March 2018

Economic considerations on Smart Networks as key enabler of the Human Centric Internet and the digital transformation research in FP9

Abstract

Framework Programme 9 as part of the next Multiannual Financial Framework of the EU from 2021 to 2027 is under preparation. For the time being the area of communication systems and networks[1] is not as clearly visible in FP9 documents as in former research programmes including Horizon 2020.

This document describes the indispensable role of communication systems and networks and its economic impact (GDP contribution) across variouos market domains and industry sectors. The report also reviews the R&D intensity and impacts on employment. Their technical capabilities of and their use in many different applications and especially for critical infrastructures show the strong relevance of communication technologies for secure, highly available and reliable networks. The network of the future will be the nervous system of the next-generation Internet. It will not only provide smart connectivity but also embedded compute and storage resources on-demand allowing an agile composition of a multitude of new services and applications on top and will increasingly be controlled by articificial intellience and machine learning. Research and innovation on the network and system level is required to turn this vision into reality. Communication technologies act as the key enabler for all the other domains and should be a visible part of the overall ICT agenda in Framework Programme 9 with sufficient budget allocation. It is critically important that Europe stays at the forefront of technology evolution, development and deployment to enable subsequent activities across the sectors beyond ICT. Such a leadership position is fundamental to keep and improve the strong and effective societal impact from ICT, communication systems and networks in order to maintain economic growth.

[1] In the following communication systems and networks are called Smart Networks.

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1. Introduction

Framework Programme 9 as part of the next Multiannual Financial Framework of the EU from 2021 to 2027 is under preparation. In the ICT domain several areas are on the agenda. Communication systems and networks are continuously being further developed towards Smart Networks. 5G is just the beginning of a new paradigm following the successful deployment of digital communication systems such as GSM, UMTS and LTE. The further development is leading towards the following requirements:

- Continuously growing network capacity has to be provided in a flexible and cost-effective manner for the ever-increasing demand of applications and services.
- Ultra-low imperceptible latencies must be supported to enable a new class of highly responsible and interactive applications as well as a new level of industrial automation.
- Massive amounts of things and systems need to be connected in a scalable and cost-efficient way.
- Global reach and optimised local service delivery capabilities need to be combined in highly flexible ways and should be available on-demand for the value chains of web-based software and IoT platforms.
- Cognitive operations making use of Artificial Intelligence (KI) and Machine Learning (ML) mechanisms are required to cope with the growing complexity of networks and systems.
- Personalised and perpetual protection has to be provided based on security, privacy and trust mechanisms that are able to cover the expanding threat surface due to the billions of IoT devices and are able to deal with the growing number of threats triggered by the increasing value of data.

Figure 1 shows the key enabling technologies, which are necessary for future complex and smart network architectures.

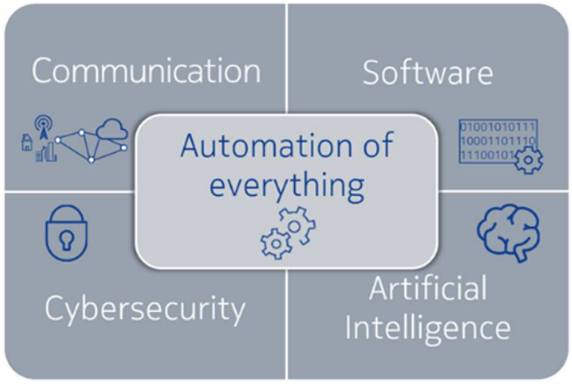

Figure 1 Key-enabling technologies for the digital automation of everything

However, the area of Smart Networks is currently not as clearly visible in FP9 documents as in former research programmes including Horizon 2020. Given the indisputable importance of this domain as the enabler for all the other domains and the upcoming challenges it should be part of the overall ICT agenda in a visible form with sufficient budget allocation.

The NetWorld2020 ETP is preparing background material to demonstrate the relevance of the area in the global context.

2. ICT as a fundamental enabler for a modern society

Today's society and economy is increasingly dependent on reliable communication systems available everywhere. This is reflected by the UN 2030 sustainable development goals (Section 2.1) and the relation between broadband access networks and economic growth (Section 2.2).

2.1. Support of UN 2030 goals and the trend towards digitalisation

The United Nations agreed in 2015 sustainable development goals until 2030 [1], which require the support by the ICT sector:

- Goal 1 End poverty in all its forms everywhere.
- Goal 2 End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
- Goal 3 Ensure healthy lives and promote well-being for all at all ages.
- Goal 4 Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
- Goal 5 Achieve gender equality and empower all women and girls.
- Goal 6 Ensure availability and sustainable management of water and sanitation for all.
- Goal 7 Ensure access to affordable, reliable, sustainable and modern energy for all.
- Goal 8 Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
- Goal 9 Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
- Goal 10 Reduce inequality within and among countries.
- Goal 11 Make cities and human settlements inclusive, safe, resilient and sustainable.
- Goal 12 Ensure sustainable consumption and production patterns.
- Goal 13 Take urgent action to combat climate change and its impacts.
- Goal 14 Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
- Goal 15 Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
- Goal 16 Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
- Goal 17 Strengthen the means of implementation and revitalize the global partnership for sustainable development.

These sustainable development goals are “at the heart of the EU’s sustainability policy” [2]. Most of these goals – especially the goals 2; 3; 4, 6, 7, 8, 9, 10, 11 and 15 – require suitable communication technology, which provides high throughput, high reliability and availability and allows cost-efficient deployment.

The digitalisation of society and economy in developing and developed countries is supporting these goals and is a key enabler for solutions. All means of digitalisation are based on communication systems and networks and their relation to vertical sectors.

While the current 5G efforts focus on making smart digital societies a reality, there are many inhabited and often densely populated areas without or very limited Internet access. Unlike modern urban areas, those areas have typically no spectrum scarcity issues, but are often suffering from lack of robust electricity availability and poor or no fixed network coverage. The regular mobile cellular solutions may not be financially feasible and robust enough for their needs and alternative solutions must be developed. A simple example would be a local caching based isolated wireless network optimized for the local service needs. Often the MNOs (Mobile Network Operators) business incentives are not supporting serving these areas and different incentives need to be put in place including public sector financial savings to

extend digital society services, like eHealth or eEducation, everywhere. Further details are available at [3].

The actual situation of access to the Internet is as follows: By the end of 2016 there will be 3.9 billion people in the world that still do not have access to Internet [4]. Similar figures have been made known by the World Economic Forum [5], revealing that over 4 billion people remain unconnected to the web. Although several barriers exist to extend the penetration of the Internet, such as the lack of skills together with the fact that most of the content is available only in a few languages, the main reasons are twofold:

- The first one is because people that are still offline, live in regions that are not covered by traditional networks, where the **population density is not sufficiently high to ensure profitability** when deploying and operating mobile networks infrastructure.
- The second reason is that many people under network coverage cannot afford to subscribe to Internet services and to purchase end-user broadband devices.

It must be mentioned that most of the under-served areas are located in least developed countries (Figure 2) [4]. This observation highlights that bringing the last billions of people online is a very ambitious goal that poses a very challenging problem from the technical and economical point of view.

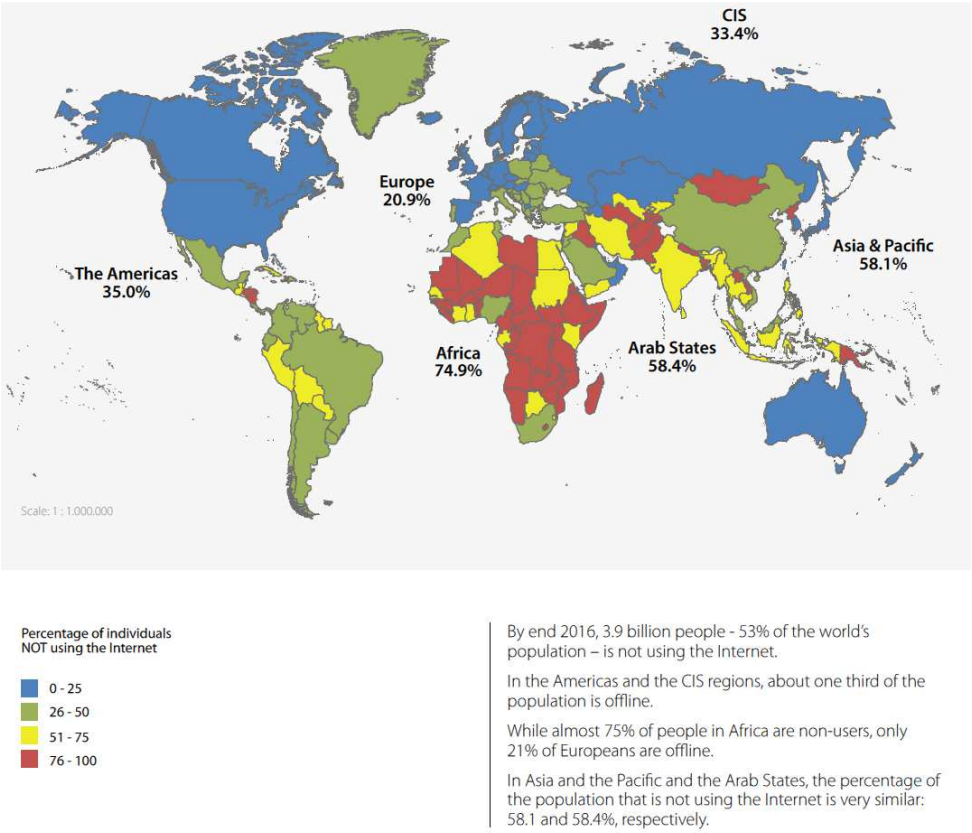

Figure 2 Internet user penetration, 2016 [6]

