



The 5G Infrastructure Public
Private Partnership (5G PPP)

Second Wave of Research & Innovation Projects



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INTRODUCTION

The 5G PPP is a 7 year partnership leading to the introduction of 5G infrastructure and the roll out of 5G services in Europe from 2020. The Public-Private-Partnership was created by a contractual agreement between the European ICT Industry, represented by the 5G-Infrastructure Association and the European Commission signed at the end of 2014.

In phase 1 from July 2015 to date 18 collaborative projects were launched and the results are emerging continually with many of these projects completing their work by mid-2017. Some will continue and finish in mid-2018.

Phase 2 of the 5G PPP has started on the 1st June 2017 and 21 new 5G PPP projects have been selected. In addition there are 2 complementary projects dealing with international relations on aspects of 5G and information on these has been included in this brochure.



EDITORIAL EUROPEAN COMMISSION



Bernard Barani
Acting Head of Unit Network Technologies
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The 5G Public Private Partnership launched by the European Commission with a financial backing of € 700 million under the Horizon 2020 research and innovation programme materialises our bold commitment to 5G. The 5G vision developed by the European industry is fully aligned with our wider strategy of digitising the European industry, as it recognises that 5G can provide novel application capabilities in “vertical” sectors as diverse as the automotive, healthcare, smart factories, energy or media sectors. In the 5G PPP, we consequently support 5G developments towards a versatile network platform that can adapt to demanding requirements of a multiplicity of B2B business models, whilst current networks are more designed as a “one size fits all” platforms. To make this vision a reality, multiple technologies are called upon to contribute to the advent of 5G networks.

The 5G PPP phase 1, covering the 2015-2017 period, has provided us with important results on core 5G technologies. Beyond advances in classical radio and network performances, cloud computing technologies have also emerged as key technologies to enable customer tailored platforms. The 5G PPP phase 2 projects will expand these results, and establish closer relations between the 5G community and vertical industries. It is very encouraging that our strategy to involve new user actors in the 5G PPP has led to more than 60% of the participating companies in phase 2 being new companies that did not participate in phase 1. This allows us to initiate demonstrations and experiment of 5G technologies in contexts closer to the user, which is much needed at a moment when many 5G regions are contemplating short to medium term 5G deployment. The 5G PPP phase two projects will support the broader objectives of the 5G Action Plan Communication, published in September 2016, to catalyse 5G deployment in Europe.

The 5G PPP phase two projects described in this booklet have been launched in June 2017 and are important actions to further validate 5G technologies and demonstrate their applicability to a number of vertical sectors. They are essential to fuel the second phase of 5G standardisation and we expect that they will boldly contribute to the “3G PP Release 16” to be launched in 2018, as this release will focus on the use cases beyond enhanced Mobile Broadband (eMBB) and be more related to use cases of the vertical industries.

This project compendium will give the reader information about the variety of running 5G PPP phase 2 initiatives. They cover a multiplicity of technological issues, especially in the domain of network virtualisation and software platforms, and propose a number of European proofs of concepts, experiments and demonstrations. They will, no doubt, contribute to place Europe in the 5G driving seat.

EDITORIAL 5G INFRASTRUCTURE ASSOCIATION



Colin Willcock

Chairman of the Board
5G Infrastructure Association



The 5G Public-Private Partnership (5G PPP) within the Horizon 2020 programme of the European Union is the biggest 5G research program in the world. Research in the 5G PPP has a very wide scope far beyond classical telecommunications. The current 5G PPP vision and technical requirements are described in a 5G vision document, which was first published at the Mobile World Congress 2015 in Barcelona in March 2015¹.

In December 2013, the 5G PPP Contractual Arrangement was signed by the EU Commission, which represents the public side, and the 5G Infrastructure Association, which represents the private side in the PPP. Public- Private Partnerships in Horizon 2020 are intended to be industry driven, to strengthen the European economy and the impact on future global standards based on research in Europe. The 5G Infrastructure Association (5G IA) is bringing together many different stakeholders from industry, network operators, SMEs, R&D centres and universities. The overall objective of the 5G IA is to promote R&D in the networks industry in order to strengthen the networks industry in the European Union, to foster technology skills in Europe by attracting students, and to increase the competitiveness of the European industry by providing new tools and capabilities for manufacturing in Europe. In addition, the 5G IA is working to mobilise the community and in particular SMEs in European collaborative research projects. It is the facilitator of the 5G PPP research program on the private side.

The 5G IA is cooperating with the EU Commission to develop the 5G work program in Horizon 2020, through a dedicated “Partnership Board” which discusses the work program and other activities of common interests to promote 5G PPP and its results globally.

In addition, the 5G IA is helping to address other issues, which are not directly related to technical issues, because the development of future networks also requires to contribute to topics like standardisation, frequency spectrum, other regulatory issues, how to address vertical sectors and international cooperation to support the development of globally accepted standards. The 5G IA has already established Memoranda of Understanding (MoUs) with counterparts in China, Korea, Japan, North America and Brazil.

The launch of the phase 2 5G PPP projects is an important milestone and represents a change in focus for the research programme. The phase 1 projects focused on fundamental 5G research driving central 5G technical issues through pre-standardisation consensus through to standardisation submission. The success of the phase 1 projects can be seen by the results in the latest 5G IA / 5G PPP white paper² which indicates the first phase projects managed to develop solutions that are able to meet nearly all the performance KPIs for 5G. In contrast the phase 2 projects are more focused on demonstrating and validating the developed technology and explicitly trying to integrate use cases from vertical industries beyond classical telecommunications. One example of this is the automotive domain where there are now dedicated phase 2 projects and in addition a new focused automotive working group has been formed.

Finally, I wish every success for the 5G PPP phase 2 projects and a further successful collaboration with the members of the 5G IA and the European Commission.

¹ Available for download at <https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf>.

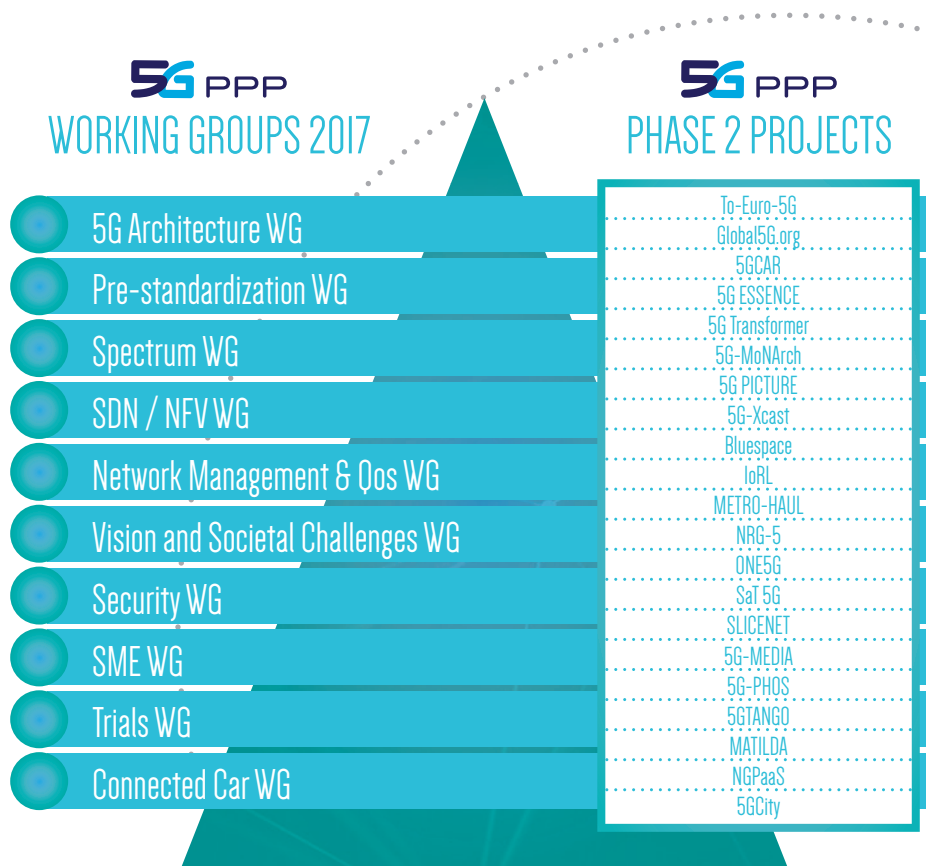
² 5G IA White paper “5G innovations for new business opportunities”

INTRODUCTION TO THE 5G PPP PROGRAMME LEVEL WORKING GROUPS

A key part of the 5G PPP working structure is a set of cross projects and cross initiative working groups. The working groups are the means to establish and publish program level opinions and positions on issues that impact all of the projects and/or may be the basis for liaison or interaction with external bodies such as other Global regions or standards bodies.

The 5G PPP working groups can be categorised as ‘Technical Work Groups’ or ‘Policy-oriented Work Groups’ depending on the ambition of the group and the impact expected from their results. Technical Work Groups tend to be organised by 5G PPP projects themselves to facilitate inter-project cooperation while Policy-oriented Work Groups are mostly initiated by the 5G Infrastructure Association to capture the specific European 5G Industry position on strategic issues such as Spectrum, Vision & Societal Challenges, Pre-standardization preparations, and European 5G Trials and demonstrations.

