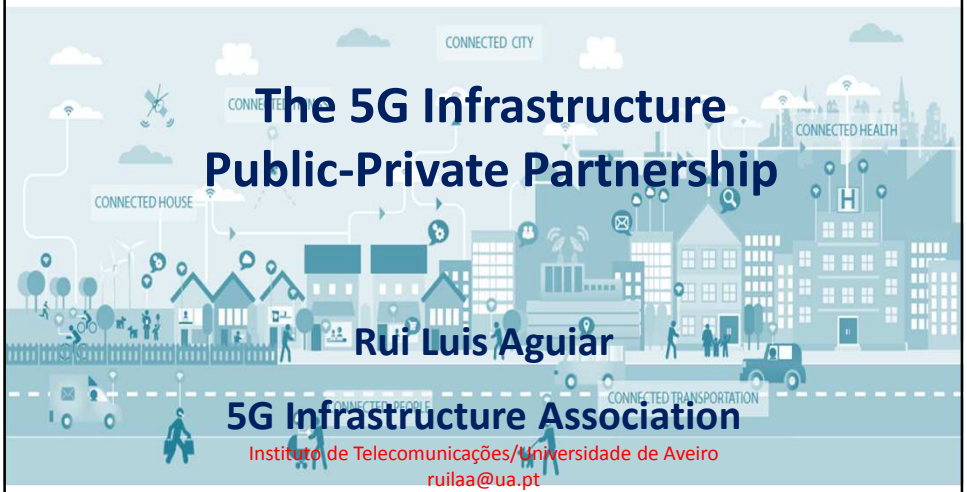
INFRASTRUCTURE ASSOCIATION



The 5G Infrastructure Public-Private Partnership

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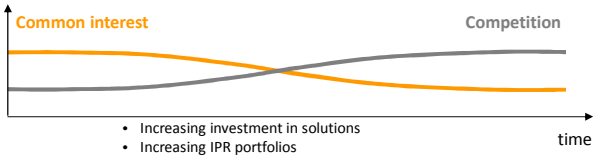
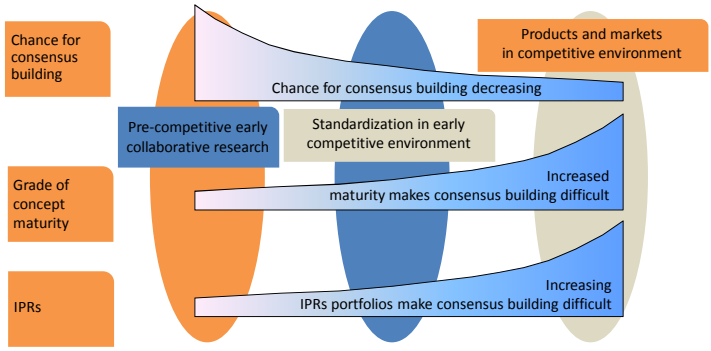
http://5g-ppp.eu/

5G Infrastructure PPP
The European path towards global next generation communication networks

Why Collaborative research? International consensus building at an early stage



- Increasing investment in solutions
- Increasing IPR portfolios



- Horizon 2020 is open for organizations from outside of Europe

Source: NetWorld2020.

Major milestones towards the 5G PPP implementation

- Commissioner Kroes asked Industry in Europe to cooperate on 5G PPP at Mobile World Congress 2013 in Barcelona
- First Call for Proposals published on December 11, 2013
- 5G PPP Contractual Arrangement signed between EU Commission and private side on December 17, 2013
- Budget for 2014 – 2020 time frame
  - Up to 700 million € public funding
  - Matched by private side including leveraging factor 5 of additional private investment results in private value of about 3.5 billion €
- 5G PPP industry launch at Mobile World Congress on February 24, 2014
- Submission deadline of proposals on November 25, 2014
- Start of first projects on July 1, 2015
- 5G Vision EU – CTO Press Event at Mobile World Congress on March 3, 2015
- 5G Infrastructure Association vision paper published

http://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf

From left to right:
- Marcus Weldon, Chief Technology Officer and President Bell Labs, Alcatel-Lucent
- Li Yingtao, President of 2012 Laboratories, Huawei
- Kyungwhoon Cheun, Executive Vice President, Samsung Electronics
- Hermann Eul, Corporate Vice President General Manager, Mobile and Communications Group, Intel
- Marl-Noëlle Jego-Laveissière , Senior Executive Vice President of Innovation, Marketing and Technologies, Orange
- Günther H. Oettinger, Commissioner for Digital Economy and Society
- Hossein Moiin, Executive Vice President, Chief Technology Officer, Nokia Networks
- Didier le Boulc'h, Chief Technology Officer, Thales Alenia Space
- Mr Seizo Onoe, Executive Vice President, Chief Technical Officer, and Member of the Board of Directors, Docomo
- Ulf Ewaldsson, Chief Technology Officer, Ericsson

Source: 5G Infrastructure Association.

