



PUBLIC-PRIVATE PARTNERSHIP

STEERING BOARD / TECHNOLOGY BOARD

5G PPP IN REVIEW

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5G - PPP . EU

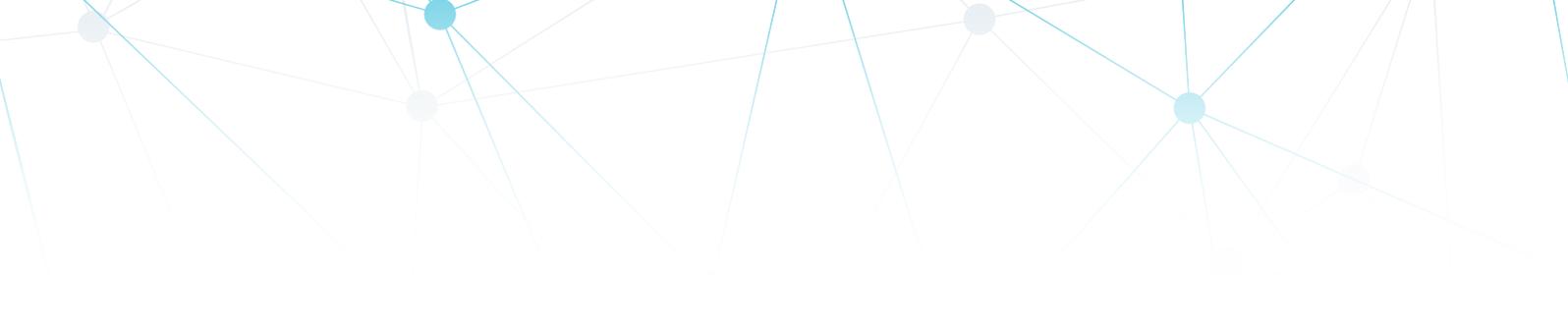


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EXECUTIVE SUMMARY

The formation of the 5th Generation Public Private Partnership (5G PPP) in 2014, as part of the European Commission's Horizon 2020 Framework Programme, set in motion what will be ten years of research into 5G Mobile Telecoms. The work of the projects, working groups and governance structure of 5G PPP has driven forward the European contribution to the development, standardisation and commercial launch of 5G technology.

The work to define 5G was necessarily a global initiative, but within that global effort, Europe has played a central and significant role. 5G PPP's 93 projects, which have fostered over 1200 standards contributions, more than 2500 publications and in excess of 50 white papers, represent a collaborative contribution from across academia, equipment vendors, network operators, SME's and most significantly, unprecedented engagement from other industries. This has enabled 5G PPP to develop new, innovative use cases that exploit the unique performance characteristics that characterise 5G as a new Generation, distinct from its predecessors.

5G PPP's structure, the progression of the focus of its projects from research to deployment to use case and proof-of-concept demonstration, its inclusivity of all aspects of the growing 5G ecosystem, and its fostering of a collaborative research community, have all ensured Europe's contribution has been felt domestically and world-wide.

This paper documents this approach, captures a summary of the delivered work and major achievements, assesses its effectiveness, and looks ahead to how the progress made by 5G PPP can be built upon by the Smart Networks and Services Joint Undertaking (SNS-JU), and more broadly through Horizon Europe.

INTRODUCTION

In December 2013, the European Commission signed a 'contractual arrangement' with the 5G Industry Association (5G-IA) to form the 5G Public-Private Partnership, or 5G PPP. 5G PPP was a highly ambitious programme to put Europe at the forefront of research into 5G technology, societal impact and economic sustainability.

5G PPP was targeted to address the need for a smart and ubiquitous network capable of connecting various entities in a flexible and powerful manner by the year 2020. The future network infrastructure was expected to connect people, things, processes, computing centres, content, knowledge, information, and goods according to specific application requirements, and to create opportunities for established stakeholders as well as new actors, including small and medium-sized enterprises (SMEs). Europe was encouraged to take action to stimulate the development of an advanced network infrastructure, ensuring the long-term competitiveness of the European network industry and other industrial sectors that rely on advanced ICT services. To facilitate this and ensure that the resulting network was fit-for-purpose, the EU required that the telecoms ecosystem expands to include Vertical Stakeholders from other industries in the discussions and definition, as early as possible.

GOALS

The contractual arrangement for 5G PPP includes a technical annex which outlines key performance indicators (KPIs) in three categories - Business-related, Performance and Societal. These were used to frame the research activities and their goals, and included providing higher wireless area capacity, significant energy savings, reduced service creation time, secure and reliable internet services, dense wireless deployments, and advanced user-controlled privacy. The technical annex of the arrangement also explains how the supporting industry organizations, SMEs, and research institutions would engage with the wider community of stakeholders to deliver the objectives.

As the work in 5G PPP progressed, the KPIs were refined in Vision documents [1], [2] while progress in achieving the goals was reported annually by the 5G-IA to the EU in the annual 5G PPP Programme Monitoring Reports (PMRs) [3].

Accordingly, the work of 5G PPP evolved over time, from low Technology Readiness Level (TRL) to higher TRL activities, as reflected by the call structure in Phase 1, Phase 2 and the various sub-phases of Phase 3. This call structure is described in greater detail in Chapter 2, Section 2.1. Achievements of the programme are described in Chapter 3, and a summary and conclusion are provided in Chapter 4.

PROGRAMME OVERVIEW

The 5G PPP organisational structure is depicted in Figure 1. The 5G PPP projects, and their respective phases, are in the centre. The Steering Board (SB) and Technology Board (TB) acted as the main governance bodies for co-ordination of activities between projects, including technological alignment, formation and retirement of 5G PPP Working Groups (WGs), organisation and attendance at industry events, and maintaining a sense of common community across the entire programme. The Working Groups fall into three categories:

- 5G PPP WGs, where each project can send representatives to participate in the WG.
- 5G-IA (and latterly, 6G-IA) WGs, where any current 5G-IA member could participate.
- NetWorld 2020 (and latterly, NetWorld Europe) WGs, where organisations that are members of NetWorld 2020 could participate.

WGs played an important role in co-ordinating activities within the specific remit and scope. The SB, TB and WGs are summarised in Annex A.

CALL STRUCTURE AND PROJECTS

As shown in Figure 1, the programme consisted of three phases ([4],[5],[6]). Phase 3 was further divided into six parts. Figure 2 illustrates the overall timeline for these phases and parts.

As is shown in Figure 2, Phase 1 projects addressed 5G Concepts, Phase 2 focused on System Development, and Phase 3 was used to validate the work of the first two phases, and to demonstrate the KPIs underpinning 5G, through the building of test platforms, and the implementation of use cases derived from other industries. Phase 3 also allowed the initial groundwork on technologies 'Beyond 5G'. Each Phase is described in more detail in the following sections.

In total, 93 5G PPP projects were funded, with 783 separate organisations involved. A total of EUR 712.5 million was granted, of which 21.95% was allocated to SMEs, which fulfilled the KPI of at least 20 %.

It is also worthy of note that the progression through the phases from one context to the next was also reflected at the project level, in Figure 3 below, the interlinkage between projects is illustrated showing how the work from projects in earlier phases of the programme was built upon and used by subsequent calls. In some cases (most notably ICT-17 and ICT-19), this relationship was built into the call for proposal, but in many others, the relationship was developed organically, showing how the 5G PPP projects fostered a collaborative community.