The 5G Initiative Steering Board (SB) reviews the activities and mandates of the Projects and Work Groups at regular intervals and may decide when a WG has completed its mandate to stop it or to start something when new WGs are needed. The SB is composed of the 5G PPP Project Coordinators and the Association representative.



The current set of active 5G PPP working groups includes:

5G Architecture WG

The goal of this Working Group is to facilitate consensus building on the 5G architecture within the 5G PPP and to serve as a common platform for discussion between 5GPPP projects developing architectural concepts and components.

Pre-Standardization WG

Identify standardization and regulatory bodies to align with. Develop a roadmap of relevant standardization and regulatory topics for 5G: Evaluate existing 5G roadmaps at international level; Propose own roadmap for 5G being aligned at international level. Influencing pre-standardization on 5G and related R&D: Potentially propose where topics should be standardized; Influence timing on R&D work programs.

Spectrum WG

This group maintains a dialogue between the 5G PPP projects concerning potential synergies and common interests in spectrum related issues. They will pursue the convergence of results on spectrum topics from the different projects to maximize the achievable outcome towards relevant technical bodies. They will liaise with spectrum groups or entities in regulatory bodies and industry associations and promote the research results in the spectrum area obtained by 5G PPP.

SDN / NFV WG

The purpose of this WG is to analyse and address unification and applicability of key research topics related to Software Networking including software defined concepts, infrastructures, systems and components for Wire and- Wireless Networks, including Networked Clouds, IoT and Services, i.e. Software Defined Networks (SDN) and Network Function Virtualization (NFV) as developed and promoted by the 5G PPP projects.

Network Management & QoS WG

Network Management aims to maintain the operations of the network in a manner that ensures that the required services are properly delivered to the users, that an expected quality of service is enforced for delivering such services to the end user and that security is maintained. To do so, network management is mainly focused on the control plane of the network to make sure all the services and operations running in the data plane are working properly.

Quality of Service covers areas such as networking, packet scheduling, traffic adaption and any other technique implemented in both data and control plane to make sure an expected quality of service is implemented for the delivery of services to the end user (bandwidth, low latency, mobility and availability).

Vision and Societal Challenges WG

The Vision work group will develop and maintain a consensus in Europe on 5G systems / infrastructures / services, together with the vertical application domains which will benefit from 5G. In addition they will identify the societal, economic, environmental, business and technological benefits obtainable from the realization of 5G main concepts. A key aspect will be to identify commonalities, bottlenecks and differences in visions and technical trends and to prepare input documents for International 5G Cooperation Activities.

Security WG

The purpose of the Security group is to bring together the projects within the 5G PPP that have common interest in the development and progression of topics related to security. The group will ensure, to as great extent as possible, that the projects are working in a complimentary manner towards consistent goals, exchanging ideas, minimizing the duplication of effort, contributing towards relevant standards and where possible cooperating on the development of compatible components, demonstrators, the exchange of data and results and the interworking of communication layers, where applicable.

SME WG

The main objectives of the SME Working Group are:

- Help and support SMEs participation in the 5G PPP and more generally in EU R&D projects, including (but not limited to) reaching the target of at least 20% of the 5G PPP funding going to SMEs.
- Ensure that the interests of SMEs, a key player in the EU economy, are adequately taken into account, more particularly in the NetWorld2020 European Technology Platform and in the 5G PPP.

Trials WG

The objectives of the Working Group are as follows:

- To develop the European Trial Roadmap based on the 5G Manifesto.
- To facilitate the involvement of verticals in the trials roadmap.
- To discuss and define business principles underpinning the economic viability of trials.
- To consider and coordinate the activity on trials with other relevant initiatives at international level (e.g. proposal from China Mobile).
- To investigate and propose how to link trials to Horizon 2020 5G PPP Phase 3 in order to get funding for parts of the overall trial roadmap.

Connected Car

- This new work group has been proposed to address the specific challenges of 5G supporting the Automotive sector and will start in 4th Quarter 2017.

The outputs of the 5G PPP working groups are published on the 5G PPP website 5g-ppp.eu under the menu item "Plans and Papers".

Further information on the workgroups is also available on the 5G PPP website: <https://5g-ppp.eu/5g-ppp-work-groups/>

5GCAR

/ Fifth Generation Communication Automotive Research and innovation

PROJECT COORDINATOR

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MAIN OBJECTIVES

Main objectives within the 5GCAR project are:

- Develop an overall 5G system architecture providing optimized end-to-end V2X network connectivity for highly reliable and low-latency V2X services, which supports security and privacy, manages quality-of-service and provides traffic flow management in a multi-RAT and multi-link V2X communication system.
- Interworking of multi-RATs that allows embedding existing communication solutions and novel 5G V2X solutions.
- Develop an efficient, secure and scalable sidelink interface for low-latency, high-reliability V2X communications.
- Propose 5G radio-assisted positioning techniques for both vulnerable road users and vehicles to increase the availability of very accurate localization.
- Identify business models and spectrum usage alternatives that support a wide range of 5G V2X services.
- Demonstrate and validate the developed concepts and evaluate the quantitative benefits of 5G V2X solutions using automated driving scenarios in test sites.

APPLICATIONS

5GCAR will define a constitutive set of 5G V2X use cases, building on other EU projects as well as organisations like ETSI-ITS and 5GAA. The detailed use case descriptions are intended to span the relevant 5G V2X space by representing a much broader set of scenarios. In 5GCAR there will also be three live demonstration use cases: Lane merge, Cooperative perception for manoeuvres of connected vehicles, and Vulnerable road user protection.

TECHNICAL AND RESEARCH CHALLENGES

5GCAR will clarify use cases and requirements for future connected vehicles and then perform evaluations and demonstrations on 5G V2X technologies and solutions to find and promote suitable end-to-end performance of the entire system. Some foreseen challenges to highlight are: the tackling of technical approaches that turn out to be complex, and to implement the three independent testbed platforms in a suitable way.

EXPECTED IMPACT

5GCAR is for instance expected to contribute to WRC-19, and to impact methodologies and models in 3GPP and 5GAA. The consortium will also collaborate and integrate the 5G V2X radio access network concepts of the project into the overall 5G RAN framework, e.g. through participation in 5G PPP initiatives and interaction with other projects.



5GCity

/ A distributed Cloud & Radio Platform for 5G Neutral Hosts

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MAIN OBJECTIVES

The ultimate goal of 5GCity is to maximize the return on investment for the whole digital market chain (users, application, cloud providers, i.e., the municipalities themselves, telecom providers, and infrastructure providers). To do so, 5GCity's main aim is to build and deploy a common, multi-tenant, open platform that extends the (centralized) cloud model to the extreme edge of the network, with a demonstration in three different cities (Barcelona, Bristol and Lucca), and thus advance the state of the art to solve the main open research challenges in the 5G-based edge virtualization domain, including the neutral host perspective in dense deployment environments such as cities. Thus, 5GCity will design, develop, deploy and demonstrate, in operational conditions, a distributed cloud and radio platform for municipalities and infrastructure owners acting as 5G neutral hosts.

APPLICATIONS

The use cases targeted by 5GCity consist of:

Neutral host (Telecom Use Case): 5GCity will leverage its virtualization platform in order to enable the cities to create dynamic end-to-end slices containing both virtualized edge and network resources and lease it to third-party operators.

Media (Industry Vertical): 5GCity consortium includes different media-related partners, a television channel, a national broadcaster, and a SME focused on content acquisition and production in the Cloud or an association of media companies. Three different media use cases will be deployed and evaluated (mobile real-time transmission, UHD video distribution, and real-time video acquisition and production in the Edge & Cloud).

Unauthorized waste dumping prevention (City Services): The city of Lucca holds some yearly events that are highly disproportionate to the city size, resulting in a number of issues including illegal waste dumping. 5GCity will use the cities' surveillance cameras and deploy (multiple instances of) a virtualized service that can process video streams near cameras automatically to identify illegal dumping.

TECHNICAL AND RESEARCH CHALLENGES

From a technical perspective, evolving cloud architectures and adapting them to the edge of the network within the 5G ecosystem brings a number of open challenges: (i) Deployment and run-time management of densely interconnected and decentralized cloud and network infrastructures; (ii) Tight-loop interactions between the computing and networking infrastructures at the edge of the network; (iii) Performance issues arising from the use of resource-constrained devices (e.g., Single Board Computers with ARM processors) placed at the edge of the network to perform workloads that have been traditionally carried out by powerful servers in centralized data centers; and (iv) Slicing and neutral hosting support at the wireless edge, where bandwidth needs to be guaranteed for different slices (e.g. media), and tenant-specific counters need to be added to support elastic usage and billing of resources.

EXPECTED IMPACT

5GCity will directly impact a large and varied range of actors: (i) telecom providers; (ii) municipalities; and (iii) a number of different vertical sectors utilizing the city infrastructure. The real strength of 5GCity, in terms of real-world impact, lies in the envisioned deployment of its 5G-based edge platform in three distinct smart cities: Barcelona, Lucca and Bristol, which is foreseen as a concrete first step towards 5G trials. Other expected impacts include, i) Open environments for creation of network apps, ii) Open repository of network apps that may be validated and leveraged by third party developers, and iii) Validation at scale of VNF aggregation capability of the proposed environment. The project will also impact 5G PPP Performance KPIs related to reduced e2e latency, reduced average service creation time, multiple times higher mobile data volume and number of connected devices.



