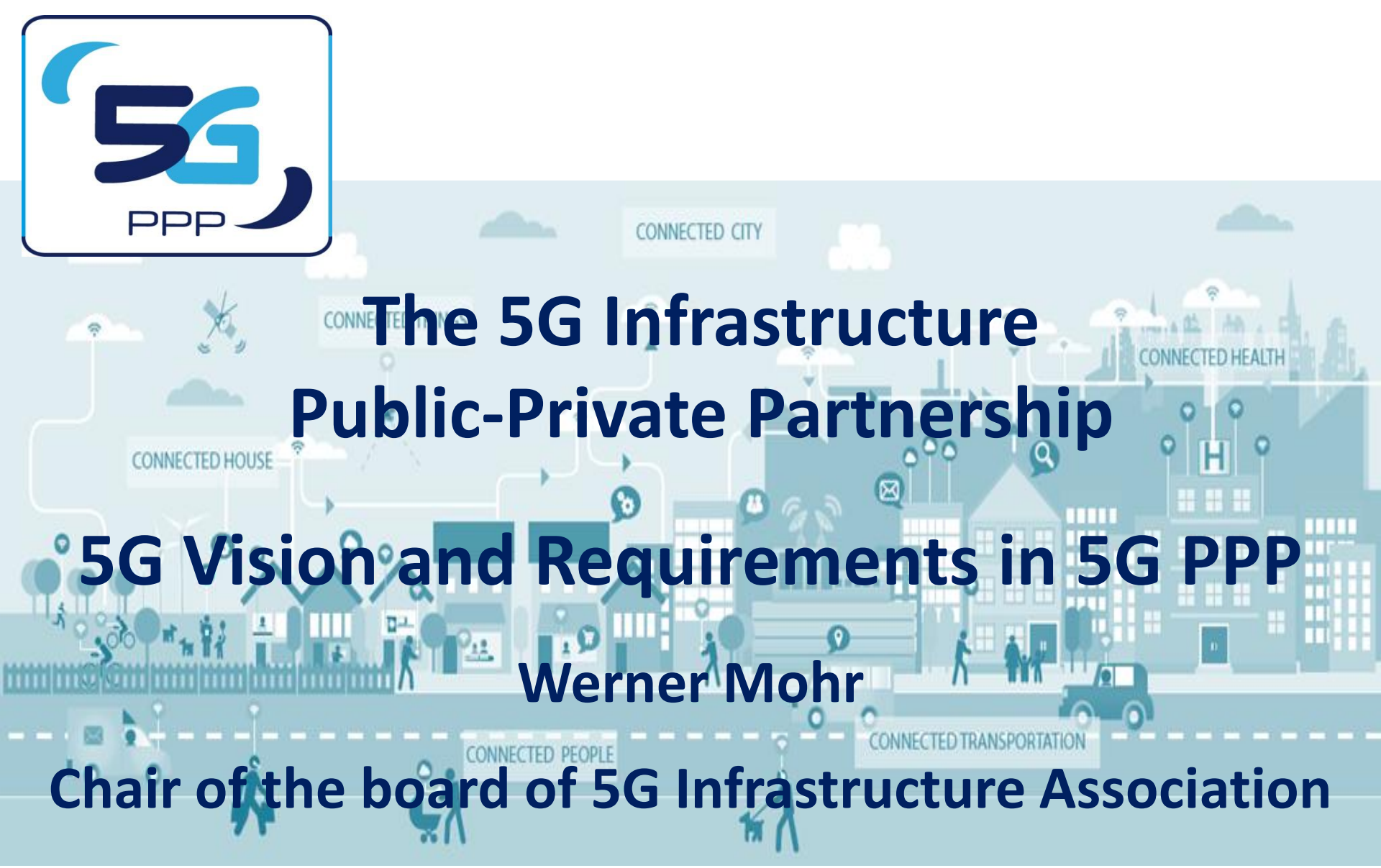

The 5G Infrastructure Public-Private Partnership

5G Vision and Requirements in 5G PPP

Werner Mohr

Chair of the board of 5G Infrastructure Association

http://5g-ppp.eu/

Outline

- 5G research projects in Framework Program 7
- International activities
- 5G PPP in Horizon 2020 of the European Union
- Indicative time plan
- Implementation of 5G PPP and Call 1
- 5G Vision and Requirements
- Conclusions

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

EU Framework Program 7
System and radio projects

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- **METIS** — **M**obile and wireless communications **E**nablers for **T**wenty-twenty (2020) **I**nformation **S**ociety
  - **Overall objective**

    https://www.metis2020.com/

    Lay the foundation & Ensure a global forum & Build an early global consensus for beyond 2020 “5G”mobile & wireless communications.
- **5GNOW** — **5**th **G**eneration **N**on-**O**rthogonal **W**aveforms for Asynchronous Signalling
  - **Overall objective**

    http://www.5gnow.eu/node/5

    5GNOW will develop new PHY and MAC layer concepts being better suited to meet the upcoming needs with respect to service variety and heterogeneous transmission setups.
- **iJOIN** — **I**nterworking and **JOIN**t Design of an Open Access and Backhaul Network Architecture for Small Cells based on Cloud Networks
  - **Overall objective**

    http://www.ict-ijoin.eu/

    iJOIN introduces concept RAN-as-a-Service (RANaaS), where RAN functionality is centralised through an open IT platform based on cloud infrastructure. Joint design and optimisation of access and backhaul, operation and management algorithms and architectural elements, integrating small-cells, heterogeneous backhaul and centralised processing.

EU Framework Program 7
Radio and security projects

- **Tropic** DisTributed computing, storage and radio resource allocation over cooperative femtocells

  http://www.ict-tropic.eu/

  - **Overall objective**

    The project aims at exploiting the convergence of pervasive femto-network infrastructure and cloud computing paradigms for virtualisation/distribution of applications and services.

- **MiWaveS** Beyond 2020 **Heterogeneous Wireless Networks** with **Millimeter-Wave Small Cell** Access and Backhauling

  http://www.miwaves.eu/index.html

  - **Overall objective**

    Demonstrate how low-cost or advanced millimetre-wave (mmW) technologies can provide multi-Gigabits per second access to mobile users and contribute to sustain the traffic growth. Hence, spectrum flexibility and the exploitation of the available mmW spectrum will be key strategies to build high-throughput and low-latency infrastructures for next generation heterogeneous mobile networks.

- **PHYLAWS** **PHY**sical **LA**yer **W**ireless **S**ecurity

  http://www.phylaws-ict.org/

  - **Overall objective**

    Design and prove efficiency of new privacy concepts for wireless communications that exploit propagation properties of radio channels. Search for realistic implantations in existing and in future Radio Access Technologies.

