUs Regulation (https://ec.europa.eu/commission/presscorner/detail/en/IP_21_702). EC also published the dedicated SNS webpage (https://ec.europa.eu/digital-single-market/en/news/europe-puts-forward-proposal-joint-undertaking-smart-networks-and-services-towards-6g). The SNS EC funded budget should be 900 ME.
HORIZON 2020 is an EU research and innovation program. Almost €77 billion of funding is available over seven years (2014-2020) distributed in different fields with the aim to foster a sustainable development related with all research and innovators European bodies. ICT topics in H2020 support core ICT industries through roadmap-based Public Private Partnerships (PPPs). The work in the last period will contribute to maintaining and developing the technology leading edge in key areas such as electronics, photonics, embedded systems, competing, robotics, etc. The projects listed here are some of the H2020 projects. A more detailed list is available on CORDIS website and also on the 5G PPP website, with a list of projects per Strategic Objectives.	**5G PPP PHASE 3, PART 5: 5G CORE TECHNOLOGIES INNOVATION AND 5G FOR CONNECTED AND AUTOMATED MOBILITY (CAM)** ICT-42 – 5G PPP – 5G core technologies innovation **COREect** – COREnect brings together the most prominent European industrial and academia players as well as industry associations in the network, microelectronics and verticals domains to jointly design a core technology roadmap. The goal is to establish a sustainable European technology sovereignty in 5G and beyond, promote innovation and business opportunities e.g., for small and medium-sized businesses (SMEs), pave the way for one or more future European champions in this area, and lay a solid foundation for the long-term success of both industries. A new COREnect community will emerge from the close collaboration between Smart Networks and Services (SNS) and Key Digital Technologies (KDT) communities as well as with other related communities, e.g., on High-Performance Computing (HPC), artificial intelligence (AI), Photonics, IoT and Cloud. Through outreach activities via its extensive industry and academia network, COREnect will have the potential to significantly impact the European R&I and industry landscape of future connectivity systems over the next ten years. **5G-RECORDS** aims to explore the opportunities which new 5G technology components bring to the professional production of audiovisual content, including Programme Making and Special Events (PMSE). 5G-RECORDS targets the development, integration, validation and demonstration of 5G components for professional content production, as part of an overall ecosystem integrating a subset of 5G network functions. The challenge is to use 5G

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

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

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

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

6G BRAINS *(Bringing Reinforcement learning Into Radio Light Network for Massive Connections)* **–** 6G BRAINS aims to bring AI-driven multi-agent Deep Reinforcement learning (DRL) to perform resource allocation over and beyond massive machine-type

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

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

[DAEMON](#) *(Network intelligence for aDAptive and sElf-Learning MObile Networks)* **–** The success of Beyond 5G (B5G) systems will largely depend on the quality of the Network Intelligence (NI) that will fully automate network management. Artificial Intelligence (AI) models are commonly regarded as the cornerstone for NI design; indeed, AI models have proven extremely successful at solving hard problems that require inferring complex relationships from entangled and massive (e.g., traffic) data. However, AI is not the

best solution for every NI task; and, when it is, the dominating trend of plugging 'vanilla' AI into network controllers and orchestrators is not a sensible choice.

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

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

Hexa-X (*A flagship for B5G/6G vision and intelligent fabric of technology enablers connecting human, physical, and digital worlds*) **–** 2030 and beyond, Europe and the world will face opportunities and challenges of growth and sustainability of tremendous magnitude; proactively tackling the issues of green

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

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

REINDEER *(REsilient INteractive applications through hyper Diversity in Energy Efficient RadioWeaves technology)* **–** The REINDEER project will develop a new smart connect-compute platform with a capacity that is scalable to quasi-infinite, and that offers perceived zero latency and interaction with an extremely high number of embedded devices. It will thereto develop "RadioWeaves" technology, a new wireless access infrastructure consisting of a fabric of distributed radio, computing, and storage

resources. RadioWeaves can be deployed as panels mounted on walls and ceilings. It brings a large number of antennas and intelligence close to devices offering consistently excellent service at minimal transmit power and making very efficient usage of network bandwidth and energy. Technologically, RadioWeaves advance the ideas of large-scale intelligent surfaces and cell-free wireless access, two theoretical concepts that bear great promise to offer capabilities far beyond 5G networks. We will characterize channels based on measurements and develop distributed platform architectures to realize the great potential in actual deployments. We will develop protocols and algorithms to establish novel resilient interactive applications that require 'real-time' and 'real-space' cooperation, for future robotized industrial environments, immersive entertainment, and intuitive care, we will co-design focusing algorithms and protocols for enhanced interaction with many energy-neutral devices. REINDEER will provide experimental proof-of-concept in versatile testbeds. The project runs for 42 months and receives funding from the European Union under grant agreement number 101013425.