International activities on 5G getting momentum

ITU-R Visions Group

EU
- Framework Program 7, e.g. METIS and 5GNow projects
- 5G PPP in Horizon 2020

Germany – 5G Lab Germany at TU Dresden

UK – 5G Innovation Centre (5GIC) at University of Surrey

US
- Intel Strategic Research Alliance (ISRA)
- NYU Wireless Research Center
- 5G Americas, MoU - signed

China
- 863 Research Program
- Future Forum
- IMT-2020 (5G) Promotion Group, MoU - signed

Japan – The 5G Mobile Communications Promotion Forum, MoU - signed

Korea – 5G Forum, MoU - signed

Taiwan – TAICS, Ministry of Science and Technology, Ministry of Economic Affairs

Russia – 5GRUS by Russia's Icom-Invest

CJK White Paper

NGMN – White paper on future requirements

- Company internal research
- Multilateral MoU on a series of Global 5G Event signed on October 20, 2015 in Lisbon
  - Two events per year, rotation between continents

Source: 5G Infrastructure Association.

International cooperation
General status of MoUs

- **China**
  - **MoU signed with IMT-2020 (5G) Pror**
    Beijing
- Japan
  - MoU signed with The 5G Mobile Com
    March 25, 2015 at NGMN Industry Co
- Korea
  - MoU signed with 5G Forum on June 1
    between EU Commission and Korean government in Seoul, Korea
- USA
  - MoU signed with 5G Americas on March 2, 2015 at Mobile World Congress 2015 in Barcelona, Spain

- Multilateral MoU on a series of Global 5G Event
  - Two events per year
  - Rotation between continents
  - MoU signed between IMT-2020 (5G) Promotion Group, 5GMF, 5G Forum, 5G Americas and 5G Infrastructure Association on October 20, 2015 in Lisbon

23/06/2016 5

Source: 5G Infrastructure Association.

5G Infrastructure PPP
The European path towards global next generation communication networks

5G PPP Contractual Arrangement
Specific Objectives

- Provide solutions and technologies for ubiquitous broadband access to interoperable and globally standardized communication networks to help overcoming the Digital Divide;
- Enable networks to support a new range of applications, from IoT to Ultra High Definition-TV (UHDTV);
- Improve the energy efficiency;
- Improve significantly network security and privacy;
- Ensure the continuous education of skilled people with regards to new systems and new application domains;
- Reinforce the European industrial leadership in network and information systems, maintaining a global 5G market share of European providers, commensurate to their network market share of today (40%);
- Support innovation through openness whilst securing IPRs and know-how with respect to global competition;
- Enable the forthcoming convergence between telecom and IT sectors;
- Drive the integration of the services and the intelligent infrastructures for highly optimised service provision across heterogeneous networks;
- Build extensive know-how and IPR base in Europe for future systems in the research community and industry;
- Create an appropriate environment for successful R&D&I activities;
- Provide a governance model, which on one hand supports the goals of openness, transparency and representativeness and on the other hand ensures an efficient management with minimized overhead;
- Support an efficient information flow between projects by respecting the interests of each partner with respect to confidentiality and access rights.

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Source: 5G PPP Contractual Arrangement.

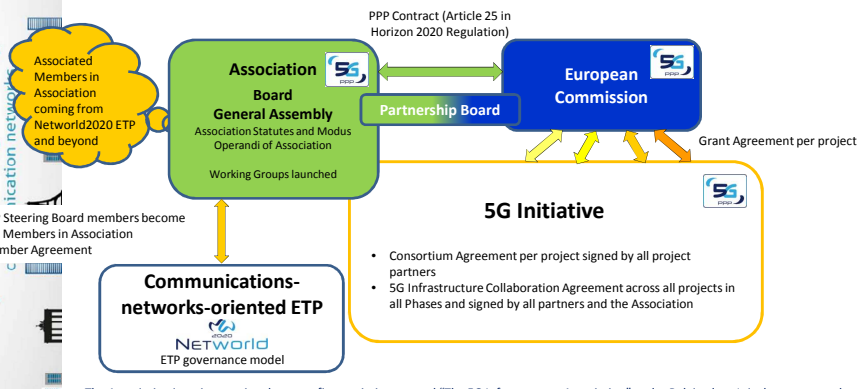
5G PPP Contractual Arrangement
KPIs for Monitoring

- Business-related KPIs:
  - Leverage effect of EU research and innovation funding in terms of private investment in R&D for 5G systems in the order of 5 to 10 times;
  - Target SME participation under this initiative commensurate with an allocation of 20% of the total public funding;
  - Reach a global market share for 5G equipment & services delivered by European headquartered ICT companies at, or above, the reported 2011 level of 43 % global market share in communication infrastructure.
- Performance KPIs:
  - Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010;
  - Reducing the average service creation time cycle from 90 hours to 90 minutes (as compared to the equivalent time cycle in 2010);
  - Very dense deployments to connect over 7 trillion wireless devices serving over 7 billion people;
  - Secure, reliable and dependable Internet with a "zero perceived" downtime for services provision.
- Societal KPIs:
  - Enabling advanced User controlled privacy;
  - Reduction of energy consumption per service up to 90 % (as compared to 2010);
  - European availability of a competitive industrial offer for 5G systems and technologies;
  - New economically-viable services of high societal value like U-HDTV and M2M applications;
  - Establishment and availability of 5G skills development curricula in partnership with the EIT.