5G ESSENCE

/ Embedded Network Services for 5G Experiences

PROJECT COORDINATOR

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MAIN OBJECTIVES

5G ESSENCE addresses the paradigms of Edge Cloud computing and Small Cell-as-a-Service (SCaaS) by fuelling the drivers and removing the barriers in the Small Cell (SC) market, forecasted to grow at an impressive pace up to 2020 and beyond and to play a key role in the 5G ecosystem.

5G ESSENCE provides a highly flexible and scalable platform, able to support new business models and revenue streams by creating a neutral host market and reducing operational costs by providing new opportunities for ownership, deployment, operation and amortisation. 5G ESSENCE leverages knowledge, SW modules and prototypes from various 5G PPP Phase-1 projects, SESAME being particularly relevant.

Among the fundamental 5G ESSENCE objectives are: Full specification of critical architectural enhancements; definition of the baseline system architecture and interfaces for the provisioning of a cloud-integrated multi-tenant SC network and a programmable Radio Resources Management controller; development of the centralised SD-RAN (Software-Defined Radio Access Network) controller to program the radio resources usage in a unified way for all CESC (Cloud-Enabled Small Cells); exploitation of high-performance and efficient virtualisation techniques for better resource utilisation, higher throughput and less delay at the network service creation time; development of orchestrator’s enhancements for the distributed service management; demonstration and evaluation of the cloud-integrated multi-tenant SC network; conduct of a market analysis and establishment of new business models, and finally, maximisation of impact to the realisation of the 5G vision.

APPLICATIONS

5G ESSENCE will accommodate a range of use cases, in terms of reduced latency, increased network resilience, and less service creation time. One of its major innovations is the provision of E2E (End-to-End) network and cloud infrastructure slices over the same physical infrastructure, so that to fulfil vertical-specific requirements as well as mobile broadband services, in parallel. The project focuses on three real-life use cases associated to vertical industries: 5G edge network acceleration for a stadium, with local video production and distribution; mission critical applications for public safety (PS) communications providers; and next-generation, integrated, in-flight connectivity and entertainment services for passengers.

TECHNICAL AND RESEARCH CHALLENGES

The technical approach exploits the benefits of the centralisation of SC functions as scale grows through an edge cloud environment based on a two-tier architecture: a first distributed tier for providing low latency services and a second centralised tier for providing high processing power for computing-intensive network applications. This allows decoupling the control and user planes of the RAN and achieving the benefits of Cloud-RAN without the enormous fronthaul latency restrictions.

EXPECTED IMPACT

5G ESSENCE introduces innovations in the fields of network softwarisation, virtualisation, and cognitive network management. It provides a highly flexible and scalable platform, capable of supporting new business models and revenue streams by creating a neutral host market and ultimately, reducing operational costs by providing new opportunities for ownership, deployment, operation and amortisation.

5G ESSENCE

5G-MEDIA

/ Programmable edge-to-cloud virtualization fabric for the 5G-Media industry

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MAIN OBJECTIVES

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. In this respect, the 5G-MEDIA project addresses the objectives of 1) capitalizing and properly extending the valuable outcomes of the 5G PPP Phase 1 projects to offer an agile programming, verification and orchestration platform for services, and 2) developing network functions and media applications to be demonstrated in large-scale deployments.

APPLICATIONS

5G-MEDIA will be based on three key use cases of diverse requirements and particular interest for the consortium partners. Areas covered are the immersive media and VR, the smart production and user-generated content, and the UHD over CDN. Based on the adoption of the open innovation approach, the 5G-MEDIA platform will be offered to third parties to develop, combine, verify, deploy and validate media applications by utilizing the SDK capabilities and Service Platform offerings.

TECHNICAL AND RESEARCH CHALLENGES

It can be argued that media applications have the most to gain from the promised vision of 5G network capabilities, Hence early innovation activities are required into how 5G networks can be exploited by advanced media applications to realise the benefits of low latency, high bandwidth and flexible dynamic configuration.

5G-MEDIA plans to innovate specifically in this area by investigating how media applications

and the underlying 5G network should be coupled and interwork to the benefit of both: to ensure the applications allocate the resources they need to deliver high quality of experience and so that the network is not overwhelmed by media traffic. This will be achieved by applying SDN and NFV concepts to media applications to flexibly and dynamically embed them as virtual network functions (in the form of virtual machines, containers or unikernels) within the 5G network and cloud infrastructure. We will use a serverless computing paradigm, close to traffic sources and sinks, and by configuring network paths and virtual slices to deliver the required network capacity and performance levels at the network edge. 5G-MEDIA will create a DevOps environment for media applications which will hide the complexity of service development and deployment on the underlying 5G network and distributed cloud infrastructure, allowing developers to concentrate on media application details; and a service virtualisation platform that will orchestrate the deployment and scaling of the media applications, interacting automatically with the underlying network for the dynamic control of the network paths and forwarding graphs by applying machine learning and cognitive optimisation techniques.

EXPECTED IMPACT

5G-MEDIA plans to create an ambitious business impact with the introduction of Streaming as a Service concept, built on top of strong, consortium-wide exploitation plans, which are supported by the complementarity of expertise of our partners in key industrial sectors of the network and media domains.

5G-MoNArch

/ 5G Mobile Network Architecture for diverse services, use cases, and applications in 5G and beyond

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MAIN OBJECTIVES

The expected diversity of services, use cases, and applications in 5G requires a flexible, adaptable, and programmable mobile network architecture. While the design of such an architecture has been addressed in 5G PPP Phase 1 at a conceptual level, it must be brought into practice in Phase 2, taking into account progress in standards and providing experimental results.

In this regard, the main objectives of 5G-MoNArch are summarized below (see figure).

1. Detailed specification and completion of 5G PPP concepts towards a fully-fledged 5G mobile network architecture.
2. Extension of the existing mobile network architecture design with a set of key enabling innovations: Inter-slice control and cross-domain management, native cloud-enabled protocol stack, experiment-driven modelling and optimization.
3. Functional innovations for the technologies required for the two use cases worked out in detail within the project. The first use case is on a resilient and secure vertical industry application, the second one on a resource elastic enhanced mobile broadband application.
4. Deployment and implementation of the developed architecture and innovations in two experimental real-world testbeds:
 - Smart sea port, implementing the resilience and security use case
 - Touristic city, implementing the resource elasticity use case
5. Evaluation, validation, and verification of the performance of the developed architecture and innovations

TECHNICAL AND RESEARCH CHALLENGES

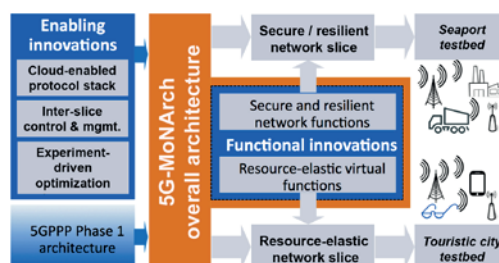
Following the above motivation, the research challenges addressed by 5G-MoNArch predominantly related to further specify and prove network slicing for the mobile network. Built on the capabilities of SDN, network function virtualization (NFV), access network orchestration, and analytics, end-to-end network slicing allows to logically sectorize the network for dedicated services, applications, or vertical industries. Each of these sectors may have different requirements in terms of quality and performance requirements, but multiple slices share the same physical / virtual infrastructure. While the concepts for defining and instantiating slices have been developed in 5G PPP Phase 1, the methods and algorithms for orchestration and optimization across slices, but also among virtualized functions are to be developed. A main technical challenge is related to the experimental implementation in the real-world testbeds, as existing networking technology has to be enhanced such that network slices can be implemented – on both, network and terminal side.

APPLICATIONS

For each of the two testbeds (smart sea port and touristic city), the project will instantiate the developed overall architecture and complement it with the use case specific functional innovations. The applications for the sea port thereby include traffic control, sensor-based environmental control, and CCTV. For the touristic city, enhanced mobile broadband services including interactive augmented reality applications will be implemented.

EXPECTED IMPACT

5G-MoNArch has a very high potential for commercial impact, including enhanced products (e.g., orchestrators or edge-cloud RAN), novel services (enabled by network slicing) and opportunities for new market players. To exploit this potential, 5G-MoNArch has elaborated a thorough and realistic innovation plan that includes patents and standards.



5G-PHOS

/ 5G integrated Fiber-Wireless networks exploiting existing photonic technologies for high-density SDN-programmable network architectures

PROJECT COORDINATOR

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MAIN OBJECTIVES

5G-PHOS aims to develop novel 5G broadband fronthaul architectures and evaluate them for Ultra-Dense and Hot-Spot areas exploiting the recent advances in optical technologies towards producing a powerful photonic integrated circuit technology toolkit. It aims to capitalize on novelties in InP transceiver, Triplex optical beamformers and multi-bitrate optical communications into next generation fronthaul in order to migrate from CPRI-based to integrated Fiber-Wireless packetized C-RAN fronthaul supporting mm-Wave massive MIMO communications.