RISE-6G (*Reconfigurable Intelligent Sustainable Environments for 6G Wireless Networks*) **–** The RISE-6G vision capitalises on the latest advances on Reconfigurable Intelligent Surfaces (RIS) technology for radio wave propagation control, in order to substantially improve them and, to conceive and implement intelligent, sustainable and dynamically programmable wireless environments that go well beyond the 5G capabilities developed under 3G PPP release 16. To this end, RISE-6G objectives are to (i) define novel network architectures and operation strategies incorporating multiple RISs; (ii) characterise its fundamental limits capitalizing on our proposed realistic and validated radio wave propagation models; (iii) design solutions to enable online trade between high-capacity connectivity, Energy Efficiency, EMF exposure, and localisation accuracy based on dynamically programmable wireless propagation environments, while accommodating specific legislation and regulation requirements on spectrum use, data protection, and EMF emission; and (iv) prototype-benchmark proposed innovation via two complementary trials with verticals. RISE-6G project is poised to actively participate in standardisation bodies and bring its technically advanced vision into the planned industrial exploitation. This will secure the European technology leadership, supporting the creation of new European-conceived service and business opportunities in the B5G/6G global race.

TeraFlow (*Secured autonomic traffic management for a Tera of SDN flows*) **–** TeraFlow will create a new type of secure cloud-native SDN controller that will radically advance the state-of-the-art in beyond 5G networks. This new SDN controller shall be able to integrate with the current NFV and MEC frameworks as well as to provide revolutionary features for both flow management (service layer) and optical/microwave network equipment integration (infrastructure layer), while incorporating security using Machine Learning (ML) and forensic evidence for multi-tenancy based on Distributed Ledgers. The target pool of stakeholders expands

	beyond the traditional telecom operators towards edge and hyperscale cloud providers. These actors will be benefited from TeraFlow by a) exploiting a new type of secure SDN controller based on cloud-native solutions while, b) achieving substantial business agility with novel and highly dynamic network services with zero-touch automation features.
	5G PPP PHASE 3, PART 1: INFRASTRUCTURE PROJECTS
	ICT-19-2019 - Advanced 5G validation trials across multiple vertical industries
	5G-SMART – 5G-SMART is foreseen as key enabler for the future manufacturing ecosystem termed Industry 4.0. 5G-SMART unlocks the value of 5G for smart manufacturing through demonstrating, validating and evaluating its potential in real manufacturing environments. 5G-SMART trials will test the most advanced 5G integrated manufacturing applications such as digital twins, industrial robotics and machine vision based remote operations by bringing first ever 5G deployment in manufacturing setup. https://cordis.europa.eu/project/rcn/223885/factsheet/en
	5G-TOURS – The fundamental feature of the 5G-TOURS concept is the dynamic use of the network to seamlessly provide different types of services adapted to the specific needs of individual use cases. 5G-TOURS will enable different capabilities such as network slicing, virtualisation, orchestration or broadcasting as well as additional features developed by the project to bring more flexibility and improved performance. The ambition is to fully demonstrate pre-commercial 5G technologies at a large scale, showing the ability of the 5G network to meet extreme and conflicting KPIs while supporting very diverse requirements on the same infrastructure. https://cordis.europa.eu/project/rcn/223874/factsheet/en
	5GROWTH – The vision of the 5Growth project is to empower verticals industries such as Industry 4.0, Transportation, and Energy with an AI-driven Automated and Sharable 5G End-to-End Solution that will allow these industries to achieve simultaneously their respective key performance targets. Towards this vision, 5Growth will automate the process for supporting diverse industry verticals through (i) a vertical portal in charge of interfacing verticals with the 5G End-to-End platforms, receiving their service requests and building the respective network slices on top, (ii) closed-loop automation and SLA control for vertical services lifecycle management and (iii) AI-driven end-to-end network solutions to jointly optimize Access, Transport, Core and Cloud, Edge and Fog resources, across multiple technologies and domains. https://cordis.europa.eu/project/rcn/223873/factsheet/en
	5G-SOLUTIONS is a 5G-PPP project supporting the EC's 5G policy by 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

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

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

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

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

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

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 Gdps reconfigurable Approach for Meshed beyond 5G networks). Teaser: Nowadays there is a shared vision among industry, operators and academy that beyond 5G wireless networks will have to provide wideband wireless access and ubiquitous computing anywhere and at any time.

https://cordis.europa.eu/project/rcn/211059/factsheet/en

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

https://cordis.europa.eu/project/rcn/211094/factsheet/en

TERRANOVA (Terabit/s Wireless Connectivity by TeraHertz innovative technologies to deliver Optical Network Quality of Experience in Systems beyond 5G). Teaser: To provide reliable connectivity of extremely high data rates in the Tbit/s regime and almost 'zero-latency' in networks beyond 5G, TERRANOVA

proposes to extend the fiber-optic systems Quality of Experience and performance reliability to wireless.
https://cordis.europa.eu/project/rcn/211078/factsheet/en

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

EPIC (Enabling Practical Wireless Tb/s Communications with Next Generation Channel Coding). Teaser: EPIC aims to develop a new generation of Forward-Error-Correction (FEC) codes to enable practical wireless Tb/s link technology—corresponding to a 10x–100x throughput improvement over the SoA.
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 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.
https://cordis.europa.eu/project/rcn/211070/factsheet/en

ICT 17 2018: 5G End-to-End Facility
"The challenges consist in providing an end-to-end facility that can i) demonstrate that the key 5G PPP network KPIs can be met; ii) be validated and accessed and used by vertical industries to set up research trials of innovative use cases to further validate core 5G KPIs in the context of concurrent usages by multiple users."