Opening access to information and communication technology (ICT) to the highest number of people, in particular affordable Internet, is essential for the achievement of the United Nation's agenda for sustainable development. Internet access has had an enormous impact on the global development and is expected to promote and drive economic growth in developing countries. In other words, connectivity may serve as a major accelerator to increase productivity and competitiveness, thus, drive economic progress in remote regions not

connected to the global market. In addition, Internet access may significantly improve the quality of health care in rural hospitals and education, by granting access to educational websites and social media in most remote parts of the continents. It also has a strong correlation with growth of GDP (Gross Domestic Product) in developing countries (Section 3). Industry associations like GSMA and NGMN have identified 100 % coverage as a strategic requirement of 5G and have defined the low average revenue per user (ARPU) use case. Based on that, communication systems and networks are opportune to mobilise the telecoms ecosystem to put the piece that is missing to be able to offer an economic sustainable Internet access in low ARPU areas, where there is a need for providing access to essential services. Communication systems and networks will act as a catalyst for its further development.

The United Nations Broadband Commission for Sustainable Development has set the 2025 Targets: "Connecting the Other Half" [7]. The document is stating

> Half the world's population is expected to be connected to the Internet by the end of 2019 at the latest. This leaves the other half – an estimated 3.8 billion people – unconnected and unable to benefit from key social and economic resources in our expanding digital world. In response, the Broadband Commission for Sustainable Development has set seven ambitious targets for 2025.
>
> 1. By 2025, all countries should have a funded National Broadband Plan or strategy or include broadband in their Universal Access and Service (UAS) Definition.
> 2. By 2025, entry-level broadband services should be made affordable in developing countries at less than 2% of monthly Gross National Income (GNI) per capita.
> 3. By 2025, Broadband-Internet user penetration should reach:
>   a) 75% worldwide
>   b) 65% in developing countries
>   c) 35% in Least Developed Countries
> 4. By 2025, 60% of youth and adults should have achieved at least a minimum level of proficiency in sustainable digital skills.
> 5. By 2025, 40% of the world's population should be using digital financial services.
> 6. By 2025, overcome unconnectedness of Micro-, Small- and Medium-sized Enterprises (MSMEs) by 50%, by sector.
> 7. By 2025, gender equality should be achieved across all targets.

These goals on provided connectivity to the other half are regarded as essential to achieve the sustainable development goals 2030 (c.f. above). The targets were launched at a joint meeting of the UN Broadband Commission and the World Economic Forum at the 2018 annual meeting, taking place in Davos, Switzerland in January 2018.

These global goals underline the importance of connectivity and the necessary communication infrastructure as the key enabler for economic growth in all parts of the world and well-advanced services and applications.

The current Internet model is mainly based on best effort communication, where certain QoS (Quality of Service) and QoE (Quality of Experience) requirements are basically ensured by overprovisioning. The regulatory environment in many regions and countries by means of net neutrality provides major economic and technical challenges for research, development and network deployment especially for critical and safety-related infrastructures and applications, which require e.g. maximum allowed latency and very high reliability and availability under conditions of limited available frequency spectrum. Therefore, in future research the Internet model needs to be reviewed and further developed to achieve a high performance global network infrastructure from the technical, application and economic perspective and to use available frequency spectrum and economic resources as efficiently as possible.

5G and further developments of communication systems and networks are a new paradigm compared to mobile and wireless communication in the past decades. Since the introduction of first analogue systems followed by e.g. GSM, UMTS and LTE the main objective was to

improve QoE by increased user experienced data rates from better voice communication to mobile Internet applications. With the increased use of ICT in most vertical industry sectors and society new requirements on very low latency, IoT and massive machine-type communication, device density, mobility etc. in addition to enhanced mobile broadband communication came up. This opens many new opportunities on B2B (Business to Business) and B2C (Business to Customer) models, which is leading to the 4th industrial revolution. The European economy is strong in many vertical industry sectors like mobility (car and train industry), energy systems including renewable energies, health etc. However, Europe and its manufacturing facilities is challenged by other regions. Therefore, it is essential to keep Europe at the forefront of the technology evolution, development and an improved early adoption of new solutions to enable a subsequent innovation across various sectors, so that the strong impact on GDP growth in Europe can be maintained in the long run.

2.2. Relation between broadband access networks and economic growth

Additional investment in ICT in Europe will contribute to a rebirth of GDP growth. A recent Worldbank study from 2016 confirmed former data from 2009 demonstrating additional 1.19 percent points GDP (Gross Domestic Product) increase per capita for developed countries and 1.35 percent points for developing countries for a 10 % increase of broadband connections (Figure 3) [8]; [9].

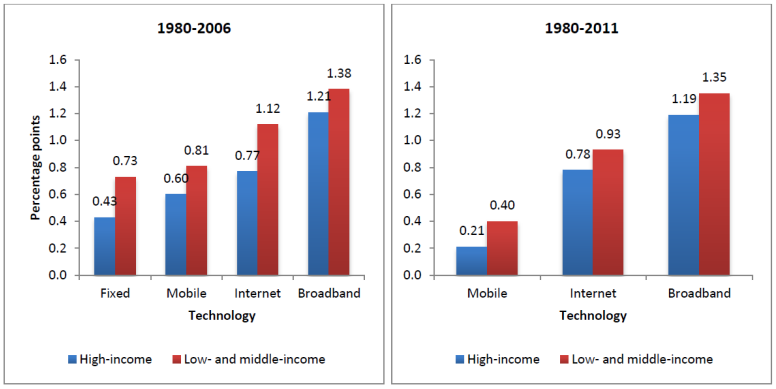

Figure 3 GDP growth impact from 10 percentage point increase in different ICTs, by country economic development category [8] (Source: Qiang et al. 2009 and Scott 2012.)

There is still a huge gap between developed and developing countries in terms of subscriptions (Figure 4) [8]. Appropriate communication technology and cost-efficient communication infrastructure is needed to close this gap. However, that would provide big opportunities for economic development.

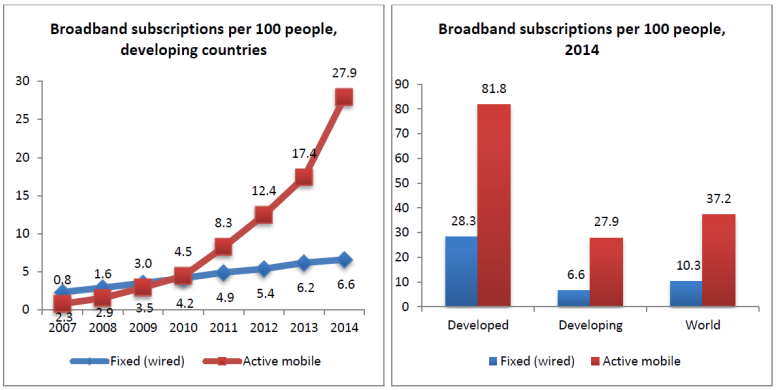

Figure 4 Fixed and mobile broadband subscriptions [8] (Source: Adapted from ITU data)

The G7 2017 also recognised in their meeting in Torino these relations on economic growth and employment [10]; [11].