EU Framework Program 7
Network and Internet projects

- **combo** **CO**nvergence of fixed and **M**obile **B**r**O**adband access/aggregation networks

  http://www.ict-combo.eu/

  - **Overall objective**

    Propose and investigate new integrated approaches for Fixed / Mobile Converged (FMC) broadband access / aggregation networks for different scenarios (dense urban, urban, rural)

- **MOTO** Evolving **MO**bile internet with innovative terminal-**T**o-terminal **O**ffloading technologies

  http://www.fp7-moto.eu/

  - **Overall objective**

    Design an integrated operator-managed offloading system and combined offloading algorithms.

- **MCN** **M**obile **C**loud **N**etworking

  http://www.mobile-cloud-networking.eu/site/

  - **Overall objective**

    Extend the Concept of Cloud Computing beyond data centres towards Mobile End-User. One Service: Mobile Network + Computing + Storage. On-Demand, Elastic, and Pay-As-You-Go. Enable a Novel Business Actor, the Mobile Cloud Provider. Mobile Network Architecture for Exploiting and Supporting Cloud Computing. Deliver and Exploit the Concept of End-to-End Mobile Cloud for Novel Applications.

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The European path towards global next generation communication networks

International activities on 5G getting momentum

5G Infrastructure PPP
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- 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
  - 4G Americas
- China
  - 863 Research Program
  - Future Forum
  - IMT-2020 (5G) Promotion Association
- Japan – 2020 and Beyond Ad-Hoc Group under ARIB's Advanced Wireless Communications Study Committee, now transformed to 5G Promotion Forum
- Korea – 5G Forum
- 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

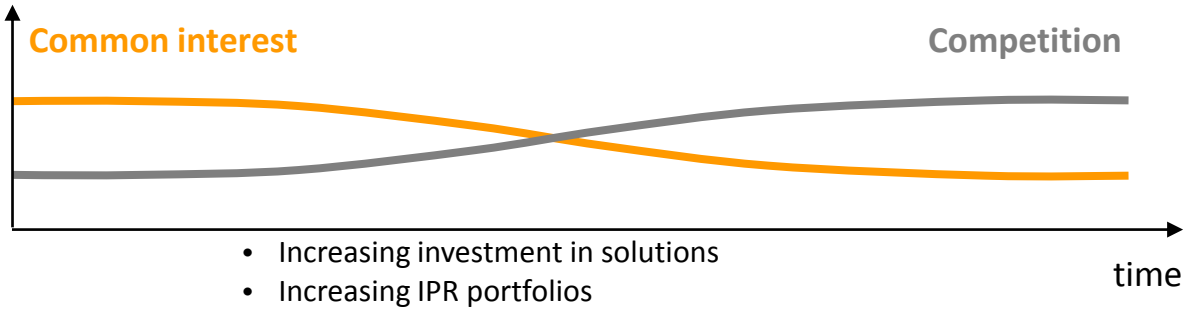
Source: 5G Infrastructure Association.

International cooperation
General status of MoUs

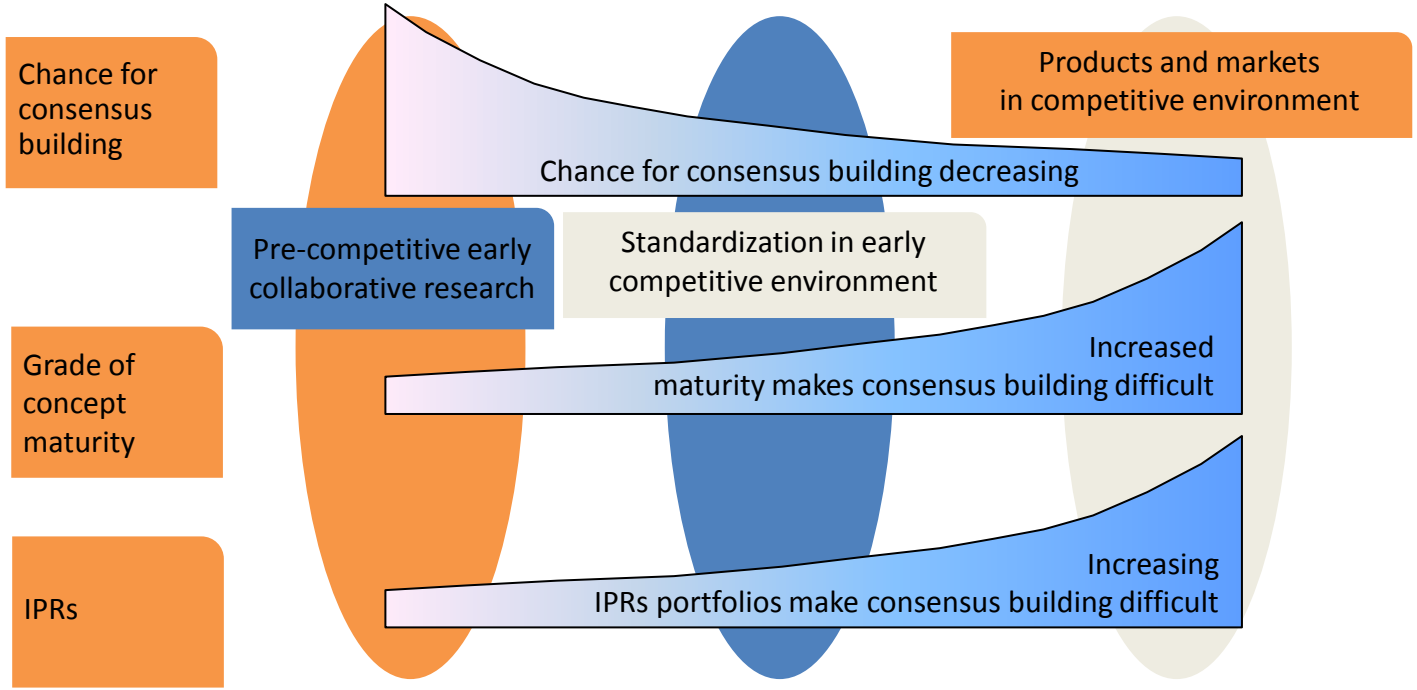
- Korea
  - MoU signed with 5G Forum on June 17, 2014 after signature of Joint Declaration between EU Commission and Korean government
- China
  - MoU text agreed with IMT-2020 Promotion Association
  - Intended date for signatures early May 2015 at visit of Commissioner Öttinger in China
- Japan
  - MoU text agreed with 5G Promotion Forum
  - Intended signature date around regular EU-Japan dialogue end of March 2015
- USA
  - MoU text agreed with 4G Americas
  - MoU signed on March 2, 2015 at Mobile World Congress 2015 in Barcelona
- Multilateral MoU intended on global annual 5G conference
  - Intention to organise an annual global 5G event
  - Rotation between continents

Source: 5G Infrastructure Association.

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.