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

(E2E) facility that validates the performance of new 5G technologies by operating trials of advanced vertical sector services.
https://cordis.europa.eu/project/rcn/218529/factsheet/en

5GENESIS (5th Generation End-to-end Network, Experimentation, System Integration, and Showcasing) **–** In the global race towards 5G, the establishment and implementation of the 5G-PPP programme in the EU has significantly strengthened the position of Europe, promoting both technological excellence and industrial leadership.
https://cordis.europa.eu/project/rcn/218507/factsheet/en

5G-EVE (5G European Validation platform for Extensive trials) **–** 5G-EVE supports this fundamental transition by offering to vertical industries and to all 5GPPP Phase3 projects facilities to validate their network KPIs and their services. Important representatives of these vertical industries are directly involved as partners of 5G-EVE exactly to influence the design of the end-to-end 5G services.
https://cordis.europa.eu/project/rcn/217999/factsheet/en

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

Research projects
5G-CARMEN (5G for Connected and Automated Road Mobility in the European UnioN) **–** European mobility is drastically changing: growing urbanisation, environmental aspects, and safety are only a few of the key indicators pointing in this direction. Road infrastructures and vehicles are blending with the digital world, becoming always-connected, automated and intelligent, delivering optimal experience to passengers, and addressing societal goals. In this respect, the European Union pushes for large-scale collaborative cross-border validation activities on cooperative, connected and automated mobility.
https://cordis.europa.eu/project/rcn/219074/factsheet/en

5G-MOBIX (5G for cooperative & connected automated MOBility on X-border corridors) **–** 5G-MOBIX will first define the critical scenarios needing advanced connectivity provided by 5G, and the required features to enable those advanced CCAM use cases. The matching between the advanced CCAM use cases and the expected benefit of 5G will be tested during trials on 5G corridors in different EU countries as well as China and Korea.
https://cordis.europa.eu/project/rcn/219128/factsheet/en

5GCroCo (Fifth Generation Cross-Border Control) **–** The possibility of providing connected, cooperative and autonomous mobility (CCAM) services along different countries when vehicles traverse various national borders has a huge innovative business potential. The situation is particularly challenging given the multi-country, multi-operator, multi-telco-vendor, and multi-vehicle-OEM scenario of any cross-border layout.
https://cordis.europa.eu/project/rcn/219082/factsheet/en

5G PPP PHASE 2 PROJECTS[1]

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

Research projects
5G ESSENCE (Embedded Network Services for 5G Experiences) **–** 5G ESSENCE addresses the paradigms of Edge Cloud computing and Small Cell as a Service by fueling the drivers and removing the barriers in the Small Cell market, forecasted to grow at an impressive pace up to 2020 and beyond and to play a key-role in the 5G ecosystem.
https://cordis.europa.eu/project/rcn/211072/factsheet/en

METRO-HAUL (METRO High bandwidth, 5G Application-aware optical network, with edge storage, compUte and low Latency) **–** METRO-HAUL is a project proposal addressing the Horizon 2020 ICT-07 5G PPP call; it is an RIA, focusing on strand 2 (high-capacity elastic – optical networks) and strand 3 (software networks). The central topic is cost-efficient optical metro networks for 5G backhaul.
https://cordis.europa.eu/project/rcn/211077/factsheet/en

IoRL (IoRL – Internet of Radio Light) **–** The Internet of Radio-Light (IoRL) project develops a safer, more secure, customizable and intelligent building network that reliably delivers increased throughput (greater than 10Gbps) from access points pervasively located within buildings.
https://cordis.europa.eu/project/rcn/211086/factsheet/en

NRG-5 (Enabling Smart Energy as a Service via 5G Mobile Network advances) **–** Despite a number of software frameworks and reference architectures have made available for 5G enabling technologies, there is a clear gap to bridge towards 5G seamless application with a number of "vertical" sectors. Energy vertical represents undoubtedly one of the most significant "test cases" for 5G enabling technologies.
https://cordis.europa.eu/project/rcn/211088/factsheet/en

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

---

[1] https://5g-ppp.eu/wp-content/uploads/2017/11/5GPPP-brochure-phase2-final-web.pdf

conceptually novel wireless technologies, contributing to the further definition of 5G and its standardization.
https://cordis.europa.eu/project/rcn/211065/factsheet/en

SLICENET (End-to-End Cognitive Network Slicing and Slice Management Framework in Virtualised Multi-Domain, Multi-Tenant 5G Networks) **–** 5G network providers are keen to offer "networks as a service" where logical network slices are created and allocated to use cases flexibly and efficiently in a multi-operator environment. SliceNet will create and demonstrate the tools and mechanisms to achieve this ambition.
https://cordis.europa.eu/project/rcn/211081/factsheet/en

To-Euro-5G (Supporting the European 5G Initiative) **–** The To-Euro-5G project has a clear objective to support the activities of the European 5G Initiative as outlined in the 5G contractual Public Private Partnership (cPPP) during the second phase of the 5G-PPP from June 2017 to June 2019, with the intention of maximizing the return on this investment for Europe.
https://cordis.europa.eu/project/rcn/211057/factsheet/en

ONE5G (E2E-aware Optimizations and advancements for the Network Edge of 5G New Radio) **–** ONE5G commits to provide technical investigations and recommendations to evolve '5G' towards '5G advanced' as requested by the work program. Release 15 from 3GPP is about to set up a valuable initial specification for paving the way to reach the ultimate goals for 5G.
https://cordis.europa.eu/project/rcn/211055/factsheet/en

