Advanced 5G Network Infrastructure for the Future Internet

Public Private Partnership in Horizon 2020

"Creating a Smart Ubiquitous Network for the Future Internet"

In Brief

The communication network and service environment of 2020 will be infinitely richer and more complex than that of today. Our expectation is that in 2020 the network infrastructure will be capable of connecting everything according to a multiplicity of application specific requirements: People, things, processes, computing centres, content, knowledge, information, goods, in a flexible, truly mobile, and powerful way. The future will encompass connected sensors, connected vehicles, smart meters and smart home gadgets way beyond our current experience of tablet and smartphone connectivity.

There is urgency to properly address the novel infrastructure that will be needed to cater for these challenging and unprecedented growth and performance characteristics. Manufacturers, service providers and also internet players, that are operating data centres, are involved in this evolution. This will lead to redefining the value chains, reinventing the roles and relationships between the players, whilst opening new innovation opportunities. In parallel, a turning point is coming in communications networks with the progressive introduction of virtualisation and of software based network functionalities to offer the required flexibility and reactivity.

These novel network requirements, technologies and architectures will introduce a wide range of industrial opportunities for both established and new actors and also for SME's. Europe must take this golden opportunity to drive the changes and position European vendors, service providers and innovative SME's in new markets and with new offers.

Europe need to take action now to stimulate the development of this advanced network infrastructure for Future Internet to ensure the long term competitiveness of the European network industry at large and of all the industrial sectors requiring advanced ICT services as part of their competitive profile.

We propose a Public Private Partnership Programme that will deliver solutions, architectures, technologies and standards for the ubiquitous 5G communication infrastructures of the next decade. The following high level Key Performance Indicators (KPI's) are proposed to frame the research activities:

- **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.**

This annex is the result of extensive discussions between stakeholders to target a new partnership initiative by means of a Public-Private-Partnership (PPP) under the European Horizon 2020 framework to address Information and Communication Technology (ICT) Infrastructures and Communication Networks. This is a direct response to the call by Commissioner Kroes in her address at the Mobile World Congress 2013 in Barcelona for a timely initiative to further strengthen European industry's competitiveness in this area.

The preparation of this annex was supported by major organisations from the industry (manufacturers, operators), the SME and the research domain. The group is being continuously extended. Contacts to other initiatives and European Technology Platforms for cooperation in the PPP have been initiated in order to involve all in wider community and stakeholders in this activity.

Acknowledgement:

The technical part of this annex is mainly based on the Strategic Research Agenda of the Net!Works European Technology Platform[1].

Some complementary elements have also been incorporated from documents of the NESSI, ISI and the Photonics21 ETPs.

In addition, information from the ETNO/Eurescom position paper “The Evolution of Network Infrastructure towards 2020” as well as the Net!Works Expert Group “5G position paper” were extensively used. The latter was also facilitated by the EU Framework Programme 7 "NetSoc" Coordination Action.

The received comments from wide public consultation, which was launched on May 10, 2013, have been carefully examined and incorporated where appropriate.

1 On October 29, 2013 the ETPs ISI and Net!Works were restructured and formed together a new communication networks-oriented ETP. Therefore, the name Net!Works will be changed in the coming weeks.

Contents

1. Vision

1.1. Scene Setter

Communication Networks: an Infrastructure of Strategic Importance

Today communication networks are essential for all areas and sectors of our societies and economies in developed and emerging countries.

They support the many services and applications of the Internet. Critical infrastructures like energy, gas, water, transportation, health are becoming increasingly dependent on Internet connectivity. Internet connectivity is a critical infrastructure for societies and economies. It is a key enabling technology for all sectors and is making other processes and the use of resources more efficient.

The communications sector significance to the European and global economies is explained in the following Sections.

Key economic figures		Source
Global ICT market	2646 billion €	EITO, 2012
Global telecommunications market	1630 billion €	EITO, 2012
Total service revenue in Europe	275 billion €	ETNO, 2011
Mobile service market in Europe	174 billion €	GSMA, 2010
Subscribers • Mobile • Fixed broadband • Internet	• More than 6 billion • Around 709 million • More than 2.4 billion	GSMA ITU Internet Statistics
Contribution to EU GDP • ICT market • Telecommunications market	• Between 5 and 6% • Between 3 and 3.7%	Different market studies
GDP growth	• Additional up to 1.38% points in low and middle-income economies • Additional up to 1.21% points in high-income economies	Worldbank, 2009
Overall employment	• 7.2 to 7.5 million employees in Europe • (rather stable between since 2002)	Digital Agenda scoreboard, 2012

A large contribution to the European Economy

According to EITO the global telecommunications market was € 1630 billion in 2012 and has been growing in recent years. The biggest markets are the APAC region with € 497 billion followed by the US with € 394 billion and Europe with € 354 billion. Within the global ICT market of € 2646 billion, the telecommunications market is 62% while the IT market is 38%, highlighting the significance and scale of these sectors.

The global IT spending will grow in the coming years (Figure 1). The telecom services market continues to be the largest IT spending market. Gartner analysts predict that this market will be predominately flat over the next several years as revenue from mobile data services compensates for the declines in total spending for both the fixed and mobile voice services markets. By 2016, Gartner forecasts that mobile data will represent 33% of the total telecom services market, up from 22% in 2012.

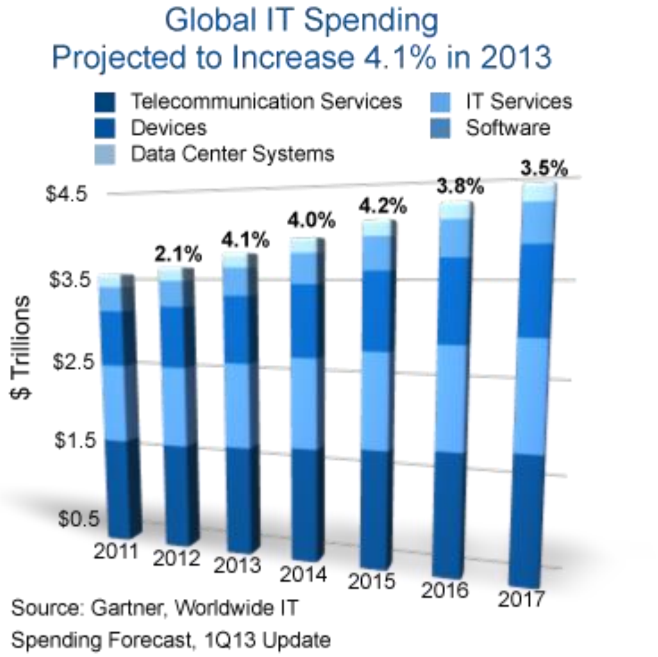

Figure 1: Global IT Spending [Gartner]

ETNO figures indicate the total service revenue for 2011 in Europe was about € 275 billion. On the mobile communication market, GSMA indicates that the service market in Europe reached a total revenue of € 174 billion in 2010, which is comparable to the aerospace industry and larger than pharmaceuticals. It corresponds to 1% of the total European Economic Area (EEA). The net sales of the 10 major European companies in the telecommunication equipment sector reached about € 85 billion in 2011 (source: JRC).

The ICT generates between 5 and 6% of the EU GDP, within which the telecommunications market ranges from 3.0 to 3.7%.

The overall employment figure has been rather stable between 7.2 to 7.5 million employees since 2002 (Source: Digital Agenda Scoreboard). The employment trend is however influenced by convergence between the IT and the telecommunications sectors, with an expected significant increase of jobs in the IT domain enabled by a pervasive, broadband and mobile underlying network infrastructure. From that interrelated perspective, the communication domain is central to economic growth and job creation, also in downstream sectors.

The sector is contributing approximately € 65 billion to European public funding (taxes) plus additional 18 billion € from related industries.

From a strategic perspective it is thus essential for Europe to maintain and strengthen the sector by continuous innovation and to increase the know how in order to keep a strong position in a strategically important market. The communication industry in Europe has a strong position and is well positioned in global competition, due to significant research and innovation investments. Other regions like China, Japan, Korea and the US have recognised the strategic nature of this domain and have initiated huge research activities to define the networks of tomorrow. Also, the strategic nature of the communication sector extends beyond its sole industrial domain as the boundaries with the IT domain tend to blur.

Enabling Additional GDP Growth and Jobs

The Worldbank has studied the impact of broadband communications on economic growth in developed and developing economies for different network systems like fixed networks, mobile communications, Internet and broadband communications. Increased broadband penetration can create additional GDP growth of up to 1.38 % points in low and middle-income economies. In high-income economies the effect is slightly smaller with 1.21 % points of GDP growth. OECD confirmed these trends.

As an example broadband investments in Germany between 2010 and 2020 are expected to add € 170.9 billion to GDP and 968,000 jobs. Similar effects can be expected in other European countries. In a similar study performed already in 2004 by Deutsche Bank estimated a significant contribution to job creation in Europe by means of mobile communication systems.

Facing an ICT Paradigm Change

Communication Networks have evolved dramatically over the past decades. In the nineties digital mobile communications were introduced, ADSL technologies have matured and more recently, at the beginning of this millennium, massive deployment of broadband fixed access, followed by mobile and full IP architectures, have nurtured the development of the Internet ecosystem. Europe has been a key player on the related technologies, and particularly in the mobile domain. This evolution will continue and even strongly accelerate over the next decade considering the ever growing needs of users and varieties of applications and environments to serve.

The anticipated variety of new professional usages brings in new requirements on availability, latency, reliability, trustworthiness and security. This demands new approaches to networking, with networking features and functionalities much more closely embedded with the applications (incl. critical physical and industrial processes) than today.

In parallel, users will be more and more demanding in terms of contents and service requirements, whilst getting increasingly sensitive to privacy and sustainability issues. These requirements will impose very strong constraints on networks and service platforms.

As a consequence, new network approaches are required by 2020 to serve the growing demand and face the associated challenges:

- How to handle the explosion of the traffic and provide the necessary capacity, spectrum;
- How to flexibly accommodate novel classes of services (IoT, M2M, or content based, and others which are not known today) whilst keeping low CAPEX and OPEX?
- How to make the Internet a ubiquitous and dependable infrastructure in mobile, wireless and fixed communications?
- How to guarantee the Quality of Service, including security / privacy needed for professional usages over the Internet?
- How to make the communication critical infrastructure as resilient as required by consumers of interconnected critical infrastructures such as smart grid?
- How to get energy consumption reduced by 90%?

It can be anticipated that the today's artificial separation of the fixed and mobile networks will disappear, with capabilities and performances of mobile networks becoming similar to those of fixed networks in terms of capacity and services diversity. This will in turn require innovative architectural approaches for mobile networks and a proactive approach to solve the anticipated capacity and spectrum crunch.

The convergence of telecommunications and IT systems in future networks will also result in open platforms, which will enable new opportunities for innovation and new business models, especially for the SMEs. This will in turn require more systematic adoption of software defined networking (SDN) concepts to adapt future networks to new requirements allowing continuous and fast innovation cycles in the communication infrastructures and in the Internet. Similarly, equipment virtualisation as widely practiced in the IT domain, is seen as a promising approach in decreasing costs, using the networking resources more efficiently and in gaining necessary flexibility.

Future 5G networks will be significantly different from today's networks. It takes on average 10 years to develop a new generation of network infrastructure. Maintaining and enhancing the competitiveness of the European communications industry at large in the long term require starting ambitious research and innovation actions now. This is also critical to ensure the competitiveness of all the industrial sectors that use advanced ICT networked services to keep a competitive advantage.

1.2. Actors behind this Annex

The Net!Works European Technology Platform (ETP) (http://www.networks-etp.eu/) has been the natural founding constituency to building the present 5G Infrastructure PPP and in fostering the involvement of a wide community. In the past, Net!Works has already developed a series of annually updated Strategic Research and Innovation Agendas (SRIA) and the latest publicly available version of the SRIA has been a basis to this document.

This annex relies on the rich and diverse expertise inherent to the actors of the Net!Works ETP community, including industry network operators and manufacturers, SMEs, Research Centres and Universities. As of today the Net!Works ETP counts nearly 900 members across Europe. Figure 2 shows the composition of the Net!Works membership with a strong representation from the SME and research domain.

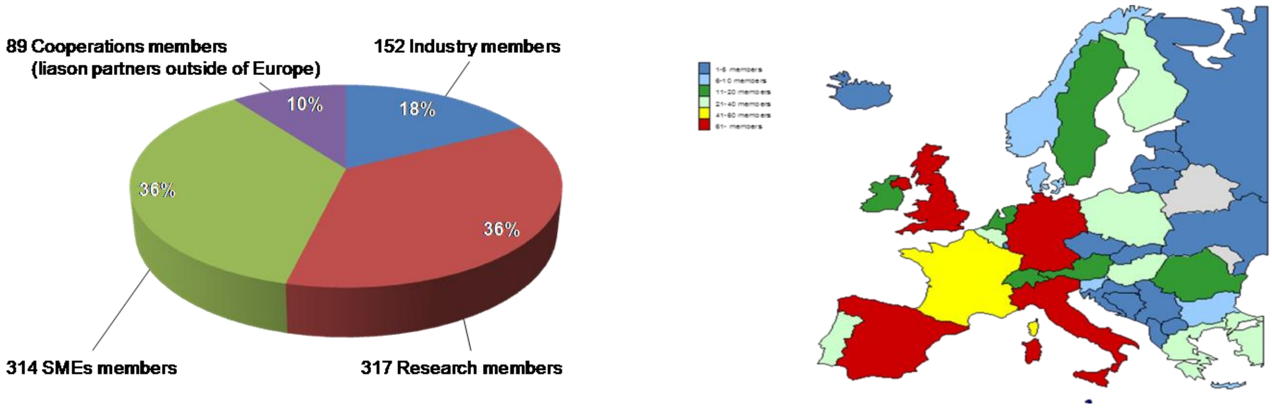

Figure 2: Net!Works membership versus stakeholder groups and countries [Net!Works ETP]

In addition, ETNO (European Telecommunication Network Operators) (http://www.etno.be/), representing a membership of 37 operators (http://www.etno.be/home/about-us/members) is supporting this annex.

The organisations supporting this annex are the major European ICT sector representatives with the capability to make the Internet economy happen. The industry partners in this group have a significant global market share in their area of business. All these players have a long history in the last decades in collaborative research projects on European level on 3G/UMTS, LTE and IMT-Advanced and beyond, optical and broadband access systems, and in particular have been actively involved in collaborative research projects on European level and in the development and standardisation of all major communication network systems and standards. Based on this research huge investments were made for development and deployment of these systems globally. It is intended to build on this success and the valuable experience gained in pre-competitive collaborative research.

This group is open and has continuously been extended in the preparatory phase of the 5G Infrastructure PPP in Horizon 2020 through the addition of organisations from industry (manufacturers and service providers), from the SME domain and from the research community. Additional organisations from the implementation domain (e.g. ARM, STMicroelectronics), and from microelectronics and RF technology are also being approached in order to ensure that new concepts and systems will be embraced by the whole industry in Europe, so as to ensure its industrial feasibility.

In particular, the SME domain is expected to provide a significant contribution to the emergence of innovative technology solutions. It is therefore important to ensure a reinforced SME participation to meet the ambitious goals.

There are different means which are considered to involve SMEs in the PPP in an efficient manner, depending on the various types of SMEs:

- SMEs that naturally come with the ecosystem of large players: The ecosystem will depend on each company and its structure. Each player has to define, which part of its ecosystem should be introduced into the PPP activities.
- SMEs that intervene independently of established links, but are attracted by the upstream research topic: Dedicated information days for SMEs will be organised ahead of upcoming calls for proposals and open calls in ongoing projects in order to present areas and possibilities for involvement in project proposals and ongoing projects. Representatives from SME organisations from the Net/Works ETP, EIT ICT Labs and other SME organisations in the Association will be asked to support such activities.
- SMEs that emerge as developers, or using opportunities offered by the new technology at testing validation level: A similar approach like in FI-PPP Phase III will be applied. Trial systems will be made available for software and application developers. This will happen either by the direct involvement in projects as partner or according to Special Clause 42 in FP 7 by means of small contracts for dedicated tasks. The experience from FI-PPP will be taken into account.
- It is expected that SME participation will increase during the lifetime of the programme in particular in later phases, where software and applications will be developed based on the provided platform and/or for trials. The overall average SME participation under this initiative will be in the order of 20 % of the resources.

It will also be critical to get users onboard timely in order to reinforce the user perspective in the PPP for the introduction and acceptance of new technology. The following steps will be implemented by the PPP Association and the 5G PPP governing bodies:

- The FI-PPP Phase I[2] "use case" projects were already aimed at collecting requirements in ICT systems from different application domains. This information is publicly available and can be used as basis for the support of vertical sectors. The FI-PPP Programme Chair will be invited to be an Associated Member of the PPP Association in order to represent the use case communities, which are supported by the FI-PPP.
- The PPP will establish formal links to application sectors like energy, health, transport etc. from FI-PPP will be used as well as from use case workshops, which are organised in the context of the FP7 NetSoc project and similar future activities.
- The PPP will also establish links to the Living Labs programme (http://www.openlivinglabs.eu/) to collect user requirements on ICT systems.
- The PPP will establish links to EIT ICT labs.
- The existing ETPs, among those which represent relevant application domains, will be approached to send representatives to be members of the PPP Association. The officially recognised ETPs by the EU Commission (status July 12, 2013) are available at http://cordis.europa.eu/technology-platforms/individual_en.html. According to the following table from the Cordis Website the following ETPs and JTIs are candidates for cooperation:
    - Energy: EU PV TP, TPWind, SmartGrids
    - Environment: WssTP
    - ICT: ARTEMIS, ENIAC, EPoSS, ISI, NEM, NESSI, Photonics21

[2] FI-PPP = Future Internet PPP (Ongoing initiative)

- To be further evaluated sectors: Bio-based economy, Production and processes and Transport.

Set of all Individual ETPs

Bio-based economy	Energy	Environment	ICT	Production and processes	Transport
EATIP	Biofuels	WssTP	ARTEMIS	ECTP	ACARE
ETPGAH	EU PV TP		EUROP	ESTEP	ERRAC
Food for Life	TPWind		ETP4HPC	EuMaT	ERTRAC
Forest-based	RHC		ENIAC	FTC	Logistics
Plants	SmartGrids		EPoSS	SusChem	Waterborne
FABRE TP	SNETP		ISI	Nanomedicine	
TP Organics	ZEP		Net!Works	ETP-SMR	
			NEM	Manufuture	
			NESSI		
			Photonics 21		

Cross ETP Initiatives
Nanofutures
Industrial Safety

The following user groups should represent the main part of the future demand:

- Network operators, which will deploy and operate respective systems.
- Application and content providers i.e. OTT and vertical sectors will use new network technology for specific applications. For these purposes novel classes of services (IoT, M2M, or content based, and others which are not known today) have to be accommodated to enable cooperation mechanism between Internet Service Providers and application/content providers for the optimal use of resources (bandwidth, computing, storage, energy, ...)
- End users of new technologies will provide views on their needs and on the acceptance of such new systems. Consolidated views from end users will be best received from end user associations (e.g. European Association for the Coordination of Consumer Representation in Standardisation (ANEC) http://ec.europa.eu/consumers/empowerment/cons_networks_en.htm#euro.

All these different groups will be represented in a Stakeholder Board, which will be organized by the PPP Association. The Stakeholder Board has the objective to discuss different views from different groups and sectors for consideration and integration into the roadmap in order to get support from the constituency. This Board will meet every 6 months either physically or in conference calls. Details on the procedure for the involvement of different groups and decision making are described in Section 4.

It is expected that the development of 5G systems will be based on an ecosystem of a close cooperation between industry, SMEs and the research community to develop innovative solutions and to ensure the acceptance and exploitation of these solutions in global standards and markets.

Industry will play a major role in the PPP with respect to the necessary long-term investment in global standardisation and the integration of all technological contributions into complex interoperable systems. Communication network manufacturers and communication service providers contribute significantly to the research and development of new global systems and standards. The continuous dialogue between both stakeholder groups is essential to define appropriate new system capabilities with respect to user experience and cost.

The private sector (industry and SMEs) in Europe supporting this annex has the strong intention to strengthen the communication sector in the development of future 5G networks as well as to maintain the high global market share in cooperation with the research community. European headquartered ICT companies had a global market share in 2011 of more than 43 % (Figure 3) and the ambition is to improve this share for 5G infrastructures.

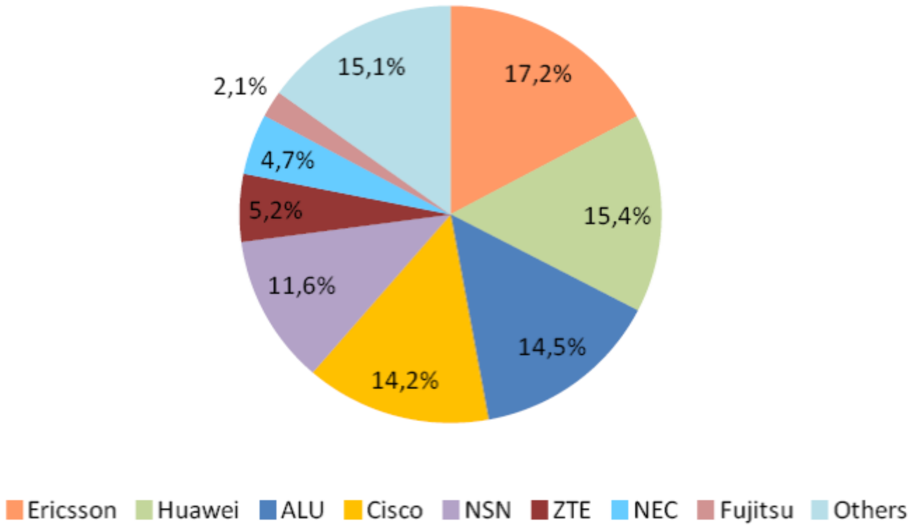

Figure 3: Global market share of major communication network vendors, 2011 [OVUM]

According to a study of the EU JRC the telecommunication sector is one of the most research intense sectors with R&D spending of about 14 % of total revenue. The following Figure 4 displays the ranking of the top 20 R&D companies in the communication equipment sector by the total R&D investment and is clearly highlighting the position of members of the group of supporting organisations from a global perspective.