APPLICATIONS

5G-PHOS expects to release a seamless, interoperable, RAT-agnostic and SDN-programmable FiWi 5G network that supports 64x64 MIMO antennas in the V-band and offers a) up to 400 Gb/s wireless peak data rate in ultra-dense networks, adopting optical Spatial-Division-Multiplexed solutions on top of the emerging 25 Gb/s PON infrastructures, delivering a packetized integrated FiWi fronthaul network and b) 100 Gb/s wireless peak data rate in Hot-Spot areas, showcasing the benefits of WDM technology and packetized fronthauling in private C-RAN solutions. These blocks will be integrated towards architecting 5G networks for Ultra-Dense and Hot-Spot use cases, evaluating their performance in lab and field experiments at the Orange Labs in Lannion, France, the deployed network of Cyprus telecom operator MTN and at the stadium of P.A.O.K. F.C. in Thessaloniki, Greece.

TECHNICAL AND RESEARCH CHALLENGES

5G-PHOS addresses the challenging ultra-dense 5G framework encompassing a range of environments with different traffic density and coverage needs. To this end, 5G-PHOS aims to meet the following technical and research challenges: 1) Release a cost-effective ultra-dense fronthaul specification with immediately commercially exploitable perspectives, 2) Meet the respective User Experience and System Performance Key Performance Indicator (KPI) metrics, 3) Synergize mm-wave wireless radio and massive MIMO antennas to provide increased capacity and link reliability and 4) Demarcate from CPRI-based schemes towards bandwidth-scalable Ethernet-friendly fronthaul solutions.

EXPECTED IMPACT

5G-PHOS will shape new network concepts that will be validated in a range of scalable lab- and field-trial demonstrators and will introduce new business models and opportunities converting them into tangible market outcomes by its industrial consortium partners. 5G-PHOS' outcomes will be demonstrated through different network use cases that have the highest probability to enter first the 5G era, tailored to serve the 5G network requirements both in performance as well as in business models and economic viability. 5G-PHOS is also expected to achieve a significant impact on various relevant standardization groups by virtue of its substantial technological outputs and time-alignment with 5G standardization and deployment roadmaps. Finally, 5G-PHOS aims to make a major step forward towards increasing the economic and social wellbeing of European citizens by providing its cost-effective, energy-efficient 5G network solutions for high-density use cases.



5G PICTURE

/ 5G Programmable Infrastructure Converging disaggregated network and compute Resources

PROJECT COORDINATOR

Eckhard Grass
IHP

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MAIN OBJECTIVES

5G-PICTURE will design and develop an integrated, scalable and open 5G infrastructure with the aim to support operational and end-user services for both ICT and “vertical” industries. This infrastructure will rely on a converged fronthaul and backhaul solution, integrating advanced wireless access and novel optical network domains. To address the limitations of current solutions, 5G-PICTURE will adopt the novel concept of Disaggregated-Radio Access Networks (DA-RANs), allowing any service to flexibly mix-and-match and use compute, storage and network resources through HW programmability. It will also rely on network softwarisation to enable an open reference platform instantiating a variety of network functions and adopt slicing and service chaining to facilitate optimised multi-tenancy operation.

APPLICATIONS

In the context of 5G-PICTURE several use cases will be examined focusing on a variety of telecom and vertical industry services. More specifically, 5G-PICTURE will demonstrate: (a) converged fronthaul and backhaul services in a smart city environment hosted by the state-of-the-art 5G “City of Bristol” network infrastructure, (b) seamless service provisioning and mobility management in high speed railway environments exploiting a real 5G-railway testbed located in Barcelona, Spain, and (c) media services supporting large venues in a 5G-stadium testbed located in Bristol, UK to address scenarios with increased density and static-to-low mobility.

TECHNICAL AND RESEARCH CHALLENGES

5G-PICTURE proposes to integrate network and compute/storage resources in a common infrastructure. This involves a hierarchical compute & storage structure supported by a network hierarchy exploiting integrated programmable wireless technologies at the edge and a hybrid passive/active optical transport network. To address the limitations of current distributed RAN and Cloud-RAN approaches, 5G-PICTURE will develop flexible functional splits that can be dynamically selected, based on transport network and service characteristics. This will be achieved through the notion of DA-RAN relying on a disaggregated resource pool. To enable this approach, 5G-PICTURE proposes a set of novel technology solutions as well as control and management platforms offering enhanced network and compute HW and SW modularity and flexibility. Another key enabler of the proposed approach is the creation and deployment of programmable network functions as well as intelligent orchestration schemes.

EXPECTED IMPACT

Currently, services with very high bandwidth and low latency requirements are supported through multiple application-specific platforms having significant installation, operational and administrative costs while advanced features vital for efficient operation of these services are not supported and the majority of existing implementations are not truly open. 5G-PICTURE addresses these inefficiencies adopting the concept of DA-RAN that allows to form any service under a common programmable open infrastructure. This will offer significant performance cost and energy efficiency benefits.



5GTANGO

/ 5G Development and Validation Platform for global Industry - specific Network Services and Apps

PROJECT COORDINATOR

Josep Martrat
ATOS

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MAIN OBJECTIVES

5GTANGO puts forth the flexible programmability of 5G networks. The main objectives within the 5GTANGO project are:

- Reduce the time-to-market for networked services by shortening the service development cycle and by qualifying those network services to be adopted.
- Reduce the entry barrier to third party developers and support the creation and composition of Virtual Network Functions (VNFs) and application elements as “Network Services”.
- Enable new business opportunities with the customisation and adaptation of the network to vertical application’s requirements.
- Accelerate the NFV uptake in industry via an ‘extended’ DevOps model and the validation at scale of Network Service capabilities of the 5GTANGO platform in vertical show cases.

APPLICATIONS

In order to illustrate the added value of the service programmability, service validation and orchestration offered by 5GTANGO, we have selected three pilots in relevant areas for 5G: a) Smart manufacturing with deployment and orchestration of network services to control machinery or factory-wide networking system processes, address network security issues and deal with operational verification and validation; b) Immersive media, introducing a solution that relies on virtualisation technologies to implement a virtual Content Delivery Network (vCDN) architecture and adaptive streaming technologies; and c) Communications Suite deployment using 5GTANGO platform to provide a self-scalable and easy to provision system.

TECHNICAL AND RESEARCH CHALLENGES

5GTANGO addresses the emerging challenges associated with both the development and validation of vertical services and applications. The following technologies are envisioned:

- 1) A modular, dependable service platform with a modular orchestration framework that will support vertical sector needs. A key evolution is a more profound separation of concerns by factoring out the verification and validation (V&V) steps to the V&V store role.
- 2) A store for Verification and Validation expertise. The V&V component is key to 5GTANGO and not present in existing NFV architectures
- 3) A NFV-specialized Software development kit (SDK) to support the development of NFV services.
- 4) An adapted DevOps methodology and associated tools that will help connect stakeholders to a modern, agile workflow that supports the rapid development cycles of software-driven networks, and helps tackle the inter-organizational challenges

EXPECTED IMPACT

5GTANGO will help to open the telecom market and to create business models adapted to the new paradigm: 5GTANGO’s NFV-enabled SDK will encourage the creation and growth of start-ups in the sector; the V&V store will be an experimental innovation environment for 5G services where collaboration from different industries will enrich service portfolios; the Service Platform with its modular orchestration framework will alleviate some of the CSPs’ pain points related to the NFV transition.

Its open source results will be made available for their use in industrial and other open source initiatives and as well as future 5G PPP projects and will be discussed with the community and by promoting and actively driving standardization.

5G-Transformer

/ 5G-Transformer: 5G Mobile Transport Platform for Verticals

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MAIN OBJECTIVES

5G-Transformer aims to transform today's mobile transport network into an SDN/NFV-based Mobile Transport and Computing Platform (MTP), which brings the "Network Slicing" paradigm into mobile transport networks by provisioning and managing MTP slices tailored to the specific needs of vertical industries. The technical approach is twofold:

- (1) Enable vertical industries to meet their service requirements within customised MTP slices; and
- (2) Aggregate and federate transport networking and computing fabric, from the edge all the way to the core and cloud, to create and manage MTP slices throughout a federated virtualized infrastructure.

The goal of 5G-Transformer is to design, implement and demonstrate a 5G platform that addresses the aforementioned challenges.

APPLICATIONS

The project will demonstrate several vertical industry use cases:

- **Automotive:** Autonomous Cruise Control (ACC) enforcement application, Collaborative Advanced Driver Assistance Systems (ADAS) application and Remote Vehicle Interaction (RVI) application.
- **eHealth:** Improvement of the municipal emergency communication network and development of a new technological solution for health workers and volunteers.
- **Media & Entertainment:** Media applications for stadia and the Olympic Games.

TECHNICAL AND RESEARCH CHALLENGES

5G-Transformer defines three novel building blocks that will be developed and demonstrated integrating the aforementioned three vertical industries:

- (1) Vertical Slicer as the logical entry point (i.e., one stop shop) for verticals to request the creation of their respective transport slices in a short time-scale (in the order of minutes).
- (2) Service Orchestrator for end-to-end service orchestration and federation of transport networking and computing resources from multiple MTP domains and for management of their allocation to slices.
- (3) Mobile Transport and Computing Platform as the underlying unified transport stratum for integrated fronthaul and backhaul networks, hence building on the foundations of 5GPPP Phase 1 projects.

EXPECTED IMPACT

5G-Transformer targets several 5GPPP KPIs, such as reduced service deployment times or OPEX and CAPEX reduction.