3. ICT industry – maintaining a strong supply side in Europe

3.1. Impact of ICT on employment

Based on the relation between access to broadband and economic growth Worldbank is recommending in [8]:

> *"In addition to the economic impact of broadband, other studies have examined different impacts or used different broadband conceptualizations. Several studies have estimated the impact of broadband on employment* ***finding gains of between 2.5 and 4.0 additional jobs for each broadband job*** *(Kelly and Rossotto 2012). Other studies have estimated the impact of broadband on the employment creation rate; a study (Katz 2009) for 12 Latin American countries found that* ***closing the broadband gap of some 11 million lines would result in an increase of 378,000 jobs****."*

According to the EU Digital Agenda Scoreboard 2017 [12] the overall ICT sector in Europe showed the following employment in 2014:

- 6.3 million people employed overall. This was the highest employment in the period from 2006 to 2014 (Figure 5).
  - 4.5 million people in the ICT services sector (excluding telecommunications) corresponding to 71 % of total ICT employment.
  - 1.1 million people in the telecommunications sector, which provides the connectivity as enabler for ICT services.
  - 477 000 people in the ICT manufacturing industries sector (excluding communication equipment).
  - 186 000 people in the communication equipment sector.

The ICT service sector showed an increase in the work force. Technology changes in the other sectors resulted in a decline of employment in the telecommunication sector, ICT manufacturing and communication equipment sectors. The overall Telecommunications sector (manufacturing and telecommunications services – connectivity) is employing around 1.76 million people. This employment is a huge and strategic know-how base for Europe and makes the employment possible in the ICT services sector. Therefore, the overall telecommunications sector telecommunications services (connectivity, ICT manufacturing and communication equipment sector should be seen together in relation to the ICT services sector with around 1.76 million people versus 4.5 million employees.

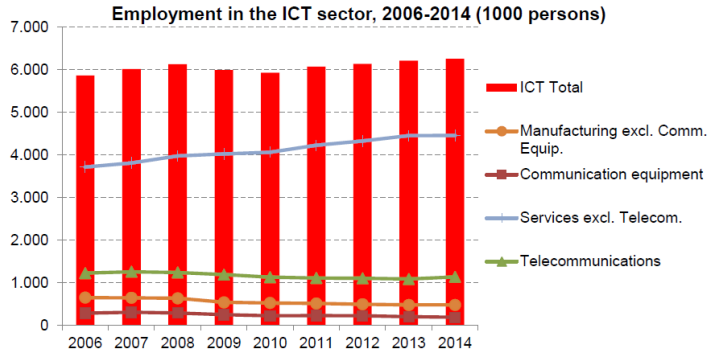

Figure 5 Employment in the ICT sector, 2006-2014 (1000 persons) [12]
(Source: JRC – Dir. B calculations and estimates, based on EUROSTAT data, PREDICT project)

The ICT employment in Europe with 2.5 % of EU total employment is similar to the US with 2.7 % by using a definition which allows comparison on global level. It is much higher than in China with 1.9 % but lower than in Japan with 3.6 % (Figure 6) [12]. This shows the strong focus of the Japanese industry on electronics and communication technology.

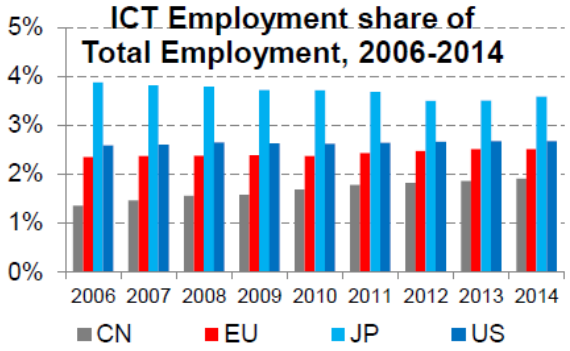

Figure 6 ICT employment share of total employment, 2006 – 2014 [12]
(Source: JRC – Dir. B calculations and estimates, based on EUROSTAT data, PREDICT project)

Other sources publish similar figures. According to GSMA there are 1.1 million direct jobs supported by the mobile ecosystem in 2016 plus an additional 1.5 million indirect jobs [13]. The employment ecosystem takes several players into account. This results in total in 2.6 million jobs in the ICT related domain (Figure 7).

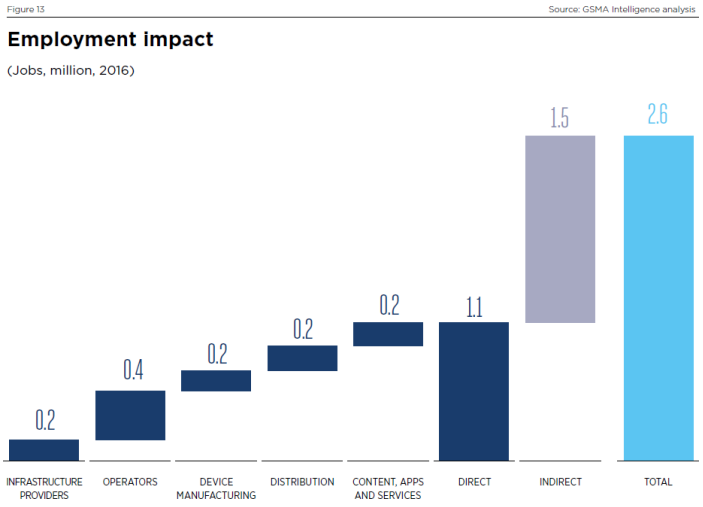

Figure 7 Employment impact of the mobile industry [13]

A report on eSkills in Europe takes a wider view on jobs in the ICT ecosystem with more than 28 million people (Table 1) [14]. The important message is that the ICT domain is a key sector, which has a leverage effect on employment in many other sectors. The trend to digitalisation of economy and society will strengthen overall employment, where appropriate skills will be needed.

Proportion of countries where the occupation is among the top-20

Rank	Occupation	ISCO-08	Frequency	Workforce EU28 (2014)[3]
1	Information and communications technology operations and user support	351	100%	1,282,000
2	Engineering professionals (excluding electrotechnology)	214	95%	3,037,000
3	Software and applications developers and analysts	251	95%	2,965,000
4	Information and communications technology service managers	133	89%	423,000
5	Database and network professionals	252	89%	466,000
6	Physical and earth science professionals	211	79%	346,000
7	Electrotechnology engineers	215	79%	831,000
8	University and higher education teachers	231	74%	1,196,000
9	Mathematicians, actuaries and statisticians	212	63%	106,000
10	Architects, planners, surveyors and designers	216	63%	1,597,000
11	Vocational education teachers	232	58%	868,000
12	Telecommunications and broadcasting technicians	352	58%	408,000
13	Physical and engineering science technicians	311	53%	4,358,000
14	Electronics and telecommunications installers and repairers	742	53%	802,000
15	Blacksmiths, toolmakers and related trades workers	722	42%	2,506,000
16	Life science professionals	213	37%	626,000
17	Metal processing and finishing plant operators	812	37%	567,000
18	Administration professionals	242	32%	3,146,000
19	Sales, marketing and public relations professionals	243	32%	2,487,000
20	Process control technicians	313	32%	652,000
	Total			**28,669,000**

Source: OECD, based on PIAAC.

Table 1 Top-20 ICT specialist-intensive occupations across countries (adapted from OECD 2015) [14] [3] Source: Eurostat Labour Force Survey (EU-LFS)

The ICT domain is a significant employment sector in key and critical industries. It is essential to maintain and develop skills and the know-how of the necessary technology in Europe.

OECD provides similar figures on employment. However, the latest published figures are from 2011 [15].

3.2. ICT market size

The strategic nature of the communications sector extends beyond its sole industrial domain, as the boundaries with the IT domain tend to blur. 5 % of European GDP, with an annual value of about € 686 billion, is generated today by the ICT sector itself [16]; [17]. The market size will be significantly extended by cooperation of vertical sectors with the ICT industry.

According to [12] the value added (VA) by the ICT sector to the European economy was € 593 billion in 2014. The impact of the financial crisis around 2009 is visible from the figures. The breakdown of the value added in 2014 is as follows (Figure 8) [12]:

- Total value added € 593 billion.
  - € 541 billion by the ICT services sector corresponding to 91 % of total ICT value added in 2014
    - € 356 billion for services excluding telecommunications and
    - € 185 billion for telecommunications
  - € 52 billion for ICT manufacturing corresponding to 9 % of total ICT value added in 2014
    - € 33 billion for manufacturing excluding communication equipment and
    - € 19 billion for communication equipment.