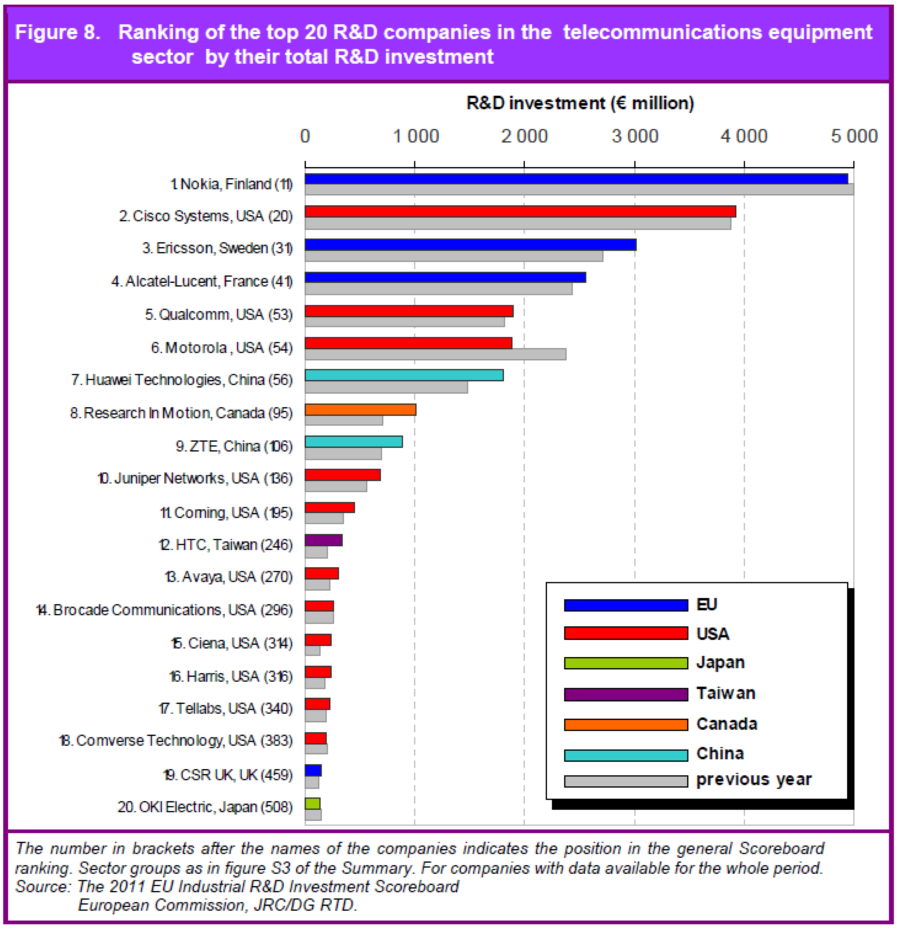

Figure 4: Top 20 R&D companies (Nokia Solutions and Networks is consolidated in the Nokia figures) [EU Commission]

Although service providers are less R&D intensive than manufacturers (2 % versus 14 %), European service providers are very well positioned compared to those in the US and Asia. Figure 5 shows the research intensity of different stakeholders in different regions of the world.

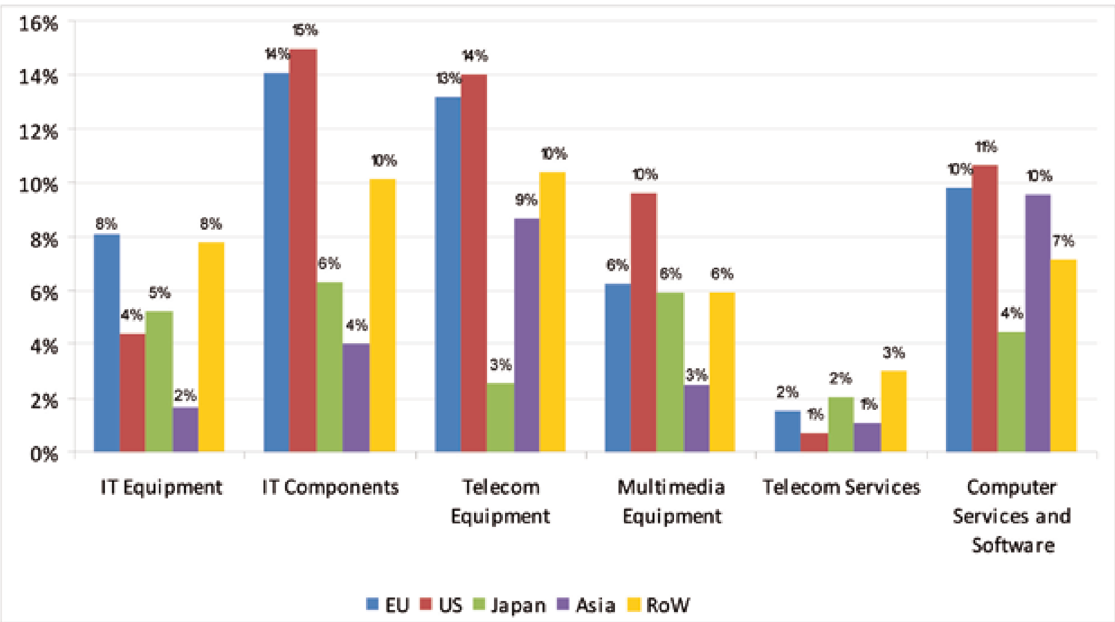

Figure 5: Research intensity of stakeholders [EU Commission, Joint Research Centre, 2011]

A growing community for the Future Internet

It is expected that this annex will serve as the foundation for the further implementation of the PPP, which will be industry driven.

The number of organisations having contributed / contributing to relevant European research is nearly 500. The evolution of this annex has not been limited just to Net!Works members. The PPP is open to any organisation active in the technical scope of this PPP. For instance, related sectors like micro-electronics and the IT domain are being actively approached to complement the necessary expertise.

The proposed governance of the PPP and the liaison to the ETP are detailed in Section 4.

1.3. Added Value of Action at Union Level

Synergy and critical mass for competition on global basis

The communication sector is one of the most research intensive sectors in industry.

European industry has been historically strong in research, development and integration of complex systems like communication networks. A wide spread and well established research community in R&D centres and universities are cooperating with industry and SMEs for knowledge and IPR generation. In addition, communication networks are increasingly using software technologies. However, know how is also required in hardware and RF design as well as in manufacturing technologies for equipment, network planning and operation.

Many systems are expected to be based on standardised hardware. This provides many advantages such as: Manufacturing of some parts close to target markets, close contact to local customers, reduced transportation cost, and help in overcoming trade barriers and potential risks of currency exchange rates. However, it is essential that some critical parts of communication networks, such as system software and special hardware components, which are considered as means of differentiation between products and global competitors, are designed and manufactured in Europe.

The technology shift from hardware-oriented systems in the past towards software- and signal processing-dominated systems today require different skills. **These skills will be developed by fostering a closer cooperation between the communication and IT industries as well as by having these industries joining forces with the research community in universities and R&D centres in Europe.**

This will further strengthen Europe in providing integrated multilayer solutions for the global market. Higher skilled jobs in this industry will be created as well as in the system design and the development of innovative applications. Therefore, the efforts should be focused on the development of such new skills in system and solution designs through major investment in education. An appropriate environment should be created to attract private sector investments. In this domain Europe is in a strong position to compete on a global basis.

To that end, cooperation at European level is essential due to the distributed research and development activities of major companies across Europe and the strong European research community in this domain.

Consensus building for standardisation

The development of new communication networks is dependent on the emergence of globally accepted standards in order to ensure interoperability, economies of scale with affordable cost for system deployment and end users. **Therefore, it is essential that major players, who are usually based with their headquarter organisations in different European countries, join forces and cooperate in the early phase of research to develop new concepts, systems, technologies and algorithms that can later be transformed into global standards.** This helps consensus building in the pre-competitive phase, which will be exploited in global standardisation under the conditions of global competition. Experience has shown, e.g. for LTE and IMT-Advanced, that such early cooperation is very efficient in the preparation of future standardisation

Technology sovereignty and security

With respect to the fact that communication networks are increasingly considered as a critical infrastructure it is essential for Europe that system research, development, knowledge creation and IPR generation are performed in Europe. All critical parts of system design need to be developed in Europe in order to have full access to the technology.

In addition, cooperation at European level by means of a PPP provides benefits to all stakeholders like:

- A one-stop-shop for a European initiative for international cooperation and international relations regarding third country initiatives in this field.
- An early identification of the roadblocks for system deployment at EU level, including regulatory, spectrum, standards and market take up conditions. In particular standardisation is key to ensuring the needed interoperability levels for communication networks, whose deployment footprint is, by nature, global.

This will not be possible by only relying on national basis, because major players could then merely cooperate via their national subsidiaries, which may not be in the position to align standardisation strategies efficiently compared to cooperation on European level. It should also be considered that counterparts in global competition are coming from other regions with huge domestic markets. In order to provide stakeholders from Europe a similar opportunity and ensure comparable impact, cooperation on European level would provide a similar size of resources and strength as in other regions.

1.4. Added Value of Implementation via a Contractual PPP

A new partnership initiative will provide a research environment allowing for inclusive research areas. From an industry perspective it is important to promote research in the pre-competitive domain, e.g. to develop early consensus on technologies and architectures, as well as to prepare future standardisation. It will also drive the optimum use of the different instruments available at EU-level which should be selected depending on the topic and activity and where it is located on the innovation cycle.

The benefits of using a Contractual PPP approach are as follows:

- Secured commitment of industry and EU Commission, including funding and investments, to meet critical societal and industrial policy objectives.
- Long-term continuity of activities in order to achieve originally set long-term (pluri-annual) goals and targets. It takes on average 10 years to develop new communication network standards including regulatory conditions and to make new frequency spectrum available. Though this is accelerating with the introduction of software platforms, the framework programme time span is fully compatible with the development of a new generation of networks and systems.
- Building on the past success of the pre-competitive collaborative research projects in Framework Programmes 6 and 7 (FP6 and FP7) towards the development of globally accepted communication network standards.
- Cooperation between different research projects in order to address a holistic system perspective, e.g. enable cooperation for interfaces definition between different network elements and entities, etc.
- Efficient management: Leaner and faster organisation and governance of new projects under the PPP umbrella, obtaining the benefits from a formalisation of the partnership (less time to set up, reduced costs, less legal and administrative burdens) without the

efforts of an institutionalisation, when the necessary legal framework for cooperation across projects is put in place by the PPP structure.

- Openness to the participation of a wide stakeholder group, including newcomers and smaller players, in transparent procedures, public consultations and open competition, and enabling also a wide inclusion of particular experiences from all EU countries.
- Emphasis on defining clear directions and priorities through roadmaps which have gained wide consensus through the activities of the underpinning European Technology Platforms.
- Appropriate structuring of programmes and individual projects in order to guarantee adequate coverage of all research priorities and provide potential synergies in order to enable the pre-determined targets and milestones to be achieved.
- High degree of accountability, through the continuous review and monitoring of progress over the course of Horizon 2020, being a clear task of the PPP, using the roadmaps.
- Greater focus on the integration of supportive measures like standardisation or training and education through dedicated actions.
- Greater flexibility and agility, capable of responding more rapidly to emerging opportunities in terms of technological development on one hand and to unforeseen, adverse conditions and a shifting economic situation on the other hand.
- More opportunities for creating coherence and complementarities with the diverse landscape of member states funding policies in the field.
- More coordinated approach between EU players to take part in the global consensus building.

The partnership initiative will be optimally realised using a set of different instruments and phases in order to enable both a shift of focus and change of activities throughout the lifetime of the overall initiative, and through this follow developments towards technology maturity, close to standardisation to ensure future market adoption and take up of results.

A well designed PPP will provide a more stable environment towards 2020 with respect to research topics and budget allocation in order to implement an agreed research programme based on a publicly accepted SRIA (Strategic Research and Innovation Agenda).

Finally, a roadmap based PPP allows to plan early in the process the downstream technology validation and exploitation activities which are needed to realise the innovation objectives targeted by both the public and private entities.

1.5. Overall Long Term Vision of the PPP

The communications environment of 2020 will be infinitely richer and more complex than the networks and services of today. Our expectation is that in 2020 the network infrastructure will be capable of connecting everything according to a multiplicity of application specific requirements: People, things, processes, computing centres, content, knowledge, information, goods, in a flexible, truly mobile, and powerful way. The future will encompass adhesive sensors, connected vehicles, smart meters and smart home devices, i.e. much more than just tablets and smartphones. We must now anticipate these unprecedented growth and performance characteristics and start the revolution in terms of infrastructure that will be needed to cater for these explosive scenarios.

With more than 2.4 billion users globally (as of June 2012) Internet usage is relentlessly growing. A key trend relates to mobility, as broadband **mobile** usage is expected to be dominant over the coming years. For data traffic and M2M communications, we expect a 40-fold increase between 2010 and 2015 (Figure 6) and a 1000 fold increase over a decade. These developments demand rethink of network designs, to support ubiquitous broadband access to all kinds of heterogeneous and customised Internet based services and applications. Another important driver is the development of M2M communications for many application domains and in particular in vertical sectors.

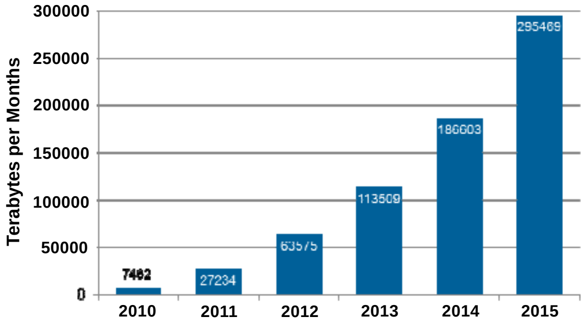

Figure 6a: Machine-to-Machine traffic to increase 40-fold between 2010 and 2015. [Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2010 – 2015]

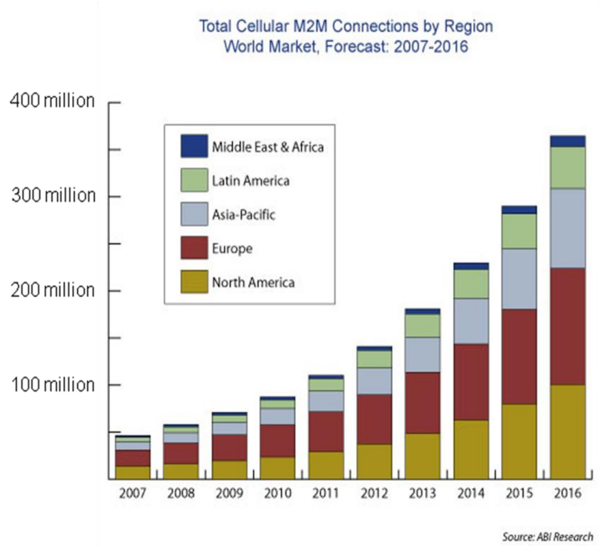

Figure 6b: The market for cumulative cellular M2M connections will rise from about 110 million connections in 2011 to approximately 365 million connections by 2016. [ABI Research]

Drivers of the Future Internet are all kind of services and applications from low (sensor and IoT) to high throughput rates (e.g. high quality video streaming) and low to high latency and for a variety of devices supporting these services and applications. Different innovation cycles (of several months in the services and applications domain, of several years for radio networks) imply that networks cannot be designed based on pre-established requirements. It is necessary to make challenging working assumptions on major basic technical requirements based on today's best knowledge in order to meet the needs in the 2020 time frame. To a certain degree software based systems will provide the flexibility to adapt to new requirements and make it easier to introduce innovation into deployed systems. Flexibility in technical requirements and the system design is key to enable further innovation and to meet unforeseen future service requirements. Therefore, from the long-term vision perspective future systems have to offer high flexibility in data throughput, mobile ubiquity and have to allow for very low latency and adaptability to new schemes. In particular, popularity of video based applications is increasingly demanding for more available bandwidth or data throughput. On the other hand emerging augmented reality services pose stringent constraints in latency. Sensor data, actuators and IoT systems may require an efficient support of very low data streams and highly bursty signalling and data traffic.

The ever-increasing demand from customers and M2M systems will impact the network, and new technologies will be introduced for transmission, (broadband) connectivity, switching, routing, naming/addressing, storage and execution.

Our vision is that in ten years from now, telecom and IT will be integrated towards a common very high capacity ubiquitous infrastructure, with converging capabilities for both fixed and mobile accesses. It will be massively based on general purpose, programmable and specific high performance hardware that will offer resources for transport, routing, storage and execution. Network elements will become "computing equivalent" equipment that gathers programmable resources, interfaces and functions based on virtualisation technologies.

Some key points of future 5G networks can be highlighted:

- Future 5G networks will not only be based on transport and routing/switching technologies anymore. They will be more flexible and open, able to evolve more easily than today's networks and also embed sensing, computing and storage resources in a converged infrastructure to orchestrate the delivery of services in a secure manner.
- Future 5G networks will cooperate with satellite networks, home networks and devices and will be able to adapt their behaviour depending on user's or terminal's contexts. They will be able to manage access selection in order to provide dynamically the best available network.
- Optimal performance needs planning and implementation from both network and end user device point of view. In future there will also be numerous other devices than end user devices. Therefore we also need to ensure optimal functioning of capable end user devices and high amount of other connected devices.
- Security will be a key requirement of future networks where embedded security will be embraced as general concept. Also, resilience to threats and robustness in emergency scenarios need to be embedded in the architecture.
- Future 5G networks will have to provide a significantly higher system capacity than today and solve the anticipated spectrum crunch.
- Future 5G networks should be based on common network management for mobile and wireless as well as the fixed network for economic network deployment and operation.
- In addition, future 5G networks will be able to satisfy a multiplicity of requirements originating from "vertical sectors" with multiple use cases originating from different application sectors. The current Future Internet PPP of the EU Commission in Framework Programme 7 offers a platform to collect such requirements.

The following topics for the development of the 5G Infrastructure PPP are identified:

1. **Faster, more powerful and more energy efficient solutions for integrated high capacity access, core and data centre networks for a wider range of services**
    - Wireless networks
    - Optical networks
    - Automated network organisation - network management and automation
    - Implementing convergence beyond the last mile access
2. **Re-designing the network**
    - Information centric networks
    - Network Function Virtualisation
    - Software Defined Networking
    - Networks of clouds
3. **Ensuring availability, robustness and security**
4. **Ensuring efficient hardware implementations**

These topics will be further detailed in the Section 2.1 of this document.

1.6. Strategic and Specific Objectives of the PPP

The 5G Infrastructure PPP has its roots in the Industrial Leadership Priority in Horizon 2020 and in particular under the Information and Communication Technologies (ICT) industrial and technological leadership challenge "Future Internet: Infrastructures, technologies and services", which also aims to support EU competitiveness and economic growth.

However, cross-cutting initiatives with other strategic areas such as Key Enabling Technologies (KETs)[3], as defined in Horizon 2020 EU Commission Communications[4], should be facilitated in later work programmes of Horizon 2020, widening the range of objectives of the PPP. Indeed advanced 5G networks and systems will gain significantly from close cooperation with the areas for future micro-electronics and photonics for instance.

The strategic objectives of the 5G Infrastructure PPP will be:

- <u>Societal objectives</u>
  - Contribute to EU 2020 objectives to provide ubiquitous broadband access of interoperable and globally standardised communication networks in order to overcome the digital divide in Europe between densely populated areas as well as rural areas to develop economy across all regions in the European Union. It will be essential to offer broadband access also to such sparsely populated areas in order to develop new business and to create new jobs in such areas. This will help to support economic growth and the development of underdeveloped areas.
  - Accelerate the adoption and use of advanced ICT services in Europe. The new 5G systems will open new opportunities for efficient services in the business, administrative and private domain, which will make the societies and economies in Europe more competitive. Therefore, the development and provision and a new 5G communication infrastructure based on secure networks will be an essential prerequisite for positive economic effects in all sectors.
  - Establish European leadership in uptake and use of ICT technologies. Europe is rather strong in the development and provision of complex communication networks. However, industry in Europe is now challenged by ambitious competitors from other regions. Extensive research and innovation activities are the precondition to maintain and extend the EU leadership position, which will have positive effects with respect to the creation of know-how, the anchorage of a skilled work force, availability of highly secure networks, the creation of a web-based industry and related jobs in secondary domains.
  - Advance the critical communications infrastructure in Europe, its implementation and its protection. The communication infrastructure in Europe is well developed. However, Europe has to keep pace with technological developments and the opportunities, which are provided by more efficient ICT systems. This will help to develop business and jobs in today underdeveloped regions and thereby the overall economic growth and job creation.
  - Support the massive amount of new applications that networks will have to support, from IoT to Ultra High Definition-TV (UHDTV).Many sectors of our societies and economies will use advanced communication infrastructure to make processes and activities more efficient, competitive and secure. Such systems will be based to a significant extend on M2M and sensor communication. A second driver is the extensive use of video applications. Communication networks in Europe have to be empowered to cope with the associated system capacity and scalability requirements. The economic opportunities can only be exploited, if the necessary communication infrastructure is deployed and available for all European citizens.

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[3] http://ec.europa.eu/enterprise/sectors/ict/key_technologies/index_en.htm

[4] COM(2012) 341- A European Strategy for Key Enabling Technologies-A Bridge to Growth and Jobs

- Improve the energy efficiency. Communication systems are consuming a significant share of the overall energy consumption. With the increasing data traffic there is a strong need to increase energy efficiency of communication networks significantly in order to reduce the CO_2-footprint. This will have positive impact of climate change and energy cost. In addition, energy efficiency in other sectors will also be improved by means of ICT.
- Improve significantly network security and privacy. Recent news on surveillance of communication networks and the Internet demonstrated the need for improved network security to ensure data security and integrity and privacy. In particular, critical infrastructures like energy, water, gas, transport health etc. are increasingly dependent on communication networks. Therefore, secure networks are essential to ensure high availability and reliability of such infrastructures.
- Ensure the continuous education of skilled people with regards to new systems and new application domains. New communication networks and the associated applications brings unique opportunities for creating new jobs in the direct communications networks domain and even to a bigger extent in secondary domains related to the application of new technologies. Studies show a significant potential for job creation and economic growth.
- From that perspective, following societal KPI's are proposed:
    - Up to 90 % reduction of energy consumption per service (see box at the end of the section).
    - European availability of a competitive industrial offer for 5G systems and technologies.
    - Economic support of novel range of services of societal value like U-HDTV and M2M applications.
    - Establishment and availability of 5G skill development curricula in partnership with the EIT.

- Economic objectives
    - Maintain and enhance the European strong position in research, development and standardisation of future communication networks in cooperation with other regions in order to provide globally accepted standards, which ensure interoperability and economy of scale.
    - Reinforce the European industrial leadership in network and information systems.
    - Strengthen industry competitiveness and promote innovation through openness whilst respecting legitimate interests of partners on securing IPRs and know-how with respect to global competition.
    - Leverage the economic advantage of 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.
- Operational objectives
    - 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 minimised overhead

- Support an efficient information flow between projects by respecting the interests or partners with respect to confidentiality and access rights.

The 5G Infrastructure PPP ambitions are to **“Create a ubiquitous smart network for the Future Internet"**.

The "Advanced 5G Network Infrastructure for Future Internet" PPP will deliver solutions, architectures, technologies and standards for the ubiquitous 5G communication infrastructures of the next decade. The following high level Key Performance Indicators (KPI's) are proposed to frame the research activities: • **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.**

2. Research and Innovation Strategy

The research of the “Advanced 5G Network Infrastructure for Future Internet” PPP will target bold and ambitious objectives as described in the table before on high-level KPI’s (end of Section 1.6). The foreseen phased projects of the PPP will work jointly towards common goals, with target metrics. The PPP will be organised in a programmatic way, building on few key streams of activities, essential to the 5G Network Infrastructure, such as wireless access, network management, optic, etc. The related research will be organised around Key Research Challenges and enable a balanced approach combining top-down focused research (industry roadmap) and bottom-up innovation-driven research. Both are essential pillars of a successful long-term research effort on infrastructures and future networks. The research roadmap will reconcile longer term research with industry driven research innovation. The organisational structure of the PPP will integrate cross-disciplinary teams (e.g. wireless systems, networks, optical networks, etc.).