EU Commissioner Kroes called industry to join EU Commission in a PPP on 5G

- Commissioner Kroes called industry at Mobile World Congress 2013 in Barcelona, Spain

  "… And today I call on EU industry and other partners to join us in a Public-Private partnership in this area. An open platform that helps us reach our common goal more coherently, directly, and quickly. European 5G is an unmissable opportunity to recapture the global technological lead. And I hope you will be able to support and join us. …"

Scoure: Commissioner Neelie Kroes, Smashing barriers and thinking big. Address at Mobile World Congress, 26 February 2013, Barcelona, Spain, http://europa.eu/rapid/press-release_SPEECH-13-159_en.htm?locale=en.

Major milestones towards the 5G PPP implementation

- 5G PPP is a new instrument in Horizon 2020
- First Call for Proposals published on December 11, 2013
- Contractual Arrangement on 5G PPP signed between EU Commission and private side on December 17, 2013

From left to right:
- Marcus Weldon, Chief Technology Officer and President Bell Labs, Alcatel-Lucent
- Hossein Moiin, Executive Vice President, Chief Technology Officer, Nokia Networks
- Neelie Kroes, Vice-President of the EU Commission, Digital Agenda

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

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- Budget for 2014 – 2020 time frame
  - 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

From left to right:
- Ulf Ewaldsson, Chief Technology Officer, Ericsson
- Neelie Kroes, Vice-President of the EU Commission, Digital Agenda
- Mari-Noëlle Jego-Laveissière , Senior Executive Vice President of Innovation, Marketing and Technologies, Orange
- Hossein Moiin, Executive Vice President, Chief Technology Officer, Nokia Networks
- Luis Sanchez Merlo, CEO SES Astra Ibérica
- Marcus Weldon, Chief Technology Officer and President Bell Labs, Alcatel-Lucent

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

Source: 5G Infrastructure Association.

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- Submission deadline of proposals on November 25, 2014
- Project start first half of 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
- Mari-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.

Key challenges

- PPP Program that will deliver solutions, architectures, technologies and standards for the ubiquitous 5G communication infrastructures of the next decade
- Program Ambitions: Key Challenges / High level KPIs
  - Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010
  - Saving up to 90% of energy per service provided. The main focus will be in mobile communication networks where the dominating energy consumption comes from the radio access network
  - Reducing the average service creation time cycle from 90 hours to 90 minutes
  - Creating a secure, reliable and dependable Internet with a “zero perceived” downtime for services provision
  - Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people
  - Enabling advanced User controlled privacy

Proposed research program

- Faster, More Powerful and More Energy Efficient Solutions for integrated High Capacity Access and Core Networks for a Wider Range of Services
  - Wireless Networks
  - Optical Networks
  - Automated Network Organisation - Network Management and Automation
  - Implementing Convergence Beyond the Access Last Mile
- Re-Designing the Network
  - Information Centric Networks
  - Network Function Virtualisation
  - Software Defined Networking
  - Networks of Clouds
- Ensuring availability, robustness and security
- Ensuring efficient hardware implementations

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.

Indicative time plan

Call 1 published
December 11, 2013

Submission deadline
November 25, 2014

Start of first projects mid 2015

2013 | 2014 | 2015 | 2016

Exploratory phase:
- Detailed requirements
- Identify most promising functional architectures and technologies
- Build on previous research work

- Detailed **system research and development**
- Basis for Pan European experimental infrastructure

- **Detailed system optimization**
- Consensus building on globally to be identified frequency bands (consider result of WRC15)
- Validation of concepts and early trials
- Contributions to **initial global standardization** activities
- **Preparation of WRC18/19**

2017 | 2018 | 2019 | 2020

- Support of **initial international standardization**
- Support of regulatory bodies for allocation of newly identified frequency bands
- Implementation of large trials for validation under close to real world conditions

- Extension of trials to non ICT stakeholders
- **Detailed standardization process**

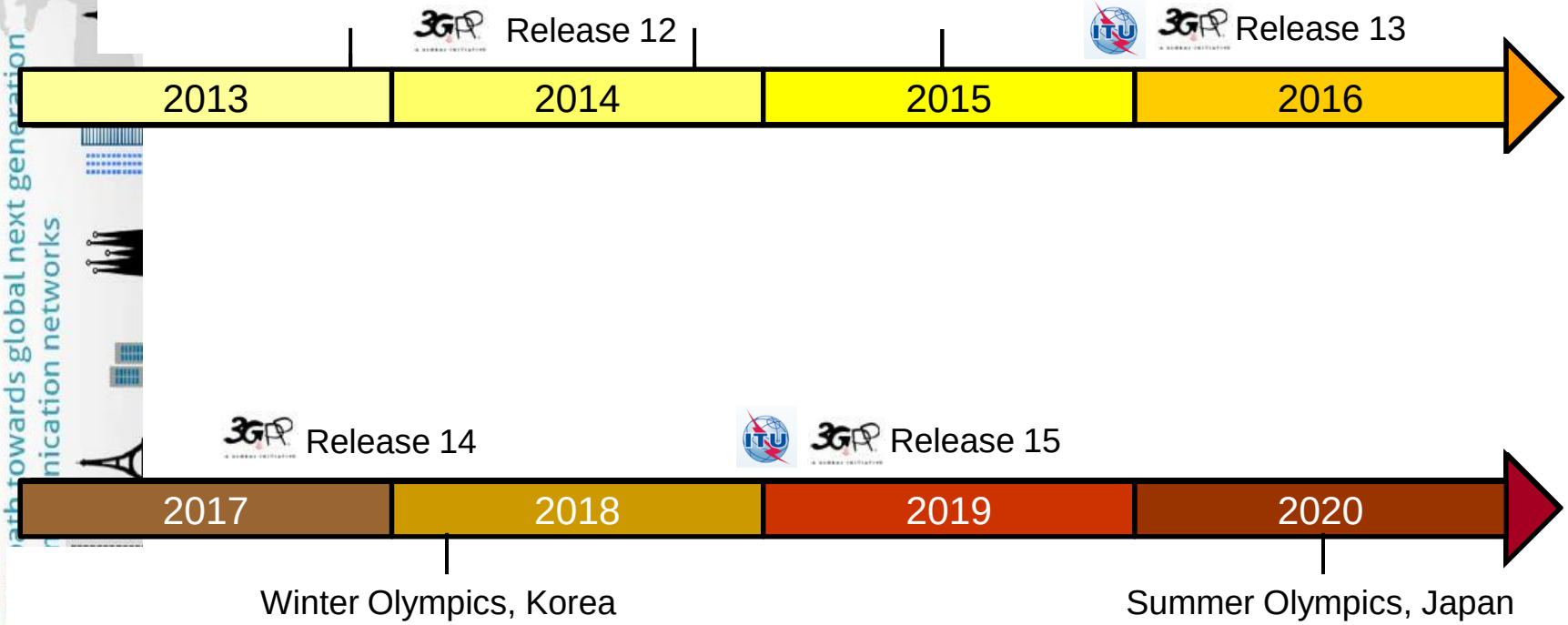
- **New frequency bands available** for trial network deployment and initial commercial deployment
- **Close to commercial systems deployment** under real world conditions to prepare economic exploitation on global basis

Large scale demonstrations and trials, scalability testing, etc.