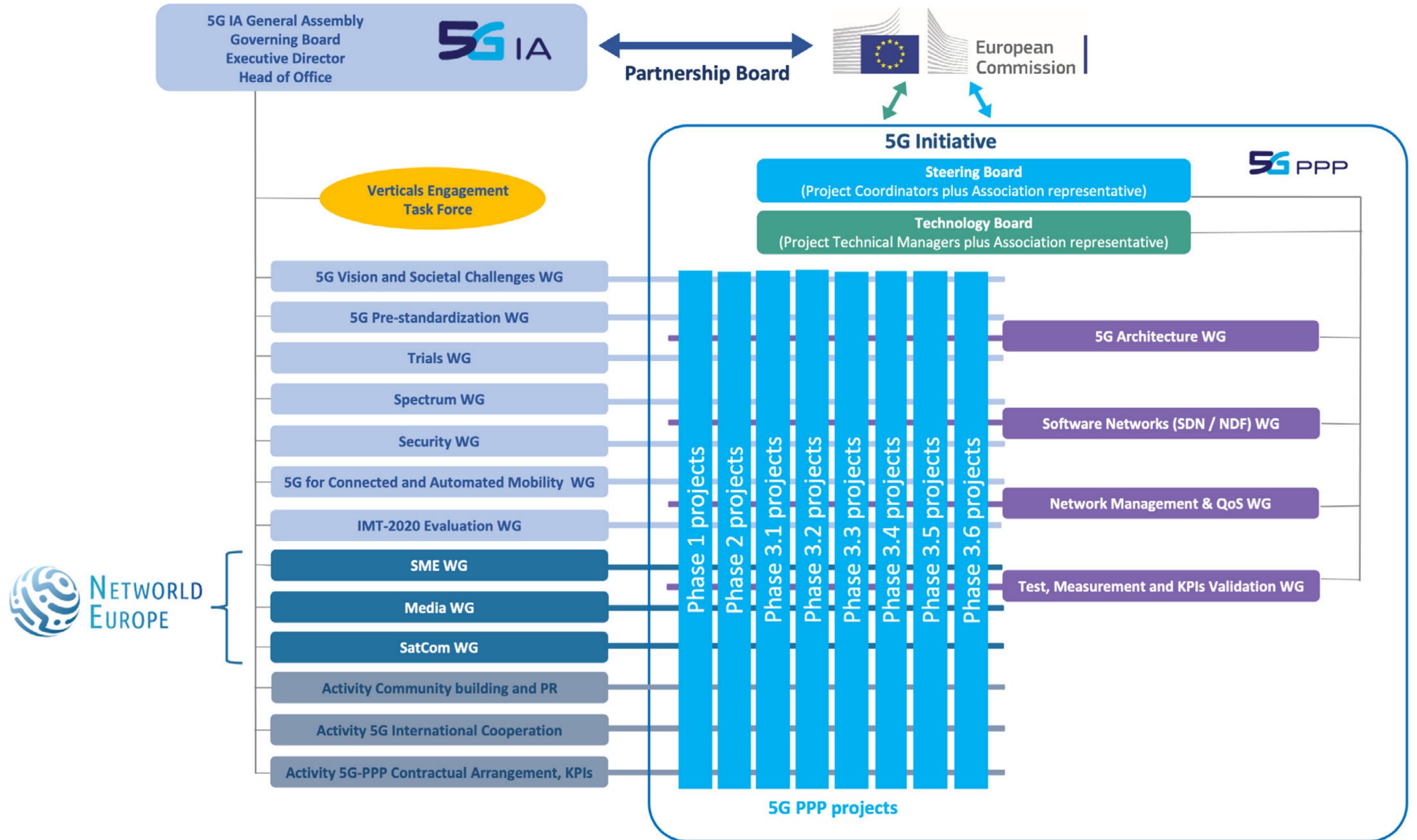


Figure 1 - 5G PPP Overall organisational structure

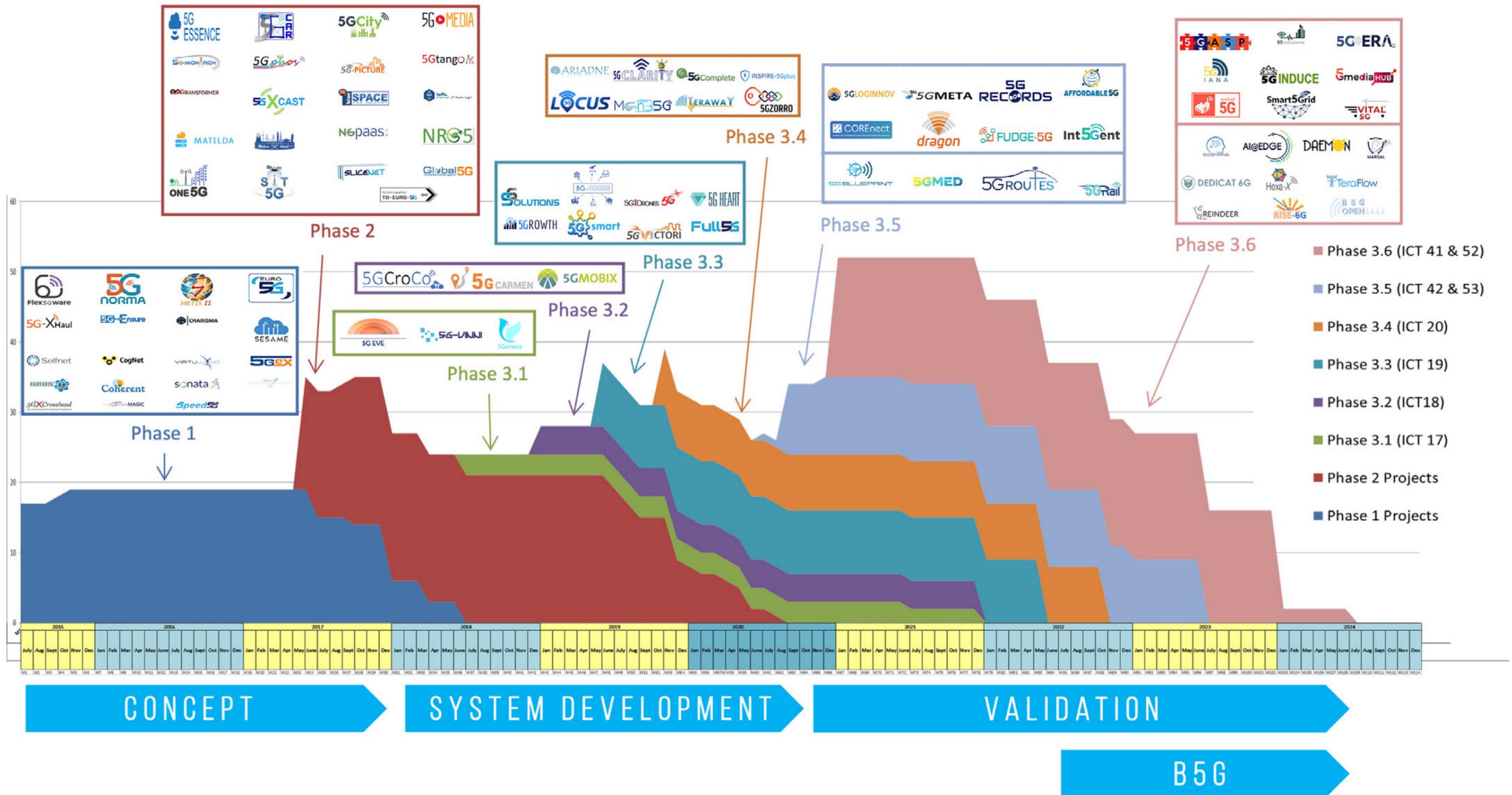


Figure 2 - The three phases of the 5G PPP programme

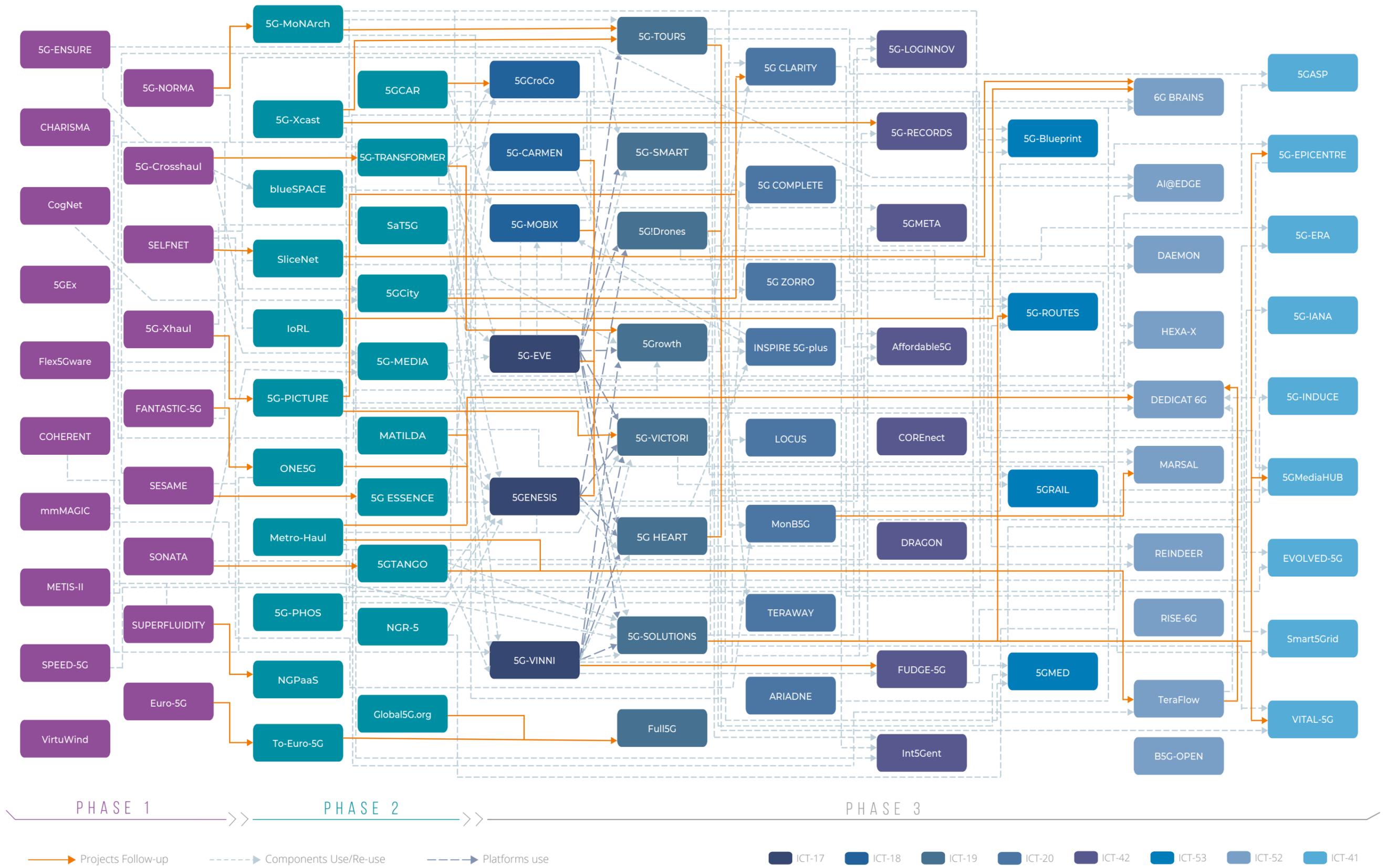
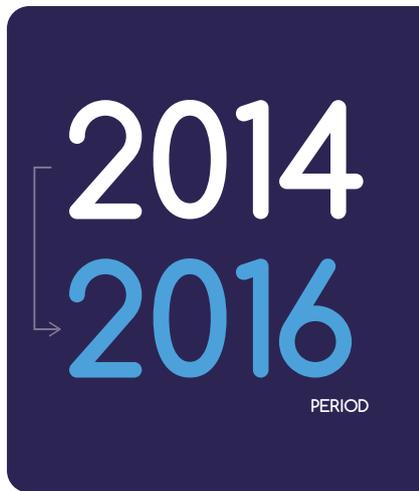