A baseline model will track the current state of the art technology in use, and a collection of potential future solutions. Associated with each Key Research Challenge will be a set of research targets broken down by technologies that identify the research required to achieve the overall target metric. When the targets across the many disciplines will be taken together, the result will truly be a combined effort that achieves the larger overall goal of the PPP. Gaps in research effort should be easily identified within this framework as some research results will fall short of targets or new targets will be introduced. This r planned roadmaping process should evolve throughout the execution of the PPP research programme, continuously focusing, and re-focusing, the research on the 2020 goal horizon. This research roadmap will be of a pre-competitive nature and address pre-standards, serving as a technical beacon for research. Once research accomplishments will be achieved, the roadmap will then provide the framework that the industry can use to build actual standards and define commercial product roadmaps, so that the resulting technologies will have a real and significant impact.

The Key Research Challenges will rely on technical and technological bricks described in Section 2.1 of this document. Each Key Research Challenge will build on phased projects.

The following draft research agenda is a basis for consensus building within industry and is derived from the target high-level challenges.

2.1. Scope of R&D and Innovation Challenges

2.1.1. Faster, more Powerful and more Energy Efficient Solutions for integrated High Capacity Networks for a Wider Range of Services

2.1.1.1. Wireless Networks

<u>Problem description</u>

Globally, the demand for broadband wireless communications is increasing dramatically every year. A major factor contributing to this growth is the ever- growing number of users subscribing to broadband internet services using their mobile wireless devices, which is accelerated by the trend towards flat-rate subscriptions and smart devices. In addition to users as human beings, there is also a variety of objects, including machines, which is increasingly connected to the network infrastructure, mainly via radio interfaces. The amount of non-human users is expected to be 10 times higher than the number of human users in 10 years from now. Taking into account also all kinds of possible sensors embedded in objects and in the surrounding infrastructure, as, e.g. buildings and roads or even the surrounding environment, the amount of connected things has the potential to reach a few trillions. On shorter time frame new devices, such as smart-phones and tablets with powerful multimedia capabilities, are entering increasingly penetrating the market particularly in developed regions and creating new demands on broadband wireless access. Finally, new data services and applications are emerging, which reshape the wireless network usage and the associated demands, and are at the same time key success factors for the mobile broadband experience. All these factors together result in an exponential increase in mobile data traffic in the wireless access system, and such a trend is expected to continue at the same pace over the next decade.

Recent studies and extrapolations from past developments predict a total mobile data traffic increase by a factor of 500 to 1 000 within the next decade. These figures assume approximately a 10 times increase in broadband mobile subscribers, and 50-100 times higher mobile data traffic per user. Besides the overall mobile data traffic, the achievable throughput per user has to be increased significantly. A rough estimation predicts a minimum of 10 fold increase on average, as well as in peak data rates. Moreover, essential design criteria, which have to be fulfilled more efficiently than in today's systems, are fairness between users over the whole coverage area achieving ubiquitous user experience, latency to reduce response time, to enable fast setup of service provisioning and to increase reliability, and better support for a multitude of broadly varying Quality of Service (QoS) and Quality of Experience (QoE) requirements originating from different services, applications, and trends.

The constantly increasing user bandwidth requirements also demands for increased capacity backhaul and fronthaul network links. Multiple technological alternatives may be called upon to satisfy the requirements: Free Space Optical (FSO) technologies, terrestrial, satellite, … radio over fibre are typical alternatives.

Further, another essential design criterion is the efficient and effective support for transmission of small payloads and diverse signalling and data traffic characteristics of wirelessly-connected objects and machines.

An important factor in the overall design of next generation systems is the energy efficiency of the network components, network operation, and its deployment strategies. The environmental impact by reducing the CO_2 emissions is essential for the ecosystem. Moreover, increased energy efficiency of the network reduces operational expenditures OPEX, which is reflected in the cost per delivered bit. This metric is important, given the expected traffic and throughput growth. The energy efficiency of base station equipment has significantly been improved in the past years.

Focus Area: Trillion of Devices

<u>The objectives for solving the problem</u>

The amount of non-human users might be more than 10 times higher than the number of human users in 10 years from now. Taking into account also all kinds of possible sensors embedded in objects and the surrounding infrastructure, like buildings and roads or even the surrounding nature, the amount of connected things might even grow to trillions.

As part of the future wireless networks, end-user devices need to be able to interact with each other and with surrounding objects and machines, e.g., sensors. This needs innovative solutions and enablers.

The conventional cellular architecture will be complemented by network topologies. Possible extensions include self-organising mesh-type networks, with direct or network-assisted user/device-to-user/device communication and different levels of cooperation or coordination between end-user devices and/or network nodes.

<u>The associated research</u>

In this area the following research priorities are proposed:

- Significant improvements of the wireless networks have to be explored, by strengthening the research efforts towards innovative cooperation and coordination schemes between network nodes/devices, in a flexible heterogeneous network deployment scenarios applied to dense, cloud-like, and massively-interacting programmable nodes.
- Enablers to discover and interact with sensors, machines and other devices in a dependable, secure and efficient way, with respect to, e.g., cost and, energy, and protocol overhead.

- Novel network topologies.
- Cross-layer optimisations, e.g. context-based forwarding and wireless proximity.
- Novel flexible and scalable network architecture.

Focus Area: Single User Throughput

The objectives for solving the problem

New devices, such as smart-phones and tablets with powerful multimedia and sensing capabilities, are launched in the market at a high pace, creating new types of demand and constraints on broadband wireless access. As a result, new data services and applications are emerging continuously, which enhance the mobile broadband experience. The ability to cope with these varied and sophisticated services and applications will be a key success factor for the for the future network infrastructure.

The associated research

In this area the following research priorities are proposed:

- How to support 10 to 100 times more traffic per end user without increasing resource usage in terms of cost or energy but reducing delay for delay tolerant applications.
- How to provide differentiated QoS guarantees for mixed applications.

Focus Area: Scalability and Capacity

The objectives for solving the problem

Future networks will need to be deployed much more densely than today's networks and, due to both economic constraints and the availability of sites, will need to become significantly more heterogeneous and use multi Radio Access Technologies (RATs).

The operation of the network needs to be able to scale its operation even for short time periods depending on the widely varying traffic capacity needs and still remain energy efficient. Devices are no longer connected to just one single access node. The full picture consists of a combination of multiple physical interfaces based on the same or different radio technologies depending on the current situation and the actual used services. Fast selection and combining of all of the available interfaces supports an adaptive set of virtual interfaces and functions depending on applications.

The associated research

In this area the following research priorities are proposed:

- How to make best use of novel possibilities offered by denser and more heterogeneous Radio Access Technologies (RATs).
- How to support widely varying traffic needs efficiently.
- New radio technologies (scale of channel modelling to small and complex scenarios, access, multiple antenna schemes, multiple simultaneous transmit and receive points, interference handling, multi-radio system co-existence) must have a high priority, in order to meet the high requirements on 5G systems.
- Wireless-optical convergence to deliver very high seamless access performance at reasonable costs.
- Derivation of a network control mechanism, comprising flow control, routing, scheduling and physical resources management that can provide QoS guarantees, and ensure network stability under a large set of service demands.

- Novel antenna technologies and designs to reduce huge and complex antenna sites to fulfil the requirements of multiple RAT with massive multiple antenna schemes and huge bandwidth. Intelligent antennas based on flexible feeder technologies.
- Understanding the scenarios of migration and interoperation towards the new radio technologies, including co-operation between legacy radio access infrastructure and the new technologies.

Focus Area: Spectrum Availability

The objectives for solving the problem

Future wireless networks will face diverse efficiency challenges, amongst which one of the most important will be to ensure that the scarce spectrum resource will be able to carry the huge foreseen data traffic, and avoid inefficient use of spectrum. On a network topology level, the main tools to cope with the spectrum crunch are denser and denser node deployments and enhanced coordination. Furthermore, “spectrum sharing” becomes an effective tool to enhance the spectrum usage efficiency and thus, to increase the effective amount of available spectrum. However, these require advancements in several other areas to make this feasible both technologically and economically, which are addressed in what follows.

Research on spectrum use has focused on the secondary use of the UHF band and TV white spaces, using mainly geo-location data base techniques as the most promising way of spectrum sharing. Also, preliminary research has been conducted on co-primary spectrum sharing between operators. The scope should be now extended to opportunistic, flexible, efficient and effective ways of spectrum sharing to any commercially viable segments of the whole spectrum, under the vision that any portion of spectrum that is not being used at a certain time and location can be used, regardless of the specific frequency range, bandwidth, and contiguity of available frequencies. The developed solutions should also be applicable under new spectrum authorisation scheme, e.g. co-primary, licensed shared access, which is considered as important complementary tools to the conventional exclusive spectrum allocation scheme. Finally, the developed solutions will involve new techniques in air-interface, interference management and network architecture etc. Recent developments in EU spectrum policy should be conducive of spectrum sharing and therefore facilitate research efforts in this field.

The associated research

In this area the following research priorities are proposed:

- Future network deployments have to allow network/infrastructure/resource sharing and reutilisation on all levels, in order to meet the fast growing demands on network resources and operation.
- Cooperative spectrum-sharing techniques in non-homogeneous bands.
- Cognitive capabilities in network design on all layers, supporting a flexible network adaptation at low operational costs, towards providing exactly the performance required for the determined user context.
- New radio access architectures, logical and physical separation between control and data planes, for achieving both spectrum and energy efficiencies.
- Radio interface that facilitates efficient use of spectrum holes and fragmented spectrum.
- Full integration between mobile broadcasting and multicasting, and mobile broadband communications.
- Antenna systems fundamental limits, as a key intelligent spectrum reuse technology, providing the performance benchmark for smart adaptability, including interactions with the user and the propagation channel, and taking an integrated approach where performance can be effectively optimised by appropriate sensing of the physical environment.

- Cognitive multi-band exploitation aware to the radio environment and the application context in order to trade-off capacity and energy efficiency for service delivery e.g. wall penetration, super long range, considering inter cell interference for nearby wireless applications.
- Investigation of new frequency bands, in particular in the millimetre wavelength regions of spectrum, and research into technologies that enable utilisation of these bands for mobile broadband communications.

Focus Area: End to End energy Efficiency

The objectives for solving the problem

Energy has been the target of significant research work in the past. Recently, the FP7 EARTH project has found significant savings (more than 50 %) for mobile broadband as provided by 4G networks. Nevertheless it has been also underlined that its solutions by far do not provide the savings which could be theoretically achieved when employing traffic statistics. EARTH identified that new concepts applied to future 5G networks and radio interfaces would help to approach optimal efficiency allowing additional 80 % savings. It should be noted that these savings are just what could be achieved when optimising a single network based on a single radio access technology.

For the wireless Internet of Things (IoT), new wireless network architectures, algorithms and protocols are needed that are optimised for traffic profiles e.g. small and periodic or bursty and sporadic traffic. New applications such as M2M and IoT put an increasing burden on the networks from a signalling and control perspective. Signalling traffic for sensor networks can be a large drain of resources relative to the small amount of actual useful data being sent over the networks. We need to investigate new signalling mechanisms, protocol state machines, and architectures that scale to billions of devices. Efficient architectures for real-time and in-network processing of the data being generated need to be investigated to handle the amount of big data being generated.

The associated research

- Air interface for improved energy efficiency allowing additional 80 % savings.
- Low power backhaul solutions (including passive optical networks and wireless options) for an increasing number of small cells deployed to cope with the traffic growth.
- Power management techniques. Increasing peak data rates and shrinking cell size result in an increased randomness of the cell traffic and load. From a power consumption perspective, this means that the gap between dimensioning of the network resources and their actual usage widens. Energy efficient hardware and power management techniques to suspend functions and blank signals in a flexible way are needed.
- Centralisation of access network functions, services and corresponding states for optimal location, in support of cost, performance and energy savings.
- More and more devices acting as a kind of multifunctional computing platform. End-to-end energy efficiency could be improved by coordinating and bundling the actual independent communication sessions and/or multimedia terminal capabilities, to reduce the overall required energy per transmitted bit.

Associated KPIs:	
• Mobile data volume supported per area	• > 1000 multiplication factor in cell throughput
• Amount of spectrum made available via new intelligent spectrum management techniques	• Starting from a today allocation of about 300 MHz (Target: in minimum doubling)
• Number of connected devices	• 10x to 100x increase

• Achievable typical user data rate	• 10x to 100x increase
• Lower energy consumption	• Additional 80 % reduction in radio access part
• Increased battery life for low power devices	• > 10x
• End-to-End latency	• < 1ms, 5x reduction

2.1.1.2. Optical Networks

Research on photonics communications will be coordinated with the Photonics PPP.

Problem description

Optical networks must undergo significant changes to cope with the increasing bandwidth demand and the requirements arising from new applications. With growing concern about energy efficiency and carbon emissions, significant changes are necessary in all network layers and segments (core/metro/access/data centre). Major needs exist to make optical networks faster, more secure, more flexible, more transparent and easier to use and to bring them closer to the customer.

Networks tend to become more complex, while strong financial pressure requires optimising investments and controlling operational costs. This calls for new optical technologies able to support automation in the network deployments as well as elasticity and scalability in operation phases. Concepts need to address all layers, the physical layer as well as higher layers and also optimisation and planning across layers. Economically sustainable migration paths have to be found to allow new technologies to develop whilst exploiting existing infrastructures.

Broadband backbones

The exponentially growing data consumption in fixed and mobile access puts more and more stress on the core of the network. In fact, based on various traffic measurements and predictions, traffic volume in the core network is expected to grow by roughly a factor of 10 within the next 5 years, and by a factor of 100 within the next 10 years. Peak throughput at core network nodes is expected to reach several 100 Tbps by 2020. Technologies utilised in optical networking are approaching theoretical limits set by physics and information theory, and will therefore require research effort on advanced techniques.

Broadband fibre based access

Next-generation optical access networks are foreseen for providing multiple services simultaneously over common network architectures to different types of customers. Access networks capable of interconnecting higher numbers of users with a symmetrical bandwidth of up to 10 Gbps per customer are required. While the aim is to achieve the requested capacity, Quality of Service, and latency in the access network by exploiting the vast available fibre bandwidth, the challenge will be to keep the network cost down. Mobile backhaul for very high capacity 5G radio networks will exacerbate this trend. Radio network fronthaul should support analogue and digital signal formats in a generic sense to allow for flexible cost and energy efficient remote radio units for indoor and outdoor deployments.

Broadband data centre connectivity:

New broadband applications are transforming the Internet into a content-centric cloud network, fuelling the proliferation of data centres and the related intra- and inter-data centre connectivity with Tpbs capacity. The new trend to warehouse-scale computing is raising the bar for high-speed data centre networks requiring unprecedented equipment densities whilst simultaneously imposing stringent requirements on the energy consumption. For emerging Exascale data centres, radically new architectural approaches are needed which make pervasive use of optical networking technologies to address next-generation throughput and latency requirements.

The objectives for solving the problem

Optical network infrastructures are a major asset for communication networks. These infrastructures based on packet and optical technologies needs to be more flexible, efficient, and easily manageable. These networks support legacy services but need to be optimised for delivering services with high growth potential such as media servers, high data rate services, e.g. upcoming new TV formats (3D, 4K, etc.).

Therefore, the advent of high quality multimedia-rich terminals and services, expected to increase in the next years, lead operators to deploy high bit rate optical networks. FTTx roll-out is a global trend, mainly in Asia but also in Europe where main operators already deploy or have announced FFTx deployment for the coming years.

Beyond the need to develop next-generation technologies and architectures several other objectives have to be taken into account:

- To make optical networks more transparent and secure. By removing unnecessary optical-electrical-optical conversions in aggregation nodes, routers and switches, whilst managing the resulting increase in heterogeneity in fibre types and network architectures. To enable future-proof and cost-effective convergence of mobile and fixed, metro and access networks. To enable secure exchange of data in the network on the lowest possible layer.
- To make optical networks more dynamic and cognitive. By introducing true flexibility in photonic networks through fast-established circuits or packets, coping with varying traffic demands, benefiting from flexibility and elasticity in format, channel spacing or bit-rate. This while reducing latency, and managing quality of service at the photonic layer, so achieving autonomous operation of photonic network elements, including self-diagnosis, restoration and optimisation with efficient use of monitoring and adaptation capabilities.
- To make optical networks faster. By deploying a disruptive mix of technologies to match the predicted capacity growth to a typical 10 Gbps per user in wired access and Tbps per channel in the core.
- To make optical networks greener by expanding the role of photonics from core down to home access.

The associated research

The key research direction consists in designing solutions able to increase capacity, flexibility and scalability of optical networks, covering the following scope for optical access, backbone and data centre networks.

- Physical layer as well as higher layers and optimisation and planning across layers: new concept needs to address all layers.
- Economically sustainable migration paths have to be found to allow new technologies to develop: existing infrastructures constitute a strong asset.
- Optical networks, thanks to their high capacity, offer new perspectives in term of global optimisation of infrastructure, notably:
  - Optical elements of infrastructure allowing centralised multi-cell efficient baseband processing, as fundamental capability to be used for enhancing the mobile networks cost and efficiency.
  - Simplification of the access architecture, thanks to the long reach capacity of the optical fibre, by reducing the number of Central Offices, and consequently the capital expenses and operational costs of the access networks.

Optical Backbones:

Future research on optical backbones should cover the design of transmission techniques with increased capacity (higher than 1 Tbps per service/wavelength), as well as the introduction of more flexibility in the optical layer, the optimisation of multi-layer optical transport architectures and the design of innovative communication techniques based on full optical technologies

- Increased capacity transmission techniques: With bitrates of the order or even higher than 1 Tbps per service/wavelength, distortions brought by the fibre would prevent reaching expected transmission performance if basic transmission techniques were to be used. Therefore, sophisticated but still cost-efficient techniques have to be investigated. Also the use of new fibre types, switching elements, and amplification techniques must be considered.
- Flexibility in the optical layer: A better use of optical resources is required to increase equivalent of increasing the transport networks capacity. More flexibility in the optical layer helps to improve spectral efficiency, to reduce energy consumption and to optimise cost. Software-defined networks approach applied to optical networks will allow a flexible end-to-end capacity assignment in which a multitude of parameters such as the optical spectrum allocation and an optical signal configuration can be adapted and dynamically changed. A control and management framework is thus required which exposes the optical layer as a programmable network resource whilst hiding its complexity to the user.
- Multi-layer optical transport architectures: Innovative multi-layer optical transport architectures in relation with the capacity increase of the optical transmission system provide means to further improve the use of the available transmission resource and therefore offer a new dimension in the overall transport optimisation. New approaches for information exchange between application, packet transport and optical transport layer are required. The programmatic control and virtualisation of optical network resources will increase network efficiency.
- New control paradigms, operational approaches, business models and service definitions are required for a wide-spread commercial adoption and need to be developed and tested under real-world conditions.
- Innovative communication techniques: Data routing in meshed optical networks can exploit new techniques (Sub-wavelength optical switching of the sub-bands which constitute super-channels as example) which should be optimised in terms of bandwidth resource usage and energy consumption.

Optical Access

A major research field relies on the design of new generations of optical access technologies, characterised by major evolutions: Significant throughput increase, optical range improvement and sharing rate increase (capability for more customers to share the same optical network resource). These technologies may be based on Wavelength Division Multiplexing (WDM), Space Division Multiplexing (SDM) in multicore or multimode fibres and rely on various energy efficient coherent detection based modulation/resource sharing procedures.

In addition, optical access networks offer new perspectives for a global optimisation of the fixed mobile-infrastructure by serving as convergence layer for different first mile technologies.

- Increased fibre capacity in access networks: The steady traffic increase along with fibre scarcity and deployment costs calls for new approaches providing a more efficient usage of the fibre capacity also in optical access networks.
- Novel architectures for optical access networks: The long reach capacity of the optical fibre offers to reduce the number of Central Offices, and consequently the capital

expenditure and operational costs of the access networks. As an element of infrastructure allowing centralised multi-cell baseband processing, optical access will play an increasing role in improving mobile networks cost and efficiency. An infrastructure sharing between different market players is also important to maximise network coverage while minimising the overall investments and stimulate competition.

- Novel approaches for control and management: Following the trend of network-assisted virtualisation and pooling of IT functions for security, bandwidth management and content delivery, the optical access and backhaul network needs to become an integral part of a programmable orchestration framework for IT and networking resources. A dynamic optimisation of the Quality of Experience as well as flexibility in support of different wholesale models needs to be addressed.

Optical data centre connectivity:

Research on novel data centre architectures is required which make use of optical switching and interconnect technologies, a tighter integration of optical and electronic functions, a more programmatic fabric control, and a flexible allocation of networking functions to orchestrate resources elastically and at scale.

- Higher capacity data centre interconnections: Tbps optical interconnections for inter- and intra-data centre connectivity are required to keep pace with the massive traffic growth in data centre networks. They need to exploit wavelength, space and modulation domains to deliver extremely cost-effective, energy effective and compact solutions for short to medium distances (up to a few km inside the data centre to around 100 km between adjacent data centres). Novel data centre network architectures: Scaling data centre fabrics to provide a large cross-sectional bandwidth while at the same time reducing the interconnections requirements is a massive problem. Employing optical switching and interconnect technologies new distributed data centre fabric architectures can be designed, which complement the switching of fine granular flows by providing large pipes for the transport of bulk data between different data centre pods or servers.
- New control paradigms: Introducing optical transport technologies for intra- and inter-data centre connectivity increases the number of network layers which need to be controlled. The development of appropriate control paradigms (as currently being investigated in the optical transport group in the Open Networking Foundation for example) as well as their integration into emerging software frameworks for network virtualisation and IT and network resource orchestration is therefore required.

Associated KPIs:	
Core	
• Capacity (>10x increase)	• Tbps+ channels 100 Tbps+ links Pbps network nodes
• Reach	• up to 2500 km
• Equipment density/Bit	• x10
• Energy reduction/Bit	• x10
• Automation & control	• 30 % network efficiency increase > 30 % OPEX savings
Access and Aggregation	
• Capacity (>10x increase)	• 10G+ peak rates CIR/EIR 1:10 or better 10x central office consolidation 10 Tbps network nodes

• Reach	• up to 100 km
• Equipment density/Bit	• x10
• Energy reduction/Bit	• x10
• Automation & control	• 30 % network efficiency increase > 30 % OPEX savings
Data centre	
• Capacity (>10x increase)	• Pbps fabrics Tbps interconnects in support of: Exascale computing Zettabyte storage
• Reach	• up to 2 km (intra-DC) up to 100 km (inter-DC)
• Equipment density/Bit	• x10
• Energy reduction/Bit	• x10
• Automation & control	• 30 % network efficiency increase > 30 % OPEX savings

2.1.1.3. Automated Network Organisation - Network Management and Automation

Problem description

The Operation and Management (OAM) of the wireless mobile network infrastructure (including WIFI) plays an important role in addressing these challenges in terms of constant performance optimisation, fast failure recovery, and fast adaptations to changes in network loads, architecture, infrastructure and technology. Self Organising Networks (SON) are the first step towards the automation of networks OAM tasks, introducing closed control loop functions dedicated to self-configuration, self-optimisation, and self-healing. The tendency introduced with SON is to enable system OAM at local level as much as possible: The OAM systems are getting more and more decentralised. The long-lasting dilemma has thus been on finding a right balance between centralised control versus distributed SON. However, first generation SON functions need to be individually configured and supervised by a human operator. This manual configuration and tuning is getting less and less practical, due to the increasing complexity of the SON system, since multiple SON functions being operated in parallel may have interdependencies, and lead to network performance degradations due to inconsistent or conflicting configuration.