SaT5G (Satellite and Terrestrial Network for 5G) **–** The introduction and global roll out of eMBB service within 5G raises coverage and network dimensioning issues in underserved and unserved areas, especially in low ARPU regions of emerging markets, and on mobile platforms (e.g. vessels and aircraft).
https://cordis.europa.eu/project/rcn/211060/factsheet/en

BlueSpace (Building on the Use of Spatial Multiplexing 5G Networks Infrastructures and Showcasing Advanced technologies and Networking Capabilties) **–** The core concept of this project is exploiting the added value of Spatial Division Multiplexing (SDM) in the Radio Access Network (RAN) with efficient optical beamforming interface for the pragmatic Ka-band wireless transmission band.
https://cordis.europa.eu/project/rcn/211090/factsheet/en

5GCAR (Fifth Generation Communication Automotive Research and Innovation) **–** There are two ongoing industrial trends, one in the mobile communications industry and one in the automotive industry, which are becoming interwoven and will jointly provide new capabilities and functionality for upcoming intelligent transport systems and future driving.
https://cordis.europa.eu/project/rcn/211068/factsheet/en

5G–TRANSFORMER (5G Mobile Transport Platform for Verticals) **–** The vision of the 5G-TRANSFORMER project is that Mobile

Transport Networks shall transform from today's rigid interconnection solutions into an SDN/NFV-based 5G Mobile Transport and Computing Platform (MTP) able of simultaneously supporting an extremely diverse range of networking and computing requirements to meet in particular the specific needs of vertical industries.
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) – 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

5G-PICTURE (5G Programmable Infrastructure Converging disaggregated neTwork and compUte REsources) – The explosive growth of mobile internet traffic introduces the need to transform traditional closed, static and inelastic network infrastructures into open, scalable and elastic ecosystems supporting new types of connectivity, high mobility and new mission-critical services for operators, vendors and vertical industries.
https://cordis.europa.eu/project/rcn/211091/factsheet/en

SLICES-RI aims at the creation of a common space among the participating research infrastructures to construct and operate an effective and timely unified research Digital Infrastructure that will lead European research activities beyond. Leveraging the legacy of the previous research projects, SLICES-RI will adopt a new reference architecture and bring advanced functionalities on the experimental based research. Having a large-scale infrastructure based on state-of-the-art technologies in architectures and services will attract researchers at all career stages and will encourage partnerships in and across different fields. Being able to run experiments at every level of the software stack over a variety of hardware devices and clusters in a reproducible and controlled way, will allow researchers to develop and experiment across the variety of DIs topics. Moreover, SLICES-RI will impact education, teaching and learning as	**SLICES-DS (H2020 – INFRADEV-01-2019-2020)** – The design, deployment and operation of complex and continuously evolving digital infrastructure is crucial to keeping our technologically advancing society humming. This is why the research community needs a test platform to address issues related to efficiency, reliability, availability, range, end-to-end latency, security and privacy. The EU-funded SLICES-DS will provide a Europe-wide test-platform designed to support large-scale, experimental research. It will provide advanced compute, storage and network components, interconnected by dedicated high-speed links. Pushing forward, the project's main goal is to strengthen the research excellence and innovation capacity of European researchers and scientists in the design and operation of digital infrastructures. **SLICES-SC (H2020 – INFRAIA-02-2020)** – SLICES-SC, we aspire to foster the community of researchers around SLICES-RI ecosystem, create and strengthen necessary links with relevant industrial stakeholders for the exploitation of the infrastructure, advance existing methods for research reproducibility and experiment repeatability, and design and deploy the necessary solutions for providing SLICES-RI with an easy to access scheme for users from different disciplines. A set of detailed research activities has been designed to materialize these efforts in tools for providing transnational (remote and physical) access to the facility, as well as virtual access to the data produced over the facilities. The respective networking activities of the project aspire in fostering the

students, engineers and researchers will be exposed to this broad set of technologies. The SLICES-RI will be used to design e-labs and MOOCs provisioned on demand where students can remotely learn, program, and practice with the technologies that they do not have in situ. There is obviously an economy of scale, a faster access to talents and an increased attractivity. Therefore, SLICES-RI will provide a research infrastructure allowing academics and industry to experiment and test future, possibly long-term and disruptive DIs which is essential for the European research. European economic stakeholders will gain a competitive advantage at the early stage of the development cycle.

community around these infrastructures, as well as open up to new disciplines and industrial stakeholders.

The SLICES community counts on 25 partners coming from 15 European countries. The consortium submitted an application to the ESFRI 2021 roadmap, on September 2020. The results are pending.

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

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 was also training young researchers in the field of inclusive radio communications, via annual training schools and short-term missions. COST IRACON started in 2016 and ended in 2020. http://www.iracon.org.