Figure 3 - Projects' heritage and connections through the 5G PPP programme phases

5G PPP PHASE 1 Key Numbers



 **19**
NUMBER OF PROJECTS (RIA, IA & CSA)

 **170**
UNIQUE BENEFICIARIES

 **62**
SMEs PARTICIPATED

 **129.8 M €**
TOTAL EU FUNDING

PHASE 1

On July 1st 2015, the first set of 5G PPP projects kicked-off their activities, addressing the mandates of H2020 call **ICT-14-2014: Advanced 5G Network Infrastructure for the Future Internet**. This Phase 1 of 5G PPP was comprised of 19 projects in total, including 15 Research and Innovation Action (RIA) projects, 3 Innovation Action (IA) projects and 1 Coordination and Support Action (CSA) project.

These first wave of 5G PPP projects were tasked with laying the groundwork for the future 5G networks in order to cope with the projected increase of traffic by 2020. More specifically, the projects had to investigate, propose, test and validate innovative solutions addressing network architecture, protocols and radio technologies, solutions for convergence beyond the last mile, novel network management approaches, virtualization and software defined network implementations, network security and more.

The Phase 1 projects were expected to reinforce EU's strong industrial base in the strategic domain of network technologies, while also enabling reliable, ubiquitous access to services and applications at a reduced environmental and financial cost. From an operational perspective the projects were expected to set the technological foundations for meeting the stringent 5G target KPIs (e.g., capacity, data rate, latency, reliability).

5G PPP PHASE 2 Key Numbers



 **21**
NUMBER OF PROJECTS (RIA, IA & CSA)

 **242**
UNIQUE BENEFICIARIES

 **92**
SMEs PARTICIPATED

 **143.2 M €**
TOTAL EU FUNDING

PHASE 2

In June 2017, the 2nd phase of the 5G PPP programme started with the kick-off of 21 projects under two different H2020 calls, namely:

- 15 projects under **H2020-ICT-07-2017 call: 5G PPP Research and Validation of critical technologies and systems.**
- 6 projects under **H2020-ICT-08-2017 call: 5G PPP Convergent Technologies.**

The specific objective of the projects under call ICT-07-2017 was to eliminate the current and anticipated limitations of network infrastructures by making them capable of supporting an extensive array of requirements with the capability of flexibly adapting to different “vertical” application requirements. In this way the shift from the “Client-Server” model to “Anything” as a Service (XaaS) model would also be supported. The selected projects addressed these objectives by investigating several innovative 5G technologies (novel radio schemes, cloudification, optical networks, etc.), validating the performance of a diverse set of vertical applications with 5G (including smart cities, e-Health, UAVs) and also proposing novel relevant business models.

The projects under call ICT-08-2017 focused on addressing the inherent challenges that rise with the convergence of multiple technologies. The increased service provisioning capabilities rising from the offering of versatile technologies and the increased complexity of integrating multiple different software and hardware components, make for an extremely complex infrastructure which presents unique scalability and usability challenges. The selected projects investigated and validated advanced access control and management systems, while making use of a wide variety of technologies including Internet of Things (IoT), sensors, robotics and automation processes.

Phase 2 projects were expected to investigate key technological innovations that would be deployed in future 5G networks as well as the harmonious coexistence and management of all the diversified components and technologies within one networking domain. All selected projects contributed in that direction and provided the components and technologies that acted as building blocks of the Phase 3 experimentation facilities, which validated 5G performance in real-life settings for multiple vertical applications.

5G PPP PHASE 3 Key Numbers



PHASE 3

The third and final phase of 5G PPP was comprised of 53 projects in total addressing 8 distinct H2020 calls for action, separated in 6 phases. The overall goal of this phase was to build extensive advanced pan-EU experimentation facilities and to use them to execute large Trials & Pilots (T&P) under varying conditions to validate the performance of various technologies and vertical applications. A separate overview per sub-phase is provided in the next sections.

PHASE 3.1 – INFRASTRUCTURE PROJECTS

Three projects were selected to address the call **H2020-ICT-17-2018: 5G End to End Facility**, tasked with creating advanced experimentation facilities, targeting i) to validate the 5G network KPIs through representative network trials and ii) to offer access to EU experimenters from other EU projects in order to validate multiple verticals use cases via extensive tests. The facilities created also offered interworking between various experimental platforms around Europe and constituted the main EU infrastructure for 5G network performance and vertical application validation, utilized by almost all of the subsequent Research and Innovation (R&I) projects.

PHASE 3.2 – AUTOMOTIVE PROJECTS

The three projects selected under this sub-phase, addressed the objectives of the call **H2020-ICT-18-2018: 5G for cooperative, connected and automated mobility (CCAM)**, focusing on qualifying 5G as a core connectivity infrastructure to address vehicle-to-everything (V2X), both from a technological and from a business perspective, for the higher automation levels (4, 5), as defined by the Society of Automotive Engineering. The three projects created advanced 5G-enabled Cross-Border Corridors across EU national borders, identified the mobility challenges that needed to be addressed for 5G-enabled CCAM applications to operate during inter-PLMN mobility, and measured and validated the performance of various 5G technologies set to improve the cross-border mobility experience for automated vehicles.

PHASE 3.3 – VERTICAL TRIAL PROJECTS

Nine projects were selected under this sub-phase to address the objectives of call **H2020-ICT-19-2019: Advanced 5G validation trials across multiple vertical industries**, namely bringing the European 5G

Vision of “5G empowering vertical industries” closer to deployment with innovative digital use cases and showcasing the possibilities for cross-industry partnerships. These projects made use of the experimentation facilities created during Phase 3.1 to validate both from a technological as well as from a business perspective several dozen 5G-enabled use cases belonging to diverse vertical sectors including e-Health, robotics and automation, smart cities, renewable energy, UAVs and more.

PHASE 3.4 – 5G LONG TERM EVOLUTION

Eight projects were selected under this sub-phase to address the objectives of call **H2020-ICT-20-2019-2020: 5G Long Term Evolution** targeting the realisation of pervasive mobile virtual services, through a network managing compute, storage and transport connectivity functions in an integrated way. The selected projects investigated the integration of innovative solutions such as Artificial Intelligence and Machine Learning (AI/ML), fibre connectivity, advanced radio technology and edgification of network functionalities, paving the way for later releases of 5G.

PHASE 3.5 – 5G CORE AND CAM PROJECTS

This sub-phase entails two H2020 calls for action and a total of 12 projects were selected which commenced their operations in September 2020. More specifically 8 projects were selected to address the objectives of the call **H2020-ICT-42-2020: 5G PPP – 5G core technologies innovation**, focused on reaping the fruits of earlier R&D investments in novel enabling technologies and hardware devices to support the emergence of new markets and new market actors in Europe. Hence, the selected projects assisted EU based SMEs to validate innovative solutions utilizing state of the art devices (e.g., IoT sensors, microelectronics, signal processing modules, etc.) in real-life pilots.