Source: 5G PPP Contractual Arrangement.

Governance model – Basic approach
Relation of Networld2020 to 5G PPP

- NETWORLD will support the 5G PPP by
  - the direct relation to the PPP Association and
  - the development of the SRAI for the 5G-PPP



- The Association is an international non-profit association, named "The 5G Infrastructure Association" under Belgian law. It is the contractual counterpart of the European Commission for signing the 5G-PPP contract, done on 17 December 2013, see http://europa.eu/rapid/press-release_IP-13-1261_en.htm.

Source: NetWorld2020 ETP and Annex to 5G PPP Contractual Arrangement.

Members of 5G Infrastructure Association including international dimension

5G Infrastructure PPP
The European path towards global next generation communication networks

Industry

- ADVA Optical Networking SE
- Alcatel-Lucent
- Airbus
- Atos
- Deutsche Telekom
- DOCOMO Communications Laboratories Europe GmbH
- Ericsson
- Huawei Technologies Düsseldorf GmbH
- IBM Research
- Intel Mobile Communications
- NEC Europe Ltd., NEC Laboratories Europe
- Nokia
- Orange Labs
- Samsung Electronics Research Institute Ltd.
- SES
- Telecom Italia
- Telefónica I+D
- Telenor ASA
- Telespazio
- Thales Alenia Space
- Turk Telekomünikasyon A.Ş.

Research

- CEA-LETI
- Centre Tecnologic de Telecomunicacions de Catalunya (CTTC)
- Consorzio Nazionale Interuniversitario per le Telecomunicazioni (CNIT)
- Fundacion IMDEA Networks
- Instituto de Telecomunicacoes
- TNO
- University of Bologna – DEI

SMEs

- Integrasys SA
- INTERINNOV
- M.B.I. S.R.L.
- Nextworks s.r.l.
- Quobis
- Sequans Communications

Source: 5G Infrastructure Association.

5G Infrastructure Association Working Groups and Activities

5G Infrastructure PPP
The European path towards global next generation communication networks

5G Infrastructure Association Board

WG 5G Vision and Societal Challenges
- Vision and requirements
- Vertical sectors
- Definition of research program
- Assessment of research portfolio
- Monitoring of performance KPIs (system capacity, energy consumption, privacy and security, reliability and availability, service creation time

WG 5G Pre-standards
- Roadmaps of relevant standards and specification bodies
- Identify topics for research and timing of availability of results
- Provide means for coordinated contributions across projects

WG SME support
- SME participation of at least 20 %
- Stimulate SME involvement

WG 5G Spectrum
- Support preparation of WRC 2019 on future spectrum requirements
- Identification new means of spectrum access based on research results

Activity Community building and PR (Public Relations)
- Dissemination of results and communication strategy
- Website and press releases
- Public consultation

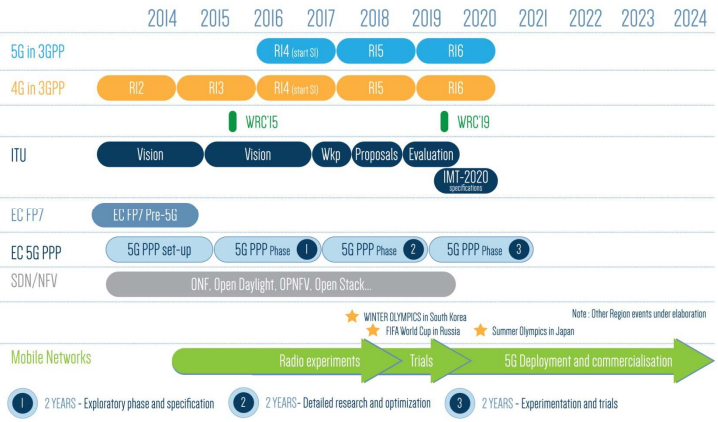
Activity 5G International cooperation
- International cooperation strategy with counterparts in other regions
- Establishment of relations
- Joint events across regions

Activity: Activities based on the 5G PPP Contractual Arrangement, KPIs
- Leveraging factor of additional private investment
- Monitor market share from European perspective
- Monitoring of generated IPR base
- Support adaptation of curricula for education of skilled personnel (e.g. via EIT ICT Labs.)

Source: 5G Infrastructure Association.

5G PPP Vision and Requirements
5G roadmap

5G Infrastructure PPP
The European path towards global next generation communication networks



23/06/2016

Source: 5G Infrastructure Association: Vision White Paper, February 2015.