COST INTERACT (Intelligence-Enabling Radio Communications for Seamless Inclusive Interactions) defines technologies to enhance the human experience of both, human-to-human and human-to-machine, communications. The Action aims to achieve scientific breakthroughs by introducing novel design and analysis methods for making future radio communication networks intelligent, meaning aware, adaptive and parsimonious, and contributing to the creation of intelligent environments. The Action will create a database on real-world scenarios, radio channels and signal data, to feed machine learning tools used to implement many aspects of the intelligent network and environments. COST INTERACT started in 2021 and will end in 2025. https://interactca20120.org/

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;

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

Distributed Computing and Services and Applications.	
FIWARE, The FIWARE Community is an independent Open Community whose members are committed to materialize the FIWARE mission, that is: "to build an open sustainable ecosystem around public, royalty-free and implementation-driven software platform standards that will ease the development of new Smart Applications in multiple sectors". The FIWARE Community is not only formed by contributors to the technology (the FIWARE platform) but also those who contribute in building the FIWARE ecosystem and making it sustainable over time. Interest in North America; Discussions are happening with USA in particular with US Ignite, and in Canada with a number of relevant organizations gathered by the 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.	In Fiware website is published different events to promote collaboration between different organizations but there is no calls or proposals allowed. https://www.fiware.org
TRANSATLANTIC ICT FORUM Project co-funded by H2020 called "Discovery" Europe-North America Dialogues for ICT Cooperation. It finished in 2017 but the website is already active. The purpose was to create the Transatlantic ICT Forum as a sustainable mechanism to support dialogues for EU-North America cooperation in the field of ICT. Partners of the Project: Inmark Europa, Life Supporting Technologies (LST)-Universidad Politecnica de Madrid (UPM), Waterford Institute of Technology-Telecommunications Software and Systems Group, NOrdforsk, Hewlett Packard Italiana srl, Georgia Institute of Technology and Emory University, European American Chamber of Commerce-New Jersey, Inclusive Design Research Centre-Ontario College of Art and Design University (OCAD University), The Governing Council of the University of Toronto.	In Transatlantic ICT Forum are published different events to promote collaboration between different organizations but there is no calls or proposals allowed.

Website: http://discoveryproject.eu/transatlantic-ict-forum	
FED4FIRE+ Is a project under the European Union's programme Horizon 2020, offering the largest federation worldwide of next generation internet (NGI) testbeds, which provide open accessible and reliable facilities supporting a wide variety of different research and innovation communities and initiatives. It started in January 2017 and will run for 60 months, until the end of September 2021. The Fed4Fire+ project is the successor of the Fed4Fire project. Fed4fire develops different testbed specialized in 5G, Big Data, Cloud, OpenFlow, IoT, Wired and Wireless	Testbed they are working on this moment are, **CityLab**, is a smart cities FIRE testbed, operated by iMEC. It is intended for large-scale wireless networking experimentation at a city neighborhood level in the unlicensed spectrum. CityLab is located in the city center of Antwerp, Belgium. **Exo Geni,** is a GENI testbed that links GENI to two advances in virtual infrastructure services outside of GENI: open cloud computing (OpenStack) and dynamic circuit fabrics. ExoGENI orchestrates a federation of independent cloud sites located across the US and rest of the world, of which UvA is one of them. ExoGENI is a widely distributed networked infrastructure-as-a-service (NIaaS) platform geared towards experimentation and computational tasks. **FIT** (Future <Internet of Things: https://fit-equipex.fr/) enables experimentation across a broad range of subject, greatly reduces the cost and time required to design, establish and monitor an experiment, and through testing, the robustness of the solutions is increased. FIT's mission is to provide a large-scale experimentation environment through the federation of testbeds that are competitive at the worldwide level, allowing to incubate advanced experiments and to stimulate of a large base of users coming from the research world as well as industry. FIT offers large-scale state-of-the-art wireless, sensing and mobility infrastructures for any builder of tomorrow's systems and services, who wish to try out, test and validate his/her solution before implementing it in real-life. FIT platforms are located across France: in Paris, Lille, Strasbourg, Lyon, Grenoble and Sophia Antipolis. They offer easy access, a library of tools and online support for wireless and wireless sensor networks including robots. You can even plug your own devices in our testbeds and run your tests there as well. **FuSeCo,** Future Seamless Communication Playground – located in Berlin – is a pioneering reference facility, integrating various state of the art wireless broadband networks. Two of its most important components are the OpenIMS Playground and the 3GPP Evolved Packet Core prototype platform. Both are discussed in the next slides. **Grid'5000,** is a large-scale and versatile testbed for Cloud, HPC, Big Data, networking, and deep learning. It is composed of 8 sites (located in France and Luxembourg), and more of 800 servers than can be reserved at the bare metal level. The sites are connected together with a 10-Gbps dedicated backbone. **OFELIA i2CAT** Island provides an open facility to test and validate experimental research aligned with Future Internet technologies, specifically Software Defined Networking (SDN) and virtualization. The infrastructure is virtualized in order to offer logical isolated substrates to enable simultaneous disruptive research experiments in productive environments without interfering to parallel research users; following an IaaS (Infrastructure as a Service) mode. **IRIS,** the reconfigurable radio testbed at Trinity College Dublin provides virtualized radio hardware to support the experimental investigation of the interplay between radio capabilities and networks. Our facility pairs underlying flexible radio and

computations resources with various hypervisors in the form of software radio frameworks to realize various research and testing configurations.

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

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

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

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

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

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

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

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

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

Virtual Wall, is an emulation environment that consists of 100 nodes (dual processor, dual core servers) interconnected via a non-blocking 1.5 Tb/s Ethernet switch, and a display wall (20 monitors)

	for experiment visualization. Each server is connected with 4 or 6 gigabit Ethernet links to the switch. The experimental setup is configurable through Emulab, allowing to create any network topology between the nodes, through VLANs on the switch. On each of these links, impairments (delay, packet loss, bandwidth limitations) can be configured.
	w-iLAB.t, testbed is composed of two separate deployments, of which initially only the one called "w-iLab.t Zwijnaarde" will be available through the Fed4FIRE federation for the first round of open call experiments. This testbed is intended for Wi-Fi and sensor networking experimentation. It is located in Zwijnaarde, a district of Ghent, and belongs to iMinds.