However, as for employment and in contrast to the evaluation in [12] telecommunications services (connectivity) and ICT manufacturing have to be seen together, because connectivity is a major infrastructure investment and is the key enabler for ICT services over the top of the available infrastructure. Under these conditions the breakdown is interpreted as follows:

- Total value added € 593 billion.
  - € 356 billion by the ICT services sector excluding telecommunications corresponding to 60 % of total ICT value added in 2014
  - € 237 billion for ICT telecommunications corresponding to 40 % of total ICT value added in 2014
    - € 185 billion for telecommunications (connectivity)
    - € 33 billion for manufacturing excluding communication equipment and
    - € 19 billion for communication equipment.

The growth in the services domain shows the increasing cooperation with vertical sectors.

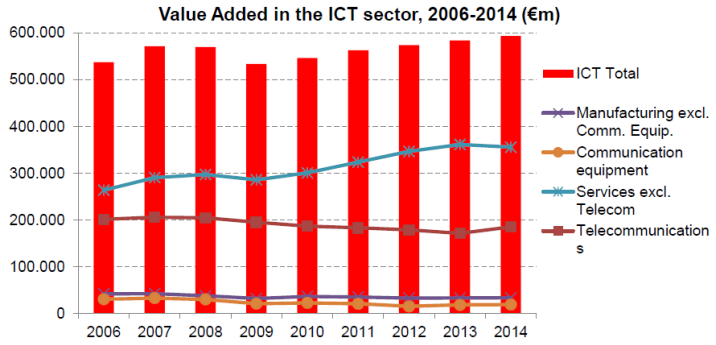

Figure 8 Value added in the ICT sector, 2006 – 2014 [12] (€m) (Source: JRC – Dir. B calculations and estimates, based on EUROSTAT data, PREDICT project)

Research, development and manufacturing and the related communication systems and networks are essential preconditions to enable the huge market success and growth in the services domain. Therefore, the different sectors should be seen together when assessing the economic importance.

With respect to the overall economy the value added in the ICT sector corresponds to 3.9 % of GDP in the EU in 2014 by using a definition, which allows comparison on global level. This contribution is lower than in Japan (5.4 %), the US (5.3 %) and China (4.7 %) in 2014 (Figure 9) [12]. However, Europe has strong other industries, which provide great opportunities for the cooperation between vertical industries and the ICT domain.

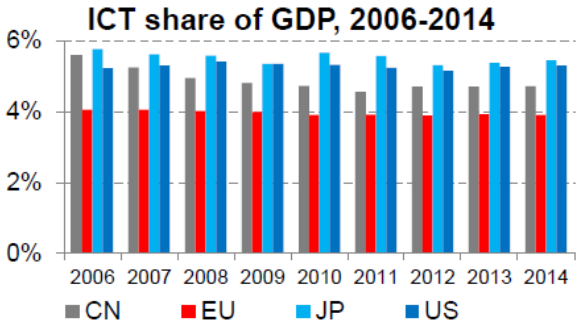

Figure 9 ICT share of GDP, 2006 – 2014 [12] (Source: JRC – Dir. B calculations and estimates, based on EUROSTAT data, PREDICT project)

GSMA is reporting in [13] that the contribution of the mobile industry to GDP in Europe will grow from € 541 billion (3.4 % of GDP) in 2016 to € 674 billion (3.9 % of GDP) in 2020 (Figure 10). This contribution comprises

- direct impacts by the telecommunication industry,
- indirect impacts by the use of communication systems and
- impacts on the overall productivity of economy.

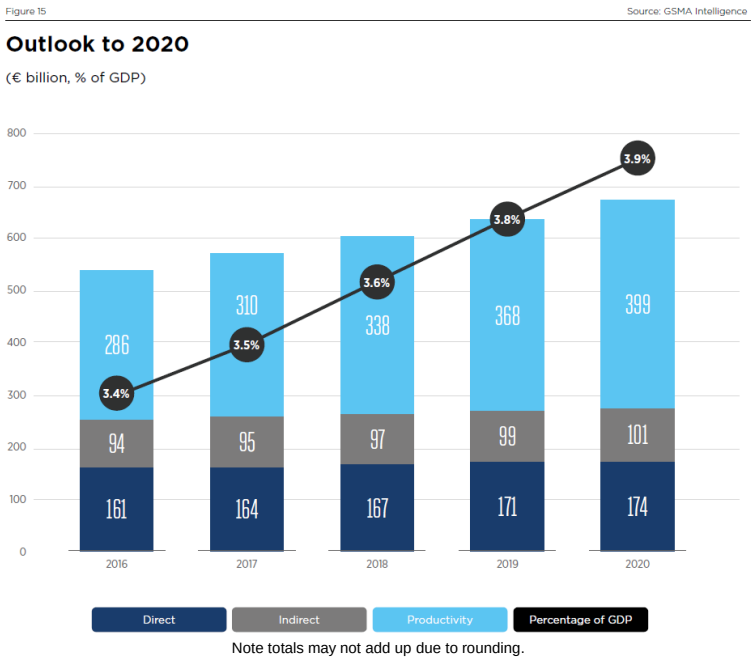

Figure 10 Total (direct, indirect and productivity) contribution to GDP (€ billion, % 2016 GDP) [13]

According to GSMA [13] 5G will reach one third of all connections in Europe by 2025. However, the adoption rate of new technologies in Europe is much lower than especially in the US, which may also have negative impacts on economic growth and jobs in Europe (Figure 11).

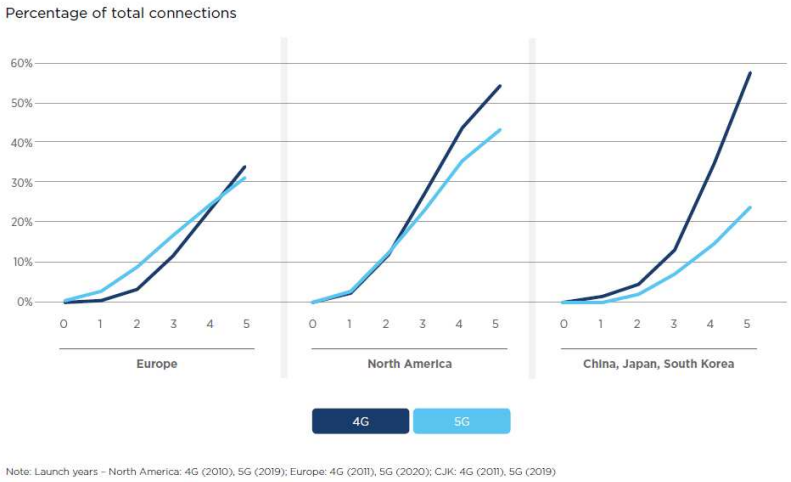

Figure 11 4G and 5G adoption, years after first launch [13]

Ericsson and Arthur D. Little are predicting that digitalisation of society and industry will generate revenue for ICT players of US-$ 3.3 billion by 2026 in 8 key sectors: public safety,

manufacturing, financial services, healthcare, energy utilities, automotive, media and entertainment, and public transport [18]. Major growth is expected from industry digitalisation and not from current operator services (Figure 12).

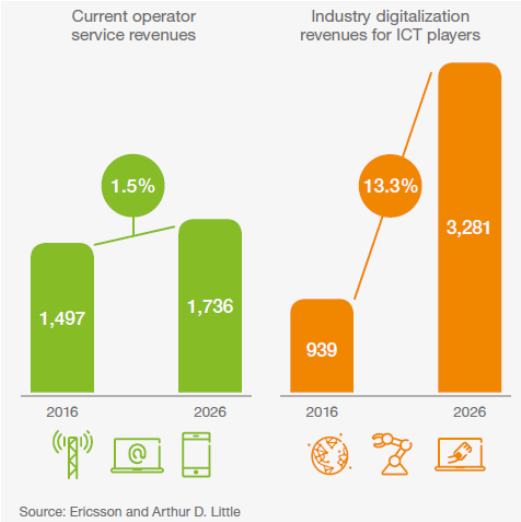

Figure 12 Revenue forecast (CAGR 2016 – 2026, US-$ billion) [18]

A McKinsey study [19] estimates the global value creation potential per year in 2025 of the Internet of Things for different sectors (Figure 13). Depending on assumptions there is a huge range from € 3900 billion (low estimate) to € 11100 billion (high estimate). Factories are seen as a main driver. With respect to the strong industrial base in Europe great opportunities can be expected.