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Horizon 2020 5G PPP Call 1 objectives
125 million € Funding

Radio network architecture and technologies

Support anticipated 1000 fold mobile traffic increase and very different classes of traffic/services

- Network architecture, protocols and radio technologies capable of at least a ten times increase in frequency reuse and new frequency ranges above 3,6 GHz
- Versatile low cost ubiquitous radio access infrastructure equally supporting low rate IoT and very high rate (>> 1 Gbit/s) access
- Flexible and efficient radio, optical or copper based backhaul/fronthaul with low latency
- Innovative architectures for 5G transceivers and micro-servers
- Experiment based research preparing for large scale demonstrator and test-beds

Convergence beyond last mile

Support integration of a ubiquitous access continuum composed of cooperative, cognitive fixed and heterogeneous wireless resources, with fixed optical access reaching at least the 10 Gb/s range

- Solving the management heterogeneity of different fixed and heterogeneous wireless networks
- Architectures to optimize reuse and sharing of functionality across heterogeneous access technologies and networks

Network management

Challenge to radically decrease network management Opex through automation whilst increasing user perceived quality of service, of experience and security

- Novel simplified (low Opex) approaches to overall management of the network (e.g. Self-organizing networks –SON) and service level management
- Combination of software defined network implementations with autonomic management of resources
- Network security across multiple virtualized or SDN domains

Network virtualization and Software Networks

Highly flexible, manufacturer-independent model of controlling reconfigurable resources supporting changing/emerging application requirements

- Virtualization of network functionalities at infrastructure level and implementation of network services
- Orchestration logic (SDN), enabling network programmability, automation of cross domain network configuration, simplification and programmability of devices
- Tighter integration between application/service layers and networking layers
- Support of open network functionalities for dynamic integration with third party and OTT cloud environments

23/06/2016

Source: EU Commission Work Program 2014-2015 / 5G Infrastructure Association.

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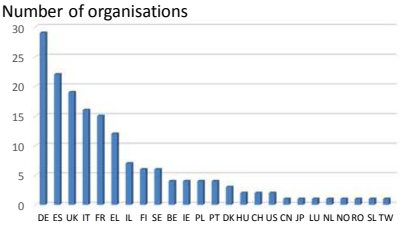
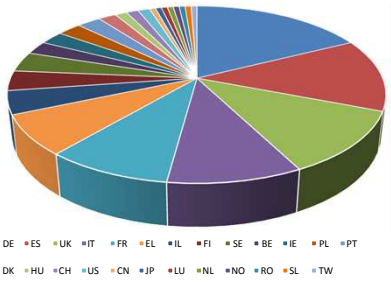
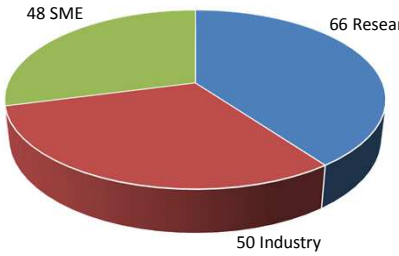
Participation in Call 1 projects
Based on available information

Number of organisations





Number of organisations



BE	Belgium	JP	Japan
CH	Switzerland	LU	Luxembourg
CN	Canada	NL	Netherlands
DE	Germany	NO	Norway
DK	Denmark	PL	Poland
EL	Greece	PT	Portugal
ES	Spain	RO	Romania
FI	Finland	SE	Sweden
FR	France	SL	Slovenia
HU	Hungary	TW	Taiwan
IE	Ireland	UK	United Kingdom
IL	Israel	US	USA
IT	Italy		

Source: 5G Infrastructure Association.

Horizon 2020 5G PPP
Call 1 selected projects

Radio-related cluster
Fronthaul/Backhaul
Hardware implementation
Network automation
SDN, NFV, Cloud and Virtualisation
Security

5G Ensure — Security (Will be added later)

CogNet — Building an Intelligent System of Insights and Action for 5G Network Management

SELFNET — Framework for SELF-organized network management in virtualized and software defined NETworks

CHARISMA — Converged Heterogeneous Advanced 5G Cloud-RAN Architecture for Intelligent and Secure Media Access

SUPERFLUIDITY — Superfluidity: a super-fluid, cloud-native, converged edge system

5GEx — 5G Exchange

VirtuWind — Virtual and programmable industrial network prototype deployed in operational Wind park

SONATA — Service Programming and Orchestration for Virtualized Software Networks

COHERENT — Coordinated control and spectrum management for 5G heterogeneous radio access networks

5G-Norma — 5G NOvel Radio Multiservice adaptive network Architecture

METIS-II — Mobile and wireless communications Enablers for Twenty-twenty (2020) Information Society-II

SPEED-5G — quality of Service Provision and capacity Expansion through Extended-DSA for 5G

SESAME — Small cEIlS coordinAtion for Multi-tenancy and Edge services

FANTASTIC-5G — Flexible Air iNTerfAce for Scalable service delivery wiThin wIreless Communication networks of the 5th Generation

5G-Xhaul — Dynamically Reconfigurable Optical-Wireless Backhaul/Fronthaul with Cognitive Control Plane for Small Cells and Cloud-RANs

Flex5Gware — Flexible and efficient hardware/software platforms for 5G network elements and devices

5G-Crosshaul — The 5G Integrated fronthaul/backhaul

mmMAGIC — Millimetre-Wave Based Mobile Radio Access Network for Fifth Generation Integrated Communications

Euro-5G — 5G PPP Coordination and Support Action

Source: 5G PPP, https://5g-ppp.eu/5g-ppp-phase-1-projects/.