5G Infrastructure PPP

Source: 5G Infrastructure Association.

Indicative time plan

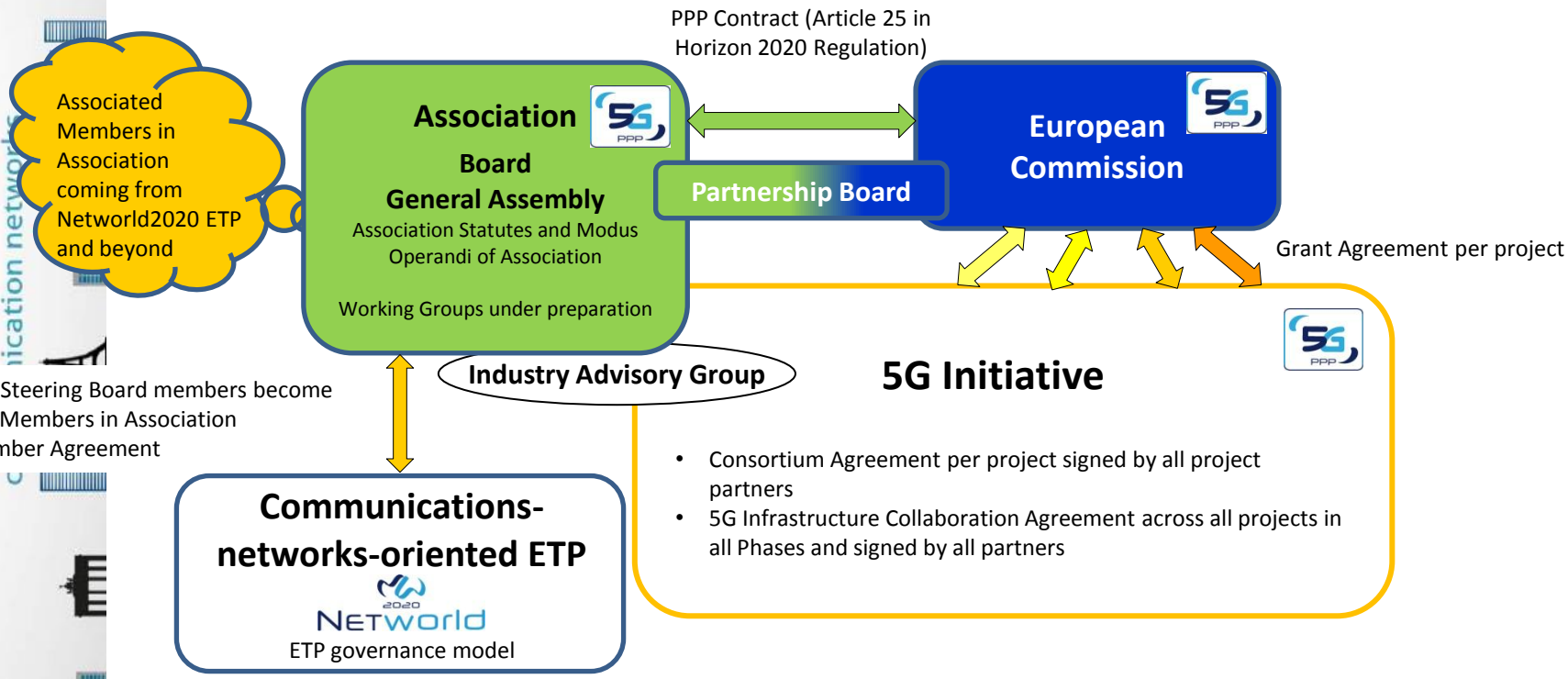


5G Infrastructure PPP

Source: 5G Infrastructure Association.

Governance model – Basic approach
Relation of new ETP to 5G PPP

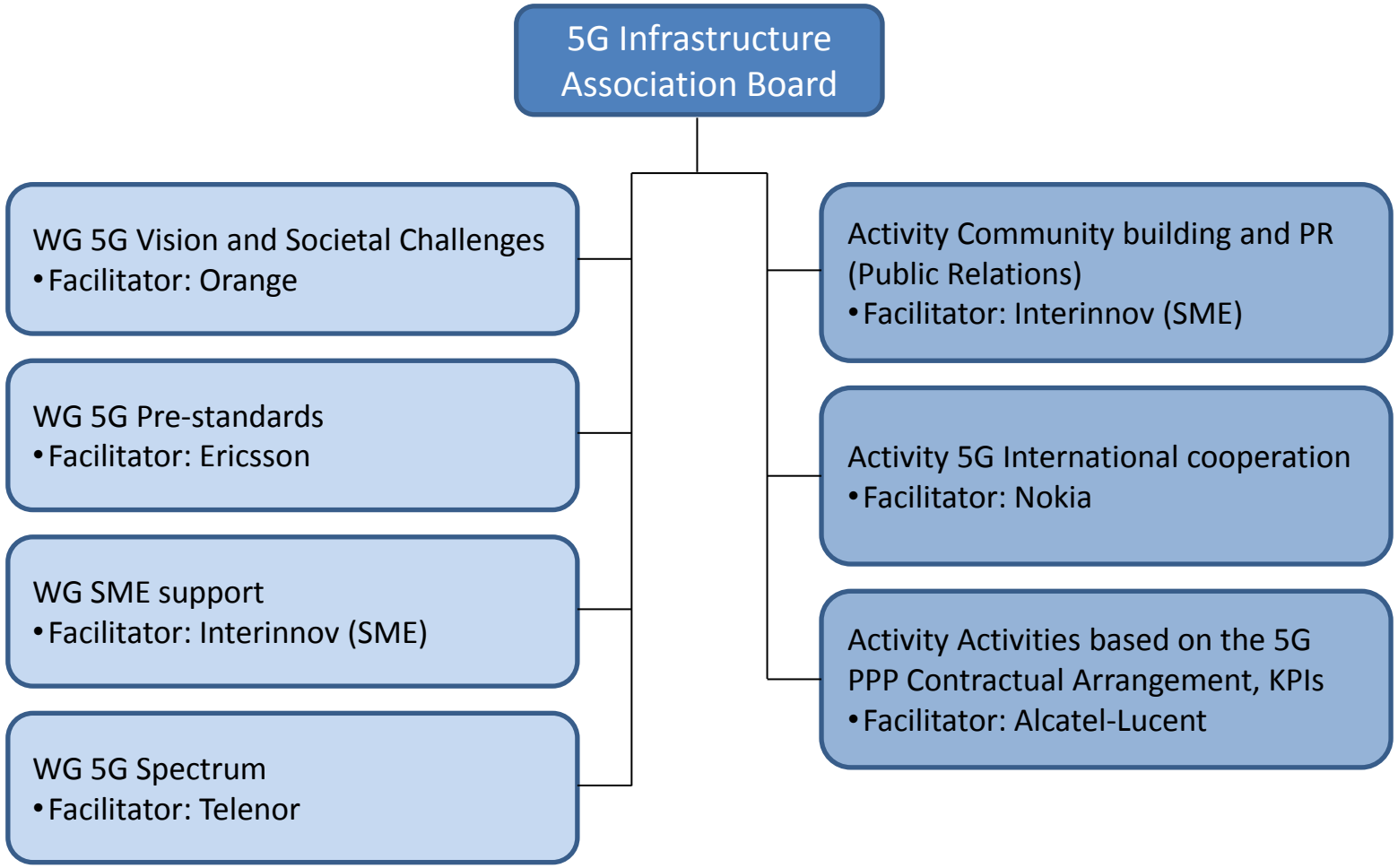
- NetWorld 2020 will support the 5G PPP by
  - the direct relation to the PPP Association and
  - the development of the SRAI for the 5G-PPP