Annex II: Updated list of related USA Activities

This annex presents an analysis of all the related research USA programmes developing technologies developing technologies for the advance wireless developing. This Annex includes all the information on USA activities from the start of the project for it to be a complete reference.

INSTITUTION	PROGRAMMES AND PROJECTS
US	
Department of Defense	**5G-to-NextG** The United States Department of Defense is at the forefront of cutting edge 5G testing and experimentation which will be transformative to the Nation's warfighting capabilities. In 2020, the Department announced $600 million for 5G testbeds across five U.S. military sites, representing the largest full-scale 5G tests for dual-use applications in the world. Through this effort, the Department partners with industry to test 5G operations such as augmented and virtual reality training, smart warehousing, and distributed command and control. In 2021, the Department will be announcing a second tranche of awards at seven more test sites. The requests for proposals will open soon.
Linux Foundation	**MAGMA CORE PROJECT** Magma connects 100 to 1,000,000 servers using the same fully distributed network architecture. Designed to be access network (cellular or wifi) and 3GPP release agnostic, it can flexibly support a radio access network with minimal development and deployment effort. - Allows operators to offer cellular service without vendor lock-in with a modern, open-source core network. - Enables operators to manage their networks more efficiently with more automation, less downtime, better predictability, and more agility to add new services and applications. - Federate between existing MNOS and new infrastructure providers for expanding rural infrastructure allows operators who are constrained with licensed spectrum to add capacity and reach by using wi-fi and CBRS. - All parts of the network are stateless except the access gateway, providing greater scale, resiliency, and simplicity. The distributed deployment model limits fault domains and allows more frequent and seamless upgrades. Founding Organizations: arm, Deutsche Telekom, Facebook, FreedomFi, Northeastern University, Open Infrastructure Foundation, OpenAir Interface, Qualcomm.

ATIS NextG alliance	The Next G Alliance is a bold new initiative to advance North American mobile technology leadership over the next decade through private sector-led efforts. With a strong emphasis on technology commercialization, the work will encompass the full lifecycle of research and development, manufacturing, standardization and market readiness.
	Mobile technology underpins the advancement of several important industries. These include Aerospace, Agriculture, Defense, Education, Healthcare, Manufacturing, Media, Energy and Transportation, all of which are vital to U.S. interests and increasingly dependent on mobile technology. Ensuring North American leadership in mobile technology across these key sectors will strengthen and promote the region's economic interests globally.
	The goals of Next G Alliance are:
	- Advance North American global leadership over the 5G evolutionary path and 6G early development. - Create a Next G development roadmap that will promote a vibrant marketplace for 6G introduction, adoption and commercialization with North American innovation in mind. - Develop a set of national priorities that will influence government applied research funding and promote incentivized government actions. - Progress a North American model that promotes development across the full lifecycle of research to realization, aligned with commercialization outcomes.
MITRE Engenuity	MITRE Engenuity is a trusted tech foundation that brings industry together to apply state of the art MITRE innovation for the public good.
	MITRE Engenuity targets 4 main areas: cyber, health, 5G and transportation.
NATIONAL SCIENCE FOUNDATION (NSF) supports fundamental research in wireless communications and wireless data networks, from the early days of the Internet. NSF has already been paving the way for 5G wireless data networks and beyond.	NSF INTEL PARTNERSHIP ON INFORMATION-CENTRIC NETWORKING IN WIRELESS EDGE NETWORKS
	Next-generation wireless networks, utilizing a wide swath of wireless spectrum and an array of novel technologies in the wired and wireless domains, are on the cusp of unleashing a broadband revolution with promised peak bit rates of tens of gigabits per second and latencies of less than a millisecond.
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).	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/
NSF investments in the next generation of data networks spread across various research programs as well as infrastructure investments in advanced testbeds.	NETWORKING TECHNOLOGIES AND SYSTEMS (NeTS) Computer and communication networks need to be available anytime and anywhere, and be accessible from any device. Networks need to evolve over time to incorporate new technologies, support new classes of applications and services, and meet new requirements and challenges; networks need to scale and adapt to unforeseen events and uncertainties across multiple dimensions, including types of applications, size and topology, mobility patterns, and heterogeneity of devices and networking technologies.
Research in 5G spans a comprehensive array of areas from advanced physical layers to the support of emerging applications in 5G networks.	COMMUNICATION AND INFORMATION FOUNDATION (CIF) CIF program supports potentially transformative research that addresses the theoretical underpinnings of information acquisition, transmission, and processing in communications and information processing systems. As a result, CIF projects strengthen the intellectual foundations of communications, information theory, signal processing, and statistical learning in a variety of network types such as wireless and multimedia networks, sensor networks, social networks, and biological and quantum networks.
	COMMUNICATIONS CIRCUITS AND SENSING-CIRCUITS (CCSS) The CCSS Program is intended to spur visionary systems-oriented activities in collaborative, multidisciplinary, and integrative research. CCSS supports systems research in hardware, signal processing techniques, and architectures to enable the next generation of cyber-physical systems (CPS) that leverage computation, communication, and algorithms integrated with physical domains. CCSS supports innovative research and integrated educational activities in micro- and nano-electromechanical systems (MEMS/NEMS), communications and sensing systems, and cyber-physical systems.
	ENHANCING ACCES TO THE RADIO SPECTRUM (EARS) The National Science Foundation's Directorates for Computer and Information Science and Engineering (CISE), Engineering (ENG), and Mathematical and Physical Sciences (MPS) are coordinating efforts to identify bold new concepts with the potential to contribute towards significant improvements in the efficiency of radio spectrum utilization, protection of passive sensing services, and the ability for traditionally underserved Americans to benefit from current and