Horizon 2020 5G PPP Call 2 objectives
148 million € Funding

- ICT-07-2017: 5G PPP Research and Validation of critical technologies and systems
- ICT-08-2017: 5G PPP Convergent Technologies
- Call 2: Opening May 10, 2016, Closing November 8, 2016

Wireless access and radio network architecture/ technologies

- Novel air interface technologies, heterogeneous set of requirements (low rate sensors including mission critical M2M to very high rate HD/3D TV and immersive services, supporting local and wide area systems), enabling usage of frequency bands above 6 GHz
- Hardware architectures technologies and building blocks
- (Radio) Network functional architectures and interfaces leading to vision / reference architecture for 5G
- Co-operative operation of heterogeneous access networks, including broadcast/multicast (terrestrial and satellite based) and supporting SDN and virtualization
- Multi-tenancy for Radio Access Network (RAN) sharing
- Integration of Satellite Networks to support ubiquitous coverage, resilience, specific markets

High capacity elastic - optical networks

- Support very high traffic and capacity increase originating from an (5G) heterogeneous access networks with matching capabilities from the core and metro environments, at ever increasing speeds and in more flexible and adaptive form
- New spectrally efficient, adaptive transmission, networking, control and management approaches to increase network capacity by a factor of >100 while at the same time providing high service granularity, guarantees for end-to-end optimization and QoS - reducing power consumption, footprint and cost per bit and maintaining reach
- Integration of new optical transport and transmission designs with novel network control and management paradigms (e.g., SDN) are expected to enable programmability

Software Networks

- Software network architecture to support access agnostic converged core network and control framework enabling next generation services
- Architecture leverages SDN/NFV paradigm to integrate/manage next generation transport and optical technologies
- Unified management of connectivity, with end to end security mobility and routing for flexible introduction of new services
- Scalability and efficiency related to increasing deployment of software-based network equipment and functions as well as corresponding more diverse services and usages
- Ease of deployment of multitenant networks, cost and energy efficiency, "five 9" reliability, flexibility and perceived "zero latency" where relevant
- Target is for a Network Operating System (NOS) with hardware and user interfaces to manage and orchestrate unified access to computing, storage, memory and networking resources
- Management and security for virtualised networks and services
- Network analytics tools, knowledge reasoning and cognition, may be extended towards network operations
- Management of security across multiple virtualised domains

Ubiquitous 5G access leveraging optical technologies

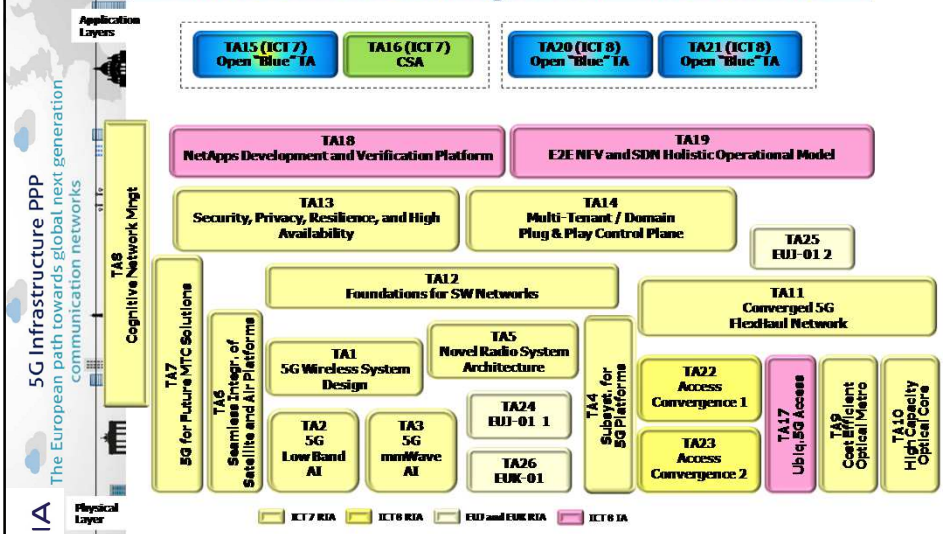
- 5G access networks have to dramatically grow in user capacity, quality of service, responsiveness, energy efficiency and number of connected devices while keeping a sustainable cost
- To develop and assess new optical access network solutions based on integrated optical device prototypes
- Co-operative radio-optical approaches are seen as very promising, also to cover intelligent interference cancellation
- Techniques to map 5G channels to optical transport and a co-design of the optical and wireless interfaces and protocols
- Scalable demonstrators validated through typical usage scenario

Flexible network applications

- Leveraging current intense research activities in relation to Virtualised Network Functions (VNF) and targeting development of a multiplicity of VNF's useful to operators, service providers and users
- Service providers or third party providers should be able to assemble virtualised 5G functions as "network apps" from NFV hosting infrastructure, to deploy them in the relevant network nodes, to orchestrate and customise resources to provision user services
- Target is for a cloud like 5G infrastructures, supporting network services, resource and service orchestration
- This environment also provides an open source development framework for control functionalities and application developments
- It also provides the link between the network –terminal functions and the app/content providers towards standards developments

Source: EU Commission Work Program 2016-2017 / 5G Infrastructure Association.