- The Association is an international non-profit association, named "The 5G Infrastructure Partnership" 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.

5G Infrastructure Association Working Groups and Activities



Source: 5G Infrastructure Association.

Members of 5G Infrastructure Association including international dimension

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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

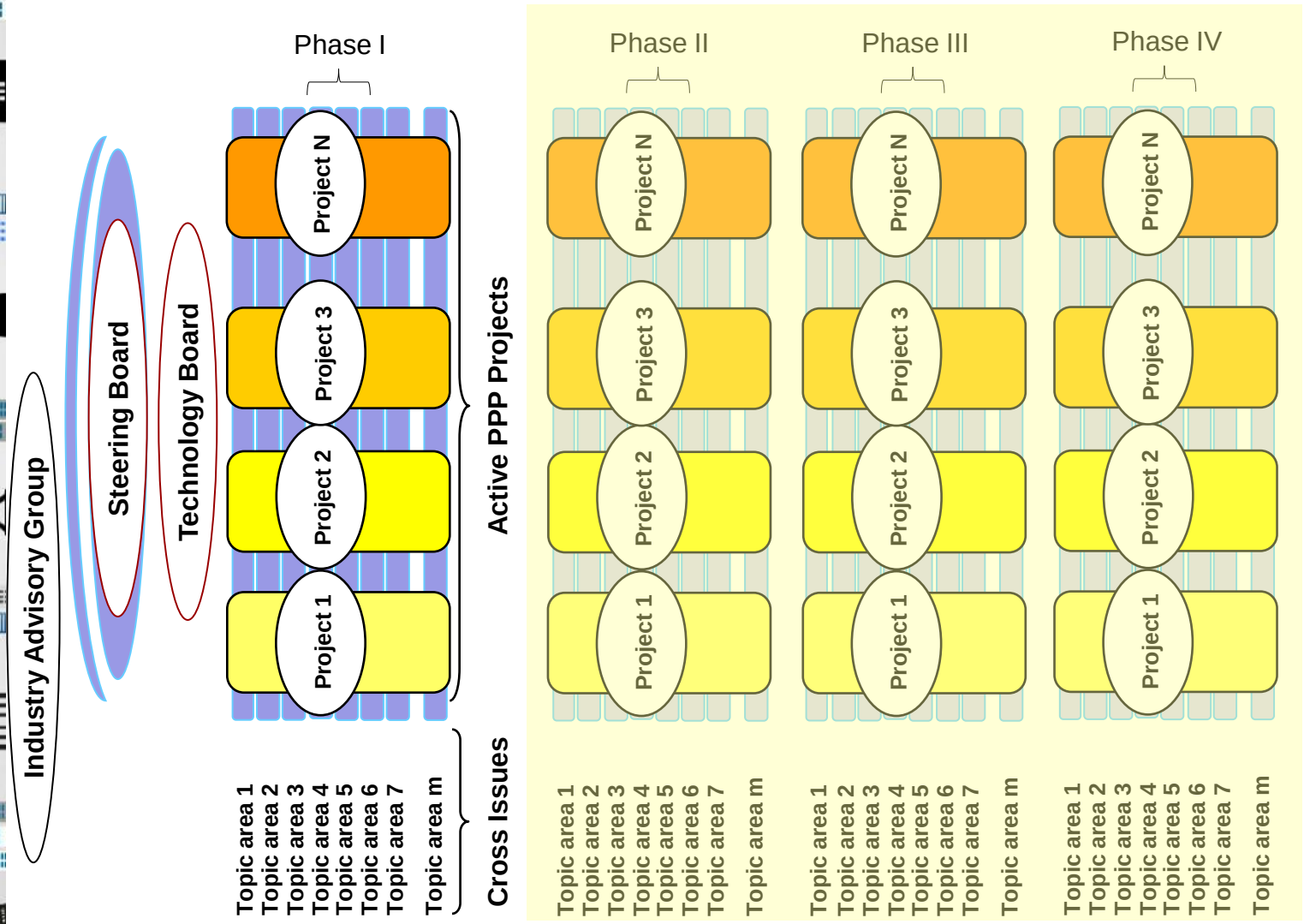
- CEA-LETI
- Centre Tecnologic de Telecomunicacions de Catalunya (CTTC)
- Consorzio Nazionale Interuniversitario per le Telecomunicazioni (CNIT)
- Fundacion IMDEA Networks
- Instituto de Telecomunicacoes
- IST – University of Lisbon
- TNO
- University of Bologna – DEI

SMEs

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

Source: 5G Infrastructure Association.

Governance model – Basic approach
Project Implementation



- Consortium Agreement per project signed by all project partners
- 5G Infrastructure Collaboration Agreement across all projects in all Phases and signed by all partners

Source: 5G PPP Annex to contractual arrangement.