The 5G-TRANSFORMER project is an ambitious initiative that will certainly have strong impact in industry. In fact, the project implements a plan for communication, dissemination, and exploitation to maximise its impact, which includes products and standardisation (e.g., ETSI, IETF and ONF). Therefore, innovation management is also a key component.

The technologies developed in 5G-TRANSFORMER are expected to strengthen the position of European companies in the upcoming 5G Mobile Network market, both in Europe and Worldwide, for the whole value chain (Verticals, Operators, Service Providers, Manufacturers, SMEs, and Complementary Industries).

5G-Xcast

/ Broadcast and Multicast Communication Enablers for the Fifth Generation of Wireless Systems

PROJECT COORDINATOR

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MAIN OBJECTIVES

5G-Xcast will devise, assess and demonstrate a conceptually novel and forward-looking 5G network architecture for large scale immersive media delivery. The project objectives are to:

- Develop broadcast and multicast point to multipoint (PTM) capabilities for 5G considering Media and Entertainment (M&E), automotive, IoT and Public Warning (PW) use cases, and evaluate 5G spectrum allocation options for 5G Broadcast network deployments.
- Design a dynamically adaptable 5G network architecture with layer independent network interfaces to dynamically and seamlessly switch between unicast, multicast and broadcast modes or use them in parallel and exploit built-in caching capabilities.
- Experimentally demonstrate the 5G key innovations developed in the project for the M&E and PW verticals.

APPLICATIONS

5G-Xcast will be the first 5G PPP project to focus on the holistic implementation of multicast/broadcast as a critical technology element in 5G systems in addition and as a complement to unicast. 5G-Xcast technologies will be also fundamental to progress towards the vision of a converged 5G infrastructure for fixed and mobile accesses, including terrestrial broadcast, to audio-visual media content. The project will take a holistic approach to harmonize the media delivery among the three considered types of networks and to provide an optimised and seamless media user experience. In order to highlight practical applications, three demonstrations of use cases will be developed: “Hybrid Broadcast Services”, “Object-based Broadcast Service” and “Public Warning Messages”.

TECHNICAL AND RESEARCH CHALLENGES

Audio-visual media services generate large volumes of data traffic on networks which is unevenly distributed over time and

geographical areas. At the same time, Quality of Experience (QoE) is strongly dependent on sustained minimum data rates and low latencies to all regardless of the total number of concurrent users. This is particularly challenging for very popular live content (e.g. sports) or unpredictable events (e.g. breaking news) that tend to cause large traffic spikes. The increasing bit-rate demands of 4k UHD TV and, in the future 8k UHD TV, and the emerging new interactive services (e.g. augmented reality, virtual reality and 360° visual media) will further increase the demand on network capacity and performance. None of the existing networks, whether fixed, mobile or broadcast, has the capability to support this type of future demand on their own due to limitations associated with capacity, delay and cost of deployment. Furthermore, the fractured landscape of protocols and APIs across them severely limits their ability to cooperate in addressing this demand. 5G-Xcast will develop a solution that targets such limitations and therefore addresses future demand, based on the key capabilities of 5G that by far exceed those of the legacy systems.

EXPECTED IMPACT

- Provide efficient, scalable and sustainable solutions for a large-scale distribution of media services fully consistent with the core 5G specifications, contributing to the definition of 5G and its standardization in 3GPP.
- Facilitate seamless integration of fixed, mobile and terrestrial broadcast networks into a unified heterogeneous and flexible 5G infrastructure, enabling better use of network resource, easier evolution paths to future functionalities and services and improved QoE.
- Enable new sustainable business models, new applications and services, and a graceful migration of M&E services from the legacy networks to 5G.
- Bring the M&E vertical into 5G PPP, bringing together for the first time major and small and medium size players from mobile/fixed/broadcast industries.

Bluespace

/ Building on the Use of Spatial Multiplexing 5G Networks Infrastructures and Showcasing Advanced technologies and Networking Capabilities

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MAIN OBJECTIVES

The core concept of BLUESPACE is to exploit 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. Both being seamlessly integrable in next generation optical access networks infrastructures with massive beam steering capabilities and with flexible network management control. The main objectives targeted by the BLUESPACE project are: to develop a truly viable and efficient path for 5G wireless communications with a 1000-fold increase in capacity, connectivity for over 1 billion users, strict latency control, and network software programming.

APPLICATIONS

The BLUESPACE architecture will serve 5G service provision in millimeter-wave regions of the spectrum. Proof-of-concept validations and a test-bed will be realized to demonstrate the merits and application of the BLUESPACE concept.

TECHNICAL AND RESEARCH CHALLENGES

- The adaptation of DRoF schemes in parallel with ARoF techniques and their adaptation to SDM network with increased degree of integration and full compatibility among the two schemes
- Development of advanced hardware solutions and modules for cost efficient ARoF transceivers, remote power distribution over SDM network for the independent powering RRUs from the CO, spatial optical beam forming schemes with simplified design requirements and direct compatibility with ARoF transceivers at the RRU, and compact SDM splitter and MCF adapters enabling advanced SDM-based ODN designs.

- The optimum allocation of the BBU pool at the CO and the design of its switching and interconnection hardware to enable SDM-compatible DCA, controlled strict latency and CoMP for both DRoF and ARoF paradigms.
- Design of optimized interfacing elements between the SDM media and the radiating elements in the RRU/RRH sites to enable advanced massive MIMO and beam steering solutions for both DRoF and ARoF architectures
- The evaluation and design of SDN control to support SDM and NFV orchestration to deploy virtual base-band units (vBBUs) in the CO, as well as network slicing to support de virtualization of the network resources and multi-tenancy (e.g. verticals).

EXPECTED IMPACT

BlueSpace proposition offers unrivalled characteristics whose impact include:

- a) Increased bandwidth provision by naturally enabling and supporting massive multiple Input Multiple Output (MIMO) in the Ka-band with seamless starting/ending interface with the fiber medium by exploiting space diversity in the RF domain with efficient beamsteering in the photonic domain,
- b) A compact infrastructure that is reconfigurable by means of Software Defined (SDN) and Network Function Virtualization (NFV) paradigms and with
- c) full integration with existing approaches for access networks such as Passive Optical Networks (PONs).



IoRL

/ Internet of Radio Light

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MAIN OBJECTIVES

Wireless networks in buildings suffer from congestion, interference, security and safety concerns, restricted propagation and poor indoor location accuracy.

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, whilst minimizing interference and harmful EM exposure and providing location accuracy of less than 10 cm. It thereby shows how to solve the problem of broadband wireless access in buildings and promotes the establishment of a global standard in ITU.

APPLICATIONS

IoRL project designs a Remote Radio-Light Head (RRLH), so that it can easily be installed in a wide range of different types of properties and Network Management & Operations Plane API for buildings where third party application developers can develop and exhibit their innovative network services in homes, businesses and public space buildings using open source development environment. Example services will be developed in the project such as one that ameliorates the need for using HeNB/HgNB or WLAN in buildings and eliminates the uplink interference that they induce. This will have the effect of incentivising all building construction companies to install an RRLH throughout their new build developments. Building landlords will be incentivized to find funding to realize this solution for their properties to increase their value resulting in a stimulated market for broadband networking products in buildings, benefiting society and stimulating the world Gross Domestic Product. Thus there are four use case scenarios for the most important type of buildings: homes, public spaces – museums, shopping malls and metro stations.

TECHNICAL AND RESEARCH CHALLENGES

The challenges are to (i) Develop broadband communication solutions for buildings by integrating VLC, mmWave and SDN/NFV technologies to exploit the pervasiveness and accessibility of the existing electric light access points, the broadband capacities of mmWave and VLC technologies and the flexibility of SDN/NFV; (ii) Industrially design a remote radio-light head solution that can be integrated into the myriad of form factors of existing electric light systems and consumer products.

EXPECTED IMPACT

The main benefit is that the IoRL architecture meets all the relevant 5G PPP KPI's for networks in buildings, namely: 1000x capacity, less than 1ms latency, 90% energy savings, 10x battery lifetime, service creation in minutes, better/increased/ubiquitous coverage, 10 times to 100 times higher typical user data rate and lowered EMF levels compared to LTE solutions, whilst also providing a further benefits that user equipment can be located to an accuracy of less than 10cm. Designing the radio-light communication system to fit into the confined space of a light rose requires a Network Function Virtualisation (NFV) solution, whose cloud computers can be variously located remote from the radio-light access points elsewhere in the Home Cell Site or in the external Cloud network, and a Software Defined Network (SDN) to intelligently manage and route data to the different parts of the radio-light network. Consequential benefits of this architecture are that its common building electric light network resources can be more easily shared between MNOs by slicing and that the NFV solution provides an API, which allows third party service providers to write specialized network applications to manage multi-MNO in buildings.



MATILDA

/ A holistic, innovative framework for the design, development and orchestration of 5G-ready applications and network services over sliced programmable infrastructure

PROJECT COORDINATOR

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MAIN OBJECTIVES

MATILDA 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 are going to be applied for the automated placement of the 5G-ready applications and the creation and maintenance of the required network slices. Deployment and runtime policies enforcement is provided through a set of optimisation mechanisms providing deployment plans based on high level objectives and a set of mechanisms supporting runtime adaptation of the application components and/or network functions based on policies defined on behalf of a services provider.