A fully functional Digital Single Market could contribute €415 billion per year to the European GDP [20]. Overall, the digitalisation is still in an early stage. For example, Europe's Digital Progress Report 2017 [21] points out that only 20 % of the companies in the EU28 countries are highly digitised and there are still many opportunities to be exploited especially by SMEs. According to an Accenture study [22] the economic opportunity from digitalisation in Europe is over € 4 billion in value per day.

The number of connected IoT devices is expected to grow significantly to about 29 billion by 2022 (Figure 14) [23].

The availability of a high-performance communication infrastructure to access the Internet and broadband services is one of the objectives of the G7 countries [10]; [11].

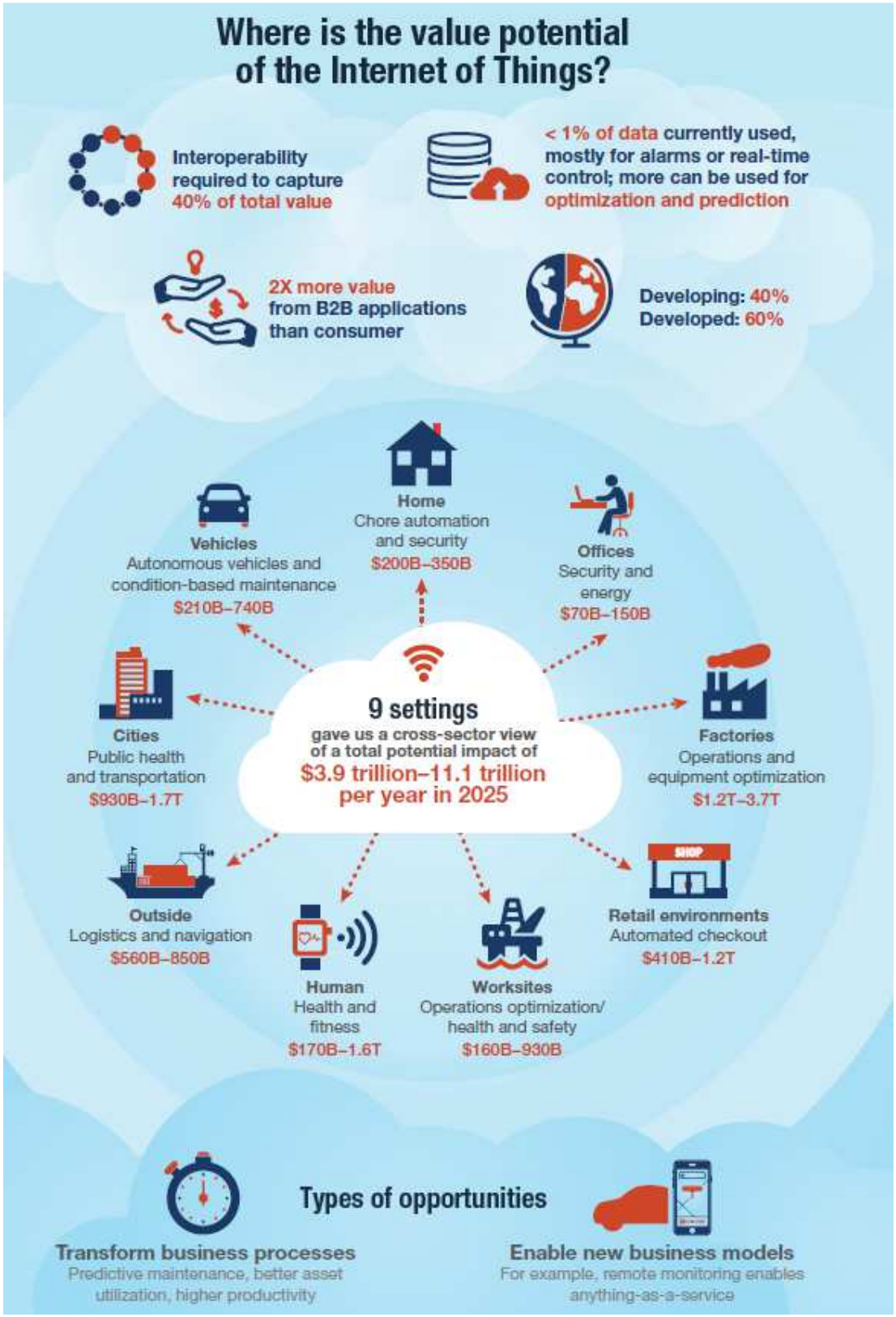

Figure 13 Where is the value potential of the Internet of Things [19]

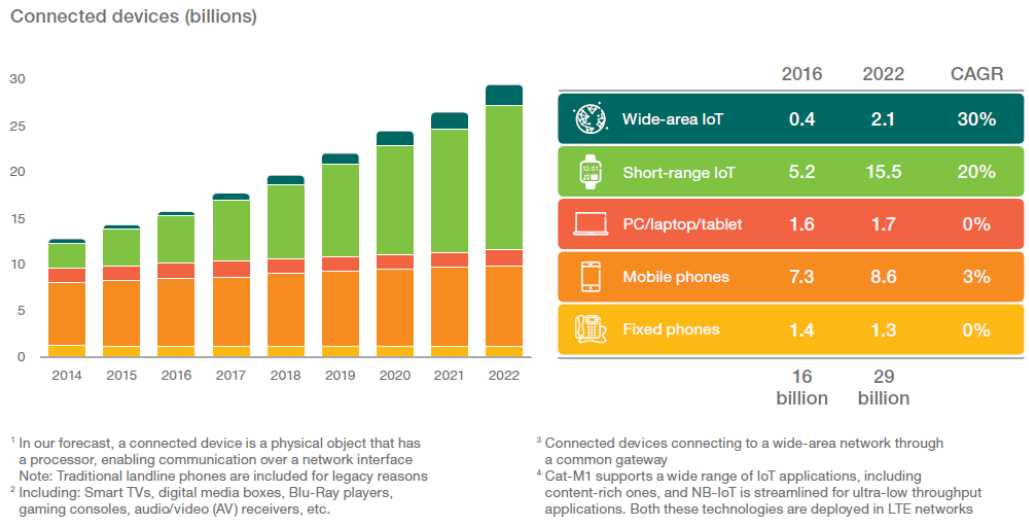

Figure 14 Connected IoT devices [23]

The nominal global GDP of 73.1 trillion US-$ (rounding errors) in 2015 comprises the following contributions from the regions

- North America 19.5 trillion US-$,
- Europe 19.5 trillion US-$,
- Asia 23.5 trillion US-$ and
- Africa, Latin America and the rest of the World 10.7 trillion US-$.

The GDP in Europe and North America in 2015 are basically the same [24]

However, in the Platform Digital Economy (e.g. Uber, Airbnb, etc.) the business is mainly concentrated in the USA by shifting value across the Atlantic (Figure 15) [25].

Figure 15 Global platform landscape, top 50 distribution globally [25]

The future network architecture must support platforms with much lower latency for access for mission critical applications, edge computing and distributed allocation of data centers. Such

a revised architecture opens opportunities for new entrants in the platform business also from Europe.

To open such new opportunities and to enable the infrastructure to support new businesses with vertical sectors especially for mission critical applications with high requirements on security, availability and reliability research, development and deployment of powerful communication networks and infrastructure (Smart Networks) is needed in Europe to make these developments happen.

3.3. R&D intensity of business enterprises

According to [12] the Business Enterprise R&D expenditure (BERD) in the ICT sector in 2014 was € 29.4 billion (in the order of € 30 billion) (Figure 16). This was the highest value in the period 2006 – 2014 and much higher than around 2009 during the financial crisis. The expenditures of the different sectors were as follows:

- Total Business Enterprise R&D expenditure nearly € 29.4 billion.
    - € 18.6 billion by the ICT services sector corresponding to 62 % of total Business Enterprise R&D expenditure in 2014
        - € 15 billion for services excluding telecommunications and
        - € 3 billion for telecommunications
    - € 11.4 billion for ICT manufacturing corresponding to 38 % of total Business Enterprise R&D expenditure in 2014
        - € 5.7 billion for manufacturing excluding communication equipment and
        - € 5.7 billion for communication equipment.

Like for the ICT market size and employment (Sections 3.1 and 3.2) and in contrast to the evaluation in [12] telecommunications services (connectivity) and ICT manufacturing have to be seen together, because connectivity is a major infrastructure investment and is the key enabler for ICT services over the top of the available infrastructure. Under these conditions the breakdown for research expenditures is interpreted as follows:

- Total Business Enterprise R&D expenditure nearly € 29.4 billion.
    - € 15 billion by the ICT services sector excluding telecommunications corresponding to 51 % of total Business Enterprise R&D expenditure in 2014
    - € 14.4 billion for ICT telecommunications corresponding to 49 % of total Business Enterprise R&D expenditure in 2014
        - € 3 billion for telecommunications (connectivity)
        - € 5.7 billion for manufacturing excluding communication equipment and
        - € 5.7 billion for communication equipment.