These topics are also covered by research activities in the area of Cognitive Networking (CN). CN was investigated as an extension of Software Defined Radio (SDR) to get a full set of functions required to deploy an overall cognitive radio system. There are a lot of research results available with focus on Spectrum-Sensing Cognitive Radio.

The objectives for solving the problem

CN describe a radio network that employs a cognitive process (i.e., involving thinking, reasoning and remembering) and learning capabilities in order to achieve end-to-end goals. This applies to both the horizontal network (i.e., including all the protocol stack of wireless networks, both radio access and backhaul/transport) and the vertical management views (i.e., abstracting network elements and their configuration towards a holistic high-level view). Control loops need to work not only for single independent functions, but also to be extended for the complete environment to be managed, which may involve several layers of control loops. The control loop diagnosis and decision making processes need to be adapted automatically by learning, e.g. based on the results of previous actions, in order to improve their effectiveness and efficiency, leading to cognitive processes driven and controlled through high-level operator goals.

Non-data base CN systems have to apply spectrum sensing means, which have certain limitations to identify, e.g. spread spectrum signals. Therefore, today the data base approach seems to be a more feasible concept for CN implementation. However, the potential of self-learning systems has to be investigated in order to become more independent from data base concepts, which require a close cooperation between different spectrum owners. Today such systems are not available with the necessary reliability.

So far the existing research is addressing Cognitive Radio (CR). First steps into the use of CR in actual deployment have been achieved in the UHF bands, after the television broadcast digital switch-over. In 2009, the US radio regulator – the Federal Communication Commission (FCC) – authorised opportunistic unlicensed operation in the TV bands. The coexistence of opportunistic radios with incumbents is enforced with a priority mechanism where opportunistic systems must guarantee that no 'harmful interference' will be incurred to the incumbents. Such rules are meant to allow the control of the deployment and use of the unlicensed service so as to avoid harmful interferences on incumbents, but not to restrict it. In the UK, OFCOM is also close to allow white space devices in the UHF bands. Other European countries are considering the same move forward under the banner of the CEPT SE43 and the Radio Spectrum Policy Group (RSPG). In March 2012 the European Parliament and Council approved the first Radio Spectrum Policy Programme (RSPP). While moving towards the freeing up of significant new pieces of radio spectrum and promoting the trading of usage rights, the Programme also sets out a number of actions with regard to spectrum sharing including CR solutions. Specifically with regard to spectrum sharing, a study was commissioned by the EU Commission and published in March 2012. Based on its RSPP principles and the outcomes of this study, the Commission released a Communication on "Promoting the shared use of radio spectrum resources in the internal market" in September 2012. New paradigms need further developments in order to enable spectrum sharing in a large scale, where coexistence, pricing and dynamic spectrum access are key challenges.

Preliminary mechanisms for coexistence have been proposed in the TVWS. They rely on a data base, or a set of data bases, which contain spectrum occupation status rules and policies that opportunistic system shall exploit. However, the efficiency of such an approach has not been proven yet and additional mechanisms may be used to provide a more accurate spectrum map. Also there are some concerns on 'who' shall maintain the data base and be responsible for the accuracy of its content. Finally, a centralised approach may be prone to security threats where deny of service or other kind of attacks may compromise the system.

<u>The associated research</u>

Advanced intelligence should be developed for realising CR networks. The intelligence of a CR network requires research work:

- On development/refinements of functional and system architectures, also taking the integration with the overall wireless world into account. In order to complement the architecture work, there needs to be elaboration, and ultimately specification, of control channels for the cooperation of the cognitive management components as well as interfaces to the other areas of the ICT like fixed networks, service provider networks etc.
- On Advanced Human Computer Interfaces (AHCIs) to define and acquire the high-level business and technology driven operator goals, end-user requirements, and network capabilities.
- On methodologies for the acquisition, analysis and improvement of knowledge representing semantics of operational goals and strategies, network properties, and historic and current network status enabling an automated reasoning for the alignment of different CR networks functionality at runtime.

Extremely automated systems have to follow high-level operator goals regarding network performance and reliability. These systems have to autonomously ensure and control a conflict-free and coordinated operation of multiple SON functions, providing automated control not only at (low-level) SON function level, but also at the high-level network management, network planning and Operations and Support Systems (OSS) level.

Associated KPIs:	
• QoE/QoS	• Increased customer satisfaction in terms of ○ throughput, ○ handover reliability and ○ call drop rate
• Network reliability and resilience	• Increase performance
• OPEX	• Reduced OPEX in terms of ○ energy consumption and ○ complexity of human operator tasks
• Scalability of the mechanisms	• In terms of ○ number of coordinated elements and ○ number of coordinated control loops

2.1.1.4. Implementing Convergence Beyond the Access Last Mile

Problem Description

The convergence of the fixed and mobile networks forms the backdrop for upgrades to operator networks. The stake is to offer customers services that use various wired and wireless networks together with the best possible customer experience, while at the same time streamlining and sharing fixed and mobile network infrastructures and equipment.

Making fixed and mobile networks converge is far more difficult than it might seem, as these networks developed independently of each other and are based on different technologies and protocols. A certain degree of convergence is emerging alongside the boom in IP-based services, as well as through the introduction of a service control layer such as IMS (IP Multimedia Subsystem). The convergence of fixed and mobile networks will take years and will require fundamental work on network architecture, technologies and protocols, the shared work of standardisation groups (e.g. 3GPP and BBF) and developments in the regulation and organisation of operators.

The objectives for solving the problem

We propose that the PPP conduct in-depth investigations into two concrete approaches of fixed and mobile network convergence:

- Functional convergence or the convergence of the functions of fixed and mobile networks: The goal is to better distribute the various functions of fixed and mobile networks by distinguishing those that should be more "centralised" from those that should be more "distributed".
- Structural convergence, or the convergence of fixed and mobile network equipment and infrastructures: The goal here is to share as much as possible the infrastructures (e.g. cables and civil engineering, cabinets, sites, buildings) and equipment of the fixed and mobile networks by envisaging, where possible and relevant, infrastructures and equipment that are shared between these two types of network.
- Understanding the incremental performance gains as structural evolution gradually takes place and access infrastructures are shared.

Functional convergence will benefit the customer by making the service independent of the access technology and the device, not through an additional service control layer but by using natively convergent technologies and protocols in the network domain. Functional convergence should also give the customer the best access to the network for a given service and in a transparent manner.

The ability to support new usages such as audiovisual content consumption is also a significant driver of fixed-mobile convergence. Thanks to an improved distribution of the key functionalities of fixed and mobile networks and the flexibility of use of the access interfaces available, functional convergence will enable shorter service access times and allow easier support of growth in traffic and developments in usages. Other expected advantages include the simplification of Authentication, Authorisation, and Accounting (AAA) functions and an intrinsic improvement in availability. For operators, functional convergence will enable easier differentiation of the products and services offered to customers, because the technical obstacles and constraints associated with service-specific networks will disappear. This will have a positive impact on quality of service and quality of experience for the customer (coverage, accessibility, latency and usability).

Structural convergence is more complex to implement, as it involves sharing the infrastructures and equipment of fixed and mobile networks. It is expected to enable new mobile front-haul and backhaul architectures in complete synergy with fixed access networks. These architectures will pave the way to the Cloud Radio Access Network (Cloud RAN) concept and could also eventually enable the sharing of fibre access infrastructures or even shared fixed and mobile equipment.

<u>The associated research</u>

In summary, in order to define the associated research towards converging fixed and mobile networks, an assessment of the evolution of each of the networks should be done.

The evolution of Mobile Access:

The evolution of services, applications and users' behaviour raises the need for an evolution of mobile networks technologies and architectures in order to face:

- The need for a very significant increase of capacity.
- The specific constraints raised by new applications and paradigms and in particular by future M2M and IoT systems.
- The required architectural convergence of mobile and fix networks as well as of the corresponding service platforms.

The evolution of Fixed Access:

The future of fix access should in principle focus on optical technologies, but copper still remain relevant in some cases (VDSL). Regarding innovation, let us refer to PONs where the more sophisticated technical evolutions are required. There is a need to increase PONs capacity (40G) and to move into long-range. Long-range translates into aggregating a large number of customers. The required capacity imposes the usage a WDM technology. Several solutions are under study; nevertheless, there is still an issue with the cost of the ONUs. ONUs could have tuneable lasers and receivers, but this is an expensive solution. Another approach consists on deploying heterogeneous ONUs, dealing with different wavelengths. This solution significantly increases OPEX and adds complexity to the manufacturing, delivery, deployment and configuration chain. Although several solutions are under study, a cost effective solution will bring value to the market.

The edge devices in a more distributed environment will be where most of the intelligence will be deployed. In particular the handling of the increasing Device-2-Device communications and the connectivity of IoT and M2M devices, the capabilities of virtualised edge environments where aggregation and consolidation of information could be performed will raise key issues to solve.

Associated KPIs:	
• Number of converged networks	• Including e.g. fixed, mobile, but also specific ones such as private infrastructures city-wide ITS (road management), PMR, future smart grids, …
• The factor of total increase in capacity	• Reduction in OPEX/CAPEX (20 %)

2.1.2. Re-Designing the Network

Today, the key players in the application and content delivery ecosystem, e.g., Cloud providers, CDNs, OCHs, data centres and content sharing websites such as Google and Facebook which often have direct peering with Internet Service Providers or are co-located within ISPs. Application and content delivery providers rely on massively distributed architectures based on data centres to deliver their content to the users. Therefore, the Internet structure is not as strongly hierarchical as it used to be. These fundamental changes in application and content delivery and Internet structure have deep implications on how the Internet will look like in the future.

What we observe today is a convergence of applications/content and network infrastructure that lead to a model of the Internet that used to separate two stakeholders: Application/content infrastructures on the one side and a dumb transport network on the other. One way to go is to enable the different stakeholders to work together, e.g., enables ISPs to collaborate with application/content providers. This can be achieved for example by exploiting the diversity in content location to ensure that ISP's network engineering is not made obsolete by content provider decisions or the other way around. Another option is to leverage the flexibility in network virtualisation and making their infrastructure much more adaptive than today's static provisioning.

2.1.2.1. Information Centric Networks

Problem description

The Internet architecture, designed in the 60s-70s, is nowadays facing complexity every day to sustain the traffic growth that never stops and to be usable from various terminals, using various link layer technologies, and for the numerous applications available to the end users. The Internet protocol (TCP/IP) is currently coping with some of its fundamental limitations by deploying architectural fixes (mobility, security, multicasting, NAT, recast, converge cast, etc.) - affixing themselves to an unmoving architecture - which may serve a valuable short-term purpose, but significantly impair the long-term flexibility, reliability, and manageability of the Internet. With the users producing and producing more and more information/content (presumes) the way in which this information/content is distributed and processed within the network becomes relevant.

The objectives for solving the problem

The mismatch between the current Internet usage and its original design is thus pushing for a radical communication model change, centred on information access. Information-Centric Networking (ICN) is a novel network architecture consisting of communications that revolve around the production, consumption and transformation of information matching user interest. As there was a shift from circuit-switched networks to packet-switched networks, ICN pushes many design principles coming from the Web directly into the network infrastructure by centring the architecture on "what" is relevant to the user and not on the "network's where" (the customer simply wants to access the desired object wherever it is). The model then changes from a host-based one to an information-based model, where the naming of objects takes a critical role for publication, retrieval and routing.

ICN aims at transforming the current communication model (the classical OSI/IP reference model) into a simplified and generic one so as to avoid all the patches and intermediates layers that have been progressively included, adding complexity and decreasing network performance. ICN is a connectionless, receiver-driven model, where user requests are expressed by an interest for a given object, routed in the network based on its name toward a node having or processing it, and where the related data is sent back along the reverse path, with the possibility for intermediate nodes to cache the object. Thanks to its design, the ICN communication model allows built-in native features aiming at optimising and simplifying future content delivery architecture, while leveraging service providers' infrastructure capabilities, such as:

- Multicasting: Interests for a same object from different users will be processed in the network as the same interest, thus requested only once, leading to a network optimisation in the delivery.
- User mobility: There are no established connections, thus the user can move, and every interest packet sent by her from her location will be independently processed by the network.
- Multipath: Interests messages can be sent to multiple interfaces in order to share load and optimise the delivery.
- Security, content protection and authentication: Via encrypted and self-certified named objects.
- Caching: Objects can be cached in the network, along the reverse path, so as to be able to deliver them more rapidly in case of subsequent request by other users.
- Dynamical adaption of the data streams and objects with respect to the special requirements of mobile radio connectivity with multiple transmit points and virtual groups of receivers/transmitters i.e. sensors.

ICN includes storage and execution capabilities, in addition to transport resources, making the network evolve from a dumb pipe transport network towards an added-value intelligent network (Figure 7).

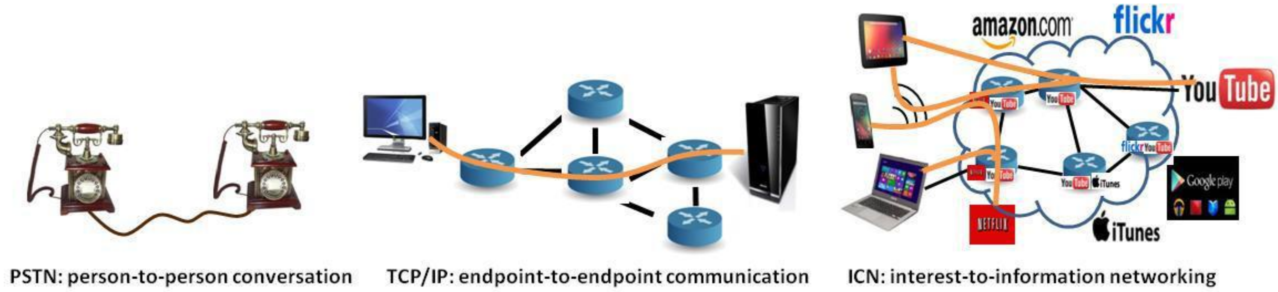

Figure 7: Information Centric Networks (ICN) Perspective

<u>The associated research</u>

- Naming scheme.
- Integration of storage capacities of end devices into ICN.
- Distribution of storage across all routers.
- Elaboration of performing content routing algorithms.
- M2M/IoT specific content-driven forwarding, e.g. based on Quality of Information (QoI).
- Interoperability (as easily than with IP).
- Tools and model for measuring the performance.
- Mobile radio aware ICN (i.e. adaption of data streams, packet lengths, source coding).

- Search along information elements.
- Seek, find and inform new nodes of their availability and functionality
- Security and privacy.

Associated KPIs:	
• Response time	• Improved response time showing the efficiency of the name resolution, data access etc., by comparing the response time of 1st data packet to the average response of the rest of the data packets
• CAPEX and OPEX	• Minimised CAPEX and OPEX related to centralised content services of operators
• QoS and QoE	• Improved data access and discovery in terms of QoS and QoE
• Signalling and traffic overhead	• Minimised signalling and traffic overhead in terms of bandwidth utilisation and QoS/QoE
• Signalling and traffic overhead	• Improved scalability in large scale network environment compared to traditional approaches
• Demonstration and test network platforms	• Number of large scale demonstration and test network platforms showing the scalability

2.1.2.2. Network Function Virtualisation

The white paper[5] of the ETSI Industry Specification Group NFV provides an excellent description of the problem area which network function virtualisation is going to provide a solution for. In addition, it provides also a comprehensive list of related challenges which are understood as areas where research is still needed. Therefore, this section includes text and figures that are directly taken from the white paper. The following text is too a significant extend based on this white paper.

Problem description

Today's networks are populated with a large and increasing variety of proprietary hardware appliances. Launching a new network service often requires yet another variety of appliance increasing the overall complexity of the network and causing a number of issues. For example finding the space and power to accommodate these appliances is becoming increasingly difficult and costly in terms of power consumption and capital investment challenges. The rarity of skills necessary to design, integrate and operate increasingly complex hardware-based appliances poses another challenge (Figure 8).

Moreover, hardware-based appliances rapidly reach their end of life, requiring much of the procure-, design-, integrate- and deploy-cycle to be repeated with little or no revenue benefit. Worse, hardware lifecycles are becoming shorter as technology and services innovation accelerates, inhibiting the roll out of new revenue earning network services and constraining innovation in an increasingly network-centric connected world.

[5] http://portal.etsi.org/NFV/NFV_White_Paper.pdf

The objectives for solving the problem

Network Functions Virtualisation aims to address these problems by leveraging standard IT virtualisation technology to consolidate many network equipment types onto industry standard high volume servers, switches and storage, which could be located in data centres, network nodes and in the end user premises. Network Functions Virtualisation is applicable to any data plane packet processing and control plane function in fixed and mobile network infrastructures.

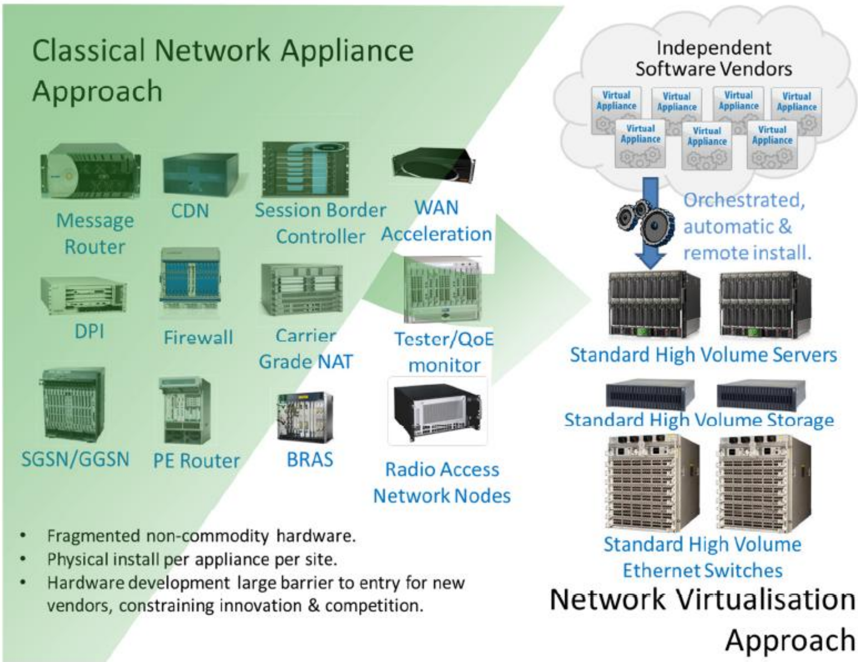

Figure 8: Network Functions Virtualisation

The associated research

There are a number of challenges to implement Network Functions Virtualisation which need to be addressed by the community interested in accelerating progress.

Portability/Interoperability

Network functions virtualisation requires the ability to load and execute virtual appliances in different but standardised data centre environments, provided by different vendors for different operators. The challenge is to define a unified interface which clearly decouples the software instances from the underlying hardware, as represented by virtual machines and their hypervisors. Portability and Interoperability is very important as it creates different ecosystems for virtual appliance vendors and data centre vendors, while both ecosystems are clearly coupled and depend on each other. Portability also allows the operator the freedom to optimise the location and required resources of the virtual appliances without constraints.

Performance Trade-Off

"Network Function Virtualisation is leading to execute network function (high level function-DPI, NAT, Firewall, etc.) on generic abstraction of the equipment (decentralised or not) which may use heterogeneous/dedicated hardware for low level function execution (cryptography, packet routing, etc.), leading to dual virtualisation layers. The generic abstraction of the equipment (virtualisation of the underlying hardware) is a challenge for computing systems to hide the heterogeneity to the Network Function Virtualisation, and is induced by the trend that efficiency and energy constraints are pushing hardware architecture towards heterogeneity and more and more use of accelerators for special functions. In fact accelerators are orders of magnitude more energy efficient than standard processors. The challenge is how to keep the performance degradation of the two virtualisation layers as small as possible by using appropriate hypervisors and modern software technologies, so that the effects on latency, throughput and processing overhead are minimised. The available performance of the underlying platform needs to be clearly indicated by service contract and dynamic management (for example), so that virtual appliances know what they can get from the hardware.

In particular, if resource limited and frequently disconnected devices (such as desktop computers or smart phones) participate in the network Function Virtualisation, a careful design is required in order to maintain the required performance.

Migration and co-existence of legacy & compatibility with existing platforms

Implementations of Network Functions Virtualisation must co-exist with network operators' legacy network equipment and be compatible with their existing Element Management Systems, Network Management Systems, OSS and BSS, and potentially existing IT orchestration systems if Network Functions Virtualisation orchestration and IT orchestration are to converge. The Network Functions Virtualisation architecture must support a migration path from today's proprietary physical network appliance based solutions to more open standards based virtual network appliance solutions. In other words, Network Functions Virtualisation must work in a hybrid network composed of classical physical network appliances and virtual network appliances. Virtual appliances must therefore use existing North Bound Interfaces (for management and control) and interwork with physical appliances implementing the same functions.

Management and Orchestration

A consistent management and orchestration architecture is required. Network Functions Virtualisation presents an opportunity, through the flexibility afforded by software network appliances operating in an open and standardised infrastructure, to rapidly align management and orchestration North Bound Interfaces to well defined standards and abstract specifications. This will greatly reduce the cost and time to integrate new virtual appliances into a network operator's operating environment. Software Defined Networking (SDN) further extends this to streamlining the integration of packet and optical switches into the system e.g. a virtual appliance or Network Functions Virtualisation orchestration system may control the forwarding behaviours of physical switches using SDN. The orchestration and federation of network resources as network functions is an important aspect of the future network ecosystem. As such research will be relevant on the way in which resources and functions are described, protecting the know-how of the network and service providers, and at the same time opening the right interfaces so as to enable new business models to appear. Service Level Agreements automated definition and monitoring/control of network functions is also a relevant topic under the management and orchestration domain.

Automation

Network Functions Virtualisation will only scale if all of the functions can be automated. Automation of process is paramount to success.

Security & Resilience

Network operators need to be assured that the security, resilience and availability of their networks are not impaired when virtualised network functions are introduced. Our initial expectations are that Network Functions Virtualisation improves network resilience and availability by allowing network functions to be recreated on demand after a failure. A virtual appliance should be as secure as a physical appliance if the infrastructure, especially the hypervisor and its configuration, is secure. Network operators will be seeking tools to control and verify hypervisor configurations. They will also require security certified hypervisors and virtual appliances.

