



5-Alive

5G: A Leadership Vision for Europe

D3.3 Strategic Research and Innovation Agenda

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Abstract

This document is a consolidation report on activities performed by the community at large consisting of both the Networks and Media experts in defining research challenges for Beyond 5G, and essential experimental facilities for proof of 5G technologies as a pathway to realisation of impacts leading to innovations. This report substitutes the original Strategic Research and Innovation Agenda (SRIA) and as agreed by the community and EC, it provides white papers on strategic and important subjects for incorporation for Future Work Programmes in the Horizon 2020. The work carried out is in the scope of WP3 and task 3.2.

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List of Authors

| Organisation | Authors | Main organisations' contributions |
|----------------------|---------------------|--|
| University of Surrey | Rahim Tafazolli | Document editorial and contributions to all sections |
| Orange | Jean-Sebastien Bedo | Contributions to all sections |

List of acronyms

| | |
|----------------|---|
| 5G | 5 th Generation |
| 5GPPP | 5 th Generation Public Private Partnership |
| 6G | 6 th Generation |
| ATAWAD | AnyTime, AnyWhere, AnyDevice |
| B5G | Beyond 5 th Generation |
| E2E | End to End |
| ETP | European Technology Platform |
| EU | European Union |
| GHz | Giga Hertz |
| H2020 | Horizon 2020 |
| HetNet | Heterogeneous Networks |
| IA | innovation Action |
| ICT | Information Communication Technologies |
| IoT | Internet of Things |
| IT | Information Technology |
| mmWave | millimetric Wave |
| NEM | NEtworked Media |
| NFV | Network Function Virtualisation |
| NOS | Network Operating System |
| OPEX | Operation Expenditure |
| OS | Operating System |
| OTT | Over The Top |
| P _x | Project number x |
| QoE | Quality of Experience |
| QoS | Quality of Service |
| RAN | Radio Access Network |
| RIA | Research and Innovation Action |
| RAT | Radio Access Technology |
| SDN | Software Defined Network |
| SLM | Service Management Level |
| SW | Software |
| TB/S | Tera Bits per Second |

5-Alive Deliverable D3.3

TV Television
WRC World Radio Conference

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1 INTRODUCTION

5GPPP Association and the expert community of Networld2020 set challenging objectives for the future generation of wireless connectivity namely 5G. This mobilised the EU academia and industry to research and innovate into advanced technologies that will meet the market requirements in the 2020 and beyond.

This document provides further work from the community on:

- Coverage and gap Analysis of current 5GPPP programme. See Annex.1
- Priority topics and actions for Work Programme 2016-17. See Annex.2
- Research and innovation challenges for “Beyond 5G”. See Annex.3
- Pathway to innovation. See Annex.4
- Impact of Content and Media on 5G research programme. See Annex.5

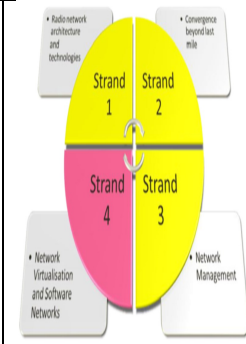
A summary of each of the above annexes is explained, hereafter.

1.1 Coverage and gap analysis of Current Programme

An independent post-mortem analysis of outcome of ICT 14 / H2020-ICT-2014-2 Call was carried out by M. Morganti and A. Munroy.

The coverage of all successful projects, the overlap between each other and missing topics compared with the original 5GPPP Association 19 projects from the 4 Strands were analysed. These are shown below for ease of reference.

| | | |
|----------|----|--|
| Strand 1 | T1 | Network architecture, protocols and radio technologies |
| | T2 | Novel requirements |
| | T3 | Versatile low-cost ubiquitous radio access |
| | T4 | Flexible and efficient back-/front-haul integration |
| | T5 | Innovative architecture for 5G transceivers and micro-servers |
| | T6 | Experiment based research |
| Strand 2 | T1 | Management of heterogeneous technologies and protocols |
| | T2 | Optimized reuse of (possibly virtualized) functionalities |
| | T3 | Optimized reuse and sharing of infrastructures |
| Strand 3 | T1 | Novel simplified (low OPEX) approaches |
| | T2 | Network level management |
| | T3 | Service level management |
| | T4 | Combination of autonomic resource management and SDN |
| | T5 | Network security in multiple virtualized or SDN domains |
| Strand 4 | T1 | Virtualization of network functionalities at infrastructure level |
| | T2 | Virtualization of the implementation of network services |
| | T3 | Orchestration logic (SDN) |
| | T4 | Tighter integration between application/service and networking layers |
| | T5 | Support of dynamic integration with 3rd party and OTT cloud environments |