The four selected projects addressing the call **H2020-ICT-53-2020: 5G PPP – 5G for Connected and Automated Mobility (CAM)**, focused on testing and validating the latest releases of 5G (Rel. 16 Stand Alone) for advanced automated mobility cases. These four projects practically build on the work performed by ICT-18-2018 projects, extend the field of validation to include automotive, transport and logistics and rail use cases (in cross-border environments), and offer comparative insights with regards to the improvements offered for this vertical sector by latest more advanced 5G system releases.

PHASE 3.6 – 5G INNOVATIONS AND BEYOND 5G

The final sub-phase of the 5G PPP programme also consisted of two calls for action, funding in total 19 projects, which began their operations in early 2021. Nine projects were selected to address the challenges of the call **H2020-ICT-41-2020: 5G PPP – 5G innovations for verticals with third party services**, focusing on the creation, testing and validation of Network Applications, as means to lower the threshold for the provision of vertical services over 5G networks. All nine projects significantly assisted in the uptake of Network Applications by the 5G ecosystem while also allowing for the onboarding and integration of multiple vertical applications from a multitude of sectors through the offering of experimentation facilities and services to 3rd party experimenters.

The ten selected projects addressing the call **H2020-ICT-52-2020: 5G PPP – Smart Connectivity beyond 5G**, worked on establishing the basis for the migration towards the next generation of networks through the offering and validation of beyond 5G (B5G) solutions. These projects prepared the ground for the realization of Smart Connectivity systems utilizing seamless and secure end-to-end interworking with computing resources and innovative devices, delivering highly flexible connectivity infrastructures which dynamically adapt to changing requirements and facilitate user data control. The output of these projects was used as the steppingstone for EU's next R&I funding programme on 6G Smart Networks and Services.

IMPACT

5G PPP, via the individual projects and the collaborative work in working groups and Board 5G-IA groups, has delivered unprecedented value to the European and Global telecom industry, and enabled the extension of the mobile telecom industry's applicability into other industries.

By revisiting the categories of objectives identified in the original arrangement, the progress made by 5G PPP can be reflected upon in regard to the original goals. The achievements described in the following sections are just a small sample of the overall strides forward made by the projects during 5G PPP's duration. A full view of the progress made can be gathered by reading documents produced during the programme, including the annual Progress Monitoring Reports (PMRs) [3], the regularly published 'Golden Nuggets', the 'Trials & Pilots' brochures, the European 5G Annual Journals, and the many working group white papers. Individual projects' have also recorded many of their major advancements under the 'Key Achievements' [7] documented on the 5G PPP webpage.

ASSESSING PROGRESS AGAINST OUR GOALS

An important lens to consider the achievements of 5G PPP through is the KPIs described in the original Contractual Arrangement. As mentioned in Chapter 1, the KPIs fell in three categories, while the KPIs themselves are essential, it is also important to consider some of the other progress made within the broad headlines.

BUSINESS-RELATED

The Contractual Arrangement targeted a private investment leverage factor of 5 to 10 times, SME funding to be at 20% of the total public funding made available, and for European headquartered companies to account for 43% of the equipment and services global market share for 5G. Progress against these goals was tracked in the PMRs, with the 2022 PMR showing that a leveraging factor of 7.64 times across all funding (10.46 times in large industry and SME) has been achieved. SME participation over the duration of 5G PPP projects stands at €156.3M, accounting for 21.95% of total funding. It is difficult to form an accurate assessment of the total global market share for European industry, but it is clear that Europe's major vendors continue to occupy leadership positions.

More broadly, however, 5G PPP projects have been at the forefront of engagement with other industries. 5G was positioned as the mobile communications technology that would allow operators to properly address the B2B (Business to Business) opportunities through the support of differentiated QoS and by allowing operators to tailor propositions to very specific business needs at scale. All projects took these requirements into account, and as the changing structure of calls moved from research to demonstration, the invaluable input and involvement of partners from other industries meant that projects increasingly were able to develop and demonstrate capabilities that showed how the telecoms industry had moved to be able to meet other businesses on their terms. The Trials WG had identified over 200 demonstrations of vertical use cases being supported within Phase 1 and Phase 2 projects. This was bolstered further by requirements included in the ICT-17 and ICT-19 call structures requiring demonstration of use cases, and ICT-18 addressing specifically the requirements for Automotive cross-border corridors of 5G connectivity. The Technology Board initiated the 'Verticals Cartography' to distil the breadth of the use cases that were being demonstrated down to a manageable number and

found that 177 discrete use cases had either been demonstrated or were being prepared, many of which had been demonstrated by multiple projects.

As 5G PPP projects come to an end, it is clear that now other industries have become engaged in 5G, there is an appetite for continuation, reflected in participation through the other Phase 3 calls, and the early SNS-JU projects. This is further confirmed by the formation of the Business Validation, Modelling and Ecosystem (BVME) subgroup of the Vision and Societal Challenges WG.

PERFORMANCE

The goals in the field of Performance laid out by the Contractual Arrangement were aspirational in nature and as a result, have proved to be both difficult to achieve and to measure. Targets such as 1000 times wireless area capacity, reduction of service creation time from 90 hours to 90 minutes, and dense deployments to connect 7 trillion devices, all assume a highly matured, globalised and economically resilient ecosystem of 5G deployments that will require many more years to come. While the work towards demonstration of use cases for parallel industries described in the Business-related section has been transformation from the perspective of engagement, the industry is still at the very beginning of seeing proof of concepts transition into techno-economic demand that will drive deployments for massive densification, enabled by a service orchestration model that is capable of rapidly and dynamically configuring network resources to guarantee the Quality of Experience and support of KPIs and KQIs that underpin such a service.

Having said this, the progress of the technical research and demonstrations of such capabilities has been significant. The Architecture WG has consistently captured the architectural evolution of 5G systems by consolidating the input from projects into a single architectural view, which at each iteration has shown increased capability in the service layer, increased support for Edge and increased levels of API exposure, while embracing the concept of '5G-as-a-service'. In the final iteration of the white paper (v4) [10], a section for 'vertical specific extensions' is included. Similarly, the consolidated work of ICT-41 projects with the Software Network WG produced a paper on a consolidated view of Network Applications, as the route to open 5G network capabilities to other industries directly via Common APIs.

Perhaps most telling about the discussion on Performance through the duration of 5G PPP has been that the focus has been on 'performance for purpose' rather than simply aiming at step changes in bandwidth or latency. Phase 1 projects were a mixture of research on new radio bearer techniques, investigating the feasibility of mmWave and new wave forms, blended with more practical projects aiming more squarely at the Contractual Arrangement goals, and less at the wider industry hype that surrounded 5G. This pragmatism in Europe's programme has proven to be highly beneficial and has been reflected throughout the phases of calls. When the Test, Measurement and KPI Validation WG was formed early in Phase 3, it was not expected to test that a headline data rate was achievable - rather, the WG represented a consolidated approach to test and measurement, to enable networks to demonstrate that the performance metrics claimed for that network could be consistently verified, and thus provide sufficient confidence to customers that technical attributes of a network could be, and would continue to be met, such that their use cases could be supported on 5G infrastructure as expected.

The net result of these developments is that 5G PPP projects have incorporated systems that can expose the network's capabilities to those that want to deploy a service on that network and enable the network and the service customer to verify together that the service is actually being delivered. This is a fundamental market making achievement which will prove invaluable as 5G B2B deployments scale and are commercialised further and will be an underpinning enabler of 6G going forward.

SOCIETAL

While topics such as energy efficiency and user privacy have, if anything, become higher profile as considerations of 6G requirements are being finalised, in the scope of 5G PPP work, these societal goals were not directly addressed. The Societal goals described in the contractual arrangement were often considered within the work of projects but did not translate into tangible requirements in the Call for Proposals, where a focus first on telecoms industry research to address more traditional (and easily measurable) KPIs, and then on the use cases enabled by those KPIs being available, was found.

The requirement for availability of a European competitive industrial offer for 5G systems and technologies was achieved almost as an incidental goal for projects and has been delivered despite competitive market pressures. That said, the need for supply chain security became an unexpected focus as a result of Covid and geopolitical impacts, regardless of locality of suppliers.

The requirement for the emergence of 'new economically viable services of high societal value', as have already been discussed in the Business-related section, is a challenge as much of business case as technical research, but the widespread trials of services in automotive, media delivery, broadcast, agriculture, defence and healthcare among many others, are expected to benefit society in the long term.

Availability of 5G skills has been tracked in the PMRs and has been shown to be the stimulus for over 4600 new curricula or educational qualifications, as well as being the source of the basis of nearly 3400 new roles in industry and academia.