Network Stability

Ensuring stability of the network is not impacted when managing and orchestrating a large number of virtual appliances between different hardware vendors and hypervisors. This is particularly important when, for example, virtual functions are relocated, or during re-configuration events (e.g. due to hardware and software failures) or due to cyber attack. This challenge is not unique to Network Functions Virtualisation. Potential instability might also occur in current networks, depending on unwanted combinations of diverse control and optimisation mechanisms, for example acting on either the underlying transport network or on the higher layers' components (e.g. flow admission control, congestion control, dynamic routing and allocations, etc.). It should be noted that occurrence of network instability may have primary effects, such as jeopardising, even dramatically, performance parameters or compromising an optimised use of resources. Mechanisms capable of ensuring network stability will add further benefits to Network Functions Virtualisation.

Simplicity

Ensuring that virtualised network platforms will be simpler to operate than those that exist today. A significant and topical focus for network operators is simplification of the plethora of complex network platforms and support systems which have evolved over decades of network technology evolution, while maintaining continuity to support important revenue generating services. It is important to avoid trading one set of operational headaches for a different but equally intractable set of operational headaches.

Integration

Seamless integration of multiple virtual appliances onto existing industry standard high volume servers and hypervisors is a key challenge for Network Functions Virtualisation. Network operators need to be able to "mix & match" servers from different vendors, hypervisors from different vendors and virtual appliances from different vendors without incurring significant integration costs and avoiding lock-in. The ecosystem must offer integration services and maintenance and third-party support; it must be possible to resolve integration issues between several parties. The ecosystem will require mechanisms to validate new Network Functions Virtualisation products. Tools must be identified and/or created to address these issues.

Associated KPIs:	
• Real deployments	• Number of real deployments
• Demonstrations of interoperability	• Demonstrations of interoperability among vendors and operators of their virtualised products and infrastructures
• Open innovation ecosystem	• The availability of an open innovation ecosystem around NFV technologies
• CAPEX and OPEX	• Figures on CAPEX and OPEX reduction (our initial estimates for this pilot are around 35 % in CAPEX and 45 % in OPEX)

2.1.2.3. Software Defined Networks

Problem description

Today packet networks are built on the paradigm of a fully distributed control plane architecture, where part of the intelligence rests in each of the network elements. These network elements (e.g. routers and switches) are "all-in-one boxes", where control and forwarding plane is vertically and tightly integrated, and which can be configured and operated mostly via vendor-specific interfaces only. For example, the introduction of new network services requiring changes in the underlying packet network infrastructure in order to guarantee certain service behaviour is a highly complex, error-prone, and time consuming task because it requires configuration and operation of individual network elements via many different and proprietary interfaces. Thus, configuration and operation of the whole network is becoming increasingly complex and inefficient.

Software Defined Networking (SDN) is considered to provide significant improvements on the issues described above and to offer further advantages especially in combination with network virtualisation and cloud technologies. The SDN concept is based on the separation of control and forwarding plane of a network, on a logically centralised control of network resources, and on providing an open/standardised (North Bound) controller interface offering the opportunity to add network applications in a programmatic way on top of the control entity. By that, SDN is providing access to the forwarding plane via well-defined interfaces and the centralised control and monitoring of the relevant network resources allow a global network view facilitating for instance an optimised problem resolution and simplified provisioning of network resources. The open APIs provide a more high-level and abstract access to network resources and enable the programmability and adaptability of network functions. Especially these APIs are considered to provide a platform for a whole innovation ecosystem: Network services will be implemented by programming instead of re-architecting the network and new network features can be introduced at significantly shorter time.

SDN is seen as highly complementary to Network Function Virtualisation and cloud computing. SDN allows to request network resources in a similar way as cloud computing allows on-demand requests for storage and computing power. The combination of these technologies – SDN, virtualisation and cloud technologies – results into the concept of a network operating system that allows unified orchestration of computing, storage, as well as networking resources in a programmable way.

Standardisation of SDN has already started (e.g. OpenFlow and OpenFlow-Config are standardised in Open Networking Foundation, or FORCES in IETF) and SDN is going to be adopted broadly in data centres. However, applying SDN also to carrier networks will still take time and will require very likely further evolvement of today’s SDN technologies.

The objectives for solving the problem

Launching activities on the following research priorities will support the adoption of SDN, will help to enable a combined control of public networks and IT networks and to leverage advantages offered by SDN in terms of flexibility and efficiency. This research will open up a whole innovation eco-system by transforming today’s networks into a flexible and versatile infrastructure and in particular by providing open and standardised interfaces and platforms fostering innovation.

The associated research

- A set of separate resource services leaving the integration role up to the user/applications. The design could also comprise layers such as a kernel able to integrate and orchestrate any combination of storage, network and computation facilities, and a service layer on top of the kernel that offers a set of resource service primitives to applications.
- Applying and further developing SDN concepts at network infrastructure level. This includes the introduction of SDN into carrier networks (mobile and fixed), the exploration of use cases leveraging the benefits of SDN (e.g. sharing of network resources, disaster handling, or fast introduction and testing of new network features), and the support of and interworking with network virtualisation abstracting from the physical network entities.
- Advance standardised and open approaches for implementing Software Defined infrastructures, including computing, storage and especially network resources, and its integration into a network cloud infrastructure. This includes in particular exploring the

design alternatives of a Network Operation System (NetworkOS) able to orchestrate a unified access to computing, storage and network functions and networking resources. Design alternatives could range from a fully integrated execution environment to a set of separate resource services leaving the integration and orchestration role up to the user/applications. The design could also comprise layers such as a kernel able to integrate and orchestrate any combination of storage, network and computation facilities, and a service layer on top of the kernel that offers a set of resource service primitives to applications.

- Develop concepts and mechanisms ensuring that the NetworkOS meets carrier-grade requirements such as performance and reliability; special emphasis should be given to security protecting the NetworkOS functions as well as the data manipulated by the NetworkOS.
- Develop a common information model describing the interfaces and operation models for all the resources that should be integrated and orchestrated within the NetworkOS – this will allow for a multi-vendor environment.
- Create elements for a SW development environment, which will allow companies and a community of developers to enrich NetworkOS both on kernel and on infrastructure service layer.

Associated KPIs:	
• Reference implementations of a NetworkOS	• Number of reference implementations of a NetworkOS, and related South Bound and North Bound interfaces
• Availability of standards on NetworkOS concepts	• Availability of standards supporting the concept of a NetworkOS, and related South Bound and North Bound interfaces
• SDN controlled network resources	• Number of SDN controlled network resources
• Backward compatibility	• Demonstrated backward compatibility with non SDN based implementations

2.1.2.4. Networks of Clouds

Problem description

One future challenge will be to guarantee and continuously improve customer experience offered by cloud-based services. Such experience relies on the End-to-End QoS, and more generally on respective SLAs in place for a given service. This includes well-known characteristics, such as latency, throughput, availability, and security, but by adopting the principles of Clouds, also elasticity, on-demand availability, lead- and disposal-times, multi-tenancy, resilience, recovery, and similar characteristics important especially in case of cloud-based services. However, in order to guarantee this kind of service level, network-based service qualities may not be enough, but need to be aligned with platform-level and Cloud specific tenets, like dynamic discovery, replication, and on-demand sizing of VMs, since previous over-provisioning best-practices inherent to hosted and managed execution environments are no longer applicable.

Furthermore, in the future, there will be many Cloud-derivatives offering different approaches and levels of QoS support. Moreover, public, private and hybrid clouds and respective infrastructure, platform, and software services are frequently compositions of many components (services) spread across many horizontal and vertical domains (e.g., different provider, network, data centre, and service-platform domains). This will inevitably result in complex multi-domain scenarios, in which logical Clouds are formed by federating different infrastructure or platform clouds and complex service compositions at application level. Obviously, such a highly-distributed environment requires reliable and capable connectivity and the ultimate customer experience depends on the performance of the overall (composite) service.

<u>The objectives for solving the problem</u>

Some business models require federation and/or orchestration capabilities. In a federation context, the stakeholders agree on jointly providing a service. For example, they can federate their regional CDNs to build a global CDN. The federated system has its own services definitions and interfaces, SLAs, etc. In an orchestration context, each entity keeps its service models, interfaces and SLAs and a specific component, that we call broker, will compose services from each stakeholder to be able to provision a requested service (Figure 9).

Both approaches can be used to extend coverage, increase capacity or enhance quality (for example deploying functionality or locating content near by the customers). The broker functionality can be implemented by one of the players or by a 3rd party. It therefore represents by itself a business opportunity.

Advanced QoS support of cloud based services and applications within federated cloud scenarios: In order to meet these multi-faceted and interconnected challenges, future research should address network support for accessing and inter-connecting complex multi-domain Cloud services. In particular the nature of on-demand, distributed, service-oriented, applications run on top of clouds need to be better understood and respective metrics must be defined.

In future ecosystems, the operator will need to efficiently orchestrate its own resources not only for cost reduction purposes, but also for being able to open the network capabilities to enable 3rd party services and federations. The single domain orchestration has many challenges such as how to describe the resources and define the interfaces in such a way that the network capabilities are exposed to 3rd parties or partners without exposing the level of detail that constitutes the operator's know how and hence its market differentiation. Interface definition, resource/price discovery, publishing and negotiation and service level monitoring and assurance are also main components of the single domain orchestration. Key elements for the orchestration are the network and service modelling and the optimisation algorithms used for resource embedding. The orchestration needs of the future network will involve not only connectivity (and its associated functions) but also computing resources enabling complex network functions ranging from platform to applications.

Once the issues of the orchestration for a single domain addressed, providing a service through a federation of network domains will need a brokerage level of orchestration. Here, the way in which single domains describe their network capabilities will have to be interoperable (standardisation opportunities); network capabilities discovery, publishing and negotiation will be basic requirements. SLA definition, monitoring and assurance will be of key importance. The QoS associated metrics will not suffice to describe service/application requirements in an ecosystem in which more personalised and individual services will be predominant. Metrics associated to user perception and business process efficiency will rise as important drivers for business. Together with the increased number of connected devices and things, the more detailed information processing needs make the Big Data network capabilities even more relevant.

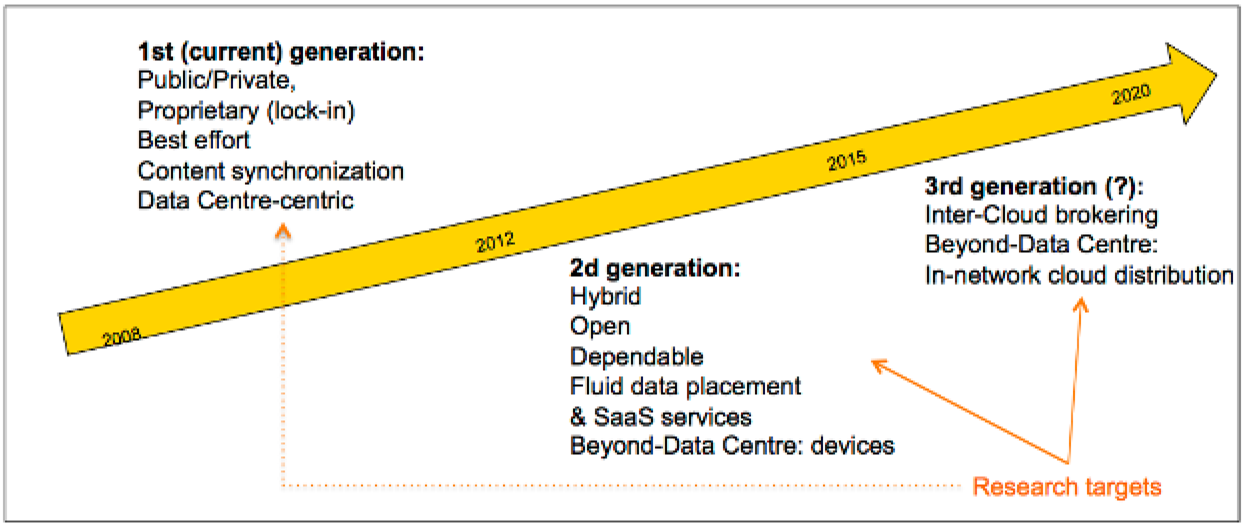

Figure 9: Networks of clouds

<u>The associated research</u>

Some initial directions would be the autonomous self-optimisation of service orchestrations, based on the traffic matrixes of such multi-service composite applications, and information about the capabilities and status of the underlying connectivity infrastructure. Such research should be supported by exploration of network traffic characteristics generated by multi-service compositions. Especially the IoT-Cloud combination may pose novel requirements and high demands on networks by firstly, massive amounts of information exchanged between the IoT domain and one-or many Clouds and secondly, the huge networks that may be very dynamic in nature in particular in the IoT space.

<u>Associated KPIs:</u>	
• QoS requirements	• Number of services with demanding QoS requirements running in hybrid cloud environments
• Availability of standards on SLA negotiation	• Availability of standards supporting proposals supporting SLA negotiation in hybrid cloud environments

2.1.2.5. Roadmap of “Re-Designing the Network”

The networks must evolve in pure capacity and connectivity speed terms in the first instance but in the 2020 scenario this will not be enough. The functional capability of the network must be matched with highly sophisticated network control functionality that is capable of overseeing the networking, ensuring all delivery promises are kept while optimising the use of resources and energy for both cost and environmental reasons. We need to consider the developments necessary and then organise these in terms of when they are needed (Figure 10).

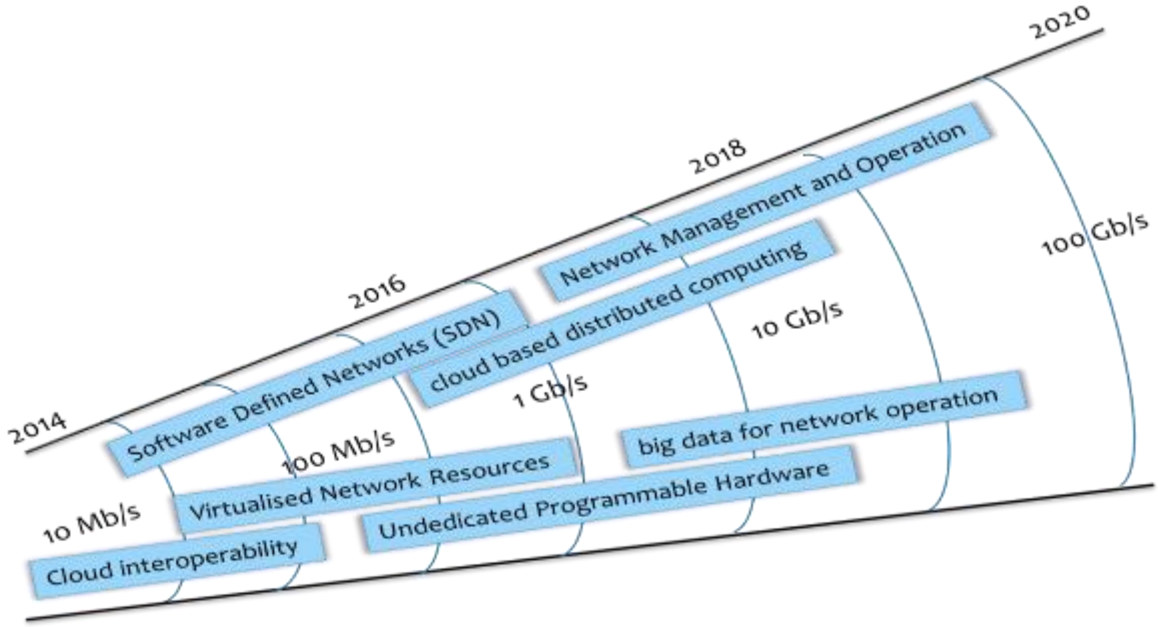

Figure 10: Roadmap

2014 - 2016 Design phase, proof of concepts, standardisation

2016 - 2018 Prototypes, technology demos, pilots

2018 – 2020 Large scale demonstrations and trials, scalability testing, etc.

2.1.3. Ensuring Availability, Robustness and Security

With the universal adoption of the Internet and IP, entire sectors of the economy have shifted their dedicated networks to the common Internet infrastructure. The "critical services" have left the narrow frame of emergency numbers to include other communications services: Medical information, financial, IoT/M2M data … Many future Internet services, such as smart grids, Intelligent Transportation Systems, Business-to-Business relationships require enhanced guarantees in terms of robustness and security. The unavailability of these services, due to a bad design, an accident or a malicious act, can then be catastrophic.

Furthermore in 2020 network infrastructures will be based on massive abstractions or virtualisation technologies (c.f. Section 2.1.2.2 on Network Functions Virtualisation). This means that services, including critical ones, will run over heterogeneous infrastructures possibly managed by several independent entities. Providing the required end-to-end SSLA (Services and Security Level Agreement) in terms of scalability, dependability, service quality and security in the broader sense is a major challenge.

<u>The objectives for solving the problem</u>

The key objective is to embed within the network infrastructure built-in resilience mechanisms that may be used to deliver more diversified and value-added services, in particular to support the most demanding critical networks. This translates into an integrated vision where network properties of QoS, availability, security are considered together in order to support a target resilience level.

<u>The associated research</u>

Network analytics

- Improve quality of network monitoring data: Create models for improving data quality and introduce data quality models to streaming and batch-oriented Big Data tools to provide better insight on the behaviour of networks – e.g. down-sampling data or throwing away low quality data.

- Deploy crowd sourcing, to allow more precise user behaviour collection, especially data submitted by large groups of network users (i.e., the "crowd") through networked media.
- Develop distributed machine learning technology to automatically learn to recognise complex user and network usage patterns and make intelligent decisions based on data. This is specially required to improve cyber security and to reduce the time to detect a security attack or breach.
- Provide social network analysis to characterise connections between users in a community or organisation, e.g., how information travels over the network, or who has the most influence over whom. This is will allow to understand and to model the behaviour of mobile networks in order to optimise the network and to gain insight into their users.
- Improve classification or cluster analysis of network usage patterns in order to support prediction of segment-specific user behaviour (e.g., mobile data consumption, churn rate, consumption rate).

Service & Security Level Agreement (SSLA)

- Provide methods and schemes to compose different and heterogeneous SSLA commitments and provide the end-to-end resulted SSLA.
- Develop mechanisms to allow services or applications to evaluate their local and contextual SSLA to allow them to be aware of the contextual chain of liability before being used in some environment.
- Develop a reputation infrastructure to assess the trustworthiness of entities (such as cloud or network service providers); this is required for a sustainable service composition eco-system.

Network resilience and security

- Develop end-to-end resilience models (risks and threats propagation of faults and attacks between heterogeneous infrastructures or platforms, system of systems).
- Develop cyber security mechanisms for the detection of rare or abnormal events (deep packet inspection, behaviour analysis, weak signals, analysis of heterogeneous information from multiple sources, collect of each incident of every stack composing a production line, etc.), observation of attack patterns and dynamic creation of countermeasures stopping attack proliferation (adaptive security).
- Provide adaptive resilience mechanisms (including rerouting, security counter-measures) based on partial knowledge of the network (through observation of traffic point).
- Develop specific, targeted security countermeasures for SDN-specific threats (both of virtualisation/slicing and software control).

Associated KPIs:	
• Collecting and processing user data	• Volume and time for collecting and processing user data
• Quality of user behaviour characterisation	• Number of patterns and connections identified per user or group

2.1.4. Ensuring Efficient Hardware Implementations

Problem description and objectives

A successful commercial exploitation and deployment of 5G will rely on readiness of innovative cost effective and efficient network components. A good matching between technological roadmaps of micro-electronics and photonics and the 5G infrastructure roadmap is thus necessary. To this end, studies need to be conducted on complexity analysis, on innovative architectures for 5G transceivers and microservers, and on the identification and prototyping of key hardware building blocks.

The associated research and KPIs

Among the critical enabling hardware technologies that 5G requirements will impose are advanced RF and digital architectures, and innovative components as outlined and justified below.

RF implementation challenges

- RF front-end technologies based on advanced CMOS process and innovative RF architecture together with antenna co-design have to be developed, providing simultaneously cost efficiency, very high level RF performance and low power consumption.
- Considering Machine-to-Machine applications, RF solutions for improving battery life and ensuring autonomy of up to 10-20 years should be a target of research.
- Millimetre wave communications are attracting interest to cope with 5G spectrum challenges, thanks to the available large bandwidth. Nevertheless mm-wave technologies for mobile communications are in an early stage of maturity and significant research should be undertaken to improve the integration of RF front-end and address high-volume with low-cost in CMOS technology (including antenna arrays for beamforming and diversity), to enhance the digital process and to reduce the overall power consumption.

Digital implementation challenges

- The digital architectures and components for 5G transceivers and micro-servers need to be researched and developed. Innovative multicore chips with high performance/energy ratio, using 3D stacking and silicon interposers including photonic interconnects are technologies to be investigated to increase the bandwidth between compute engines and memories up to 450 Gbps between memory and processing.
- Solving some important challenges of advanced computing systems is essential for the success of 5G. In fact high level of energy efficiency can be achieved by using heterogeneous hardware in combining parallel processor cores with accelerators. Efficient programming of these structures is a major challenge, where computing resources are required to be virtualised to process a large range of tasks, independent of underlying hardware, and even allowing dynamic task allocation and migration to truly virtualise network and computing resources. Research is needed for efficient distributed virtualisation solutions with resilience, data security and protection.

Associated KPIs:	

• Hardware performance improvements	• Simultaneously cost efficiency
	• Very high level RF performance and low power consumption
	• 50 % more efficient in terms of
	  ○ power consumption
	  ○ much lower leakages
	• Operations as low as 0.5 V

• RF solutions	• Improved battery life and ensuring autonomy of up to 10-20 years • Reduce gap between µW range from possible harvested energy and mW range for electronics and RF communication • RF front-end receiver power consumption below 1 mW • Ultra-miniaturisation of antennas while maintaining high efficiency
• Millimetre wave communications	• Improved integration of RF front-end with CMOS technology (including antenna arrays for beamforming and diversity)
• Digital architectures and components for transceivers and micro-servers	• Innovative multicore chips with high performance/energy ratio • Bandwidth between compute engines and memories up to 450 Gbps
• Energy efficiency by using heterogeneous hardware in combining parallel processor cores	• Efficient distributed virtualisation solutions with resilience, data security and protection

2.2. Key Stakeholders along the Value Chain

The key stakeholders are the following ones:

- Manufacturers in the network, IT and microelectronics domains to perform research and development of exploitable solutions as well as global standardisation.
- Communication service providers to provide requirements on new systems and cooperate with manufacturers and the research community for research, development and standardisation of new systems.
- Research community (R&D centres and universities) to provide new ideas and concepts for advanced solutions.
- SMEs to provide particular know how and innovative solutions for specific concepts.
- Cooperation with application developers and vertical sectors to understand at an early stage requirements and challenges for new networks.
- International standardisation bodies and cooperation partners in other regions in order promote new concepts, systems and solutions for global adoption in international standards.
- Regulatory bodies to increase awareness of barriers for the adoption and deployment of new systems e.g. with respect to economic conditions and business cases and to mobilise the necessary investments.

2.3. Indicative Timeline and Estimated Budget

Mid 2014: Expected start of first projects under the PPP umbrella.