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

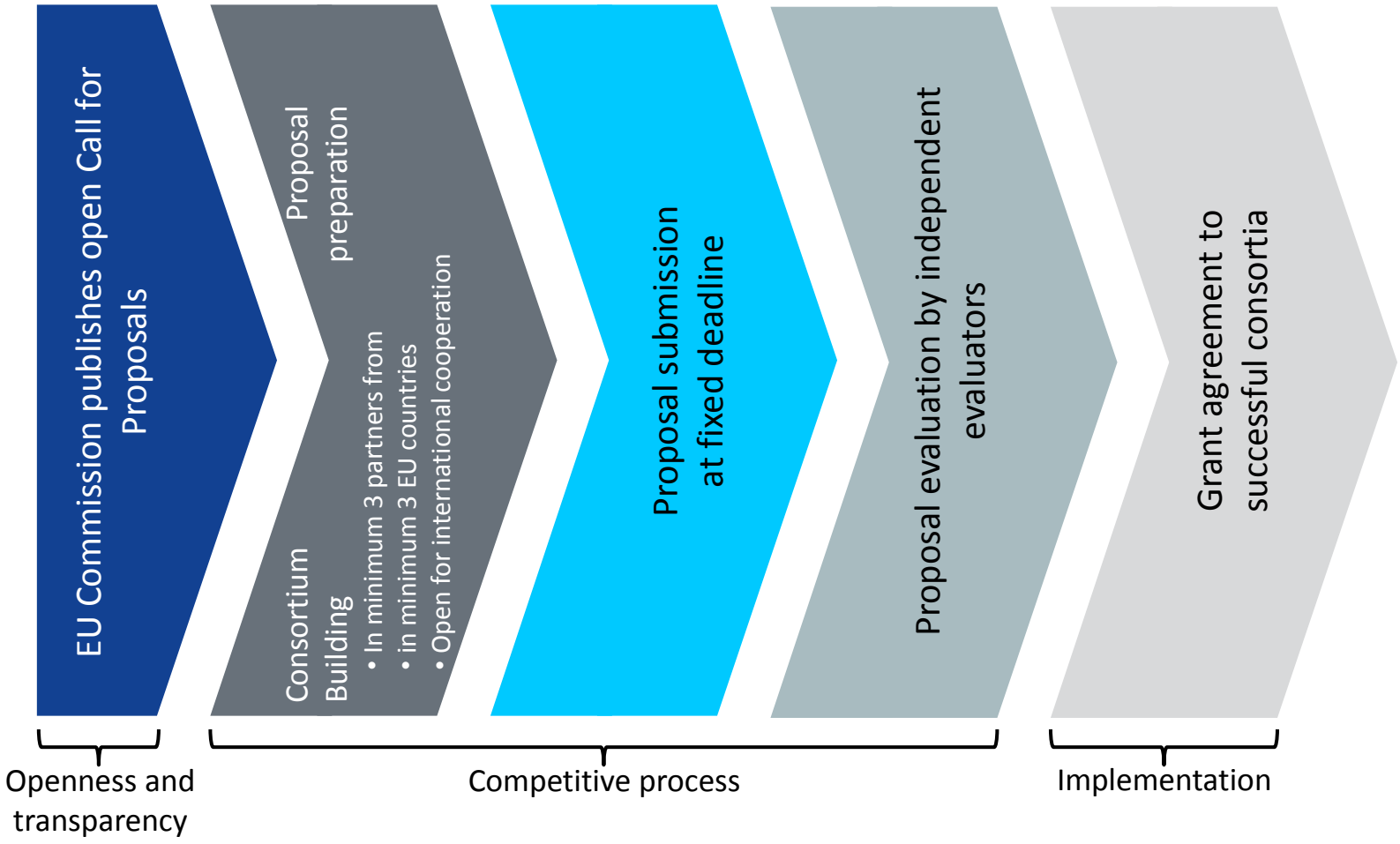
Network virtualization and Software Networks

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

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

How to start a project?
Major steps



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Source: 5G Infrastructure Association.

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

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

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**

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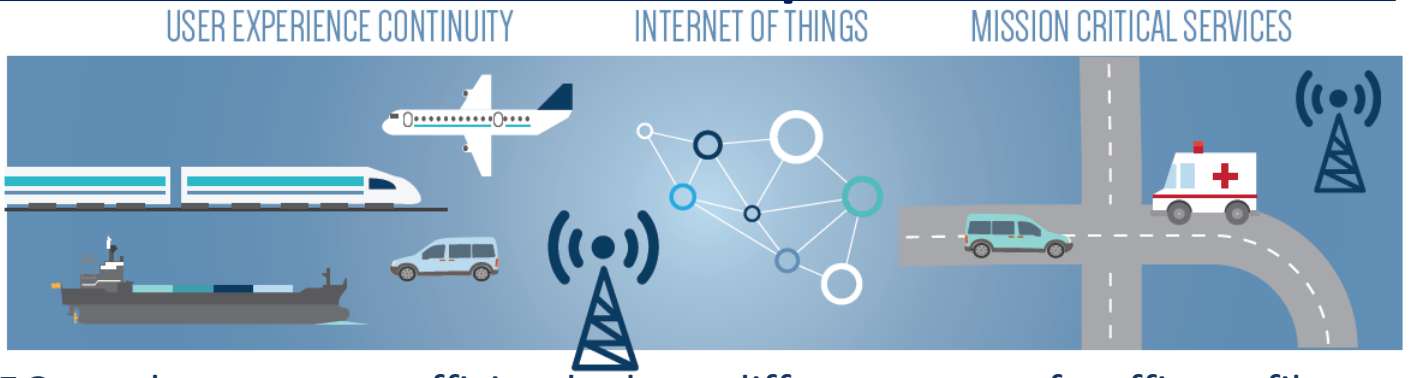
Source: 5G Infrastructure Association: Vision White Paper, February 2015.

5G PPP Vision and Requirements
5G new service capabilities



- 5G needs to support efficiently three different types of traffic profiles
  - high throughput for e.g. video services
  - low energy for e.g. long–living sensors
  - low latency for mission critical services
- 5G covers network needs and contributes to digitalization of vertical markets
  - automotive, transportation, manufacturing, banking, finance, insurance, food and agriculture
  - education, media
  - city management, energy, utilities, real estate, retail
  - government
  - healthcare
- Sustainable and scalable technology to handle
  - anticipated dramatic growth in number of terminal devices
  - continuous growth of traffic (at a 50-60% CAGR)
  - heterogeneous network layouts
  - without causing dramatic increase of power consumption and management complexity within networks
- Larger ecosystem, more open to new players, start-ups and other sectors