More specifically, key issues addressed in the assessment were:

- Coverage of the Call by the project proposals eventually retained for funding (19 RIAs and 3 IAs);
- Coverage, by the same proposals, of the 5G PPP Pre-Structuring Model V2.0;

Furthermore, for all identified gaps an assessment has been made of the additional coverage that each of the four other project proposals evaluated above -threshold (3 RIAs and 1 IA) would have provided, had they been retained;

It is to be noted that coverage of a given topic is not intended here only in the sense that it is generically addressed in the proposal text, but that there is also sufficient evidence, in the proposal workplan, of activities aimed at advancing its State of the Art towards the Call specific challenges. Excellence, quality and credibility of the proposed work, instead, are not within the scope of this assessment, as they already were the specific objective of the Call evaluation process.

1.2 Research and innovation challenges for “Beyond 5G”

This white paper is looking at a system beyond the year 2030 horizon. The first discussion on this topic took place on the 29th October 2014 in Paris in a workshop organized by the 5GPPP Infrastructure Association and the Networld2020 ETP. The workshop had a large number of participants. It soon became clear that there is some uncertainty of what aspect(s) of 5G will be deployed and by when. This somewhat muddled the definition of a follow-up set of research and innovation challenges.

The timelines that seem to be now accepted around the 5G discussion are as follows:

- 5G Phase 1: Technically introduced 2018/20 using spectrum allocated in WRC 2015 below 6GHz. This is what is referred in this document as “5G”.
- 5G Phase 2: Technically introduced in 2025 timeframe, and maybe lasting to 2030 based on spectrum that will be allocated in WRC 2019 above 6GHz.
- Post-5G Phase 2: After 2030 with what might be lead to 6G.

The idea of this document is to provide inputs to an EU research programme B5G. This could be 5G phase2 or Post-5G phase. The vision in this document is mostly targeting 5G Phase2. Industry, in particular, views B5G as 5G Phase2. Academia is not so uniform in their views, and depends on the area: some fields, especially new system architectures, may probably be for Post-5G Phase2 (and then again, if these system views reach standardization before, then they will become 5G evolutions). As the three phases above are unlikely to be revolutions and more likely to be evolutionary, in this document B5G is considered as a mixture of 5G Phase 2 and Post-5G, but with an emphasis on the first.

Thus, this document aimed at identification and clarification of potential research and innovation areas relevant for B5G networks that need to be considered in the Horizon 2020 future calls.

The paper provides extensive coverage of the following areas:

- i. 5G Scenarios
- ii. Fundamental Techniques For TB/S Communications
- iii. Spectrum and Radio Management
- iv. System Design
- v. Alternative Technologies And Designs

1.3 Pathway to Innovation

The path to 5G is a multi-facet and highly multidisciplinary unlike previous generations. It consists of various applications from narrowband to wideband, different radio environments with extremely challenging performance requirements in terms of reliability, latency, capacity, connectivity, energy efficiency, flexibility and so on. It relies on convergence between Communication technologies, Network engineering and Information Technology. To capitalise on unique strengths of the EU in integrated and end-to-end solutions and for impactful research on 5G there is needs for appropriate experimental facilities for proof of concepts developed within the research projects and for optimisation of integrated solutions which will ultimately results in new ideas, solutions and innovations.

Europe needs a large-scale experimental platform able to support through its testing capabilities the development and exploitation of 5G techniques and infrastructures. Much effort and investments have been made in Europe in the past years to create test-beds and experimental facilities with the purpose of serving industry and the scientific

community. The result is a large number of fragmented and isolated platforms, however valuable assets to have in Europe. Federation of test-beds was also considered as a solution to fragmentation in some cases. Simply interconnecting facilities, that were initially devised as separate entities, does not result in a coherent framework.