The expenditures of the service domain are growing and expenditures of manufacturing are declining in Europe due to technology changes and the impact of globalisation.

The comparison of Figure 8 and Figure 16 shows that the research intensity for infrastructure systems and communication equipment (49 % of expenditures for 40 % of value added) is much higher than in the services domain (51 % of expenditures for 60 % of value added). Therefore, there is strong need for collaborative research in Framework Programme 9 in the domain of Smart Networks (communication systems and networks) to enable the industry in Europe to maintain and improve its position in fierce global competition and standardisation.

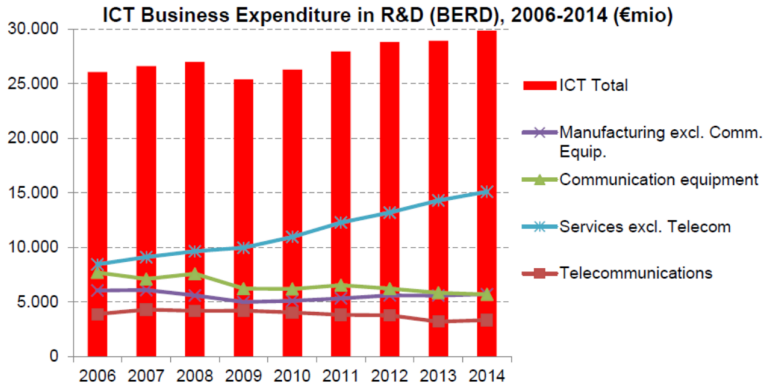

Figure 16 ICT Business Expenditures in R&D (BERD), 2006 – 2014 (€m) [12] (Source: JRC – Dir. B calculations and estimates, based on EUROSTAT data, PREDICT project)

There is a huge difference in R&D intensity of the ICT sector compared to other regions. By using a definition which allows comparison on global level, BERD corresponds to 5.3 % of the value added in 2014 compared to a similar value in China of 5.2 %. But there is huge gap between Europe and the US with 12.3 % and Japan with 11 % (Figure 17) [12].

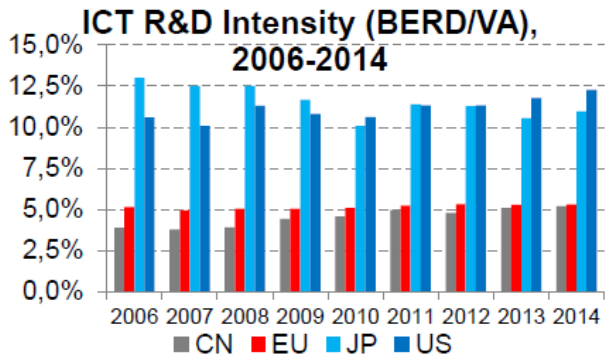

Figure 17 ICT R&D intensity (BERD/VA), 2006 – 2014 [12] (Source: JRC – Dir. B calculations and estimates, based on EUROSTAT data, PREDICT project)

It is essential to include Smart Networks with a significant budget and highly visible in the Framework 9 research programme to maintain and improve the position of Europe in global competition with industry from North America and Asia.

4. Trends towards future systems and innovations

4.1. Traffic demand and future network architecture

Traffic in communication networks is still growing exponentially. Therefore, network capacity needs to be increased further. Within the next 10 years the capacity must be increased by at least a factor of 100. However, available frequency spectrum resources are scarce and wider additional frequency bands can only be made available at higher frequency bands in the radio domain. Fiber-to-the-x infrastructure will become indispensable to deliver the necessary bandwidth to homes, businesses, and access nodes in an energy-efficient way and with low latency. Figure 18 shows this traffic growth, which is driven by virtual reality and video applications [26].

Similar predictions are made in [23]. Video applications are the dominating source of traffic (Figure 19).

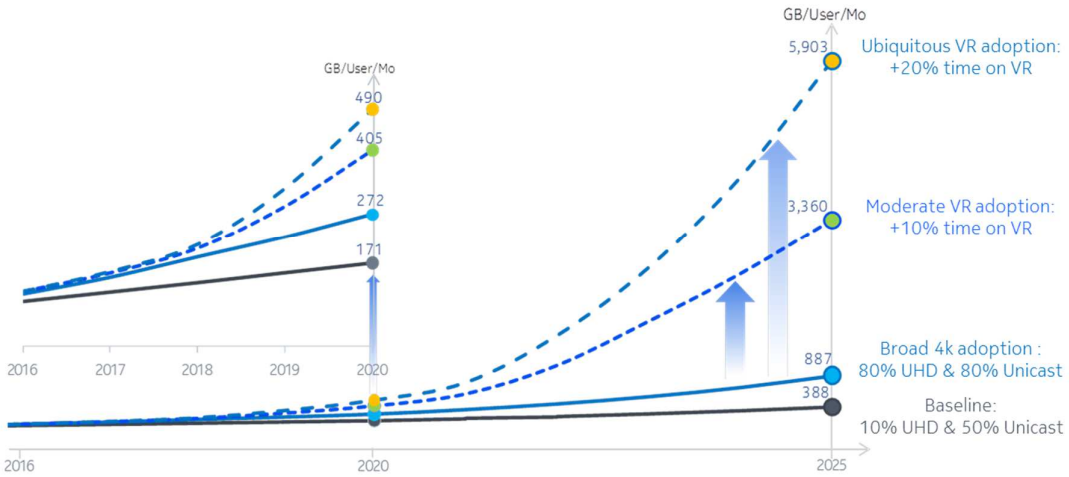

Figure 18 Seemingly infinite capacity demand - Exponential traffic growth drives massive capacity needs [26]

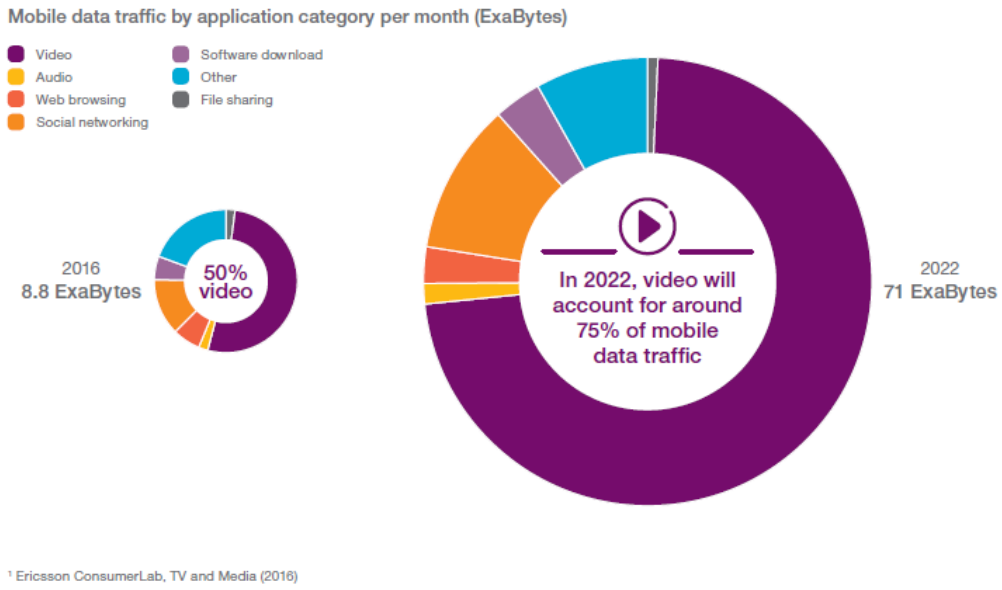

Figure 19 Mobile data traffic by application category per month (ExaBytes) [23]

Vertical sectors are increasingly using communication systems and networks. Many of these vertical sectors are critical infrastructures like energy, water and gas, smart city applications, traffic including autonomous vehicles, health etc. Therefore, network security, high availability and reliability are essential for such application domains. The many different application domains have very different technical requirements in terms of throughput and latency. Especially applications, which require imperceptible latency, redefine network requirements (Figure 20).