What has been clear during the lifetime of 5G PPP is the increasing focus on societal values as a whole. This has culminated in forming of the Societal Needs and Values Creation sub-group of the Vision and Societal Challenges WG but has also been reflected in the requirements being addressed by projects and working groups, particularly towards the end of the programme. In considering what 6G networks need to deliver, TMV working group published a white paper on 'Towards Sustainable and Trustworthy 6G', while the Architecture WG white paper on 'The 6G Architectural Landscape' begins with a consideration of societal trends across the breadth of the UN's Sustainable Development Goals. Topics such as accessibility, gender equality and socio-economic disparity are going to be fundamental in our work on 6G. There has even been an acknowledgement of our own societal disparity with the establishment of the Women in Telecoms and Research initiative, which has now progressed to become a 6G-IA working group for the SNS-JU era and beyond.

WIDER IMPACT AND LEGACY

Throughout the work in 5G PPP, the continuity and progression of work from projects in one Phase to the next has been of huge benefit, allowing projects to build cumulative knowledge and to feed off of the innovations and deliverables of previous projects heritage, as illustrated in Figure 3. This is expected to continue with 5G PPP projects providing a range of capabilities and platforms for SNS-JU projects to build upon.

5G PPP projects have generated open-source and ready-to-use platforms that cover specific needs of vertical sectors. These include:

- a flexible platform adapted to serve the specific needs of the Transport and Logistics sector focused on the creation, deployment, management and validation of Network Applications.

- an Automotive Open Experimental Platform (AOEP), as well as a repository environment for Network Applications and VNFs to ease the design and chaining of new Automotive-related services.
- software support tools for Continuous Integration and Continuous Deployment (CI/CD) of VNFs in a secure and trusted environment, together with an Open-Source Software (OSS) repository and a VNF marketplace, so that it can facilitate an early validation and/or certification of products and services for 5G (with a focus on Automotive and Public Protection and Disaster Relief (PPDR)).
- middleware which enables cloud native resource provision over autonomous robots.
- an experimentation infrastructure hosting cloud-native Network Applications for PPDR.
- an end-to-end orchestration platform for 5G applications that can be easily ported, deployed and managed in the Industry 4.0 sector, with similar approaches available for media services and energy grids.

The legacy of 5G PPP programme does not originate just from the R&I projects, but from the Coordination and Support Action (CSA) projects as well. These projects were tasked with supporting the entire 5G PPP community, with appropriate tools, processes, event organization and many other actions. Three targeted tools were created and given to the 5G PPP researchers to facilitate their work and to enable cross-project knowledge transfer. These tools are:

- The Standards Tracker [8] is a pivotal collaboration platform, streamlining the integration of 5G benefits across diverse industry verticals. Simplifying the intricate standards development process ensures that investments in 5G align with end-user needs. Designed to assist industry newcomers and standards specialists, the tool currently emphasises 5G standardisation led by 3GPP and associated entities.
- The Verticals Cartography [9] monitors Europe's 5G PPP advancements in crafting 5G solutions across varied market sectors, showcasing tangible 5G examples through proofs of concept, prototypes, and trials. Initiated in September 2018, this Cartography has served as a continuous global resource, frequently reporting on the evolution and influence of 5G use cases within the 5G PPP. Almost 200 use cases have been included in this online platform.
- Two KPIs radars – a programme KPI radar and a technical KPI one – will be launched in 2024 and will be initially populated with KPIs from the still active 5G PPP R&I projects. They aim to provide a bird's eye view of the evolution of EU-funded 5G and 6G R&I projects, and finally centralizing and streamlining the tracking of the progress of the PPP both on technical and programmatic levels.

As 5G evolves, and B5G and 6G technologies are investigated as part of the SNS-JU, all these tools will be migrated to the SNS-JU domain and suitable updates will take place, by the designated CSA project (SNS OPS). An improved version of the Standards Tracker will be released, adding new taxonomies and addressing emerging 6G standardisation discussions and roadmaps. Just as importantly, the Verticals Cartography will be sublimated into a Vertical Engagement Tracker, creating a needed link between use cases promoted by SNS-JU research projects and relevant Vertical Associations to enhance collaboration and increase the chances for market output. Finally, the two KPIs radars will incorporate technical and programme datasets from SNS-JU R&I projects.

5G PPP in numbers



Mobilization of stakeholders

783

Unique organizations

24.43%

SME participation

25

MoUs and 3
LoIs signed with
global "5G"
stakeholders

3399

New skills
and/or jobs
created
(estimate)

44%

Increase in
annual revenue
of SMEs
(estimate)

34% of which are peer reviewed
journal publications



2500+

Scientific
publications



50+

White Papers



250+

Use-cases demonstrations,
trials and pilots



445+

Innovations on
Commission innovation
radar

OUTPUTS

The 5G PPP projects' outputs are available in project deliverables and other publications. Apart from deliverables, more than 2500 publications have been produced, out of which 34% are peer reviewed journal publications, as well as more than 50 white papers [10] produced by projects and WGs directly, and at least 3 books. Further, there were more than 1200 standardisation contributions and more than 445 innovations highlighted in the Commission innovation radar. The projects continuously engaged in major scientific events, covering conferences, workshops, and panels - more than 100 events in 2022 alone. In terms of stakeholder mobilization, 5G PPP engaged 783 unique organizations, 24.43% of which were SMEs while EU economy is estimated to have benefitted from 5G PPP activities with a substantial increase in new skills/jobs and SME revenue. The figure on the previous page provides some highlights of the 5G PPP stakeholder mobilization and output.

On programme level 5G PPP has encouraged projects to collaborate and share their learnings. For instance, project key achievements were identified in phase 1 (v1.0), phase 2 (v2.0) and phase 3 (v3.0, v3.1, v3.2). Other examples are construction of reference figures, different types of cartographies, and trials and pilots brochures (n°1, n°2, n°3, n°4) containing selected demonstrations among the huge number of trials and pilots conducted within the programme.

LESSONS LEARNED

As much as the technical and research achievements of 5G PPP are a testament to the things that have gone well, many lessons have been learned along the way, and it is important that this understanding is passed forward to the SNS-JU and beyond.

The first important lesson has been the importance of cross-project collaboration. It has been a characteristic of the work of 5G PPP that projects have collaborated well throughout the programme. It is sometimes difficult to transition from the 'competitive' bid and submission process to a collaborative, cross-project, full programme view. The role of SB, TB and working groups in achieving this has been very important. By identifying common areas of interest and empowering projects to take control to be able to proactively identify topics, events and initiatives of common interest, a genuine community of interest has been created. It helps that in mobile telecoms, the modus operandi of standards fora is broadly collaborative, and this in part sets an expectation that research and innovation should always be looking for a common conclusion that promotes the industry globally, enabling a shared market that is greater than the sum of its parts. However, it has also been a testament to the chairs of the different 5G PPP groups that they have succeeded in fostering environments where projects see the benefits of collaborative efforts, rather than feeling they are still trying to outdo one another. It should also be recognised that the structure of the Calls for Proposals, particularly in Phase 3, has included a strong focus on cross project work and the necessity for one set of projects to build on the legacy of the previous ones.

Building upon this, the benefits that 5G PPP has gained from engagement with other industries, particularly in Phase 3 of the work, should be maintained and expanded upon going forwards. At the beginning of the 5G process, the need to use 5G as a bridging technology that would enable B2B commercialisation and opportunity, drove many of the requirements that 5G PPP and the wider industry strove to achieve. However, few initiatives have included representatives of other industries to

the extent that 5G PPP has. Use cases, trials and Proof-of-Concepts have been at the centre of much of the work in 5G PPP projects, and studies into the business benefits for both telecoms and other industries have run alongside the demonstration of the advanced technical capabilities that open 5G to a much wider customer base than any previous mobile technology. This has been underpinned by engagement with SMEs from other industries, with a significant learning curve on both sides to understand the language used by each side to describe what 'good' service looks like. The swell of membership in 6G-IA from other industries as 5G PPP hands over to SNS-JU is a testament the work that went before.

For all the careful planning and engagement, creating a call structure that fostered collaboration and expansion of the applicability of the telecom's ecosystem, there are always challenges that emerge in unexpected ways, and so adaptability and agility in working methods, when needed, must be embraced. In the duration of 5G PPP, the unprecedented challenge of Covid-19 threatened to bring all work to a halt. At the point when the pandemic forced Europe into lockdown, ICT-17 projects were just gathering momentum to on board use cases from ICT-19 projects and others. Much of this integration work needed to be done in person, on site, with equipment needing to be installed and commissioned, and then actual demonstrations being executed. All ICT-17 projects had to be extended, but not unduly, and participants found ways to work remotely, to adapt to circumstances, and to continue to deliver. Other situations that needed the programme to adjust and adapt occurred, but none as significant as Covid-19. Life, work and the nature of research itself has a strong element of unpredictability, and so it has been vital to 5G PPP's success to be prepared to adapt and change when needed, even when changes of significantly lower profile than a global pandemic occur.