Multi-site management of the cloud/edge computing and IoT resources is supported by a multi-site virtualized infrastructure manager, while the lifecycle management of the supported Virtual Network Functions Forwarding Graphs (VNF-FGs), as well as a set of network management activities, are provided by a multi-site NFV Orchestrator (NFVO).

Network and application-oriented analytics and profiling mechanisms are supported based on real-time as well as a posteriori processing of the collected data from a set of monitoring streams.

APPLICATIONS

In MATILDA, a set of use cases are going to be realised for validation and evaluation of the proposed solution, in the following domains:

- 5G Emergency Infrastructure and Services Orchestration with SLA Enforcement;
- High Resolution Media on Demand;

- Smart City Intelligent Lighting Systems;
- Remote Control and Monitoring of Automobile Electrical Systems;
- Industry 4.0 Smart Factory.

TECHNICAL AND RESEARCH CHALLENGES

To come up with a holistic approach for enhancing 5G with intelligent orchestration platforms able to support end-to-end 5G-ready applications and services provision over a programmable infrastructure, a set of challenges that should be tackled have been identified, as follows:

- Define the appropriate abstractions for the design of 5G-ready applications for industry verticals able to take advantage of a 5G programmable infrastructure.
- Develop an agile programming and verification platform for designing, developing and verifying industry vertical 5G-ready applications and network services.
- Support mechanisms for automated or semi-automated translation of application-specific requirements to programmable infrastructure requirements.
- Support unified and intelligent orchestration mechanisms for managing the entire lifecycle of 5G-ready applications.
- Support mechanisms for multi-site network, compute and storage resource management.

EXPECTED IMPACT

The vision of MATILDA is to design and implement a novel holistic 5G end-to-end services operational framework tackling the overall 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.



METRO-HAUL

/ METRO High bandwidth, 5G Application-aware optical network, with edge storage, compute and low Latency

PROJECT COORDINATOR

Andrew Lord
BT

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MAIN OBJECTIVES

The overall Metro-Haul objective is to architect and design cost-effective, energy-efficient, agile and programmable metro networks that are scalable for 5G access and future requirements, encompassing the design of all-optical metro nodes (including full compute and storage capabilities), which interface effectively with both 5G access and multi-Tbit/s elastic core networks.

Metro-Haul has taken the 5G KPIs and already determined their implication for the optical network with these 5 targets: (i) 100 x more 5G capacity supported over the same optical fibre infrastructure, (ii) 10 times less energy consumption, (iii) Latency-aware metro network in which latency-sensitive slices are handled at the metro edge ensuring the metro network adds no additional latency, (iv) End to end SDN-based management framework enabling fast configuration time to set up or reconfigure services handling 5G applications, specifically 1 minute for simple network path set-up and 10 minutes for full installation of a new VNF and 1 hour for setting up a new virtual network slice and (v) reduction in CAPEX of a factor of 10, plus a reduction in OPEX of at least 20%.

APPLICATIONS

The two main Use Cases in Metro-Haul are: (i) Video Security for Smart Cities and (ii) Crowdsourced Video Streaming.

The first Use Case will showcase intelligent video security based on automatic object/person identification and tracking. The demo implements a video-based automated security system relying on stationary and mobile cameras (e.g. body cams, or cameras mounted on drones) with wired and/or wireless access. As a basis for the infrastructure, the demo will use the 5G Berlin testbed coupled with DT's Berlin metro infrastructure.

The second Use Case shows the simultaneous sourcing of video from different individuals in an event with a large crowd. The different video sources need synchronising and clustering to be usable for broadcast, and the role of a dynamic and controllable metro network is indispensable.

Additional portable demonstrations will be planned to be showcased in relevant events.

TECHNICAL AND RESEARCH CHALLENGES

Challenges are many and in multiple areas. There is a significant optical challenge, focused on making metro optical transport simultaneously cost effective and agile, involving both the optical architecture and also innovative new optical component technologies.

There is also a challenge around network management. Metro-Haul will design and implement an SDN/NFV control framework and architecture supporting 5G operational and both end-user and vertical oriented services, including slicing. Coupled to that is a challenge around monitoring – both implementation and AI-based tools for interpreting the vast amount of data.

EXPECTED IMPACT

The impact of the project should be felt in different directions. Europe has some large optical vendors who will get a head-start in their plans to support 5G, based on Metro-Haul know-how. The 5G KPIs, applied usually to the radio access end of the network, will be compromised without an optical metro-haul support, and the project will provide all that is needed for this.

Metro-Haul will take advantage of its close links into the standards community to press for wide-spread adoption of its concepts and solutions.



NGPaaS

/ Next Generation Platform as a Service

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MAIN OBJECTIVES

The ideal 5G Platform-As-A-Service (PaaS) not only facilitates building, shipping and running classical virtual network applications (VNFs) with “telco-grade” quality but also provides an ecosystem that breaks the barriers between connectivity and computing, combining all sorts of third-party applications with those VNFs for creating exciting more versatile and powerful cloud objects. This 5G PaaS does not exist today. The main goals of NGPaaS is to build it by targeting:

1. *A Telco-grade PaaS* to support different configurations and a large set of deployment targets such as FPGA/ARM/x86, private/public cloud in a scalable and unifying manner.
2. *A Dev-for-Operations model* to remove the vertical barriers that create isolated silos, not only between different teams of the same organisation or organisations of the same industry, but also between different industries (vendor, IoT/Vertical, operator).
3. *High quality and high-performance* development and operational environments: If we want developers from the IT industry to embark on the 5G platform, it is important to support tools for ensuring the same quality and SLA as the ones found in telecom environment.
4. *OSS/BSS model* for interfacing with cloud resources supporting the Telco-grade PaaS optimised for cost and performance in a highly dynamic environment.

APPLICATIONS

To illustrate the platform performance and the “build-to-order” principle, several use-cases will be supported in the telco and the vertical domain. These use-cases should be highly representative of the advanced capabilities of the platform. The telco use-case demonstrates advanced network softwarisation such as ‘RAN-as-a-Service and ‘EPC-as-a-Service’. The second use-case is related to IoT energy monitoring scenarios. The third use-case shows a mix of telco and 3rd party IoT components (e.g. local analytics). Heterogeneous IaaS will be considered.

TECHNICAL AND RESEARCH CHALLENGES

Specificities to 5G systems require innovations not yet available in current PaaS:

- Adoption of the ‘cloud stack’ based on a layered approach: infrastructure/ platform/ business layers.
- Component modularity to implement “build-to-order” principle and to support recursion to build efficiently complex PaaS structures.
- Unstructured and flexible stack disrupting current approach today where a fixed combination of options in each layer is imposed.
- Carrier-grade enhancements implemented directly and natively in the control, orchestration, virtualisation and operational frameworks.

EXPECTED IMPACT

NGPaaS’s ambition is to:

- build a reference stack for future 5G networks, ready to be deployed for industrial usage.
- create a new ecosystem and the opportunity for all players to collaborate and develop new business models they can each benefit from.
- deliver innovative technologies enabling and accelerating the telco-grade PaaS transformation across the industry (operator, IoT/verticals and vendors), increasing the market scale and improving market economics.

NGpaas

NRG-5

/ Enabling Smart Energy as a Service via 5G Mobile Network advances

PROJECT COORDINATOR

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MAIN OBJECTIVES

The NRG-5 project aims to contribute to the 5G PPP/5G Initiative research and development activities and participate at the relevant 5G Working Groups, by delivering a novel 5G PPP compliant, decentralized, secure and resilient framework, with highly availability, able to homogeneously model and virtualize multi-homed, static or moving, hardware constrained (smart energy) devices, edge computing resources and elastic virtualized services over communications' and energy utilities' infrastructures.

The ultimate project objective is to make the deployment, operation and management of existing and new communications and energy infrastructures (in the context of the Smart Energy-as-a-Service) easier, safer, more secure and resilient from an operational and financial point of view.

Furthermore, NRG-5 will investigate on extensive modelling and virtualization of electricity and gas infrastructure assets combined with the telecommunications infrastructure covering the full spectrum of the communication and computational needs.

APPLICATIONS

The NRG-5 project is based on the concept of short iterative cycles of work, with highly parallel streams of activities brought together by a mutual focus on developing 5G technologies driven, by a set of Smart Energy three defined use cases and a well-defined time to market context.

In collaboration with 5G initiative, NRG-5 will develop, validate, promote, standardize and exploit 5G results on the smart energy vertical demonstrators to be used by Telcos, Utilities and service providers. NRG-5 will examine how already defined 5G radio features (e.g.

from METIS II) could be used in the Critical Infrastructure use case, while NRG-5 results (e.g. security solutions, 5G prototypes, VNFs and xMEC) will be available for 5G services provisioning.

TECHNICAL AND RESEARCH CHALLENGES

Technological advances, political visions and market liberation are transforming the energy network from a closed, monolithic and highly predictable infrastructure to an open, multi-owned, decentralized ecosystem, posing huge challenges, both in functional (i.e. stability, resiliency and highly availability) and in non-functional (i.e. sustainability, security, privacy and CAPEX/OPEX) directions. In this new and time varying energy landscape, NRG-5 and 5G initiative are challenged to guarantee optimal communications of the energy grid, which is believed to be the most complex, heterogeneous and gigantic machine ever made in human history.