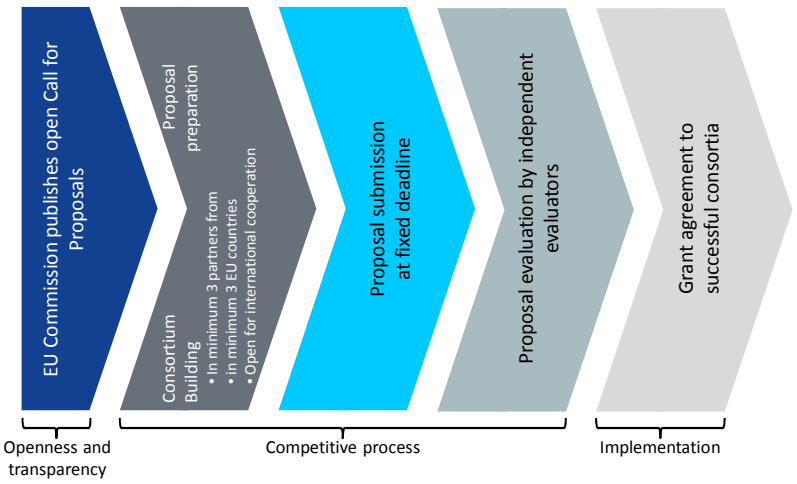
H2020 5G Infrastructure PPP
Phase 2 Pre-structuring Model – TAs Portfolio



Note: The size and the orientation of the TAs boxes do not indicate the potential size or manpower of future Projects

Source: 5G Infrastructure Association.

How to start a project? Major steps



23/06/2016

Source: 5G Infrastructure Association.

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5G PPP Vision and Requirements Economic impact of ICT and 5G

- **5% of European GDP**, corresponding to an annual value of about **€ 660 billion**, is generated today by the ICT sector itself
- Impact of communication sector extends beyond the industrial domain
- Additional investment in ICT in Europe could contribute to rebirth of **GDP growth** in Europe up to (Source: World Bank)
  - about **1.2% points** in high-income economies and
  - about **1.4% points** in low and middle-income economies
- Overall employment level of ICT sector in Europe has been rather stable between 7.2 to 7.5 million employees since 2002 (Source: Digital Agenda Scoreboard)
- Strong industrial base in Europe in research, development, integration and manufacturing of complex systems like communication networks
- Wide spread well-established research community in universities and R&D centres cooperating with industry and SMEs for knowledge and IPR generation
- Novel 5G network requirements, technologies and architectures opens wide range of opportunities for both established and new actors including SMEs

23/06/2016

Source: 5G Infrastructure Association: Vision White Paper, February 2015.

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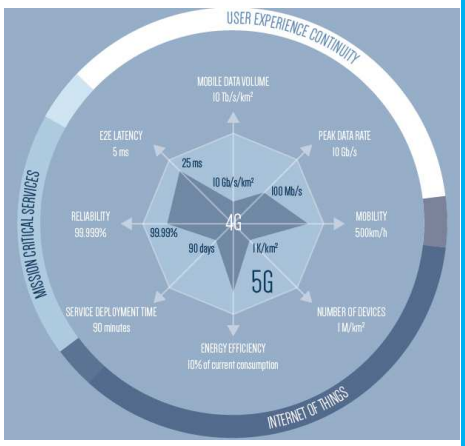
5G PPP Vision and Requirements
5G key drivers

- The start of commercial deployment of 5G systems is expected in years 2020+
- 5G is an **opportunity for the European ICT sector** which is already well positioned in the global R&D race
- 5G will bring **new unique network and service capabilities**
  - user experience continuity
  - Internet of Things
  - mission critical services (low latency, high reliability)
- 5G targets a **unified and programmable infrastructure**
- 5G will support **multi tenancy models**
- 5G will be designed to be a **sustainable and scalable technology**
- 5G will create an **ecosystem for technical and business innovation**

Source: 5G Infrastructure Association: Vision White Paper, February 2015.

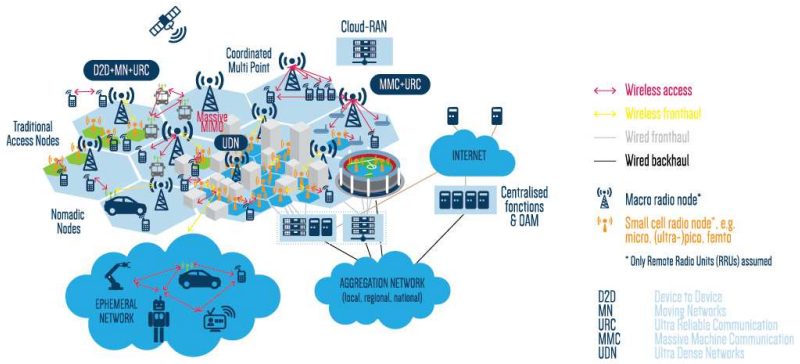
5G PPP Vision and Requirements
5G will have disruptive capabilities

- **5G will provide an order of magnitude improvement in performance** in the areas of more capacity, lower latency, more mobility, increased reliability and availability
- **5G infrastructures will be also much more efficient** in terms of
  - energy consumption
  - service creation time
  - hardware flexibility