2014 Exploratory phase to understand detailed requirements on **5G** future systems and to identify most promising functional architectures and technology options which will meet the requirements. These activities will build on previous research work in industry and research framework programmes as well as global activities in other regions and standards bodies.

2015 Detailed system research and development for all access means, backbone and core networks (including SDN, virtualised network resources, cloud systems, undedicated programmable hardware, …) by taking into account economic conditions for future deployment. This work will set the basis for a Pan European experimental infrastructure serving all network domains. The proof of concepts in particular for core network elements is expected in this phase.

2016/2017 Detailed system optimisation by taking into account all identified requirements and constraints.

Finalise consensus on globally identified frequency bands for mobile and wireless communications (also taken into account the result of WRC15) and final system definition and optimisation by means of simulations, validation of concepts and early trials. The PPP will develop contributions to initial global standardisation activities and will build the Pan European experimental infrastructure in collaboration with GEANT and FIRE initiative.

Preparation of WRC17/18.

Support of initial international standardisation activities, which will continue in the following years.

2016/2017 Support of regulatory bodies for the allocation of newly identified frequency bands for the deployment of new systems. New frequency bands should be available around 2019/2020.

2016/2017 Implementation of large trials of new systems for validation under close to real world conditions, complementary research work as the need will arise as technologies are assessed.

2016 to 2019 Investigation, prototypes, technology demos and pilots of network management and operation, cloud-based distributed computing and big data for network operation.

2017/2018 Extension of trials to non ICT stakeholders to evaluate the programme results and its impact in the real economy.

2017/2018 Detailed standardisation process based on validated system concepts by means of simulations and close to real world trials.

2018 to 2020 Large scale demonstrations and trials, scalability testing, etc.

2019/2020 New frequency bands available for trial network deployment and initial commercial deployment of new systems.

2019/2020 Close to commercial systems deployment under real world conditions with selected customers to prepare economic exploitation on global basis.

Estimated Budget

Future systems will be researched and developed from a holistic perspective including all means of mobile and wireless access as well as fixed/optical access, the backbone network and networking means, including software and micro electronics competences. Therefore, a wide range of expertise and skills will be needed. The development and deployment of early and bigger trials will require the development and provision or the necessary hardware systems as well as the necessary system software. In particular these trial-oriented activities are very costly.

The programme will have during its lifetime several ongoing parallel projects to address the different aspects and layers of system research and trial preparation.

It is expected that the overall budget in the 7-years period of the MFF from 2014 to 2020 of 1400 million € will be needed. From the today's perspective it is expected that about 70 % will be used for research actions and about 30 % for innovation actions, where the share for innovation actions will increase during the programme life time. The expected total public funding envelope should be in the order of 700 million €, which is matched by a direct private investment in 5G PPP research projects by a similar amount of 700 million €. With respect to the development of early trials and bigger trials towards the end of the programme the annual funding per year is expected growth from programme start towards the programme end linearly in a first estimate according to the following table. The programme will implement the PPP SRIA as developed by the ETP, the industry roadmap and research actions as developed in the Association and the PPP and endorsed by the Association. The different programme phases will be refined based on the roadmap and the SRIA with respect to the allocation of budget and activities (research, testing and trials, innovation, standardisation and dissemination). Different instruments in Horizon 2020 (use in downstream phases the full palette of instruments like SME actions, ODI (Open Disruptive Innovation) schemes etc.) will be taken into account for the most appropriate approach.

Year of call for proposals	2014	2015	2016	2017	2018	2019	2020	Total [million €]
Global budget	140	160	180	200	220	240	260	1 400
Estimate research actions	110	120	140	140	150	160	160	980
Estimate innovation actions	30	40	40	60	70	80	100	420

From a wider perspective public investment is public funding in research programmes and also potentially Structural Funds for the deployment of new systems in eligible regions, where a market-driven approach will not ensure the availability of new systems.

Private investment is manifold in this context, which is going beyond the implementation of PPP projects:

- Matching investment to public funding for projects in the PPP (cf. 700 million € above) and the following additional investments.
- Private R&D investment for research, development and standardisation of new systems on the vendor side. This refers to bigger industry as well as to SMEs.
- Private R&D investment for research, development and standardisation as well as the deployment of new systems on the operator side.
- Investment in R&D in research centres and universities is to a large extent public investment. However, these institutions also receive private funds for cooperation projects in this context.

3. Expected Impacts

3.1. Description of Industry Commitments

The Advanced 5G Network Infrastructure for Future Internet PPP will organise and structure the research so that it is clearly business relevant, creates a critical research mass and involves relevant partners from the entire value chain.

The PPP will support the development and standardisation of new, globally harmonised, 5G communication networks, which will meet the requirements in the 2020 time frame and beyond in order to strengthen the position of industry in Europe in future global communication networks markets.

It will be based on principles of openness, transparency and representativeness in particular for the definition and implementation of the SRIA in respective collaborative research projects. The PPP will in particular initiate specific actions to attract innovative SME's and gather the views of key stakeholders as identified in Section 2.2.

In order to launch the PPP an association will be created **by November 2013** to represent the counterpart to the EU Commission in the contractual agreement according to Article 19 in "Regulation of the European Parliament and of the Council establishing Horizon 2020 - The Framework Programme for Research and Innovation (2014-2020)". The detailed development of the Articles of Association and the 5G Infrastructure Collaboration Agreement will be initiated as soon as the PPP Contractual Agreement and the Horizon 2020 Model Contract will be available in order to comply with these documents. It is expected that draft documents will be available in September 2013 and final document in October 2013.

The 5G PPP is starting on the stable ground of an existing agenda already agreed between the main stakeholders: the "Strategic Research and Innovation Agenda" for the communication network sector. This agenda has been developed and annually updated during the last few years and is endorsed by the sector. It describes the interests and contributions of different stakeholders. However, new developments in technology, the regulatory environment and the application domain are influencing the necessary research activities. Therefore, the future Strategic Research and Innovation Agenda for the 5G-PPP will have to embrace new ambitions and be regularly updated (most probably on annual basis). Once the initial agenda for the 5G-PPP will be finalised on the basis of the existing Agenda described above, we expect further updates to be incremental in order to ensure continuity and consistency. This underlines the critical importance of establishing the initial agenda in a robust and forward-looking manner. In addition, road-mapping of milestones based on the agenda will be updated regularly in order to keep pace with external developments. These activities will be performed in the PPP CSA project, which is facilitating the PPP operation, and monitored by the PPP Association.

The PPP will further analyse the research results to ensure that the implemented projects are contributing to the target PPP objectives according to the agreed roadmap and to the identified KPI's. The Association from its side will also in execution of the PPP Contract do certain tasks in the field of ex-post evaluation of PPP projects.

The PPP, through the Association, will analyse the European related R&D investments in the target sectors, in view of monitoring **the leveraging factor for further investment outlined in Section 3.3**, where industry will invest significantly higher budgets than provided by public funding in the PPP.

The PPP budget will be a catalyst for cooperation between stakeholders and consensus building towards future standardisation and to create future global markets. The research activities in the 5G PPP will trigger a substantial amount of additional R&D activities in particular in the private sector for conducting detailed system development, international standardisation and product development for the global market. The necessary R&D expenses for a 5G communication infrastructure per vendor including its ecosystems suppliers and SMEs will be in the order of the total cost of the 5G PPP. The deployment of new systems by operators will require even much higher investments than the development cost. Such systems will be continuously further developed by future releases during the entire system lifetime. Application development will start as soon as the system platform will be available and will also be a continuous process during system lifetime. Therefore, the private sector is committed to invest about 10 times more than the PPP total cost in product development and maintenance and even much higher amounts for system deployment.

It is the intention of the parties involved in this PPP to use achieved results for global standardisation to ensure globally interoperable systems. Based on international standards industry in Europe will exploit results economically in system and product development for future communication networks for the global market to the benefit of European economy and to provide communication platforms for application developers and other users of such systems.

Research results will be secured by **building up IPR portfolios**.

PPP actors will identify potential barriers for the deployment of future systems and will develop, in consultation with regulatory bodies, analysis and position papers in critical domains like spectrum and standards to support the deployment of the developed technologies.

Industry in Europe will develop the basic communication solutions for highly secure infrastructure networks, which can be used for vertical sectors and in particular for critical infrastructures like energy, gas, water and traffic systems.

3.2. Expected Impacts of the PPP and Strategic Objectives

The network industry is supporting the global market and is facing global competition. Therefore, expected impacts have to be seen in the global context.

According to the vision in Section 1 networks of tomorrow will be based on significantly new architectures and technologies.

<u>The strategic objectives of this PPP are thus:</u>

- To support and reinforce the European industry to successfully compete on global markets with the adequate portfolio of technologies and solutions meeting the anticipated change in usage patterns.
- To pave the way towards successful introduction of innovative business models based on more powerful open networks.
- To support the emergence of global standards ensuring competitiveness and interoperability.
- To address non-technological barriers such as regulatory issues and spectrum availability.
- To validate technologies from a technical and a business perspective through early trials and reference deployments.
- To develop a significant portfolio of essential IPRs to secure the position of industry in Europe.
- To develop the skilled personnel, which is needed to research, develop, provide and operate advanced communication networks as well as use of such new systems in secondary and vertical markets.
- To provide a reliable and trustworthy communications infrastructure, which secures critical infrastructures from cyber attacks.
- To develop 5G infrastructure solutions, to be used for providing solutions to societal challenges following the Digital Agenda. This will make the European society and economy smarter and more efficient for the benefits of European citizens and beyond.

The following impacts are expected:

A European PPP in this time frame can achieve the following significant impacts:

- The PPP will provide the critical mass platform for collaborative research of all necessary stakeholders to build consensus on new 5G communication networks by means of early cooperation in the pre-competitive phase. Coordination between EU activities and local as well as member state activities will then improve the overall impact.
- This consensus will be exploited in global standardisation and will enable industry in Europe to establish essential IPRs in global standards.
- The PPP will assist global standards to enable economies of scale and thereby affordable cost.
- The PPP approach by involving a big number of stakeholders will generate global visibility of European research.

Impact on society and opportunities for a wide range of applications:

- A major societal benefit is that preparing and providing the new infrastructure will empower European citizens by giving them access to the most advanced capabilities for the benefit of their social wellbeing and to enable their inclusion into all aspects of European Life in accordance with the Digital Agenda.
- For Europe at large the expected impact will be to:
  - Accelerate the adoption and use of advanced ICT services in Europe.
  - Attain European leadership in uptake and use of new ICT technologies.
  - Advance the critical communications infrastructure in Europe and its implementation.
  - Drive the integration of services and smart infrastructures for highly optimised service provision across heterogeneous networks.
  - Deliver innovative efficient network technologies which will support the EU's target of reducing CO_2 emissions.
- Acceptance of new technology by society and consumers:
  - Organisations representing user groups will be involved as Associated Members of the Association.
  - Potential barriers for accepting new technology will be identified.
  - From experience electromagnetic emissions are an area of concern. A second area is network security and privacy issues, which have to be addressed by future systems.
  - The involvement of such organisations will help to identify at an early stage potential barriers and concerns in order to develop mitigation strategies.
  - Industry will use means of Corporate Social Responsibility for the introduction of new technologies.
  - If there are ethical issues involved from the new research, public consultations will be organised.

Impact on economic and industrial development:

- New ubiquitously available communication networks will improve competitiveness in Europe for all sectors of the economy and society, where the communication industry is the enabler. Communication networks are a cross-cutting technology, which will help to improve the quality of experience for new generation multimedia services (UHD, 3D, augmented reality), as well as the overall environmental conditions by more efficient utility networks (energy, gas and water), traffic systems, health systems, education and the support of the elderly society. Communication networks provide new business opportunities for SMEs and other sectors to develop new products and services to generate new growth in Europe.

- An advanced communication infrastructure in Europe will be a major precondition for a new wave of growth in economy in an increasingly globalised world.
- The 5G Infrastructure PPP will reinforce the European industrial leadership in Network and Information Systems that will support growth in Europe, with the objective of maintaining and of improving the industry's markets share worldwide.

International cooperation:

- International cooperation will be needed to reach consensus on the scope ("perimeter") of 5G, the target time frame, and to develop agreements on open standards and specification, to avoid competing standards or regional standards, and to have access to the required competence and the global market.
- International activities will be launched to support frequency spectrum identification and planning on global basis. The first step will be WRC 2015 is already very far advanced and first PPP projects will have started shortly before WRC 2015, which will set the agenda of the next conference in 2017/2018. The next WRC around 2017/18 will be the most critical as it will decide on most of the starting frequencies for 5G, and it is also where the PPP can contribute to the preparation from the very beginning. This conference will be the main focus of activity towards additional frequency spectrum. The preparatory work will start shortly after WRC 2015. The PPP will be instrumental to support the spectrum planning process by providing its expertise and make coordinated contributions to the international debate, in particular on a more flexible spectrum use and new frequency bands of interest in the microwave and millimeter wave range. In addition, also other frequency bands will most probably be under consideration.
- Results of PPP projects will be suitable for global standardisation in bodies like 3GPP, IEEE, IETF and other standards and specification bodies in the IT domain etc., which can be contributed via established channels of PPP partner organisations to respective standards bodies. These channels will be used to exploit research results in international standardisation.
- Further activities towards international cooperation are the organisation of PPP workshops in other regions in order to disseminate results and information and to support consensus building on global basis towards the adoption of concept and system proposals in global basis.
- It has to be noted that already major non-European companies are supporting the PPP, which will ensure global links of the research effort. The direct involvement of global companies, which do not have their headquarters in Europe, will help build global consensus and to agree global standards. We would also observe that the project contains key partners from the Americas, Europe and Asia, and encompasses the bulk of the world's population as a result.
- Key countries for international cooperation in research are Japan, Korea and Brazil for technology development and the adoption of European standards and solutions. China will be an important partner for cooperation to prepare future standards.
- The CSA for the support of the PPP will work on detailed activities towards international cooperation to identify relevant programmes for information exchange and coordination of activities in order to achieve consensus on new solutions.
- From the today's perspective the following regional programmes and bodies are identified for international cooperation
    - US: NSF on virtualization, SDN and access to radio spectrum.
    - Japan: NiCT on New Generation Networks and Future Internet (Akari project on Future Internet), research at NTT docomo.

    - China: MOST on 5G Research Initiative and the 863 programme on radio systems and beyond. Potentially also the 973 programme applies.
    - Korea: Korean 5G Forum (established May 2013), ETRI and major research activities in industry.
- International cooperation will also address more classical technology research in order to achieve early convergence on basic solutions, architectures and interfaces. Experiments and trials are already close to the competitive phase. However, the objective of cooperation in this phase will be to check interoperability of interfaces. Information exchange on user requirements (users in our sense are vertical sectors, end users, M2M, …) is also expected in the initial phase of the PPP.

3.3. Ability to Leverage EU Funding with Additional Investments

The organisations participating to the 5G Infrastructure PPP will:

- Build on results from EU Framework Research programmes, Horizon 2020 projects, EIT KIC ICT Labs, EUREKA Clusters projects, National projects/programmes.
- Bring in company internal research results and standardisation activities in order to exploit results in global standards.
- Use independently developed trial systems as basis for early trials for further development towards bigger systems trials.
- Leverage on EIT KIC ICT Labs to develop skills and competences on the basis of the 5G Infrastructure PPP developments. An MoU with EIT ICT Labs will be established to support training and education activities on new 5G technologies.
- Cohesion funds will be targeted in eligible regions for the deployment of trials and the involvement of selected users.

The annual R&D investments by the major communications industry in Europe amounts to well over 10 billion € as reported by JRC/DG RTD as compared to the investment of roughly 1 billion € in collaborative research programmes of the European Union for participants from the private sector as well as public research institutions (R&D centres and universities). Therefore, the private sector investment is significantly higher. However, private investment in the communication networks domains is to a significant extend triggered by collaborative research, which paves the way for the development of basic solutions and consensus building towards future standards. These results and this environment are then exploited economically.

Therefore, a leveraging effect from the public investment by the EU Commission in research in the PPP in relation to the private investment in R&D for systems in the scope of the PPP between 5 to 10 is expected and targeted.

The monitoring of the respective R&D investment in the PPP in relation to the overall R&D investment will be a task of the Association in cooperation with the PPP CSA project. Monitoring of R&D investment can only be done by an independent trusted research organisation of market research organisation, which is collecting such data from industry players on confidential basis and is aggregating such data in anonymised form for monitoring and reporting purposes, whether the PPP is working according to its roadmap and is achieving the expected leveraging effect. R&D investment on certain areas is usually confidential and competitive information and will not be publicly available. Potential partners for such an activity could be the Joint Research Centre of the EU Commission or Eurostat. This should be described in the statutes of the Association in relation to the PPP CSA.

With respect to net sales the leveraging effect is much bigger, when the research intensity of the telecom sector in the order of 13 to 14 % is taken into account. There is a huge leverage effect from publicly funded collaborative research to private investment.

The market size according to the same study amounts to roughly 85 Billion € annually. The collaborative Research investments can be seen as a nucleus to foster critical research and prepare for product development, as already demonstrated with developments of previous generations of mobile network.

Based on the experience in collaborative research and the achieved global impact on standardisation the communications technology sector in Europe is willing to invest in the further development of communication networks in order to support further economic growth and to improve competitiveness in the global market. The performance of industry is monitored annually in scoreboards, where potential impacts of investment in research on economic performance can be observed.
(E.g. EU R&D Scoreboard – The 2012 EU Industrial R&D Investment Scoreboard. Joint Research Centre of the EU, http://www.eurosfaire.prd.fr/7pc/doc/1354893182_sb2012_final_draft.pdf).

3.4. Strategy and Methodology/Mechanism for Coordinating the Implementation and Measuring Progress

The term Public-Private-Partnership – PPP in the context of this annex is defined as follows. The PPP corresponds to the overall structure including

- the **Association** with the Industry Advisory Board and
- the **5G Initiative**, which comprises the selected projects under the PPP umbrella in all programme phases, the Steering Board and the Technology Board. This 5G Initiative is organised under the 5G Infrastructure Collaboration Agreement,
- the **Net!Works European Technology Platform** as representation of the wider sector via its direct link (Members Agreement) to the Association.

The PPP will have a number of parallel mainstream RTD and Innovation projects to investigate the different technical concepts and systems as well as optimising their performance and validate their feasibility as indicated in the SRIA priorities.

In addition, it is foreseen to coordinate the cooperation between RTD and Innovation projects for interface definition and alignment through an efficient Coordination Action. Each project will have dedicated tasks and allocated resources for these common activities in order to ensure commitment to the holistic approach. This coordination action will also support the bodies in the PPP governance for monitoring the programme progress, for the identification of programme issues and for initiating mitigation actions.

Figure 11 shows the proposed approach. This model (WWI-model as applied in FP6) was successfully used to develop the basic concepts of IMT-Advanced and LTE – today globally deployed mobile and wireless communication systems. It provides means for cooperation between different collaborative research projects. The collaboration should be facilitated by a dedicated support action, which is organising the necessary bodies in the PPP and is managing the necessary infrastructure and joint activities like dissemination events. The proposed model ensures the cooperation between stakeholders based on a cooperative approach. Participating projects are linked by cross-issues for particular topic areas. Cooperation depends on topic areas and interfaces, where cooperation is needed.

The partnership initiative can be realised using Collaborative Projects (CPs) of appropriate size for RTD and Innovation activities and a CSA to facilitate the PPP operation. These projects will be launched in the different phases of the PPP, which could be consecutive and/or partly overlapping. The work programme and Calls for Proposals for later phases may be adapted to updated Strategic Research and Innovation Agendas in order to keep the PPP actual with respect to changes in the environment during the lifetime of the overall initiative. Therefore the seven years PPP lifetime will be subdivided in three phases, which will address

- in Phase I basic research work, concept and system development including dissemination activities,

- in Phase II system optimisation by taking into account the results of WRC 2015 and early trials for key concepts, promotion of new system concepts globally and contributions to international standardisation and
- in Phase III large-scale trials, the extensive involvement of web-entrepreneurs and SME for application development in order to demonstrate the potential of new communication networks for global adoption and the preparation of future markets.

The project internal relation between partners is described in a Consortium Agreement on private basis. The relation between PPP projects and all PPP partners is described in a 5G Infrastructure Collaboration Agreement on private basis.

The following bodies are foreseen in the direct governance model of the 5G Initiative:

- An **Industry Advisory Group** of senior representatives, who are coming from PPP participants but not actively working in the projects, plays the role of providing strategic guidance to the overall partnership initiative, ensuring that results, concepts and systems are adopted more efficiently for economic exploitation in the market. Industry players are committed to staff this group. The Industry Advisory Group also plays the role for strategic steering and discussions. This group is part of the Association and will be described in the Statutes of the Association (Section 4.3). It will be supported by the PPP CSA.
- The 5G Initiative **Steering Board** comprises the project coordinators of active projects in the PPP. It handles the daily management of the overall partnership initiative. For example the partnership initiative will organise the cooperation between projects and joint events to promote results of the partnership initiative, concepts and systems. This group is part of the PPP governance model and will be described in the 5G Infrastructure Collaboration Agreement (Section 4.5).
- The 5G Initiative **Technology Board** is composed of the Technical Managers of the active projects in the PPP. This group handles all technical matters across PPP projects such as interface definitions. This group is part of the PPP governance model and will be described in the 5G Infrastructure Collaboration Agreement (Section 4.5).