EXPECTED IMPACT

NRG-5 balances innovation and development activities, simultaneously exposing concrete and targeted dissemination, communication and standardization plans in close collaboration with 5G PPP Initiative. NRG-5 will demonstrate progress towards core 5G PPP KPI's, novel business models through innovative sharing of network resources across multiple actors and eventually NRG-5 will define 5G network architecture and core technological components.

ONE5G

/ E2E-aware Optimizations and advancements for the Network Edge of 5G New Radio

PROJECT COORDINATOR

Frank Schaich
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PARTNERS

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MAIN OBJECTIVES

- To propose the necessary 5G extensions, [...] to address the two selected scenarios ('megacities' and 'underserved areas')
- To build consensus on new features [...] and provide technical recommendations for moving 5G towards '5G advanced (pro)'
- To propose advanced link technologies and enhancements beyond release 15 to enable multi-service operation and practical implementation of '5G advanced (pro)', with future-proof access schemes, advanced massive MIMO enablers and link management.
- To research and deliver highly generic performance optimization schemes [...], in order to achieve successful deployment and operation, including optimizations for both the network operator and the E2E user-experienced performance.
- To identify the cost driving elements for the roll-out and operation and to propose adaptations to allow sustainable provision of wireless services in underserved areas under constrained circumstances.
- To validate the developed extensions and modifications through different approaches: analytically, by means of extensive simulations and with the help of proof-of-concepts for selected aspects.

SERVICE CATEGORIES

Enhanced Mobile Broadband (eMBB), Ultra-Reliable Low Latency Communications (URLLC), massive Machine Type Communications (mMTC).

TECHNICAL AND RESEARCH CHALLENGES

- Future proof multi-service access solutions
- Massive MIMO enablers
- Advanced link management based on multi-cell processing
- Optimized multi-link management for improved E2E performance
- Network and user-experienced E2E performance optimization and context awareness

EXPECTED IMPACT

Standardization: release 16 and 17 of 5G New Radio.

Commercial and market impact: Empower traditional operators and vertical industries to efficiently exploit the opportunities of 5G New Radio

Scientific and technological impact: Drive forward technical advances in the areas given above.

Socio-economic and environmental impact: Enrich both private life and business/ industrial activities with enhanced wireless communication services.



SaT5G

/ Satellite and Terrestrial Network for 5G

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MAIN OBJECTIVES

The project vision is to develop cost effective “plug and play” satcom solutions for 5G to enable telecom operators and service providers to accelerate 5G deployment in all geographies and at the same time create new and growing market opportunities for satcom industry stakeholders.

The six principal project objectives are to:

1. Leverage relevant ongoing 5G and satellite research activities to assess and define solutions integrating satellite into the 5G network architecture;
2. Develop the commercial value propositions for satellite-based network solutions for 5G;
3. Define and develop key technical enablers for the identified research challenges;
4. Validate key technical enablers in a lab test environment;
5. Demonstrate selected features and use cases with in orbit satellites;
6. Contribute to the standardisation at ETSI and 3GPP of the features enabling the integration of satcom solutions in 5G.

APPLICATIONS

SaT5G will focus its efforts on the following key use cases:

- Edge delivery and offload of multimedia content and MEC VNF software, through multicast and caching to optimise the operation and dimensioning of the 5G network infrastructure;
- 5G fixed backhaul, to provide 5G service especially in areas where it is difficult or not possible to deploy terrestrial communications;
- 5G to premises, to provide 5G service into home/office premises in underserved areas via hybrid terrestrial-satellite broadband connections;
- 5G moving platform backhaul, to support 5G service on board moving platforms, such as aircraft, vessels, trains, etc.

TECHNICAL AND RESEARCH CHALLENGES

The technical challenges that need to be addressed for the realisation of cost effective “plug and play” satcom solutions for 5G are:

- Virtualisation of satcom network functions to ensure compatibility with the 5G SDN/NFV architecture;
- Developing the enablers for a converged 5G-satcom virtual and physical resource orchestration and service management;
- Developing link aggregation scheme for small cell connectivity mitigating QoS and latency imbalance between satellite and cellular access;
- Leveraging 5G features/technologies in satcom;
- Optimising/harmonising key management and authentication methods between cellular and satellite access technologies;
- Optimal integration of the multicast benefits in 5G services for both content delivery and VNF distribution.

EXPECTED IMPACT

SaT5G will demonstrate the key role and integration of satellites in the 5G ecosystem by delivering:

1. Integrated satellite-terrestrial solutions meeting 5G KPIs for unserved and underserved regions;
2. Virtualised satellite network architecture for seamless interoperability with 5G;
3. 5G testbeds integrating satcoms for the development of future 5G end-to-end platforms;
4. Global standards to ease the market acceptance of satcom solutions by 5G stakeholders;
5. “Plug and play” satcom solutions established and certified to foster the 5G eMBB roll out.

SLICENET

/ End-to-End Cognitive Network Slicing and Slice Management Framework in Virtualised Multi-Domain, Multi-Tenant 5G Networks

PROJECT COORDINATOR

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MAIN OBJECTIVES

SLICENET targets to achieve truly E2E slicing to maximise the benefits of full infrastructure sharing and to provide a highly innovative, integrated verticals' QoE oriented slice provisioning, control, management and orchestration framework, meeting the diverging requirements from diverse verticals.

APPLICATIONS

SLICENET use cases will challenge 5G slicing capabilities to its limit:

The 5G Smart Grid Self-Healing Use Case will increase automation in power distribution with self-healing solutions towards a smarter grid. Altice Labs and EFACEC will jointly deploy this use case in Portugal.

The 5G eHealth Smart / Connected Ambulance Use Case will advance the emergency ambulance services using the ambulance as a connection hub (or mobile edge) for the emergency medical equipment and wearables. The use case has the support from the Irish National Ambulance Services through Irish Department of Public Expenditure and Reform.

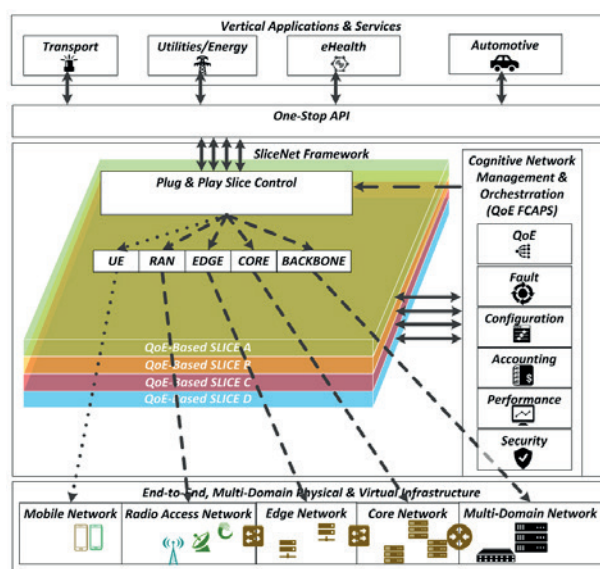
The 5G Smart City Use Case will implement remote water metering and the Intelligent Public Lighting system in the city Alba Iulia, in Romania, and access the various technical and operational KPIs against the initial status quo in the city.

TECHNICAL AND RESEARCH CHALLENGES

SLICENET will design, prototype and demonstrate an innovative, verticals-oriented, QoE-driven 5G network slicing framework, focusing on cognitive network management and control for end-to-end slicing operation and slice-based/enabled services across multiple operator domains in SDN/NFV-enabled 5G networks.

EXPECTED IMPACT

SLICENET will advance slicing-based softwarisation of 5G systems with architectural enhancements and infrastructure integration, as well as novel enablers for the slicing control plane, management plane and cross-plane orchestration. For 5G network operators, SLICENET will enable a truly end-to-end multi-domain network management paradigm with integrated FCAPS (Fault, Configuration, Accounting, Performance and Security). For 5G service providers and users, SLICENET will achieve significantly higher service quality towards warranted perceived quality through the intelligent QoE-driven design. For 5G vertical businesses, SLICENET will facilitate them to employ 5G services in a much rapid and efficient manner through a 'one-stop-shop' approach.



To-Euro-5G

/ Supporting the 5G PPP

PROJECT COORDINATOR

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MAIN OBJECTIVES

The To-Euro-5G project has a prime objective to support the activities of the European 5G Initiative during the second phase of the 5G PPP from June 2017 to June 2019.

The 5G PPP Phase 2 projects will be obliged by Article 41.4 of their respective grant agreements to enact a Collaboration Agreement and participate in a number of strategic cross project horizontal activities and To-Euro-5G will assist with orchestrating this agreement and these activities.

The To-Euro-5G project will further develop and progress a strategic communications plan to ensure the best possible impact is achieved with the technical results of the 5G PPP projects and the horizontal activities of the 5G PPP programme.

The To-Euro-5G project will support the 5G PPP high level goal of maintaining and enhancing the competitiveness of the European ICT industry, and seeking European leadership in the 5G domain. The European 5G Action Plan will require an overview of the 5G PPP projects trial/demo/showcase potential. The To-Euro-5G project will facilitate the new Trials Working Group, which was launched by the 5G Infrastructure Association in 5G PPP in September 2016.

The To-Euro-5G project also has the underlying ambition to ensure that European society, via the Vertical sectors, can enjoy the economic and societal benefits these future 5G networks can provide.