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

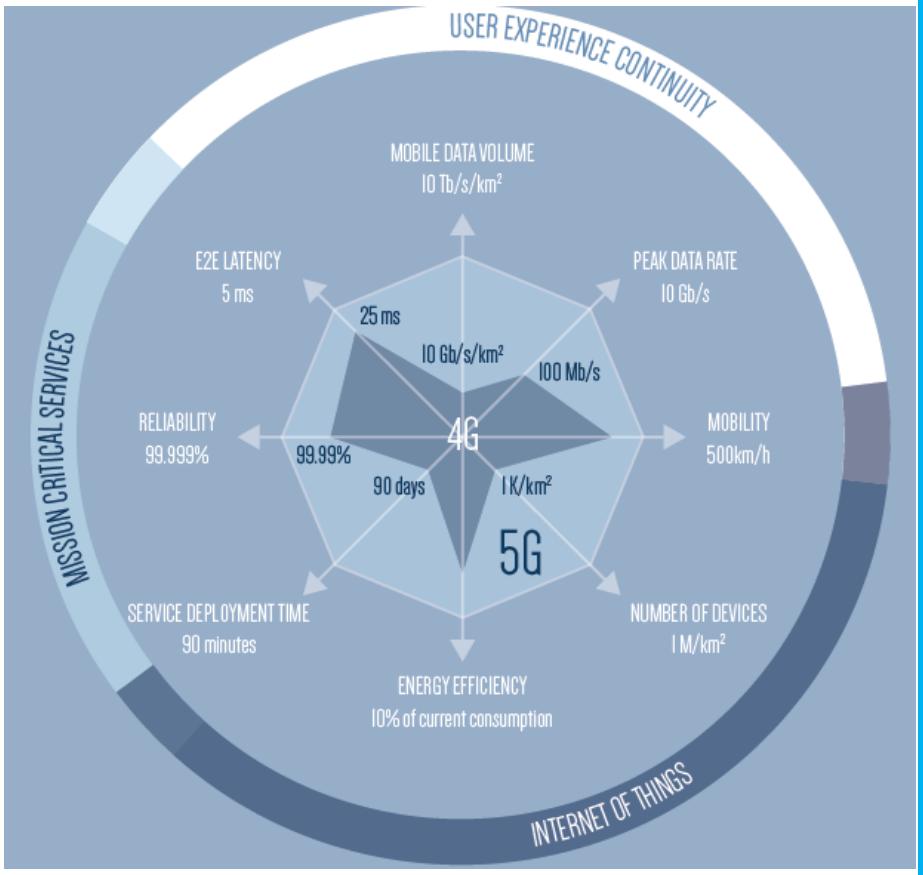
5G PPP Vision and Requirements
Disruptive capabilities

- Order of magnitude of improvement in performance in terms of
  - more capacity
  - lower latency
  - more mobility
  - more accuracy of terminal location
  - increased reliability and availability
- Connection of many more devices simultaneously
- Improved terminal battery capacity lifetime
- 5G will help European citizens to manage their personal data, tune their exposure over the Internet and protect their privacy
- More efficient 5G infrastructures in terms of
  - enhanced spectral efficiency
  - energy consumption for same amount of transmitted data
  - reduced service creation time
  - built on more efficient hardware

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

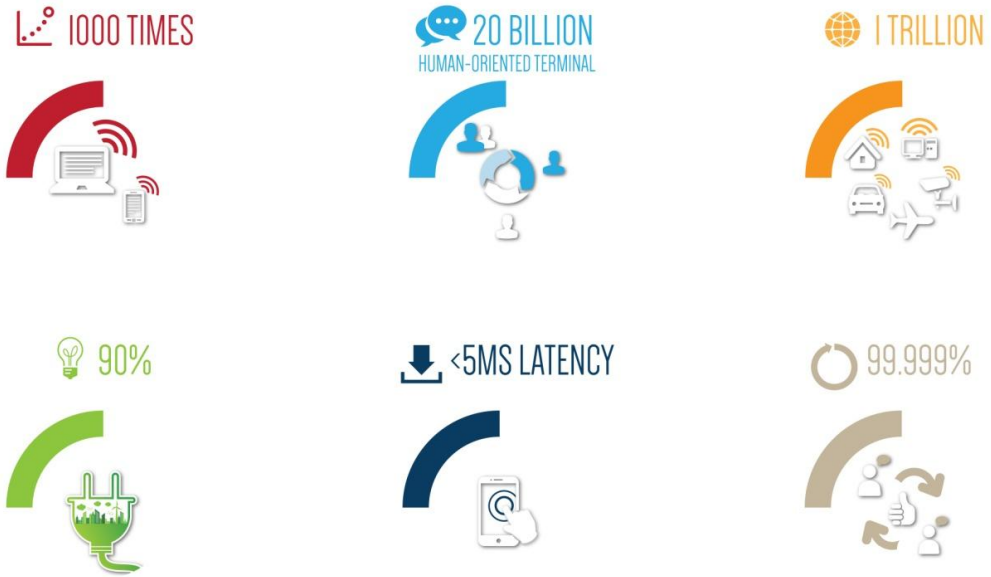
5G PPP Vision and Requirements
5G will have disruptive capabilities

- **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
Key requirements



- 1,000 X in mobile data volume per geographical area reaching a target ≥ 10 Tb/s/km^2
- 1,000 X in number of connected devices reaching a density ≥ 1M terminals/km2
- 100 X in user data rate reaching a peak terminal data rate ≥ 10Gb/s
- Guaranteed user data rate >50Mb/s
- 1/10 X in energy consumption compared to 2010
- 1/5 X in end-to-end latency reaching 5 ms for e.g. tactile Internet and radio link latency reaching a target ≤ 1 ms for e.g. Vehicle to Vehicle communication
- 1/5 X in network management OPEX
- 1/1,000 X in service deployment time reaching a complete deployment in ≤ 90 minutes
- Mobility support at speed ≥ 500km/h for ground transportation
- Accuracy of outdoor terminal location ≤ 1m

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

5G PPP Vision and Requirements
Key technological components

- 5G wireless will support a heterogeneous set of integrated air interfaces
  - from evolutions of current access schemes
  - to brand new technologies
- 5G networks will encompass cellular and satellite solutions
- Seamless handover between heterogeneous wireless access technologies
- Simultaneous radio access technologies to increase reliability and availability
- Deployment of ultra-dense networks with numerous small cells requires new interference mitigation, backhauling and installation techniques
- 5G will be driven by software and will heavily rely on emerging technologies
  - Software Defined Networking (SDN)
  - Network Functions Virtualization (NFV)
  - Mobile Edge Computing (MEC)
  - Fog Computing (FC)

  to achieve required performance, scalability and agility
- Easer and optimised network management by means of exploitation of Data Analytics and Big Data techniques
  - to monitor users Quality of Experience
  - while guaranteeing privacy