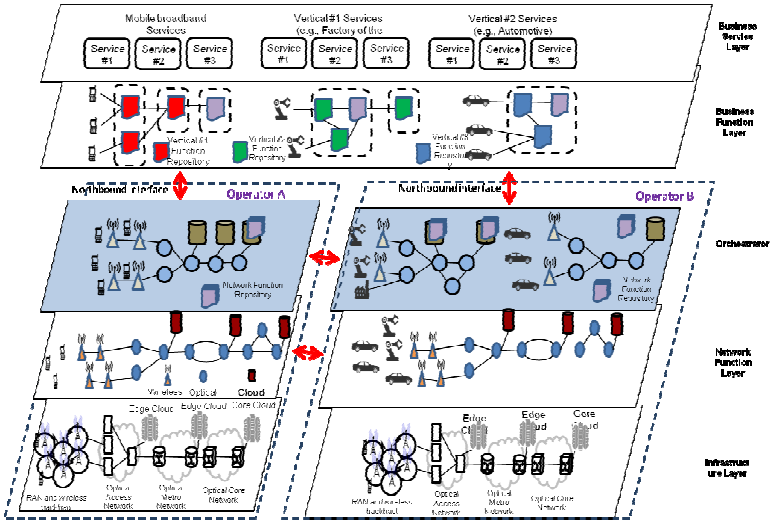
Source: 5G Infrastructure Association: Vision White Paper, February 2015.

5G PPP Vision and Requirements
5G networks and services vision



Source: 5G Infrastructure Association: Vision White Paper, February 2015.

5G Ecosystem



Source: 5G PPP Architecture Working Group.

Vertical sectors

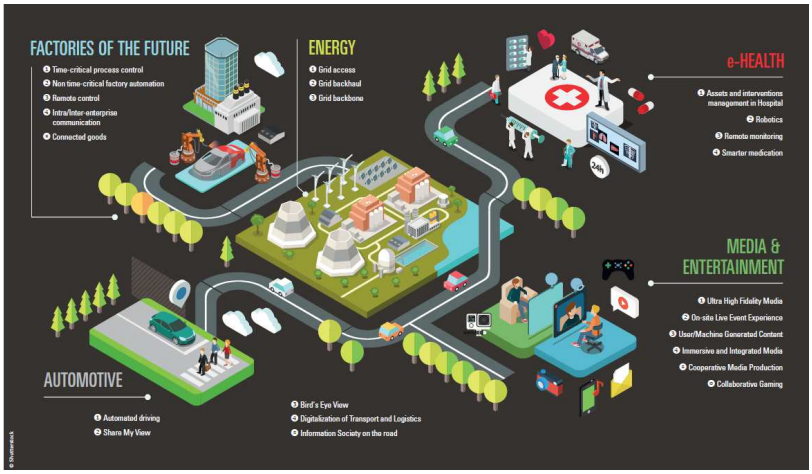
- White papers on
  - 5G and Factories of the Future
  - 5G and Healthcare
  - 5G and Energy
  - 5G and Media
  - 5G and Automotive

- Identification of
  - main use cases
  - requirements and
  - areas for research and innovation

- Vertical workshops
  - June 18, 2015
  - November 9, 2015
- White Paper published at Mobile World Congress 2016
  https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf

Source: 5G Infrastructure Association.

5G – A driver for industrial and societal changes (5G PPP)



Source: 5G Infrastructure Association: 5G Empowering vertical industries. White Paper, 2016, https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf.

Networks will be transformed into intelligent orchestration platforms (5G PPP)

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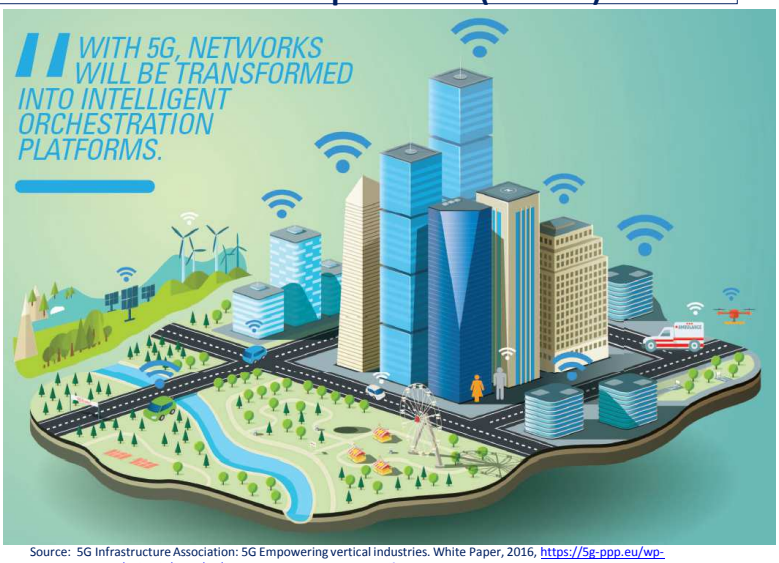

Source: 5G Infrastructure Association: 5G Empowering vertical industries. White Paper, 2016, https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf.