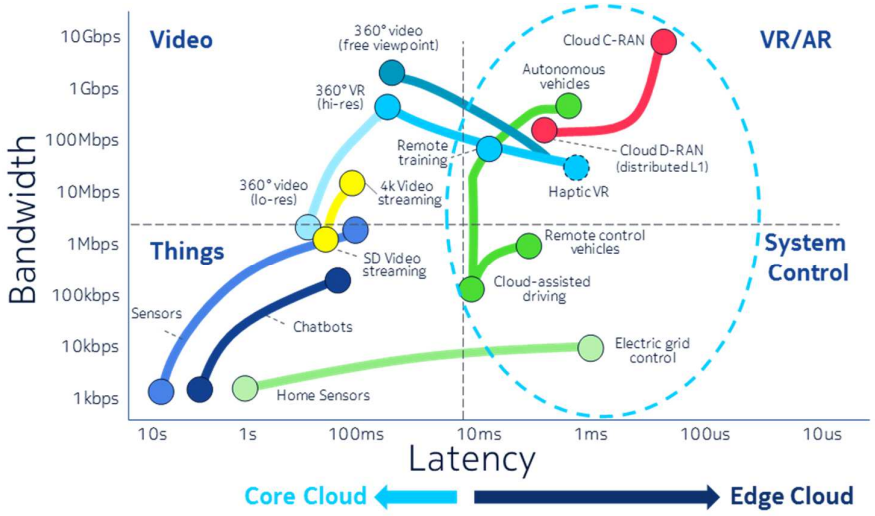

Figure 20 Requirements on throughput and latency depending on application (Source: Nokia)

Drivers for low latency are:

- Virtualized cloud access
- Interactively-intense Augmented Reality/Virtual Reality applications
  - virtual remote control
  - real time cloud rendering
  - haptic interaction
- Critical control systems
  - industrial/utility
  - vehicular automation.

New network architectures will be shifted to a highly distributed cloud architecture (Figure 21), where the network infrastructure and communication systems are the core to enable communication across different applications, clouds, big data applications etc. This Smart Network infrastructure is the precondition for all services and applications in higher layers and enables the huge contribution to GDP in Europe by the services domain. The success of the future, Human-Centric Internet and many other initiatives critically relies on a smart cloud infrastructure layer underneath. It amalgamates network, compute and storage resources so that they can be used in a sliceable and on-demand manner supporting a dynamic creation of new services on top. Artificial intelligence and machine learning will increasingly be used for network management to deal with the growing complexity and flexibility.

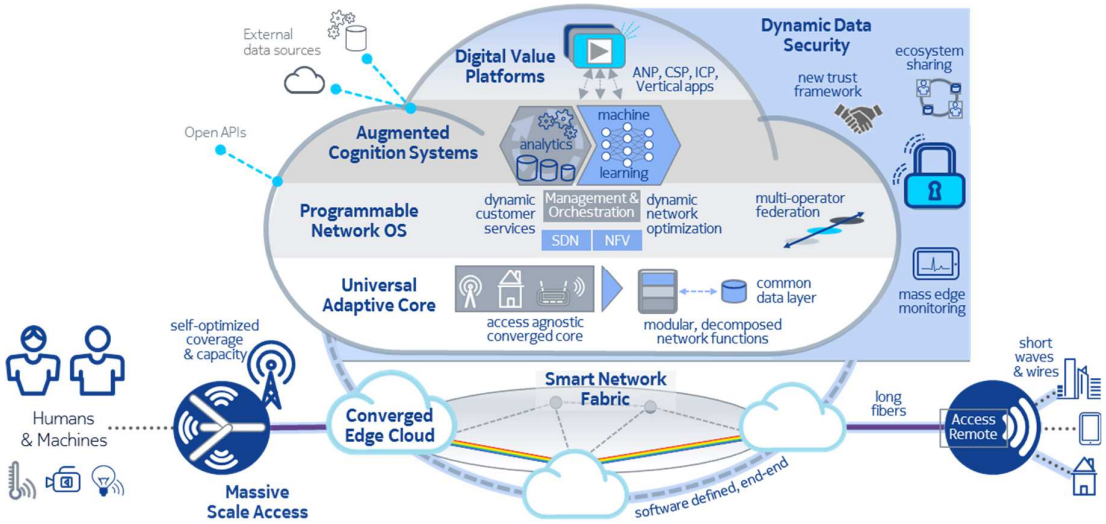

Figure 21 Potential high-level future network architecture (Source: Nokia)

Many vertical application domains are critical infrastructures and thereby also the necessary communication networks are a critical infrastructure, which are essential for the functioning of the EU, its Member States and the society.

4.2. Network security

Critical infrastructures and services especially in vertical sectors require high security, availability and reliability of the necessary communication networks and systems [10]; [11]. In today's network infrastructure an increased number of cyber-attacks is observed. It is expected that in 2020 97% of APT (Advanced Persistent Threat) attacks will be successful. There are 120 separate families of ransomware. The criminal use of network infrastructure for ransomware campaigns is increasing by 3,500 % in the time frame 2011 to 2020 (Figure 22) [27]. Investments in research and development of solutions to mitigate APT attacks must keep pace with the increasing number of attacks.

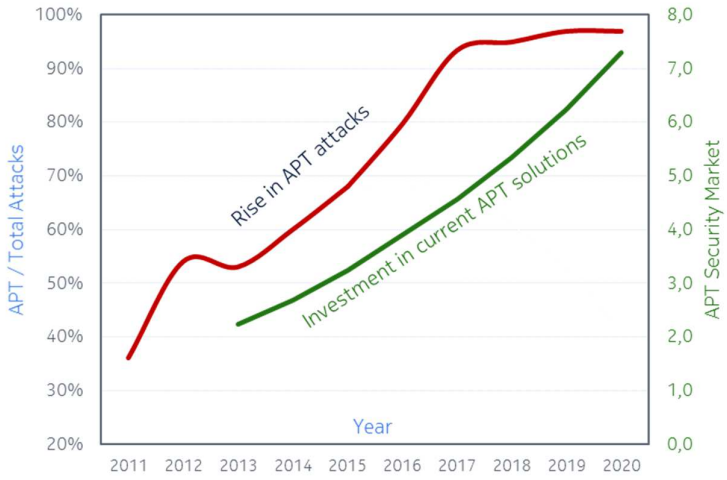

Figure 22 The rise of Advanced Persistent Threats and Ransomware [27]

With an increasing number of IoT devices and systems especially for critical infrastructures the number of security-critical and security-sensitive devices is increasing (Figure 23).

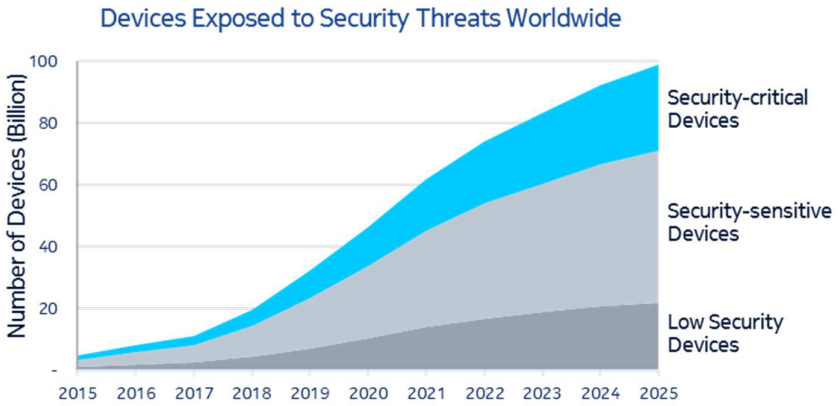

Figure 23 Number of IoT devices (Source: Nokia Bell Labs Consulting)

Therefore, investment in research, solutions and skills for network infrastructure and security applications in communication is essential to maintain a reliable overall infrastructure in the EU. This requires the necessary know-how and access to secure network infrastructure and devices products in Europe. It will not be sufficient to rely on access to products on the world market from outside of Europe, where it is difficult to assess the provided security level.

5. Technology research, development, innovation and sovereignty

With respect to the Sections above the European society and economy is increasingly dependent on communication networks and systems for critical infrastructures like energy, water and gas as well as transport and health etc. and the associated communication infrastructure. The global Wannacry attack in May 2017 demonstrated the vulnerability of today's infrastructures [28].

Europe should ensure technology sovereignty with own know-how, research and development of communication networks to secure the European infrastructure. The European strength in research, development and innovation is the key to sovereignty and of strategic importance and needs to be further improved. That requires a clearly visible part in Framework Programme 9 on Smart Networks (communication systems and networks) research with sufficient budget allocation that other elements in ICT research build on latest developments of communication systems and infrastructures.