A coherent framework for experimental facilities need to consider the complexity of network and IT paradigms that will merge into 5G (cloud networking and processing, distributed versus centralised Radio Access Network solutions, Internet of Things and Machine Type Communications, Device-to-Device links, Software Defined Networking, Network Function Virtualisation, etc). Experimental facilities require a flexible, large-scale, unified experimental framework that is able to serve all industry players in the field, to test the advanced techniques and solutions in an open-source context.

5G will be a pervasive, highly flexible and ultra-low latency infrastructure capable of “bridging” a sheer large number of terminals, smartphones, tablets, wearables and any other intelligent machine around users, with the enormous processing and storage power available in the Cloud.

From the infrastructure side, this experimental framework should allow testing of different architectural approaches to SDN, NFV, and their deep integration with Cloud/Edge/Fog Computing (e.g., validating the delicate balance of centralised versus distributed control and execution of functions, new operations processes): this includes also testing of (and operating) different Core and Radio Access solutions, using frequencies above and below 6 GHz, spectrum cognitive approaches (for specific applications), novel and traditional transmission techniques: it concerns also the integration of Core and Radio Access with Optical Networks (also strictly required to minimize latencies) and Satellite Networks. From the terminal and device side, it should integrate seamlessly all different types of traffic sources and prosumers: smart terminals, things, machines, body-worn devices and even robots and drones.

To accomplish this goal, the fragmentation of experimental activities needs to be tackled through focused and concerted actions, aiming at creating a pan-European test-bed open to all projects and stakeholders for creating innovation.

Moreover, in order to enable a sustainable and scalable experiment facility, it is recommended to focus initially on development of an overarching Operating System (OS). The OS that spans from terminals, to the network to the Cloud and it will act as the “glue” for proper federation of the available experimental facilities for 5G in the EU to produce the impact. It should be designed leveraging the available OS solutions and experiences, implemented in open source, and exploited in a way that existing experimental facilities can be integrated rapidly and with minimum effort. Later, this overarching OS will represent the enabling facility for the development of 5G solutions and applications. A new Network OS (NOS) developed through experimental research could itself be a valuable innovation for future agile and open networking in 5G.

This White Paper does not discuss the possible verticals of relevance to the development of 5G. Many of the existing facilities listed can be used to test technologies for several of the application areas currently envisaged for 5G. In few cases the test beds are specifically focused towards a specific vertical. In such cases a short description of the testbeds and their focus is provided in the White paper.

1.4 Impact of Content and Media on 5G research programme

In addition to “connectivity” Research and innovation programme, as was defined by the 5GPPP Association, further work was undertaken between NetWorld2020 and NEM technology platforms on strategic research and innovation from viewpoint of “networked contents and media” which ought to be considered in the future network (5G) architecture and functionalities research and design.

The position paper identifies 5 closely coupled factors that need to be considered in the 5G research:

- End user device factor: 10 times as many devices, but with economics that will be up to 10 times lower per device.
- End user demand factor: 100 times more bytes to be delivered, which at today’s economics means 100 times lower cost per byte.
- Scalability factor: Demands a unification of tens of different network domains and hundreds of disparate operator networks into a federated global and open network.
- Elasticity factor: Which requires that the dedicated systems that were used to reliably deliver a fixed set of services be replaced by IT systems that deliver an infinite set of services with a completely different reliability model.
- Velocity factor: Mandates a 100 times increase in the rate of service introduction and 100 times decrease in service management complexity

The position paper provides a comprehensive coverage of the following research topics:

- vi. Content delivery
- vii. Interactivity
- viii. Content security
- ix. Network capabilities
- x. Content popularity
- xi. Content Lifetime
- xii. IoT content
- xiii. ATAWAD (Any Time, Any Where, Any Device)
- xiv. End to End Quality

2 SUMMARY OF PROPOSED TOPICS FOR FURTHER RESEARCH AND INNOVATION

The results of the independent analysis of the current 5G programme in 5GPPP together with priority topics and actions for **Work Programme 2016-17** (See Annex 2 for further details) which was prepared by 5G Infrastructure Association summarised in the Table 1.