Other more practical lessons going forwards were captured during the 5G PPP Passing the Torch event [11]. The Chairs of the working groups identified the importance of cross-WG collaboration, use of a common terminology and framework, finding synergy between projects but minimising overlaps, and the importance of extensive results dissemination, to maximise the productivity of the programme as a whole. In addition, the importance of maintaining a tight alignment between technological development and the KPIs that are measurable in association with technology, that context is important when looking for insights from results, and a general call for all to 'think beyond the funded project', can all be invaluable guidance for SNS-JU projects and WGs.

SUMMARY AND CONCLUSION

When reflecting upon any long-term research programme, it is always easy to reframe the original goals to fit the conclusions that were reached, but that in some ways does a disservice to the nature of research and the journey that a research programme goes on. In 2014, when 5G PPP was initiated, the aspiration was to create a global technology that would enable a step change in technical metrics, but also to enable use cases that had previously proven technically non-viable on mobile networks up to that point. 5G PPP's focus was much more on this pragmatic, market making area and as such, the programme was somewhat differentiated from similar regional initiatives.

Now, as 5G PPP's final projects come to an end, the engagement in the European telecom's ecosystem has never been stronger. Having enabled participation from SMEs, and fostered strong ties with other industries, 5G PPP can rightly be considered to have pioneered new use cases, new technologies to enable other industries to define and enable services, and to have laid the foundations for new business models for mobile network operators to deliver. There are some aspects that research cannot and should not attempt to influence - the commercial terms, the appetite for risk, and the actually practical deployment of technology all remain in the hands of those that must understand the value of 5G, and then must determine how to monetise that potential. In 5G PPP's work, hopefully many tools for creating a positive environment for those decision to be taken, have been provided.

The programme had synchronised timing with 5G's transition from research to standardisation and demonstration, and then to initial commercialisation. It also endured the disruption created by a global pandemic, and yet it has still delivered extraordinary results. These may not have been exactly the goals stated at the outset, but they have progressed the industry forwards through 5G, and now into the beginnings of 6G.

Perhaps the most impressive way to think about the progress made is to compare the starting points of 5G PPP and SNS-JU. 5G PPP brought with it the advent of 5G-IA, which has become 6G-IA. From a new, regional industry association, 6G-IA now has a wide and diverse membership covering large and small businesses, representations from a multitude of industries, SMEs, academia, R&D centers and other industry fora. That membership is feeding into the SNS-JU programme to ensure that projects both build on the work of 5G PPP, and also allow new ideas and methods to be brought into their research. So, while 5G PPP may not have achieved all of its goals, it did achieve many, and it has positioned the European research community perfectly to continue its influence on the global stage in the development of future generations of mobile telecoms, and ensure those generations are embraced to the fullest.

A background featuring a network diagram with nodes and connecting lines, overlaid on a light blue gradient. The nodes are represented by small circles, and the lines are thin and light blue. The overall aesthetic is clean and modern, typical of a corporate or technical document cover.

ANNEX A

GOVERNANCE

The following sub-sections summarise the work of all bodies and working groups of the 5G PPP, which had been working within the organisational structure of the programme. All white papers that are mentioned are available through the main 5G PPP website at a dedicated download location [10].

STEERING BOARD

The Steering Board of 5G PPP is made up of the project coordinators for all active projects, with the project leads of completed projects invited to participate as observers. It had responsibility for coordinating cross-project activities including the formation, tracking and closing of 5G PPP Working Groups, engagement with the Technology Board, co-operation around events (particularly EuCNC and Mobile World Congress) and general project engagement.

During 5G PPP, as the nature of the projects shifted from Research in Phase 1, to deployment in Phase 2, and then broader ecosystem engagement through Proof-of-concept and trials in Phase 3, so too did the make-up of the SB, and its focus. The SB also dealt with the top-level principles in how to deal with project impacts as a result of the Covid pandemic, and the initiation of the work on IMT-Advanced evaluation. The SB was a highly collaborative environment throughout 5G PPP's existence, and the tone set by SB in this regard has permeated throughout the other 5G PPP groups and projects.

TECHNOLOGY BOARD

All 5G PPP projects were invited to take part in the Technology Board (TB) through representative(s), in the corresponding fashion as for the Steering Board. Through regular TB meetings discussions were triggered, insights shared, and new topics to collaborate on identified. At times, learnings were shared in publications like TB white papers, key achievements, and reference figures, and in public events like EuCNC and the virtual 5G PPP passing the torch to SNS-JU event [11].

5G PPP WORKING GROUPS

ARCHITECTURE

Founded in 2015, the Architecture WG has brought 5G PPP projects to attain the European view on the overall architecture and the network domains. To this extent, the WG has provided a consolidated view on the technical directions and concepts for the architecture design for 5G and beyond networks. On this basis, the WG has been established as a collaborative platform to foster cross-project awareness and collaboration. While the initial focus of the WG has been on the 5G system design, it has gradually shifted toward 6G.

The Architecture WG has released five white papers within its scope, contributed to the dissemination

of other 5G PPP actions, e.g., white papers and webinars, arranged a series of workshops and special sessions at international conferences, e.g., IEEE Globecom, IEEE 5G WF, and EuCNC, and represented the European architecture view at bilateral workshops, e.g., between 6G-IA and NextGA. Via the international dissemination events, the WG has aimed at extending the European footprint globally and attracted the interest of non-European fora and institutes, which have contributed to the white papers via public consultation or cited them accordingly. As final milestone, the WG, jointly with the 6G flagship project Hexa-X, has published the 6G book titled “Towards Sustainable and Trustworthy 6G: Challenges, Enablers, and Architectural Design,” which has capitalized on the outcome of the 16 5G PPP Phase 3 projects and more than 180 contributors [1].

TEST, MEASUREMENT, AND KPIS VALIDATION

The Test, Measurement, and KPIs Validation (TMV) Working Group was established in Feb. 2019 as part of the 5G PPP effort to promote commonalities across projects that have strong interest in Testing & Monitoring (T&M) methodologies needed to provide support to the vertical use cases in 5G Trial Networks. Such efforts include the development of test and measurement methods, test cases, procedures as well as the KPI formalization and validation to the greatest possible extent, to ensure a unique European vision on how the entire lifecycle of the 5G network, ranging from R&D to actual deployed environments, can be supported.

In addition to setting a common framework and provide recommendations, the TMV WG was trying to produce insights by analysing results coming from different 5G PPP projects (addressing different verticals and executing trials with different technologies and deployment options). In this direction, the TMV WG produced several white papers presenting KPI related 5G PPP projects' results, while time and effort were allocated in order to provide insights based on project feedback.

The TMV WG during its lifetime published 8 white papers, organised two workshops and tried to disseminate the results outside of EU ecosystem: provided contribution to ETSI INT and to ITU Working Party 5D (WP5D). In addition, two Task Forces (TFs) were established inside TMV to address vertical service KPIs and Electric and magnetic fields (EMFs) topics.

SOFTWARE NETWORKS

The software networks working group has been created since 5G PPP Phase 1 focusing initially on SDN and NFV. Starting from January 2018, a high priority was given to the cloud native transformation, since 5G and Beyond network has to offer a high degree of flexibility and dynamicity to easily embark the vertical industries.

Following the first white paper titled “From web scale to Telco, the cloud-native journey” published in June 2018, the WG worked on how 5G PPP projects interpret cloud-native design patterns. This helped to identify the different cloud-native adoption barriers. Based on a survey collecting technical inputs from the different phase 2 and phase 3 projects about their use-cases, the virtualization technologies they use, and the architecture patterns they follow, the WG published a second White Paper, titled “Cloud-Native and Vertical's Services -5G PPP projects analysis”. Our findings and conclusions are referred in 5G-Americas white paper on 5G wireless industry putting the EU/5G PPP at front on this kind technology.

In 2020, the WG tackled the role of exposure via the release of the white paper on “Network applications”. A second version is released in July 2023.

The WG was an important platform to enabling stakeholders to exchange, knowledge, ideas, results and insights. This has helped the 5G PPP community to improve its understanding of the underlying issues, optimal design of solutions and get immediate feedback among the projects.

NETWORK MANAGEMENT AND QOS

The 5G PPP Working Group on Network Management and QoS (NMQ) was established in October 2015 to address network management and quality of service in the context of 5G networks. The group focuses on maintaining network operations, ensuring service delivery to users, enforcing quality of service, and maintaining network security. The NMQ Working Group collaborates with other projects within the 5G PPP to promote consistency, exchange ideas, minimize duplication of effort, and contribute to relevant standards. The NMQ WG actively worked from its creation until mid-2019 with contributions from several 5G PPP projects. The outcomes of their work include a white paper on cognitive network management for 5G, workshops on network management, quality of service, and security for 5G networks, and a brochure addressing network management challenges for vertical sectors.