	future wireless-enabled goods and services. This EARS program seeks to fund innovative collaborative research addressing large-scale challenges that transcend the traditional boundaries of existing programs.
	FUTURE INTERNET ARCHITECTURES – NEXT PHASE (FIA-NP) Continuing its long-standing commitment of supporting groundbreaking research in large-scale networking systems
	INDUSTRY/UNIVERSITY COOPERATIVE RESEARCH CENTERS PROGRAM (I/UCRC) The Industry-University Cooperative Research Centers (IUCRC) program develops long-term partnerships among industry, academe, and government. The Centers are catalyzed by an investment from the National Science Foundation (NSF) and are primarily supported by industry Center members, with NSF taking a supporting role in the development and evolution of the Center.
	WIRELESS INNOVATION BETWEEN FINLAND AND US (WIFIUS) The US National Science Foundation (NSF) and the Academy of Finland have signed a Memorandum of Understanding (MOU) on research cooperation in the area of wireless networking. This MOU provides an overarching framework to encourage collaboration between the US and Finland research communities and sets out the principles by which jointly supported activities may be developed.
	NSF SBIR/STTR PROGRAM This program helps startups and small businesses transform their ideas into marketable products and services. It is focused on high-risk and high-impact technologies.
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.	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, 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, 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.

https://cosmos-lab.org/

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.

https://aerpaw.org/

4. ARA: Agriculture and Rural Communities. Is an at-scale platform for advanced wireless research to be deployed across the Iowa State University (ISU) campus and surrounding research and producer farms as well as rural communities in central Iowa, spanning a rural area with diameter over 60km. It serves as a wireless living lab for smart and connected rural communities, enabling the research and development of rural-focused wireless technologies that provide affordable, high-capacity connectivity to rural communities and industries such as agriculture.

Collectively, the ARA hardware and software systems enables cross-discipline, cross-community collaborative

	research, education, and innovation, thus enabling the forging of the ARA Consortium of public-private partners in advanced wireless systems and applications. These collaborations are expected to generate not only the scientific and technological foundations of advanced wireless but also provide the pathways for its real-world adoption. https://arawireless.org/
	SMART GIGABIT COMMUNITIES US Ignite's Smart Gigabit Communities (SGC) program is a network of more than 25 communities, each committed to the goal of accelerating the development, deployment and sharing of smart community/ Internet of Things (IoT) applications as an important element of their efforts to drive local innovation economies. Participating SGC communities leverage local resources Including high-speed networks, local university researchers and innovation steering committee of local stakeholders to support application deployment and sharing.
	CLOUDLAB TECHNOLOGY The software stack that manages CloudLab is based on Emulab, a testbed control suite that has been developed by the Flux Research Group at the University of Utah. Emulab's primary strength lies in provisioning an ensemble of resources at the physical level, giving experimenters "raw" access to compute, network, and storage resources. The description of an ensemble includes a full description of the network, enabling Emulab to tightly control network topologies and to do network-aware resource placement. → **Geni:** is a distributed infrastructure built by the National Science Foundation to support research in networks and distributed systems. CloudLab uses many technologies that were originally developed for GENI.
DARPA. Defense Advanced Research Projects Agency. Its main mission is to make pivotal investments in breakthrough technologies for national security. The ultimate results have included not only game-changing military capabilities, but also such icons of modern civilian society such as the Internet, automated voice recognition and language translation	**Open, Programmable, Secure 5G (OPS-5G)** DARPA's Open, Programmable, Secure 5G (OPS-5G) aims to address this risk by pursuing research leading to the development of a portable standards-compliant network stack for 5G mobile that is open source and secure by design. OPS-5G seeks to create open-source software and systems that enable secure 5G and subsequent mobile networks such as 6G. The signature security advantage of open-source software is increased code visibility, meaning that code can be examined, analyzed, and audited, either manually or with automated tools. In addition, the portability of open-source serves, as a desired side-effect, to decouple the hardware and software ecosystems. This significantly raises the difficulty of a supply-chain attack and eases the introduction of innovative hardware into the market. The program seeks to enable a "plug-and-play"