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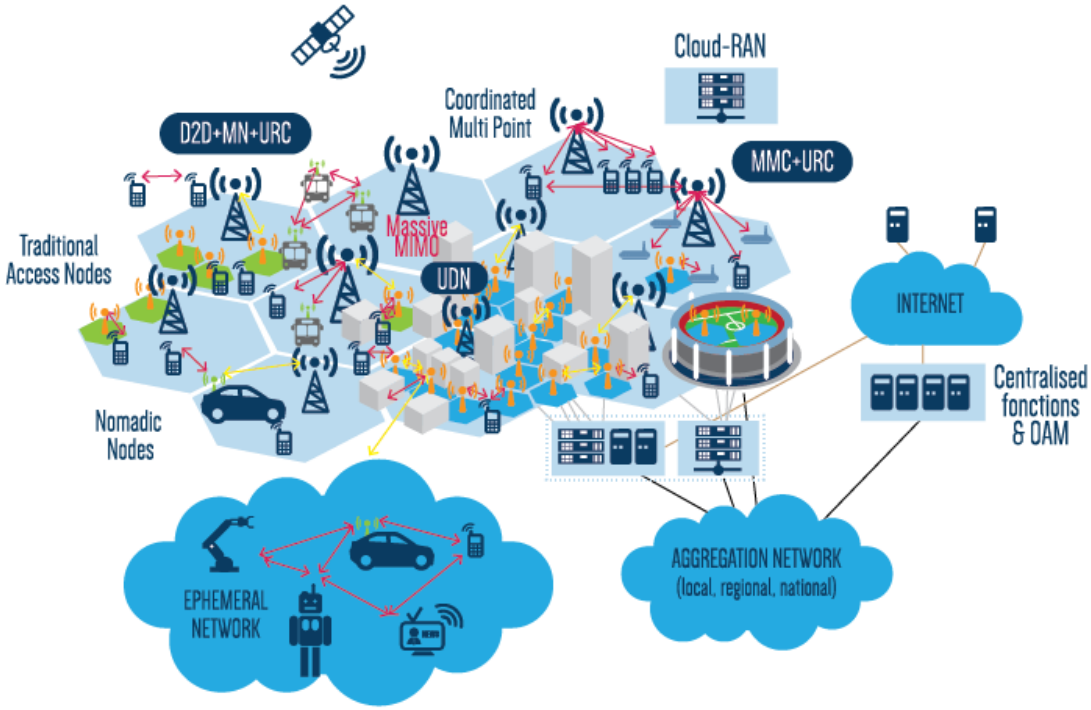
Source: 5G Infrastructure Association: Vision White Paper, February 2015.

5G PPP Vision and Requirements
Key design principles and technologies

- Key design principles
  - Small cells will be pushed further leading to Ultra Dense Networks.
  - New Radio Area Network paradigms such as Device to Device (D2D) and Moving Networks (MN) will emerge.
  - Operators of ICT infrastructures need more network and services flexibility, scalability and business sustainability.
  - 5G design need to be inspired by modern operating system architectures
  - New business models will be created thanks to open interfaces (APIs for resources, connectivity and services enablers)
- Key technologies
  - Wireless technologies will be the starting point
  - 5G will leverage on the strengths of both optical and wireless technologies
  - 5G will be driven by software
  - Efficiency and security will be of paramount importance

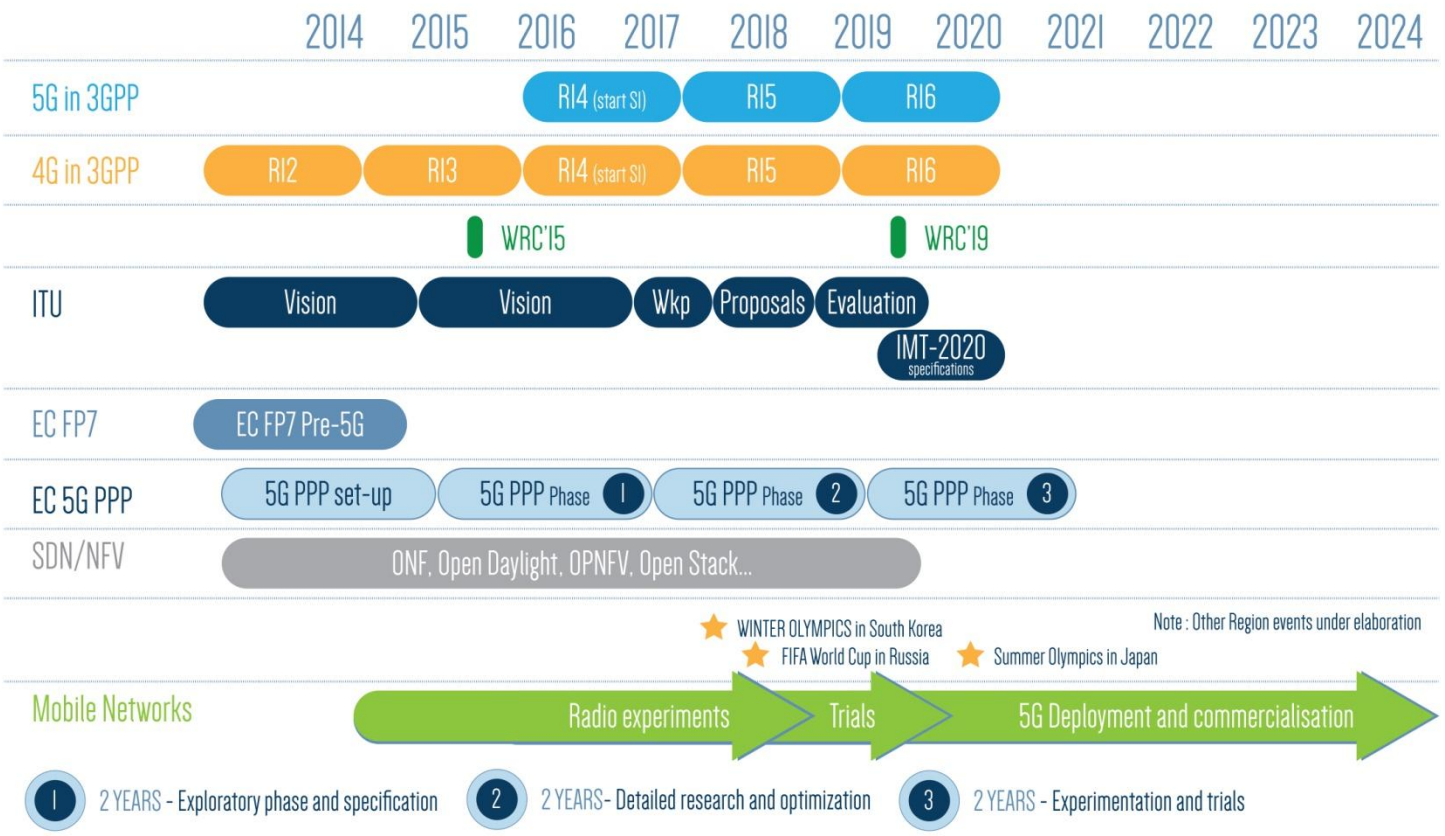
Source: 5G Infrastructure Association: Vision White Paper, February 2015.

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



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

5G PPP Vision and Requirements
5G roadmap



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

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
- Call 1 for Proposals are currently under evaluation
- Big bunch or research projects will start mid of 2015
- 5G PPP published a Vision and Requirements White Paper at MWC 2015
- Horizon 2020 is open for international participation

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http://5g-ppp.eu

Thank you for your attention!