The NMQ WG has interacted with other 5G PPP working groups, including the 5G Architecture WG, Software Networks WG, Security WG, and Vision and Societal challenges WG, to ensure consistency across the 5G PPP programme. Due to resource limitations and the progress of standardization groups, the NMQ WG’s activities slowed down in 2019, leading to its closure. However, it is recommended that a new working group be formed if new topics of importance arise and there is sufficient support from current and future projects.

5G-IA WORKING GROUPS

VISION AND SOCIETAL CHALLENGES

The purpose of the 5G-IA Vision and Societal Challenges Working group (VSC WG) is to develop a comprehensive vision for the next generation mobile telecommunications systems and their environment under the scientific, technical, socio-economic and societal points of view. The consensual vision is expressed in terms of required technological topics and their challenges (as research roadmaps) and analysed under economic, societal, regulatory and other applicable aspects.

To embrace a large diversity of views, the VSC WG has worked in close alignment with other 5G PPP/5G-IA working groups and other organizations, most notably with the large expert community of NetworldEurope ETP, both through direct exchanges and through contributions to common white papers or the development and updates of an agreed Strategic Research and Innovation Agenda (SRIA).

Through the results and outcomes from its various subgroups (SGs), the VSC WG has shed light on the complex required interplay of technological, economic and societal developments:

- The Smart Network and Services Vision (SNSV) SG has helped develop and update a technology roadmap, culminating in the publication of the white paper “European Vision for the 6G Network Ecosystem” in June 2021.
- The Pre-Structuring Model (PSM) SG has worked on defining the consecutive PSMs for the proposed Projects Portfolios over the PPP Phases, building on the EC Work Programmes and presenting features and recommendations to allow a smooth integration of new projects. PSMs were also targeting system recommendations to develop future efficient cross-projects cooperation, ensuring a comprehensive coverage of R&I topics, with no gaps or redundancies.
- Business Validation, Models, and Ecosystem (BVME) SG has offered insights on business validation and ecosystems in the 5G domain, most notably through its recent white paper “5G and Beyond 5G Ecosystem Business Modelling”. Also, sustainability-oriented business modelling has been integrated to ensure sustainable growth of markets and ecosystems.
- The Member State Initiatives (MSI) SG has monitored and tracked relevant Member State initiatives creating a list of contacts of the permanent representation offices of Member States in Brussels, reporting on the most important 5G deployment-related activities in key European Member States as “5G Deployment in Europe” within e.g. the book “5G in Italy” and by establishing a series of reports on “5G, beyond 5G and 6G Activities promoted by Member States”, published yearly.
- Last but not least, the Societal Needs and Value Creation (SNVC) SG has focused on developing a concept of Key Value Indicators (KVI), which is a method of gauging impact from technology use, on which the SG has published a white paper and arranged multiple workshops and seminars since the formation in late 2021.

The group has supported the obtained insights by suggesting effective research roadmaps through the work in the Pre-Structuring Model (PSM) SG, contributing to the proposed definition of the Projects Portfolios for the different PPP Phases while considering both European and Member State activities in the respective sectors and branches. Renamed in Portfolio Structuring and Analysis SG recently, the SG has developed and released Heritage Brochure/Figure summarizing the interconnections between PPP projects under three specific categories (1) Projects follow-up, (2) Components use/re-use and (3) ICT-19 Verticals Pilots / ICT-17 Platforms use.

PRE-STANDARDISATION

The Pre-Standardisation WG, originating from 5G-IA, was created with the aim to build a bridge between the 5G PPP research projects and the relevant standardisation activities. The primary objectives of the working group have been: #1 facilitating 5G PPP research projects impact on standards and #2 disseminating the project achievements in this respect.

Towards its primary objectives, the working group has been organising a variety of activities. On “impact facilitation”, the working group provided periodical debriefs from standardisation and regulatory bodies plenary meetings and events (e.g., 3GPP, ETSI, ITU) to ensure projects alignment with the relevant standard roadmaps. Additionally, a “research with potential standard impact” roadmap has been developed, to identify the ideal timing for projects to transfer research results to the relating standards. Finally, a series of events (e.g., series of online webinars, joint workshops and special session with ETSI) have been organised, bringing together actors from telecom, vertical industries as well as academia, for early alignments on how to bring requirements and technologies from research to standards. On “achievements dissemination”, the working group has been quarterly running the “SDO

Impact Reporting”, calling all projects to report on their latest achievements. The reported impact has been regularly statistically elaborated, aiming at identifying how the 5G PPP research programme as a whole was covering the key 5G standardisation activities.

SPECTRUM

The Spectrum WG was established to promote research results in the spectrum area obtained by 5G PPP/H2020 projects. By establishing dialogue between 5G PPP projects concerning potential synergies and common interests in spectrum related issues, the WG aimed to pursue the convergence of results on spectrum topics from the different projects to maximize the achievable outcome towards relevant technical bodies. The Spectrum WG established a knowledge base from European and other global project results concerning advances in spectrum research, liaised with spectrum groups or entities in regulatory bodies and industry associations, and work for improved understanding of collaborative spectrum research importance.

The activities of the Spectrum WG peaked in the early phases of 5G PPP work on topics surrounding sub-6GHz and mmWave bands, particularly in the build up to World Radiocommunications Conference 2015. However, once 5G spectrum bands stabilised, and 5G PPP work progressed more to use cases, the Spectrum WG has become relatively dormant.

SECURITY

The 5G Security WG started in Phase 1. The objectives of the 5G Security WG to be the place where projects could exchange and cross fertilize on number of topics established as of shared interests (e.g., 5G security architecture, 5G Trust Model, Access Control 5G, 5G Security Monitoring and Management, Slicing and virtualisation, 5G Security standardization). The working group published the 5G PPP Phase 1 Security Landscape as a white paper, as well as a separate extensive white paper, which is used and recognized as a reference to convey the challenges but also pave the way towards 5G Security.

Around mid-term in the programme, the 5G Security WG was transitioned to a 5G-IA WG for the work to be continued and amplified considering the importance of the 5G Security topic in view of the growing needs/demands and expectations. This has benefited the work of the WG allowing contribution from projects’ representatives, but also from 5G-IA members active on the 5G Security. This led to new opportunities to not only reinforce presence on some of the topics but also consider new topics proposed by 5G-IA members who had joined based on their expertise.

In addition, the 5G Security WG has monitored and contributed to other WGs of interest (e.g., 5G Architecture WG, Pre-standardization WG, Vision WG) it has also identified and liaised with relevant projects outside of 5G PPP and has also engaged with a number of bodies reengaging from ENISA till ECSO going through ETSI and GSMA.

Last but not least the 5G Security WG has also joined a number of conferences such as EuCNC, ARES and others, where it has contributed specific workshops.

TRIALS

The Trials Working Group was established by the 5G-IA in September 2016 following the release of the 5G Manifesto in Europe and the 5G Action Plan by the EU Commission. The group aimed to facilitate discussions on technology trials and Pan-European trials with vertical sector use cases. The WG operated through various Streams, including 5G Private Trials, 5G Verticals, 5G Trials Cities, and 5G International Cooperation.

During its tenure, the Trials WG achieved significant milestones. Among others it developed the 5G Trials Roadmap, which was presented at international events, and maintained the 5G PPP Verticals Cartography, a tool to track distribution of trials and use cases across verticals. The WG created and disseminated four brochures showcasing selected Trials and Pilots from Phase 2 and Phase 3 PPP projects.

The Trials WG actively contributed to the white paper on “Edge Computing for 5G Networks” and is preparing a white paper on “5G and towards 6G Verticals” to identify use cases beyond 5G requirements. It released a report on smart city trials, emphasizing lessons learned in building 5G-enabled living labs.

In terms of international collaboration, an initiative was established to share information on trials and pilots with peer organisations in other regions globally, which among others led to the organisation of a webinar on “5G Trials and Pilots” in cooperation with TSDSI, focusing on experiences in the EU and India. The trials WG worked closely with the EU 5G Observatory, participating in webinars and workshops. Finally, the WG played a vital role in defining Stream D (‘SNS Large Scale Trials and Pilots with Verticals’) in the SNS Work programme, contributing to its drafting, budgeting, and scope.

5G4CAM

The 5G for Connected and Automated Mobility (CAM) Working Group was created with the aim to become a meeting point for all the 5G PPP projects which were contributing to the CAM ecosystem from a 5G perspective. Even though it was originally named “5G Automotive Working Group”, it was renamed afterwards to become more inclusive, not only focusing on the automotive sector, but also any other means of transportation such as railways, air platforms, vessels, etc. By doing so, in addition to expanding its scope, it also became more visible to external stakeholders, such as the entire CCAM community with whom bridges have been built over the last years.