Vertical sectors
Main technical requirements

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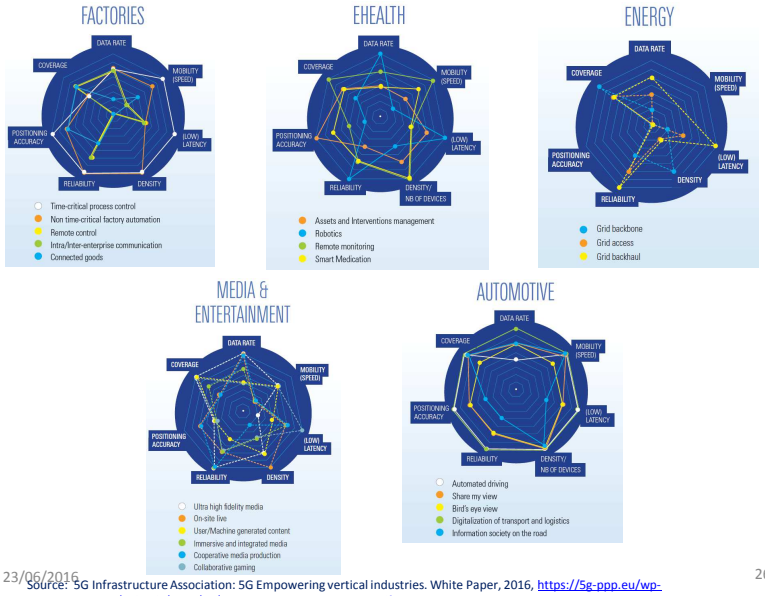


Source: 5G Infrastructure Association: 5G Empowering vertical industries. White Paper, 2016, https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf.

Networking opportunities

- Networld2020 website: http://www.networld2020.org/
- 5G PPP website: https://5g-ppp.eu/
- Participation in Networld2020 and 5G PPP activities like working groups
- Preparation of a Pre-Structuring Model
  - as recommendation to the community
  - as a mapping of the Call for Proposals
  - to Target Research Areas
- Information days are planned in 2016
  - first meeting on January 21, 2015 in Brussels
  - second meeting on March 17, 2016 in Bologna
  - third meeting on May 18, 2016 in Warsaw
  - fourth meeting on June 30, 2016 in Athens after EuCNC 2016
  - fifth meeting (potentially) in September 2016 in Slovakia
- Brokerage Platform on 5G PPP website: https://5g-ppp.eu/brokerage-platform-new/

Source: 5G Infrastructure Association.

Brokerage service for Phase 2

- 3 stage process based in www.5G-ppp.eu
  - Web form for submission
    - Profile or Proposal
    - Main characteristics – company skills or project idea
    - Background – references, work being built on
    - Link to pre-structuring model (if any)
  - Creation of a meaningful web index
    - based on the number and complexity of offers
  - Creating an easily navigable web site with search facilities and allowing people to contact submitters

Source: Euro-5G CSA.

Conclusions

- 5G research started in EU Framework Program 7
- 5G research is getting momentum globally
- Collaborative research as means for consensus building even between competitors to prepare future standards
- In Europe 5G PPP launched in December 2013 as part of new research program Horizon 2020
- 5G PPP is addressing the future communication network including support of vertical sectors
- In addition to system and technology development support of policy objectives
- Horizon 2020 Call 1 projects are currently under implementation
- Big bunch or research projects started on July 1, 2015
- 5G PPP published a Vision and Requirements White Paper at MWC 2015
- Horizon 2020 is open for international participation

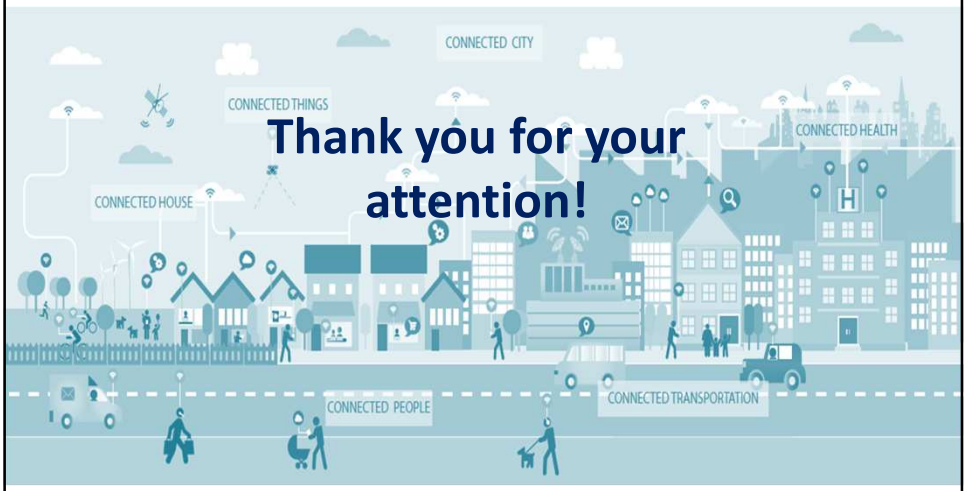
Acknowledgement: The author would like to thank his colleagues for their contributions.

Source: 5G Infrastructure Association.

5G Infrastructure PPP
The European path towards global next generation communication networks

5G IA INFRASTRUCTURE ASSOCIATION

http://5g-ppp.eu



Thank you for your attention!

A copy of the slides will be provided by the organization.