	approach to various software components which reduces reliance on untrusted technology sources.
	COLOSSEUM Is an electronic arena funded under the Grand Challenge called the Spectrum Collaboration Challenge. The Colosseum testbed can emulate tens of thousands of possible interactions among hundreds of wireless communication devices—including cell phones, military radios, Internet-of-Things devices, and a litany of others—operating simultaneously in a square-kilometer expanse. That's an area some 40 times that of the Roman Colosseum's six acres. • The Colosseum testbed is a 256-by-256-channel RF channel emulator, which means it can calculate and simulate in real-time more than 65,000 channel interactions among 256 wireless devices. • it resides in a mere 30-foot by 20-foot server room on the campus of the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, MD, • Each simulated channel behaves as though it has a bandwidth (information content) of 100 MHz the testbed supports 25.6 GHz of bandwidth in any instant. • Each channel's transmission and reception frequency is tunable between 10 MHz (as in broadcast FM radio) and 6 GHz (as in WiFi). • The amount of digital RF data coursing through the Colosseum each second, more than 52 terabytes, exceeds the estimated amount of information contained in the entire print collection of the Library of Congress. • Engineers at APL assembled the Colosseum with 128, two-antenna, software defined radio (SDR) units built by National Instruments (NI). Emulating electromagnetic waves from these radios traversing the physical world is no small task. To tackle this, APL partnered with NI to put 64 field programmable gate arrays (FPGAs) to the task. The FPGAs enable the Colosseum to make the SDRs behave as though they are operating in any of countless environments, each designed like an electromagnetic movie set.
5G AMERICAS is an industry trade organization composed of leading telecommunications service providers and manufacturers. The organization's mission is to advocate for and foster the advancement and full capabilities of LTE Wireless technologies and their evolution to 5G Americas is invested in developing a connected Wireless community while leading 5G development for all the Americas. 5G Americas is headquartered in Bellevue, Washington.	5G Americas publishes regularly white papers, some of their most recent publications are the following, • The Status of Open Source for 5G, February 2019 • 5G Spectrum Vision, February 2019 • 5G Communications for Automation in Vertical Domains, November 2018 • New Services & Applications with 5G Ultra-Reliable Low Latency Communications, November 2018 • Evolution of Security in 5G, October 2018

Companies involved: at&t, Cable&Wireless, Cisco, Commscope, Ericsson, Intel, Kathrein, Mavenir, Nokia, Qualcomm, Samsung, Shaw), Sprint, Telefónica, T-Mobile, WOM. Website: http://www.5gamericas.org/en/newsroom/press-releases/	
INTERNATIONAL CENTER FOR ADVANCED INTERNET RESEARCH (iCAIR), The mission of iCAIR is to Accelerate Leading-Edge Innovation and Enhanced Digital Global Communications through Advanced Internet Technologies, in Partnership with the International Community. The Center accomplishes its mission by undertaking research and development (R&D) projects in four key areas; Advanced Applications, Advanced Network Middleware,Advanced Infrastructure, and Public Policy Initiatives. This organization is working on different research projects to promote international relations based on its four keys areas.	**Grid Networks:** Next Generation Networks and Computational Grids, the development of new types of information technology continues to progress rapidly. It has often been noted that one way to view the future is to visit an advanced technology research lab where innovative developers are creating powerful new architecture, protocols, integrated systems. Optical Network Architecture and DWDM, **Optical Metro Network Initiative (OMNI)** is developing a reference model for multiple next generation large scale communication services, based on optical technologies that allow for lightpath-based services supported by advanced photonic technologies. One of the key projects of this initiative is the OMNInet testbed. OMNInet is an inter-organizational cooperative research partnership, which includes iCAIR, Nortel, SBC (now AT&T), the Electronic Visualization Lab at the University of Illinois at Chicago, the MCS Division of Argonne National Lab, CANARIE (the Canadian Advanced Network for Advanced Research, Industry, and Educations. Experiments on the testbed have been extended via NetherLight to SurfNet in the Netherlands. **Optical Dynamic Intelligent Network (ODIN)**, experimental architecture is being developed by iCAIR to explore new techniques for lightpath provisioning, in particular as a mechanism for bringing directly into applications capabilities that traditionally are placed deep within the core of networks. **Simple Path Control (SPC)** Protocol, is a signaling mechanism that allows for edge processes, including applications, to communicate requirements for specific paths through a network by signaling to a server capable of establishing such paths using core network resources. **OptIPuter** is a national and international distributed facility that closely relates multiple IT components, including optical networking, Internet Protocol (IP), high performance computational clusters, computer storage, and visualization technologies. It is an infrastructure envisioned as one that will tightly couple computational resources over parallel optical networks using the IP communication mechanism. **Distributed Optical Testbed (DOT)**. DOT is being designed and implemented by an inter-organizational cooperative research partnership to facilitate the research and development of innovative techniques that require the efficient execution of distributed applications.

	Global Lambda Integrated Facility (GLIF), iCAIR is a founding member of the Global Lambda Integrated Facility (GLIF) is an international organization that is advancing new concepts, architecture and services related to dynamically provisioned lightpath (lambda) networking. **National Lambda Rail,** One such initiative, the National Lambda Rail(NLR), has created a distributed fiber facility across the US. Half of that fiber can be used for research projects. iCAIR is participating in several projects that are using the NLR for experimental projects. The connection point for these research projects is the StarLight facility. Several of these projects use the CaveWave, a 10 Gbps research circuit between UIC and UCSD managed by EVL. **Multiple 10 Gbps Computational Clusters**. Traditionally, iCAIR computational clusters have been based on racks of compute nodes with I/O for each node provided by a GE link to a high performance L2 switch, aggregate the single GE flows to 10 GE. Currently, iCAIR is designing computational clusters that will have 10 G NICs as part of each node. iCAIR is evaluating and experimenting the various components required, high performance backplanes, NICs based on various protocols, Linux stacks, protocols, off-load technologies, writable processors, and others.