The WG has been organized around two main streams: one for Research and Innovation activities, and another one for Deployment-related activities.

From the R&I Stream, the main activities have focused on having regular presentations from projects to exchange knowledge and foster discussions, allowing know-how and best-practices to be spread across multiple projects, thus facilitating the evolution of the projects. In addition, this stream has led the elaboration of different white papers (all of them available on the 5G PPP website, [10]) presenting discussions about the business case evaluation for CAM, lessons learnt in the execution of trials, and vision towards 6G technologies from the CAM perspective. This stream has also produced various versions of a very visual brochure summarizing the main trials and pilots going on in Europe, pointing and key use cases and key technologies being tested.

From the Deployment Stream, the activities have been focused on contributing (and in fact, leading) the development of the 5G Strategic Deployment Agenda, seeking for collaborating and creating bridges with the 5G for CAM stakeholders Europe-wide, the CCAM community and the CEF Digital

programme for 5G Corridors. A first version of the 5G SDA was produced and released in 2020, and new versions of this strategic document are being prepared for release by the end of 2023 and 2024, respectively.

IMT-2020 EVALUATION GROUP

ITU-R WP5D launched an evaluation process for Radio Interface Technologies (RITs), which were submitted by SDOs (Standards Developing Organisations) to ITU-R to be recognised as member of the IMT family of systems for mobile and wireless communications [13]. In addition to the self-evaluation by SDOs ITU-R was looking for independent second opinions by independent Evaluation Groups. The final evaluation report was due in February 2020. The 5G PPP Evaluation Group registered end of 2016 at ITU-R and is one of the finally 15 globally registered groups. ETSI registered as a second European Evaluation Group only in case to act under certain conditions. All other groups came from other continents. The 5G-IA Evaluation Group had the following objectives:

- To perform an independent evaluation of IMT-2020 proposals to support ITU-R WP5D for the finalisation of the IMT-2020 recommendation in 2020.
- To prepare a complete evaluation report from the European perspective in the global context of other evaluation groups from other regions and to demonstrate the importance and global presence of communication technology industry and the research community in Europe.
- To focus evaluation activities on the 3GPP Releases 15 and 16 to check, whether this proposal meets the minimum 5G requirements of ITU-R and whether this proposal can be regarded as an IMT-2020 system.

This Working Group was organised under the umbrella of 5G Infrastructure Association (5G-IA) with participants from active 5G PPP projects.

The evaluation process was following the requirements of ITU-R on minimum requirements for IMT-2020 (Key Performance Indicators) and detailed evaluation guidelines (system simulation procedures, analytical approach, inspection approach, usage scenarios, test environments, network layout, evaluation configurations including detailed parameter settings, antenna characteristics and channel models for IMT-2020 for system and link level simulations) by means of analytical evaluation, inspection of RIT proposals and simulations [14], [15], [16].

The evaluation process was started by ITU-R WP5D in a workshop ahead of the WP5D meeting in October 2017 in Munich, Germany. A preliminary evaluation report was submitted to the ITU-R WP5D workshop in December 2019 in Geneva, Switzerland, where first discussions with SDOs and Evaluation Groups took place. Some additional evaluations for selected key performance indicators were performed for the ETSI DECT, TSDSI (India) and nufront (China) proposals, However, the focus was on the 3GPP proposal, where 5G PPP also contributed to. The final 5G-IA Evaluation Report with a complete evaluation of the 3GPP proposal was submitted to the ITU-R WP5D Workshop in February 2020 in Geneva, where all available evaluation reports were presented and discussed. The final 5G-IA evaluation report was one of only a few complete reports on the 3GPP proposal. The 5G-IA report confirmed that the 3GPP proposal is supporting the ITU-R minimum requirements to be recognized as an IMT-2020 family member. Results of the 5G-IA Evaluation Group are published in [17].

Based on all submitted evaluation reports ITU-R performed the overall evaluation and prepared the IMT-2020 recommendation and specification in February 2021. 5G PPP and 5G-IA made a global impact on the selection of IMT-2020 family members and the global specification.

NETWORLD EUROPE

SME

Established in 2014, the NetworldEurope SME WG is the voice of the SME community in the sector of telecommunications as well as their networking place of reference. It gathers almost 350 members, a number that has been steadily increasing over time, which hold regular meetings on a wide range of topics such as information on projects, particularly open calls targeting SMEs, events of interest, and other relevant opportunities.

To improve the visibility of its members and promote their skills and competences, the SME WG produces a brochure "European SME Expertise in 5G and Beyond" featuring the different companies and their success stories, annually. The latest edition was issued in December 2022. It also manages the brokerage site "Find your SME" to facilitate that mainly large industries research organisations identify suitable partners. In November 2020, the SME WG released its "SNS Position Paper".

Various webinars were organised in cooperation with other SME-related initiatives, including the European DIGITAL SME Alliance or and ScoDIHnet. The SME WG is also very active in social media with a Twitter account and a LinkedIn page, where members can read the latest news, promote their activities and overall, engage with other members of the community.

As the representative of the SMEs, the WG reports to NetworldEurope Steering Board and participates in several bodies such as the 5G PPP Steering Board. It also has a strong link to the 5G-IA, with one of its representatives in the Board of the Association. Similarly, the SME WG is invited to participate in various activities, from meetings to events.

The SME participation in 5G PPP projects exceeded the original objective of 20% participation defined as a Key Performance Indicator (KPI). According to the H2020 dashboard, the participation of SMEs in the 5G PPP accounted for 24.43% of the total participation and 21.95% of EU funding, worth a total of EUR 156.3 million. Some 65% participated in one project while 35% did it in two or more.

In 5G PPP Phase 3 projects, there are 167 SMEs accounting for approximately EUR 100 million. Although the participation of SMEs in 5G PPP projects has been quite stable throughout the various phases of the programme, Phase 3, especially the "5G innovations for verticals with third party services" call, which stated "50% of SMEs are targeted for this action", boost the numbers with SMEs receiving 49% of the EC funding. Remarkably, despite this peak in participation with this call for Innovation Actions (IAs), the global level of participation of SMEs in Research and Innovation Actions (RIAs) and in IAs is similar in the 5G PPP.

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ABBREVIATIONS AND ACRONYMS

3GPP	3rd Generation Project Partnership	JU	Joint Undertaking
5G PPP	5G Public Private Partnership	KPI	Key Performance Indicator
AI/ML	Artificial Intelligence and Machine Learning	KVI	Key Value Indicator
API	Application Programming Interface	MSI	Member State Initiative
ARES	Availability, Reliability and Security (International Conference)	NFV	Network Function Virtualisation
BVME	Business Validation Modelling and Ecosystem	NMQ	Network Management and QoS (5G PPP)
CAM	Connected and Automated Mobility	PLMN	Public Landline Mobile Network
CCAM	Cooperative Connected and Automated Mobility	PMR	Programme Monitoring Report
CSA	Coordination and Support Action	PSM	Portfolio Structuring Model
DECT	Digital Enhanced Cordless Telecommunications	RIA	Research and Innovation Action
DOI	Digital Object Identifier	RIT	Radio Interface Technologies
EC	European Commission	SB	Steering Board (5G PPP)
ECSO	European Cyber Security Organisation	SDA	Strategic Deployment Agenda
EMF	Electric and Magnetic Fields	SDN	Software Defined Networks
ENISA	The European Union Agency for Cybersecurity - European Network and Information Security Agency	SDO	Standards Developing Organisation
ETP	European Technology Platform	SG	Sub-Group
ETSI	European Telecommunications Standards Institute	SME	Small / Medium Enterprise
EU	European Union	SNS	Smart Networks and Services
EuCNC	European Conference on Networks and Communications	SNVC	Societal Needs and Value Creation
EUR	Euro (currency)	SRIA	Strategic Research and Innovation Agenda
GSM	Global System for Mobile Communications	TB	Technology Board (5G PPP)
GSMA	GSM Association	TF	Task Force
IA	Infrastructure Association	TMV	Test, Measurement and KPI Validation
ICT	Information and Communications Technology	TRL	Technology Readiness Level
IEEE	Institute of Electrical and Electronics Engineers	TSDSI	Telecommunications Standards Development Society India
IMT	International Mobile Telecommunications	UAV	Unmanned Aerial Vehicle
INT	Core Network and Interoperability Testing (ETSI Technical Committee)	URL	Uniform Resource Locator
ITU	International Telecommunication Union	V2X	Vehicle-to-Everything
		VSC	Vision and Societal Challenges (5G-/6G-IA)
		WF	World Forum
		WG	Working Group (5G PPP)
		WP5D	Working Party 5D - IMT Systems (ITU)

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