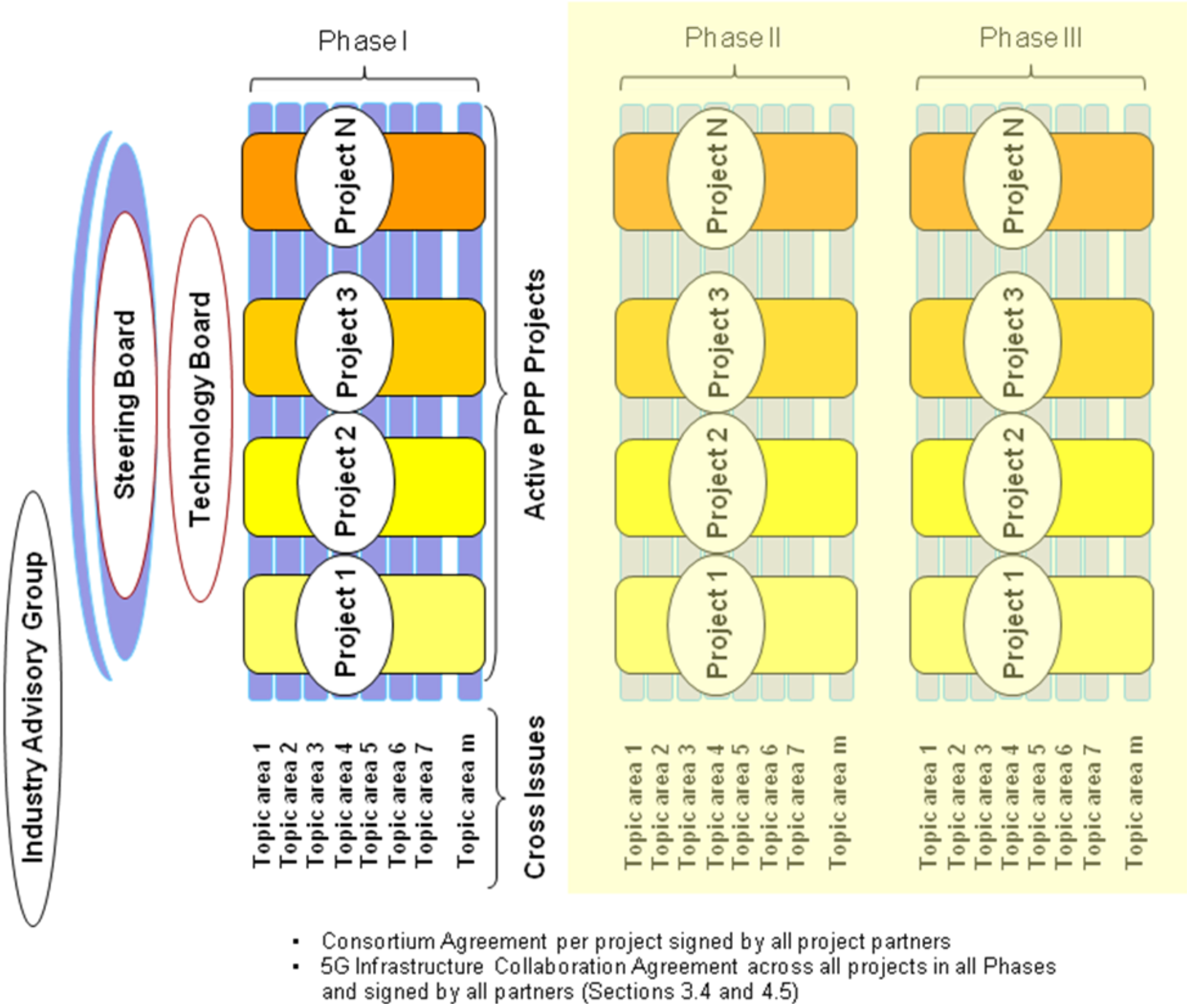

Figure 11: Proposed structure of the 5G Initiative

The legal aspects pertaining to the organisation of the projects and the collaboration between the projects will be dealt with as follows. Based on existing experience from Framework Programme 7 in the currently running "Future Internet PPP" (FI-PPP), the expectations on Horizon 2020 documents and already available documents on the Collaboration Agreement and the Consortium Agreement the necessary documents will be developed:

- Grant Agreement per participating project with the EU Commission handles the relation between the EU Commission and the projects:
    - Based on the Horizon 2020 model Annex II (today available EU Commission: FP7 Grant Agreement - Annex II General Conditions).
    - The Grant Agreement may be amended by a Special Clause on the cooperation between projects and access rights to IPRs (today available EU Commission: List of all Special Clauses Applicable to the FP7 Model Grant Agreement for the Implementation of the Seventh Framework Programme of the European Union and Euratom).
- Consortium Agreements per project handles the internal relation between project partners per project.
- 5G Infrastructure Collaboration Agreement across projects in the PPP to handle the relation between projects and partnership initiative-level bodies e.g. to ensure necessary access rights to IPRs based on the FI-PPP model in FP7.

3.5. Identified Indicators

The proponents propose specific joint operational performance indicators:

- Selection of the most relevant set of projects with respect to Industry roadmap.
- Percentage of industry (target > 50%) including significant SME participation (target > 20%) participation.

The proponents propose specific PPP operational performance indicators:

- PPP roadmap refreshed every two years at least
- Number of peer reviewed scientific publications/results.
- Number of standards influenced by the research, and generated patents.

Scientific & Technical performance indicators (KPIs):

Wireless Networks (LTE baseline)	
Associated KPIs:	
• Mobile data volume supported per area	• > 1000 multiplication factor in cell throughput
• Amount of spectrum made available via new intelligent spectrum management techniques	• Starting from a today allocation of about 300 MHz (Target: in minimum doubling)
• Number of connected devices	• 10x to 100x increase
• Achievable typical user data rate	• 10x to 100x increase
• Lower energy consumption	• Additional 80 % reduction in radio access part
• Increased battery life for low power devices	• > 10x
• End-to-End latency	• < 1ms, 5x reduction
Optical Networks	
Associated KPIs:	
Core	
• Capacity (> 10x increase)	• Tbps+ channels 100 Tbps+ links Pbps network nodes
• Reach	• up to 2500 km
• Equipment density/Bit	• x10
• Energy reduction/Bit	• x10
• Automation & control	• 30 % network efficiency increase > 30 % OPEX savings
Access and Aggregation	
• Capacity (>10x increase)	• 10G+ peak rates CIR/EIR 1:10 or better 10x central office consolidation 10 Tbps network nodes

• Reach • Equipment density/Bit • Energy reduction/Bit • Automation & control	• up to 100 km • x10 • x10 • 30 % network efficiency increase > 30 % OPEX savings
Data centre • Capacity (>10x increase) • Reach • Equipment density/Bit • Energy reduction/Bit • Automation & control	• Pbps fabrics Tbps interconnects in support of: Exascale computing Zettabyte storage • up to 2 km (intra-DC) up to 100 km (inter-DC) • x10 • x10 • 30 % network efficiency increase > 30 % OPEX savings
Automated Network Organisation - Network Management and Automation	
Associated KPIs:	
• QoE/QoS	• Increased customer satisfaction in terms of ○ throughput, ○ handover reliability and ○ call drop rate
• Network reliability and resilience	• Increase performance
• OPEX	• Reduced OPEX in terms of ○ energy consumption and ○ complexity of human operator tasks
• Scalability of the mechanisms	• In terms of ○ number of coordinated elements and ○ number of coordinated control loops
Implementing Convergence Beyond the Access Last Mile	
Associated KPIs:	
• Number of converged networks	• Including e.g. fixed, mobile, but also specific ones such as private infrastructures city-wide ITS (road management), PMR, future smart grids, …
• The factor of total increase in capacity	• Reduction in OPEX/CAPEX (20%)
Information Centric Networks	

Associated KPIs:	
• Response time	• Improved response time showing the efficiency of the name resolution, data access etc., by comparing the response time of 1st data packet to the average response of the rest of the data packets
• CAPEX and OPEX	• Minimised CAPEX and OPEX related to centralised content services of operators
• QoS and QoE	• Improved data access and discovery in terms of QoS and QoE
• Signalling and traffic overhead	• Minimised signalling and traffic overhead in terms of bandwidth utilisation and QoS/QoE
• Signalling and traffic overhead	• Improved scalability in large scale network environment compared to traditional approaches
• Demonstration and test network platforms	• Number of large scale demonstration and test network platforms showing the scalability
Network Function Virtualisation	
Associated KPIs:	
• Real deployments	• Number of real deployments
• Demonstrations of interoperability	• Demonstrations of interoperability among vendors and operators of their virtualised products and infrastructures
• Open innovation ecosystem	• The availability of an open innovation ecosystem around NFV technologies
• CAPEX and OPEX	• Figures on CAPEX and OPEX reduction (our initial estimates for this pilot are around 35 % in CAPEX and 45 % in OPEX)
Software Defined Networking	
Associated KPIs:	
• Reference implementations of a NetworkOS	• Number of reference implementations of a NetworkOS, and related South Bound and North Bound interfaces
• Availability of standards on NetworkOS concepts	• Availability of standards supporting the concept of a NetworkOS, and related South Bound and North Bound interfaces
• SDN controlled network resources	• Number of SDN controlled network resources
• Backward compatibility	• Demonstrated backward compatibility with non SDN based implementations

Networks of Clouds	
Associated KPIs:	
• QoS requirements	• Number of services with demanding QoS requirements running in hybrid cloud environments
• Availability of standards on SLA negotiation	• Availability of standards supporting proposals supporting SLA negotiation in hybrid cloud environments
Ensuring Availability, Robustness and Security	
Associated KPIs:	
• Collecting and processing user data	• Volume and time for collecting and processing user data
• Quality of user behaviour characterisation	• Number of patterns and connections identified per user or group
Ensuring Efficient Hardware Implementations	
Associated KPIs:	

• Hardware performance improvements	• Simultaneously cost efficiency
	• Very high level RF performance and low power consumption
	• 50 % more efficient in terms of
	  ○ power consumption
	  ○ much lower leakages
	• Operations as low as 0.5 V

• RF solutions	• Improved battery life and ensuring autonomy of up to 10-20 years • Reduce gap between µW range from possible harvested energy and mW range for electronics and RF communication • RF front-end receiver power consumption below 1 mW • Ultra-miniaturisation of antennas while maintaining high efficiency
• Millimetre wave communications	• Improved integration of RF front-end with CMOS technology (including antenna arrays for beamforming and diversity)
• Digital architectures and components for transceivers and micro-servers	• Innovative multicore chips with high performance/energy ratio • Bandwidth between compute engines and memories up to 450 Gbps
• Energy efficiency by using heterogeneous hardware in combining parallel processor cores	• Efficient distributed virtualisation solutions with resilience, data security and protection

3.6. Proposed Methodology for Monitoring Industrial Commitments

The industrial commitment will be monitored against the following high level general KPIs:

- Level of involvement by industry like mobilised resources.
- Number of launched projects.
- Participation in supporting Group.

and the high level KPIs according to Section 1.6:

- Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010.
- Saving 90% of energy per service provided. The main focus is in mobile communication networks where the dominating energy consumption comes from the radio access network.
- Reducing the service creation time cycle from 90 hours to 90 minutes.
- Creating a secure, reliable and dependable Internet with zero perceived downtime for services.
- Facilitating very dense deployments of wireless communication links for over 7 trillion wireless devices serving over 7 billion people.
- Ensuring User controlled privacy.

The KPIs summarised in Section 3.5 for the different focus areas will be taken as baseline for monitoring progress and industrial sector commitments towards the realisation of the PPP objectives.

4. Governance

The supporting partners commit to make the 5G Infrastructure PPP the major European initiative to boost research, development and innovation on 5G network infrastructures and future Internet.

The proposed governance approach is subject to the compatibility of the future clauses of the PPP Contractual Agreement with corporate legal procedures of the supporting partners.

4.1. General Considerations

The key principles for the governance of the 5G Infrastructure PPP are transparency, openness, representativeness and efficiency. The Association will be the counterpart for the Commission to sign the PPP Contract, to monitor progress of the PPP and to endorse the SRIA. The detailed purpose is described in Section 4.3.3.2. However, the Association is not involved in the implementation of under the PPP programme.

The internal relation between PPP projects and participants in the 5G Initiative will be described in the 5G Infrastructure Collaboration Agreement.

The Technology Board in the 5G Infrastructure Collaboration Agreement and Working Groups in the Net!Works ETP will produce and iteratively update the SRIA. This SRIA will form a major input for the call for proposals in the 5G PPP. Out of this SRIA, and its updates, an industry roadmap including the research actions will be produced by the Association, and regularly updated, based on the strategic areas presented in Section 2, to identify the next steps of the programme.

The evolution of the roadmap shall be a continuous interactive process, monitored by the 5G Infrastructure Collaboration Agreement Steering board and the Industry Advisory Group in the Association. The Association will endorse the SRIA in execution of the PPP Contract. There should be flexibility in the lifetime of Collaborative Projects (CPs) to respond and amend their work plans depending on the evolution of the roadmap.

The Association will be responsible for the link with the 5G Initiative. The Association will organise an evaluation of the projects selected after the Grants have been awarded in order to evaluate to which extent these projects contribute to the roadmap and what aspects of the roadmap need further commitment. The following elements will be taken into account (not exhaustive):

1. The coherence with the PPP roadmap, SRIA ambitions and KPIs.
2. The relevance of the exploitation plan.

The supporting partners are fully in agreement with the concept of reserving part of the budget of the different projects to invite individual solution providers to join this work as it progresses, hence also contributing to further openness of the overall process. There are many examples of large scale systems where many elements of the important functionality are provided by SMEs which have inherent skills and adaptability for the special needs of particular scenarios. It will be ensured that these opportunities are maintained and properly integrated.

4.2. Description of the Organisational Structure

An efficient and workable model is the target. The organisational structure ensures transparency of the activities, openness to access to information by respecting access rights of project participants and fairness to participate in PPP activities. There are three entities in the governance model that will have to be taken into account (Figure 12):

- The **Association**:
    - The EU Commission and the Association conclude the PPP contract according to Article 19 in the Horizon 2020 Regulation, which will describe high-level objectives and KPIs of the PPP.

- The newly to be created Association, hereinafter, will have the main task to enter into the so-called PPP Contract and to Implement that contract in partnership with the EU Commission (Section 4.3).
- The Association is representing the wider community of more than 1000 organisations including the Net!Works ETP as the core networks community and all other necessary stakeholders in the PPP scope, representatives from vertical sectors and user groups in order to take into account views and requirements for the development of the PPP roadmap and research actions based on the SRIA as developed in the ETP. Therefore, members of the Association are coming from the Net!Works ETP Steering Board, additional Net!Works member organisations, and from outside of Net!Works. This open membership ensures openness for the development of the SRIA and transparency of activities. The SRIA will be endorsed by the Association to the EU Commission as major input to the PPP Work Programme and Calls for Proposals.

- The **Net!Works ETP**:
  - The existing Net!Works ETP also plays a role as a wide representation of the community, developing and up-dating the SRIA on a regular basis. This unincorporated organisation will continue to exist, but some adaptations will be needed to create consistency between the different levels of the governance model (Section 4.4).
  - The Net!Works ETP has an open and democratic governance model. The Steering Board is fully elected. The Steering Board members will become Full Members of the Association. They will be bound by a Members Agreements to decisions in the ETP in order to ensure that the Association is representing the wider community and decisions in both organisations are aligned.

- **The 5G Initiative structure and projects**:
  - It will be realised through a 5G Infrastructure Collaboration Agreement between the partners involved in the projects selected in order to describe the internal relations between PPP projects and partners (Section 4.5).
  - Fairness of participation is ensured by the standards procedures of Horizon 2020 like open Calls for Proposals and proposal evaluation and selection by means of external and independent experts.
  - The PPP will support consortia building by providing information on upcoming Calls and the SRIA in tight connection with the Association.

The different entities are described in detail in the following Sections.

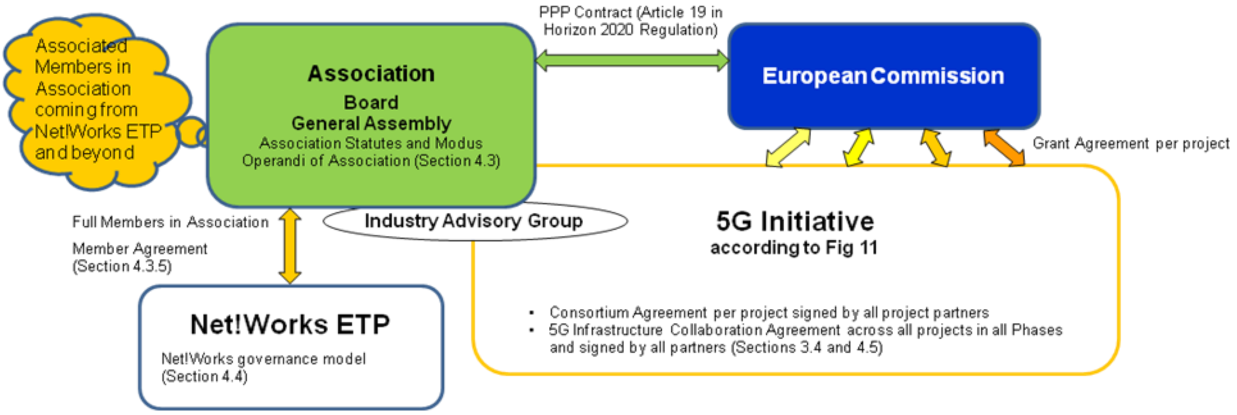

Figure 12: Overall structure of the PPP in relation to the EU Commission and the Net!Works ETP

4.3. Association Statutes and Modus Operandi of Association

4.3.1. Optimising Openness combined with Efficiency

The Association has to remain of manageable size in terms of number of member organisations to ensure that the goal of a full innovation trajectory will be achieved with the necessary focus to guarantee impact.

The proposed structure is that there are two categories of Full Members: Full Members Cat A of the Association are those organisations having a member in the Steering Board of the Net!Works ETP and additionally elected members from Net!Works as explained below, being Full Members Cat B. These Full Members have a mandate via election in the Net!Works General Assembly and thereby they are representing the Net!Works membership and the sector. The Net!Works ETP will have new elections to the Net!Works Steering Board before the Association will be launched. However, the statutes of the Association will also foresee that other entities from outside the Net!Works ETP Steering Board or even outside the Net!Works membership can become Associated Member, however without voting rights. This means that there will be two categories of membership,

- Full Members (Cat A and Cat B) with full voting rights and
- Associated Members without voting rights.

The Associated Members will have full access to information and will have the right to attend and to speak at the relevant meetings of the Association. This does not prevent the Associated Member to upgrade to Full Member status, as soon as an Associated Member would fulfil the membership criteria for full membership. After the upgrade, the former Associated Member will exercise all the rights of a Full Member, including the voting rights. This approach ensures that decision making in the Association is based on a transparent mandate and openness for a wide membership and that all necessary expertise in the scope of the 5G PPP will be represented in the Association in order to ensure good representativeness of the sector. This will allow keeping the Association of a manageable size whilst guaranteeing transparency and openness to the widest possible relevant constituency.

The mechanism of election of the Net!Works ETP Steering Board ensures that the representatives of the sector into the Association is guaranteed. The Net!Works ETP Steering Board is elected by all the interested organisations in the Net!Works ETP gathered in the General Assembly. In the Net!Works ETP Steering Board a number of seats are allocated to industry (different sectors), SMEs and the research community, but the ETP Steering Board should be industry-lead. The selection procedure for the Net!Works Steering Board is open and based on candidature (Section 4.4).

Membership in the Association may thus change after new elections in the Net!Works ETP Steering Board in order to have an Association, which has a mandate from the Net!Works ETP membership.

It should be noted that the Net!Works ETP membership is open for organisations with research activities in Europe, therefore new organisations could become part of the Net!Works ETP and thereafter be elected in the Net!Works ETP Steering Board, and hence become a Member of the Association.

The legal mechanisms to link the Association to the Net!Works ETP is through the **Members Agreement** (Section 4.3.5). There will be a direct link between the ETP and the Association decision making, in the sense that the Full Members of the Association will have to commit in a Members Agreement to respect the decisions taken by the ETP bodies. Members of the ETP are legal organisations (not individuals). ETP bodies will be the Net!Works ETP General Assembly and the Net!Works ETP Steering Board. Additional Full Members Cat B in the Association, which are members of the Net!Works ETP and elected by the Net!Works membership but not coming from a Net!Works Steering Board organisation will also be bound by the Members Agreement. The Net!Works ETP Steering Board is elected by the Net!Works ETP General Assembly every two years according to the actual Net!Works governance model and can act within the limits of

Net!Works ETP General Assembly decisions. Full Members of the Association commit that for ETP decisions taken related to PPP matters they shall vote in line with the decisions taken on the same matters by the Net!Works ETP Steering Board. Also the terms of reference of the Net!Works ETP will have to be reworked, in order to ensure full consistency. This will be organised in the Net!Works ETP restructuring discussion. As an example, when taking a decision on the SRIA in the Association, **the representatives in the bodies of the Association will be bound by the terms of the Members Agreement,** which makes sure that the decision taken by the Association is in line with the decision taken by the bodies of the Net!Works ETP. **With this process, the Members Agreement mechanism ensures that the decision of the Association reflects the interests of the widest possible constituency gathering under the ETP.** The approach has thus an in-built control loop that the Association will act in the interest of the Net!Works membership.

Therefore, the proposed legal entity for the Association will be representative for the whole sector and will be able to reflect the commitment of the sector.

4.3.2. Commitments of the Association

The undertakings by the Association are understood as being global sector untertakings. Individual Members and PPP participants are expected to fully support the global sector commitments but do not incur any legal liability for the undertakings. The untertakings are further explained in the PPP contract.

It is expected that activities of the Association will be supported by the PPP CSA to facilitate the programme.

4.3.3. Characteristics of the Association

The Association will be a not for profit international association under Belgian law, for unlimited duration, based in Belgium. This is a flexible form of a legal entity, often used in the context of EU Commission programmes and cooperation. The costs of this Association should be light.

4.3.3.1. Board and General Assembly

The Association will be industry-led to ensure relevance of research and later economic exploitation of results.

There will be a Board and a General Assembly in the Association. In the General Assembly all the Members of the Association are present or represented, the Board would be composed of a limited number of directors, the chair and the vice-chairs of the Steering Board of the Net!Works ETP be nominated Members of the Board of the Association.

Annual meetings of the General Assembly of the Association could be combined with annual meetings of the Net!Works ETP.

Transparency is ensured by disseminating minutes of the Board meetings and of the General Assembly of the Association.

4.3.3.2. Purpose of the Association

The proposed purpose of the Association is (key points):

- Signature of the PPP Contract with the EU Commission.
- Endorse the SRIA as developed by the ETP Working Groups and the 5G Infrastructure Collaboration Agreement Technology Board.
- Initiation of continuous update of the SRIA.
- Initiation and endorsement of continuous update of the roadmap.
- Define research actions to be addressed in the consecutive PPP phases with the largest relevant constituency base in cooperation with ETP bodies.

- Evaluation of PPP Projects after Grants have been provided by the EU Commission to projects for the purpose of verifying, whether the PPP projects contribute to the roadmap and to the research and innovation objectives.
- Monitor the leveraging effect between public funding and private investment.
- Liaise with the Net!Works ETP.
- Represent and look after the interest of the R&D actors in the ETP.
- Collaborate and communicate with the EU Commission with regard to all Net!Works ETP matters and implementation.
- Represent and address the legitimate interests of the Association Members and the wider community towards the EU Commission, other public authorities and stakeholders, without the authority to legally bind Members.
- Share information of common interest among the Members and the Net!Works ETP to the purpose mentioned, as far as legally permitted.
- Identify dissemination and publicity of important results and events.

4.3.4. Statutes of the Association – Terms of Reference

The full text of the Statues of the Association is under preparation. A sketch is hereafter provided

Chapter 1 Definitions

Chapter 2 Name, form, head office, purpose, duration

- Name: To be determined.
- Place: Belgium.
- Form: International non-profit Association with scientific purpose based on Belgian law.
- Purpose: See Section 4.3.3.2.
- Duration: Indefinite period of time.

Chapter 3 Membership

- Full Members Category Cat A: Legal entities that are organisations, which are represented in the Steering Board of the Net!Works ETP and are a party to the Members Agreement. Full Members Category A will have full voting rights.
- Full Members Category Cat B: Legal entities that are organisations, which are members of the Net!Works ETP and are a party to a Members Agreement. Full Members Category B will have full voting rights. The number of Full Members B is limited to 20 % of the Full Members A.
- New Full Members Cat A, admission procedure: When a new Full Member organisation of the Steering Board of the Net!Works ETP is elected, this organisation will accede to the Association.
- New Full Members Cat B: The Full Members B will be able to join the Association based on an election procedure by the Net!Works membership, either by application to the Net!Works Steering Board and/or an initiative by the Net!Works Steering Board to complement expertise. The Net!Works Steering Board will evaluate the represented sectors and will issue a dedicated call for candidates to the Net!Works Membership. This candidate list is the basis for election of Full Members B.
- Full Members B will have to meet the following criteria:
    - Be a member of the Net!Works ETP.