Additionally the Table 1 contains a summary of all research and innovation topics identified in the **5G Experimental Facilities in Europe** produced by the Expert group of NetWorld2020 that identifies research topics and innovation opportunities through experimentation. In this White Paper, a comprehensive list of all existing testbeds with their capabilities and scales in Europe is provided. The proposal is to utilise the existing facilities with some enhancements and develop a novel network operating system (NOS) that “glues” all the existing and relevant testbeds as well as developing the novel NOS for future agile networking.

The Expert Group of NetWorld2020 work on “**Beyond 5G**” era and the jointly developed Position Paper between **NetWorld2020 and NEM** ETPs identified a number of important research areas. These are all summarised in the table 1. The table has two columns of **Research & Innovation** and **Innovation**. Under each column appropriate strategic topic is listed for consideration in the future Work Programme in the Horizon 2020.

| Research & Innovation | Innovation |
|---|---|
| 5G gap topics in the Connectivity | |
| <ul style="list-style-type: none"> • Project P10 in Strand 2: 5G Services E2E Brokering and Delivery • P12 in Strand 3: SLM & Metrics for QoS/QoE • P16 in Strand 4: Multi-Domain SW Networks are only marginally addressed and overall poorly covered. • Project P9 in Strand 2: Enabling Technologies Unified Control | |
| Work Programme 2016/17-Priorities | |
| <ul style="list-style-type: none"> • Advanced Multi Antenna Transceiver techniques • mmWave RATs • Channel Model for 5G • Novel RAN Architectures • Machine type Communications • Intelligent Radio Resource Management • Integrating satellite networks | |
| <ul style="list-style-type: none"> • Programmable, elastic and high capacity optical networking | Optical networking for converged and ubiquitous 5G access |

| | |
|---|--|
| <ul style="list-style-type: none"> • Novel Views on Network Architecture • The Software Network: Interface Abstractions and Layering • “On the fly” Virtualization and Adaptability | <ul style="list-style-type: none"> • Efficient RAN Sharing for Multi-Tenancy • Cloud Orchestration |
| <ul style="list-style-type: none"> • Smart Orchestration and Use of Network Analytics and Big Data for network management | <ul style="list-style-type: none"> • Agile Management Frameworks and Network Operating System (NOS) |
| <ul style="list-style-type: none"> • Security Privacy and Trust • Energy Efficient Devices and Networks • Highly Flexible Communication Systems | |
| <p>5G Content, Media and Connectivity Priorities Convergence: Internet, phone, TV, mobile and content</p> | |
| <ul style="list-style-type: none"> • Any device and multiscreen, seamless access to any content • Flexibility in support of different rights management and rights information management • Personal device synchronisation and auto discovery • Geo-location information • Support Quality of experience placement of content in the network, graceful degradation, complexity hiding from content providers • Virtualisation and Visualisation as a Service” business models • Improve accessibility for the disabled users • Support of big data handling and analytics | |
| <p>Beyond 5G Priorities</p> | |
| <ul style="list-style-type: none"> • Terabit communication: spanning from physical devices to communication models, to integration wireless-fibre, to advanced HetNets processing. • Massive MIMO realization • Spectrum management • Rural Broadband systems • software systems with levels of multi-tenancy, scalability and flexibility and Conflict • interaction of human aspects (Anticipation, proactivity, participation) • Optical wireless, dynamic radio systems, cellular radar, self-powered systems, device-level softwarization (and slicing), and body-level interactions. | |

Table 1: Summary of research and innovation topics for 5G and beyond 5G era

3 ANNEXES

3.1 Annex.1: Coverage and gap Analysis of current programme

3.2 Annex.2: Priority topics and actions for Work Programme 2016-17

3.3 Annex.3: Research and innovation challenges for “Beyond 5G”

3.4 Annex.4: Pathway to innovation

3.5 Annex.5: Impact of Content and Media on 5G research programme.