PROJECT CONCEPTS

The To-Euro-5G project Concept is to provide the necessary support for the operation of the 5G PPP in the most efficient and effective way possible. While the support action cannot provide the unified solutions for 5G itself, the project team realise that the support for interworking between the projects and the presentation of the combined results on the global stage can have a significant impact on the adoption and use of the European 5G solutions.

TECHNICAL AND RESEARCH CHALLENGES

At the first organisational level in the programme To-Euro-5G project will organise a Steering Board (SB) composed of the mandated coordinators of the all running 5G PPP projects.

The next operational level will be a Technology Board (TB) where the issues of complementary scope, consistence and interoperability, interfaces as well as the technical planning of joint demonstrations will be considered. All cross-project technical issues will be addressed here.

The third level of activity organisation will be the establishment and operation of joint Working Groups (WG) across projects and the wider community as necessary.

EXPECTED IMPACT

- An efficient and effective 5G PPP programme
- Optimum profile for the European 5G initiative in a global context
- Widespread dissemination of 5G PPP results
- Launch of necessary 5G standards work
- Measurable Programme Progress and KPIs
- A holistic view of 5G implementation for 2020
- Enhancement of 5G Vision
- Growth of the 5G constituency
- Supporting early exploitation of results



PROJECT COORDINATOR

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MAIN OBJECTIVES

The overriding goal of Global5G.org is providing a European-led contribution to the international vision of 5G networks, addressing a large set of requirements from different vertical industries, with specific focus on market analysis, standardisation and policy & regulation. Global5G.org fills an existing gap in today's efforts to implement a European "5G PPP vision" in an international context, by engaging all relevant stakeholders.

APPLICATIONS

Global5G.org recognises the need to address vertical industry requirements, to limit market fragmentation, and to support standardisation as essential for ensuring interoperability, security, privacy and data protection. A set of representative use cases will be identified, starting from the Healthcare, Automotive, Factories of the Future and Energy vertical sectors. Special focus will be dedicated to the Healthcare sector, to identify and highlight opportunities for 5G as the foundation for new healthcare models, provide insights into overcoming barriers to digital transformation in healthcare delivery and assessing the maturity of the healthcare industry to establish an association bringing together the principal players in the 5G healthcare scenario.

Global5G.org will facilitate EU and international initiatives with vertical use cases in communicating their standardisation and spectrum requirements, acting as a bridge across the 5G PPP and Standards Bodies, by engaging with vertical industries standardisation to monitor progress, streamline efforts and help increase awareness and consensus.

TECHNICAL AND RESEARCH CHALLENGES

Global5G.org will support European 5G research that address challenges of spectrum efficiency, capacity, ubiquitous coverage, ultra-high reliability, ultra-short latency, enhanced security, privacy and data protection, trustworthy interoperability across heterogeneous domains, network slicing, network programmability and virtualisation techniques.

Global5G.org is also providing a study on the regulatory issues for the deployment of dense networks across the EU with the aim to identify best practices and models to harmonise and improve regulations in EU, and to define drivers for incentivizing all stakeholders towards network densification, accelerating the rollout of small cells.

EXPECTED IMPACT

The Global5G.org Standardisation Tracker will lower the barrier to access standardisation efforts and results, highlighting the timelines and measuring progress on broad global and Industry consensus. The Global5G.org Trial and Testbed Monitor will help increase research efficiency on 5G by constantly tracking pre-commercial/pre-standards trials as beneficial to the Industry, sharing major results to streamline research efforts among diverse actors in the 5G ecosystem, while sensing market needs as they arise through the Global5G.org Market Watch.

The Strategic Research & Innovation Agenda (SRIA), with recommendations for 5G development plans of international breadth, and insight reports from highly relevant events, chart a course for a Global 5G International Cooperation Roadmap that strongly supports the "from research to standardisation" approach, covering vertical use cases and technical specifications. Interaction with standards bodies will thus play a fundamental role in the road-mapping activity, driving global harmonisation in key areas.

5G-CORAL

/ A 5G Convergent Virtualised Radio Access Network Living at the Edge (EU-Taiwan Project)

PROJECT COORDINATOR

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MAIN OBJECTIVES

5G-CORAL aims at delivering a convergent 5G multi-RAT access through an integrated virtualised edge and fog solution that is flexible, scalable, and interoperable with other domains including transport (fronthaul, backhaul), core and clouds. The major objectives are to:

- Develop a system model that includes use cases, requirements, architecture, and business models to design and validate the 5G-CORAL solution
- Design virtualised RAN functions, services, and applications for hosting in the 5G-CORAL Edge and Fog computing System (EFS)
- Design an Orchestration and Control system (OCS) for dynamic federation and optimised allocation of 5G-CORAL EFS resources
- Integrate and demonstrate 5G-CORAL technologies in large-scale testbeds making use of facilities offered by Taiwan, and measure their KPIs
- Disseminate and contribute 5G-CORAL results into international research and innovation venues to pave the way for their successful exploitation

APPLICATIONS

5G-CORAL project will be validated in three testbeds.

- 1.Shopping mall (Taiwan): The goal of the testbed is to verify the developed technologies in dense scenarios by allowing massive connectivity, high throughput, network and computation offloading, and to provide time critical services to the users.
- 2.High-speed train (Taiwan): The goal of this testbed is to verify traffic offloading in the high-mobility scenario. One anticipated goal is to provision breakout and mobility functions

on the on-board Fog computing devices (CDs) that could potentially mitigate the burden of passengers' mobility signalling on the backhaul.

3.Connected cars (Taiwan and Italy): The goal of the connected car testbed is to demonstrate the benefits of 5G-CORAL to V2X communications supported by Fog CDs nearby or on-board the cars.

TECHNICAL AND RESEARCH CHALLENGES

5G-CORAL project leverages on the pervasiveness of edge and fog computing in the Radio Access Network (RAN) to create a unique opportunity for access convergence. This is envisioned by means of an integrated and virtualised networking and computing solution where virtualised functions, context-aware services, and user and third-party applications are blended together to offer enhanced connectivity and better quality of experience. The proposed solution contemplates two major building blocks, namely (i) the Edge and Fog computing System (EFS) subsuming all the edge and fog computing substrate offered as a shared hosting environment for virtualised functions, services, and applications; and (ii) the Orchestration and Control System (OCS) responsible for managing and controlling the EFS, including its interworking with other (non-EFS) domains.

EXPECTED IMPACT

Through the 5G-CORAL solution, several Key Performance Indicators (KPIs) can be achieved, notably an ultra-low end-to-end latency in the order of milliseconds. Moreover, new business prospects arise with new stakeholders in the value chain, notably small players owning computing and networking assets in the local service area, such as in shopping malls, airports, trains and cars.

Clear5G

/ Converged wireless access for reliable 5G MTC for factories of the future (EU-Taiwan Project)

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MAIN OBJECTIVES

Clear5G aims to investigate and demonstrate some of the key enablers necessary to support Machine Type Communications (MTC) traffic in 5G networks, in particular in the Factories-of-the-Future (FoF) environment. Specific objectives include:

- Define, investigate and develop physical layer enhancements for reliable MTC supporting massive numbers of devices, achieving extreme low latency and reduced signalling and control overhead.
- Design and implement Medium Access Control layer enhancements for integrated convergent access supporting low latency, high reliability, massive connection density, and high energy and spectrum efficiency.
- Design, configure and optimize radio network architectures and management mechanisms to fulfil the needs of FoF applications in terms of latency, wireless networking heterogeneity, reliability, scalability and manageability.
- Provide security enhancements at the physical layer, contributing to the overall security solutions in a FoF environment.
- Validate and demonstrate the performance of the project use cases in a realistic environment using testbed facilities both in Europe and Taiwan.
- Support the ongoing 5G Standardization.

APPLICATIONS

The Clear5G applications focus on FoF environments employing time-critical processes, relying on timely delivered data from massive numbers of sensors, and having to make and execute decisions in less than milliseconds.

Indicative examples include:

- Remote maintenance of sensors monitoring machines' status, machine reconfiguration for product customization, goods inventory, and zero defect assembly line with continuous check quality during production.

- Closed loop control systems.
- Large factory plants covered by cellular systems.

TECHNICAL AND RESEARCH CHALLENGES

Clear5G will deliver technical solutions addressing the challenges of massive deployment of connected devices, security, ultra-low latency and ultra-high reliability in FoF applications, like remote maintenance and closed loop control systems. The requirements of these complex scenarios will be met through the convergence of different wireless technologies, enabled by protocol and architecture enhancements proposed by Clear5G.

Clear5G will focus on providing physical, medium access control, and architectural enhancements to meet the strict requirements of FoF applications in terms of KPIs: latency, reliability, connection density, spectrum, and energy efficiency, thus contributing to the ITU-R objectives (e.g., 1000 fold connection density) for the next generation mobile network.

EXPECTED IMPACT

Clear5G contributes to strengthen manufacturing capabilities of both Europe and Taiwan. More specifically, Clear5G investigates and demonstrates some of the key enablers necessary to support MTC traffic in 5G networks, in particular in the FoF environment. In addition, Clear5G will become a bridge between the 5G PPP and the FoF PPP activities, enabling their strong cooperation and synchronization in terms of factory related standardization activities.

To ensure that the highest possible impact of the project findings is achieved, Clear5G will actively contribute to the most relevant and most impacting standardization bodies and groups.



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