- Have additional expertise, complementing the sectors and expertise, which is available in the Net!Works ETP but is not represented via the Net!Works Steering Board.
- Be elected by the Net!Works membership based on a candidate list.
- The details of the election procedure are described in the Net!Works governance model.

* Associated Members in the Association not coming from a Net!Works Steering Board member or even not being member of the Net!Works ETP: Any legal entity being active in research in Europe and complements expertise in the Association in order to have a complete representation of different stakeholder groups and technology areas of the 5G infrastructure sector. Associated Members will not have voting rights. However Associated Members will participate to all Association meetings and discussions, like other Full Members. The use of voting would only happen in case consensus cannot be reached on a specific issue.

* The Associated Members will be able to join the Association, either by application to the Chairman of the Board of the Association, or by invitation by the Chairman of the Association, acting on behalf of the Board of the Association.

* In any case the Associated Members will have to meet one of the following criteria:
  - be involved in significant R&D activities in Europe,
  - contribute and/or support the overall value chain,
  - be an organisation that represents interests that are relevant for the 5G Infrastructure PPP.

* Associated Members will contribute their views, which will be considered for integration into the PPP roadmap as contribution to the work programme.

  - Representatives from user groups like from other ETPs or other organisations/associations will be involved in the PPP Association as Associated Members. These Associated Members should preferably be representatives from organisations which represent certain interests which are relevant for the PPP. An example is the Mobile Manufacturers Forum or MMF, which is an international non-for profit association under Belgian Law, dealing with the health and safety aspects of electromagnetic emissions. The MMF is interested to become an Associated Member.

  - SMEs are involved as Full Members in the Association based on their membership in the Net!Works Steering Board and also potentially as Associated Member by application to the Chairman of the Board of the Association, or by invitation by the Chairman of the Association.

  - It is expected that entrepreneurs and start-ups will mainly be involved in later phases of the programme for research and development activities in the form of smaller contracts according to Special Clause 42 to the Grant Agreements when the 5G infrastructure platform is available. The governance model will provide the means from the very beginning to include the Full Members and Associated Members in the Association even if for example representatives for entrepreneurs and start-ups may be involved in later phases of the PPP based on open calls in projects. Therefore, the statutes of the Association, will describe the Full Members and the Associated Members, the criteria for both categories, and the procedures to admit new Full Members and Associated Members.

* Number of Members of the Association: The number of Associated Members will not exceed the number of Full Members Cat A.

* The interests and views of all different relevant groups and stakeholders in particular requirements on future systems will be accommodated by a Stakeholder Board by means of consultations. This Stakeholder Board will be implemented as a Working Group of the Association.

- Rights of the Members.
- Obligations so the Members.
- Termination for Full Members Cat A: Automatic termination in case of termination of the mandate in the Steering Board of the Net!Works ETP.
- Termination for Full Members Cat B: Membership criteria not fulfilled anymore. To be noted that the election as candidate Full Member Cat B by the Net!Works is for a limited period of time, and will be subject to renewal.
- Termination for Associated Members: Membership criteria not fulfilled anymore. To be noted that the election as Associated Member by the Association is for a limited period of time, and will be subject to renewal.
- Exclusion: In case of noncompliance with Statutes, By Laws and if membership criteria are no longer fulfilled.
- Effects of termination.
- Assets of the Association: Amongst others subsidies, membership contributions.

<u>Chapter 4: General Assembly</u>

- Powers of the General assembly: Amongst others
  - Endorse the SRIA.
  - Approve the PPP Contract.
  - Set membership fees.
  - Approve/reject annual accounts, annual budgets.
  - Elect and dismiss members of the Board of the Association and grant discharge.
- Composition of the General Assembly.
  - Full Members: Each Full Member shall have one representative and shall have one vote.
  - Associated Members: Each Associated Member shall have the right to attend the General Assembly and shall have the right to speak at that meeting, but shall have no voting rights.
- Quorum, majority of Full Members of the Association.
- Decision making: Decisions will be taken in principle by consensus. Where no consensus can be reached, voting by the Full Members will take place.
- Meetings, agenda, resolutions.

<u>Chapter 5: Board</u>

- Functions: A.o.
  - Monitor progress of activities of the Association.
  - Manage budget.
  - Annual accounts.
  - Represent the Association towards the EU Commission.
- Term of Board members, Chairman, Term.
- Meetings, quorum, majority.

Decision making: Decisions will be taken in principle by consensus. Where no consensus can be reached, voting by the Full Members will take place.

Chapter 6: Membership fees, financial year, annual accounts

Chapter 7: By Laws

- Providing for the internal regulation of the Associations.

Chapter 8: Amendments to the Statutes, dissolution of the Association

4.3.5. Members Agreement: Terms of Reference

The Members Agreement is a contractual arrangement between the members of the Association. The full text of the Members Agreement is under preparation.

Definitions

Net!Works ETP Matters: Those matters that are related to the SRIA and to the priority setting towards the Horizon 2020 PPP work programmes, derived from the SRIA

Scope

- Parties, being Candidate Full Members Cat A commit to establish the Association.
- Parties commit to approve the signing by the Board of the Association of the PPP Contract, in the form as it will be attached.

Party's criterion

- Each party to the Members Agreement, shall be a member of the Steering Board of the Net!Works ETP or a potential additionally elected Net!Works member by the membership and shall sign the Members Agreement. Only these member organisations in the Association can commit to comply with decisions of ETP bodies via the Members Agreement.
- Associated Members in the Association without a mandate by the ETP General Assembly will not be a party of the Members Agreement.

Accession to the Members Agreement

- When a new member organisation of the Steering Board of the Net!Works ETP or an additional member (Full Member) is elected, this organisation will accede to the Association and to the Members Agreement.

Net!Works matters in relation to the PPP

- Any decision to be taken by the Parties as Members of the Association that are related to Net!Works matters in relation to the PPP, shall be voted upon the representatives of the Parties in the General Assembly, and such voting shall always be fully in line with the decisions taken on the same Net!Works ETP related matters by the Steering Board of Net!Works ETP.

Term, termination and consequences

- The agreement will terminate automatically for a Party when:
  - the Full Member Cat A loses its capacity of member of the Steering Board of Net!Works ETP, in accordance with the terms of reference of the Net!Works ETP,
  - the membership of the Association terminates, for one or another reason For the Full Member Cat B and the Associated Member this could mean that the term of the membership ends, and is not renewed.

4.4. The Net!Works ETP

As stated above, the Net!Works ETP will continue to exist as unincorporated organisation as a wide representation of the community, but some adaptations will be made to the terms of reference in order to create consistency between the different levels of the overall governance model. The following description is based on the governance model of the Net!Works ETP, which is illustrated in Figure 13:

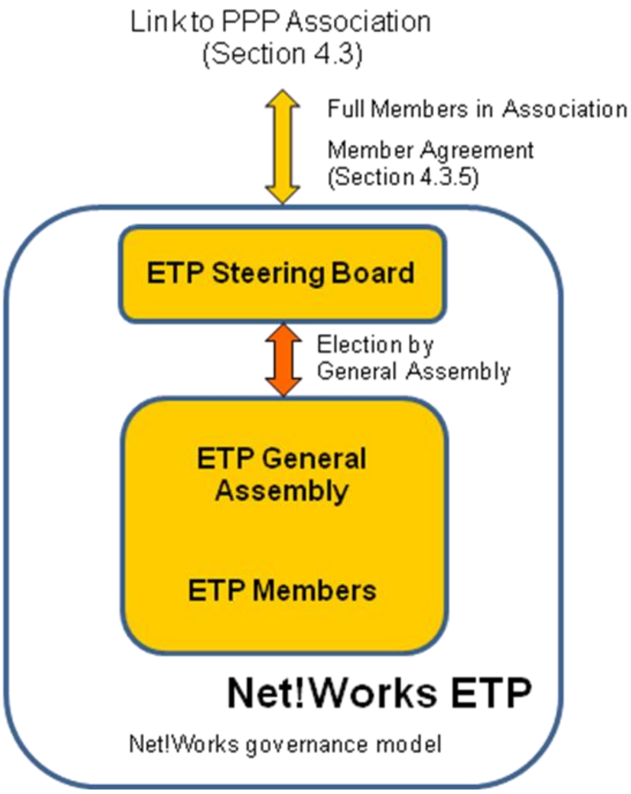

Figure 13: Net!Works ETP governance model

Point to be considered under the terms of reference for the Net!Works ETP:

- Mission

  Net!Works is the European Technology Platform for communications networks and services. Communications networks enable interaction between users of various types of equipment, either mobile or fixed; they are the foundation of the Internet. The Net!Works European Technology Platform gathers nearly 900 players of the communications networks sector: industry leaders, innovative SMEs, and leading academic institutions.

  The mission of the Net!Works ETP is:

  - To develop position papers on technological, research-oriented and societal issues, which are agreed in Net!Works bodies to receive a joint mandate.
  - To seek discussion of issues with decision makers in the political and public domain as well as in the industry and research community to bridge the gap between research and innovation and the expectations from the European society.
  - To regularly develop an updated Strategic Research and Innovation Agenda (SRIA) for Europe in the communication networks domain in an open process in order to guide industrial and long-term oriented research and to provide means for future economic exploitation in global standards and the widespread deployment of communication systems and networks.

- To strengthen Europe's leadership in networking technology and services so that it best serves Europe's citizens and the European economy.
- To support the 5G PPP initiative through the provision of the Association Members, the provision of the SRIA (including revisions) and promoting the active involvement of the ETP community in 5G initiative proposals and projects.

Further details are available at: http://www.networks-etp.eu/.

- Organisation
  - General Assembly: Participation of all member organisations.
  - Steering Board: Participation of elected organisations according to the defined election procedure in the ETP governance model.
  - Executive Group: Responsible for the daily work formed out of Steering Board organisations.
  - Expert Advisory Group: Participation for experts from academia and industry to support the Steering Board.
  - Mirror Group: Participation for representatives of public authorities, national and regional bodies.
  - Working Groups: Participation out of the Net!Works Platform member organisations established on ad hoc basis depending on needs.

- Membership of the Net!Works ETP
  - Legally established corporation and individual firm, partnership, university and research institute, government body or international organisation.
  - The Net!Works members represent the wide community of the communications network domain.
  - Member organisations are from industry, SMEs and the research community.
  - A membership breakdown is presented in Section 1.2.

- General Assembly
  - All member organisations.
  - Responsibilities
    - Election of two Vice-Chairpersons for the General Assembly.
    - Election of the members of the Steering Board in the different Stakeholder Groups.
    - Decision on accepting new members in the Net!Works Platform.
    - Decision on suspension, exclusion or expulsion of members in the Net!Works Platform.
    - Confirmation of the appointment of up to 3 observers in the Steering Board based on a Steering Board decision.
    - Contribute to the Strategic Research Agenda, reports and recommendations.
    - Contribute to the workplan for the establishment of Working Groups and the preparation of project proposals.
    - Contribute to the Terms of Reference and the organisational structure.

- Steering Board
    - Members of the Steering Board are representing the three stakeholder groups, where the stakeholder groups and figures below comply with the actual governance model of the Net!Works ETP:

- Industry domain:	18	members with voting rights
- SMEs domain	6	members with voting rights
- Research domain	6	members with voting rights
- Observers	3	members without voting rights
- EU Commission observer	1	member without voting rights
- European Space Agency	1	member without voting rights

    - Election of the members of the Steering Board
        - The Steering Board is fully elected.
        - Each Net!Works member organisation can propose candidate organisations and can nominate the own organisation.
        - In order to ensure the above composition of the Steering Board and the guaranteed number of seats per stakeholder group each stakeholder group is nominating its candidates and is electing its representatives.
        - The Observers are selected by the Steering Board.
        - The EU Commission decides on its representative.
    - Main tasks of the Steering Board
        - Decision on all matters related to Net!Works related matters.
        - Election of the Steering Board Chairperson and three Vice-Chairpersons. The Chairperson will also chair the General Assembly.
        - Implementation of the Net!Works Platform.
        - Initiation of the elections of Steering Board members in the General Assembly in time.
        - Guidance on strategic direction, conflict resolution and the related proposals for the General Assembly.
        - Invitation of members of the Expert Advisory Group.
        - Decision on the appointment of up to 3 observers in the Steering Board. The observer from the Commission is nominated by the Commission Services.
        - Decision on changes in the Terms of Reference and the organisational structure.
        - Development and approval of the Strategic Research and Innovation Agenda, of reports and recommendations.
        - Development and approval of the workplan for the establishment of Working Groups and the preparation of project proposals.
        - Launching of complementary and cooperating project proposals by taking into account contributions of the General Assembly.
        - Handling of membership issues such as accepting new members in the Net!Works Platform.
        - Proposals for suspension, exclusion or expulsion of members in the Net!Works Platform.

- Organisation of General Assembly meetings.
- Organisation of voting procedures by e-mail in the General Assembly.

4.5. Governance Model of the Partnership – 5G Infrastructure Collaboration Agreement

This governance model is describing the internal organisation of the PPP.

4.5.1. 5G Infrastructure Collaboration Agreement

The governance of the PPP will be laid down in a **5G Infrastructure Collaboration Agreement** to be established between the partners involved in the programme projects under consideration. Experience from the FI-PPP in FP7 will be taken into account, where many of the necessary documents are basically available (FI-PPP Collaboration Agreement, description of governance structure). The specific legal situation for Horizon 2020 will have to be taken into account.

The basic principle should be a collaborative approach by respecting the legitimate interests of all programme partners, which excludes top-down decision making by a small number of organisations on behalf of the others.

Bodies in the 5G Infrastructure Collaboration Agreement (Figures 11 and 12):

- 5G Initiative Steering Board, where all active projects (Coordinators) are represented. The Commission is represented as observer.
- 5G Initiative Technology Board, where all Technical Managers of all active projects are represented. The Commission is represented as observer. This group is responsible for building and updating the roadmap and associated architectures based upon input from its subcommittees. The Technology Board also evaluates proposals for new architectures, organises technical meetings and workshops, and establishes calls within the organisation for research proposals to address research gaps.
- 5G Infrastructure Industry Advisory Board for strategic guidance and feedback on economic relevance of the approach to ensure future exploitation and impact of research results.
- Under the 5G Infrastructure Collaboration Agreement, it may be provided that Working Groups can be established on a need basis for activities, which require the involvement of more than one project.

There will be a 5G Infrastructure PPP Industry Advisory Board however as part of the Association to provide a second opinion from an independent perspective.

In order to avoid legal uncertainties it is desirable to have the same Consortium Agreement for all projects in order to have a consistent legal framework.

The governance structure will be acknowledged in the 5G Infrastructure Collaboration Agreement and it will be provided that the Association is receiving the necessary information from the 5G Infrastructure Collaboration Agreement in order to allow the Association to fulfil its tasks.

4.5.2. Principles Regarding the Sharing of Information and Dissemination of Results and Handling of IPR benefits of the Sector, as will be applicable for Projects in the 5G Infrastructure Collaboration Agreement

It is one of the major objectives of the PPP to use achieved results for global standardisation to ensure globally interoperable systems. The PPP projects will develop solutions with open and publicly available interface specifications, where the access rights conditions of the existing legal framework in Horizon 2020 and respective standardisation and specification bodies will be respected.

To both strengthen industry competitiveness and promote innovation through openness whilst respecting legitimate interests of partners on securing IPRs and know-how with respect to global competition, those reference implementations might be valorised under different access rights models depending on the research area and the owner IPR Policy at the time of valorization.

As example:

- In areas with high relevance to standardisation IPRs have to be secured, because this will have a significant impact on future exploitation in the global market. FRAND conditions may be the preferred option.
- For specific software-oriented topics more open approaches may be considered, such as open source implementations. In the cases when it could be applicable, the selected open source scheme will have to be considered and the appropriate agreements established.

The following basic rules will be applied for access rights to IPRs within individual projects:

- The Rules for Participation for Horizon 2020, as further detailed in Annex II to the Grant Agreement (or an equivalent document) will provide the binding rules for Ownership and Access Rights for the implementation of research and use (economic exploitation) for foreground and background.
- The partners in a project will supplement the provisions of the Grant Agreement in a Consortium Agreement. As we understand it, it will be a requirement of the Commission that the Consortium Agreement is signed at the latest when the Grant Agreement is signed. It is our aim that all the project partners in the PPP Projects would apply the same model consortium agreement.
- The model Consortium Agreement that is typically used by ICT industry is the so called IPCA. The IPCA provides for different models of open collaborative innovation, laid down in several options: partners can choose for a model whereby all the results of the project may be used on a royalty-free basis by all the other partners in the project, or they can also opt for a model whereby access rights for commercialisation/use are granted on FRAND conditions (fair and reasonable non-discriminatory conditions) to the other partners in the project, to the extent they need these results for the exploitation of their own results. Parties will choose the IPR model from the IPCA that best fits their business needs.
- In the IPCA special attention is paid to software clauses, which are for obvious reasons essential for the ICT industry. A distinction is made between access to object code, access to API and access to source code. In principle, the access to source code is always more restricted than the access to object code or API's.
- The ICT industry is at present discussing about the new model consortium agreement for Horizon 2020 projects. The ICT industry is making an effort to adapt the consortium agreement to the new rules from the Rules of Participation and the Model Grant Agreement. The expectation is that different options will be included, meaning that the open model of royalty-free access rights for commercialisation/use will still be a valid option, that parties will choose when it fits with their business model.

We emphasize that the decision on how the ownership and access rights are arranged, is in principle a decision for the project partners, it always being understood that the conditions of the model grant agreement have to be complied with. The access conditions may differ for different research areas. In particular in areas with high relevance to standardisation IPRs have to be secured, because this will have a significant impact on future exploitation in the global market. FRAND conditions may be the preferred option. For specific software-oriented topics, the approach could be more open by means of open source implementations. However, the selected open source scheme has to be considered and appropriate approvals from other project partners will have to be obtained.

Between 5G PPP projects the following principles apply:

- This will also apply to software results. It is expected that there will be a Special Clause 41 to the contract to describe the access conditions between PPP projects.
- Rights and obligations, including access rights for partners in the different projects under the PPP Contract, will be further elaborated in the Collaboration Agreement between the different PPP projects. Access rights for third parties, which are not partners in the PPP, will usually be subject of bilateral agreements, which is usually not royalty-free for organisations, which have not invested in the respective research. The approach will be similar like in the FP7 FI-PPP.
- Details will have to be worked out further, based also on the Rules for Participation for Horizon 2020 and the Model Grant Agreement, which are both still under discussion or elaboration in the EU Commission.
- Dissemination of results should be encouraged by taken into account legitimate interests of partners and should be based on agreed approval procedures like in the IPCA model.

Joint dissemination events will be organised to promote achieved results and concepts with the final objective of adoption in global standards.

4.5.3. 5G Infrastructure Collaboration Agreement

The following Chapters will be addressed in the 5G Infrastructure Collaboration Agreement in the context of the development of the other legal documents:

- Chapter 1 - Definitions
    - Grant Agreement Definitions
    - Additional Definitions
- Article 2 – Purpose and general provisions
- Chapter 3 – Governing bodies, roles and responsibilities
    - 3.1 The Steering Board
    - 3.2 The Technology Board
    - 3.3 Secretariat
    - 3.4 Working Groups
    - 3.5 Relation to the Industry Advisory Group in the Association
    - 3.6 No Decision Authority
    - 3.7 Observer Status for the Commission
    - 3.8 Responsibilities of each Party
- Chapter 4 - IPR & ACCESS RIGHTS
    - 4.1 Intellectual Property Rights
    - 4.2 Access Rights
    - 4.3 Confidentiality
    - 4.4 Publications and Standards
- Chapter 5 – Liability and indemnification
    - 5.1 Liability
    - 5.2 Claims between the Parties

- 5.3 Force Majeure

- Chapter 6 - Miscellaneous
    - 6.1 Miscellaneous
    - 6.2 Assignment
    - 6.3 Term and Termination
    - 6.4 Settlement of Disputes
    - 6.5 Language and Headings
    - 6.6 Notices
    - 6.7 Applicable Law
    - 6.8 Entire Agreement - Amendments - Severability
    - 6.9 Accession

4.5.4. Timing and Planning

The following timing and planning for the preparation of the necessary legal documents is envisaged:

- First drafts of all legal document
    - Association Statutes, Modus Operandi of Association and Terms of Reference: The starting point will be other already existing documents.
    - Members Agreement: The starting point will be other already existing documents.
    - 5G Infrastructure Collaboration Agreement: The basis is the FI-PPP Collaboration Agreement and new governance description text in FI-PPP Phase II.

  available end of June 2013.
- Agreement of stable drafts of these documents with the supporting organisations of this proposal end of September 2013.
- Legal documents
    - Association Statutes and Modus Operandi of Association
    - Terms of Reference
    - Members Agreement
    - 5G Infrastructure Collaboration Agreement

  ready in October 2013.
- Creation of the Association in November 2013, legal personality to be granted by Royal Decree after creation.

List of Acronyms

API	Application Programming Interface
ARPU	Average Revenue per User
CAPEX	Capital Expenditure
COTS	Commercial Off The Shelf
CR	Cognitive Radio
EC	European Commission
EEA	European Economic Area
ETP	European Technology Platform
EU	European Union
FDN	Fibre Distribution Network
FP7	Framework Programme 7
GDP	Gross Domestic Product
HCI	Human Computer Interface
ICT	Information and Communication Technologies
IoT	Internet of Things
IP	Internet Protocol
IT	Information Technologies
ITU	International Telecommunications Union
LTE	Long Term Evolution
LTE-A	Long Term Evolution – Advanced
M2M	Machine to Machine
NGN	Next Generation Networks
OAM	Operation, Administration and Maintenance Operation and Management
OFDM	Orthogonal Frequency Division Multiplexing
OPEX	Operational Expenditure
OSS	Operations and Support Systems
PaaS	Platform as a Service
PC	Personal Computer
PON	Passive Optical Network
QoE	Quality of Experience
QoS	Quality of Service
R&D	Research & Development
RAN	Radio Access Network
RAT	Radio over Fibre
RRM	Radio Resource Management
RTD	Research and Technology Development
SDK	Software Development Kit
SLA	Service Level Agreement
SME	Small Medium Enterprise
SON	Self-Organising Networks
SRIA	Strategic Research and Innovation Agenda
TCO	Total Cost of Ownership
TV	Television
UHD TV	Ultra High Definition Television
UHF	Ultra High Frequencies
UMTS	Universal Mobile Telecommunications System

USA	United States of America
WDM	Wavelength Division Multiplexing
WDMA	Wavelength Division Multiple Access
Wi-Fi	Wireless Fidelity
WRC	World Radio Conference
WWI	Wireless World Initiative
3D TV	Three-Dimensional Television