6. Positioning of the domain of Smart Networks (communication systems and networks) in Framework Programme 9

DG Research in the EU Commission is responsible for the development of Framework Programme 9. In the ICT Domain DG Connect is contributing to this process. According to actual discussions in the EU Commission Digital Missions will be defined in Framework Programme 9 The actual version of the Areas of Intervention are described in [29]. In [29] the domain of communication systems and networks is only mentioned in a single bullet at:

- Part II – Global Challenges,
- Cluster Digital and Industry under the
- Area of Intervention Next Generation Internet:

Therefore, in the actual status of discussion communication systems and networks are not prominently visible in Framework Programme 9.

1. *Programming*
2. *Complementarities*

Part I

Open Science

1. *European Research Council (ERC)*
2. *Marie Sklodowska-Curie Actions (MSCA)*
3. *Research Infrastructures*

Part II

Global Challenges

1. *Health*
2. *Resilience and Security*
3. ***Digital and Industry***
   - *3.3 Areas of Intervention*
     - *3.3.1 Manufacturing Technologies*
     - *3.3.2 Digital technologies*
     - *3.3.3 Advanced materials*
     - *3.3.4 Artificial intelligence and robotics*
     - ***3.3.5 Next Generation Internet***

Introduction:

The Internet has become a key enabler of the digital transformation of all sectors of the economy and society. However, Europe needs to take the lead in driving the next generation Internet towards a human-centric ecosystem that provides users with greater control, and that is inclusive, disintermediated, language transparent and brings to the digital world the social and ethical values that we expect and enjoy. Investing in the Next Generation Internet (NGI) will improve Europe's industrial competitiveness in the global economy.

Lines of activities and operational objectives:

NGI addresses a coherent mix of research actions and large-scale pilots, including a major industrial initiative, to enable the next wave of innovations in digital services for citizens and businesses, and to accelerate industrial transformation and social inclusion including learning and skills. The NGI will address:

- ***Creating new technological opportunities in delivering a secure, energy-efficient and high performance NGI network and service infrastructures, (beyond 5G connectivity, software defined infrastructures, Internet of smart things, cognitive clouds), leveraging virtualisation and decentralised management (edge computing, block chains, shared contexts and knowledge).***
- *Enabling a next wave of advanced applications for consumers, industry and society promoting highly personalised access to objects, information and content, including social media and networks; ensuring better user control of data; leveraging new interactive technologies (language and interaction modality of choice; mixed real and virtual world) while remaining usable by all.*
- *Advanced software technologies supporting a cognitive data economy embedding artificial intelligence, data analytics, and security predicated on the free flow of data and knowledge.*

   - *3.3.6 High Performance Computing and Big Data*
   - *3.3.7 Circular Industry*
   - *3.3.8 Low-Carbon Industry*
   - *3.3.9 Space Technologies*
   - *3.3.10 Services from Space*
4. *Climate, Energy and Mobility*
5. *Food and Natural Resources*

Part III

Open Innovation

Strengthening the European Research Area

As described in the Sections above communication systems and networks are the glue between the different elements of the future communication infrastructure, services and applications, data centers, Big Data applications and the support of critical infrastructures.

- ☞ **Therefore, the NetWorld2020 ETP is proposing to establish a new Area of Intervention in Framework Programme 9 on <u>Smart Networks</u>, which is providing the links between the other Areas of Intervention in the Digital and Industry cluster**
  - **Manufacturing Technologies**
  - **Digital technologies**
  - **Advanced materials**
  - **Artificial intelligence and robotics**
  - **Next Generation Internet**
  - **High Performance Computing and Big Data**
  - **Circular Industry**
  - **Low-Carbon Industry**
  - **Space Technologies**
  - **Services from Space**

- The Challenges Health, Resilience and Security, Climate, Energy and Mobility and Food and Natural Resources will use platforms, which will be developed by the Challenges above.
- The Open Science domain will perform basic and very forward-looking research, which results will be used by other Challenges in later phases of the programme.
- The ERC (European Research Council) and EIC (European Innovation Council) in the Open Innovation domain will complement the other parts of the programme. In Horizon 2020 the ERC is an ”investigator-driven”, or ”bottom-up” approach, which allows researchers to identify new opportunities and directions in any field of research [30]. The EIC pilot in Horizon 2020 supports top-class innovators, entrepreneurs, small companies and scientists with bright ideas and the ambition to scale up internationally [31].

Figure 24 shows the proposed positioning of the area of **Smart Networks** in Framework Programme 9 to support overall objectives like technology sovereignty and a secure European infrastructure as well in the communication infrastructure as in critical infrastructures of the society and economy.

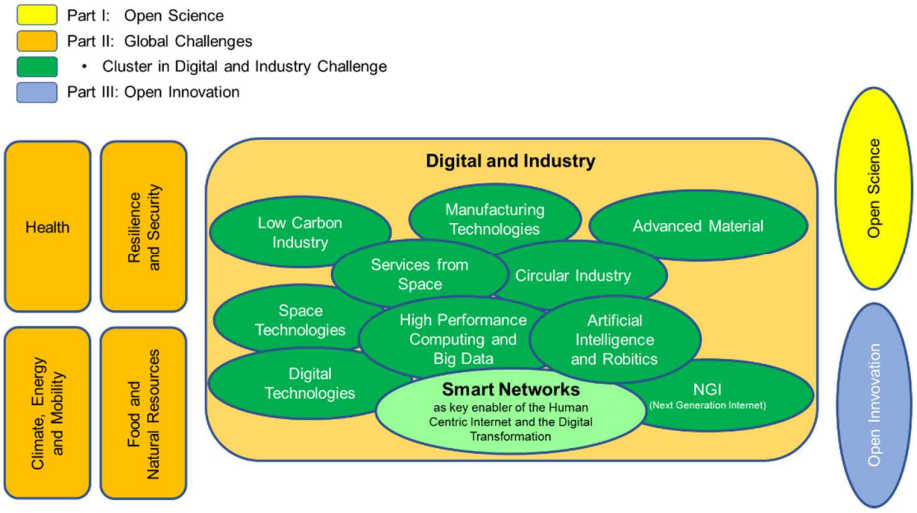

Figure 24 Positioning of the domain of Smart Networks in the current FP9 Programme concept

7. Research topics for Framework Programme 9 on Smart High Networks

The NetWorld2020 European Technology Platform developed a Strategic Research and Innovation Agenda (SRIA) [32], which is based on an open process in the NetWorld2020 Visions Workshop in October 2017 [33] and contributions by NetWorld2020 members. The SRIA will be published for public consultation to align views with the community in Europe, which is active in the Smart Networks domain.

8. Success stories from Framework Programme 7 and Horizon 2020

European research framework programmes provide a unique environment for cooperation between different stakeholders (competitors, customers and research experts) in the precompetitive domain under a clear legal framework. Collaborative research projects are a means for consensus building between many different players, e.g. ahead of future standardisation to develop basic concepts and solutions jointly.

Especially in the domain of mobile and wireless communications interoperability of systems, global roaming and global circulation of equipment are essential for a great user experience and the global support of solutions in a digitised world, e.g. for eHealth and mobility applications. Therefore, global agreements on relevant interfaces are the precondition to facilitate these objectives, which can be achieved by formal standardisation or industry standards. These are preconditions for successful economic exploitation of research results, the development of new markets and the deployment of new systems and solutions in all domains of society and economy.

History has shown that EU research programmes are playing an important role to achieve these objectives. About every 8 to 10 years new mobile and wireless communication systems are researched, developed and deployed, which offer significant improvements compared to former generations.

Mobile communications are an international success story which has its origins in EU-funded research projects. The growth of mobile communications, since the launch of the GSM system on the market in 1991, has been phenomenal. Mobile communications have changed people's lives for a better world by enabling people to communicate anytime and anywhere. Mobile communication drives productivity growth and economic performance across all sectors of the society and economy and is expected to continue to do so for many years to come. The services enabled by mobile networks made a strong contribution to the rapid growth in the ICT sector in Europe and generated several millions new jobs. The results of Framework Programme research projects have played a key role in enabling this growth. The projects developed the basic concepts, processes and product innovations, contributing to several generations of mobile communication systems and services (e.g. GSM, UMTS, DVB, LTE and IMT-Advanced and now 5G), over a 30-years period. The introduction of mobile technology accelerated the global growth in the ICT sector. ICT has become a ubiquitous technology and investments in ICT are responsible for at least 50 % of European productivity growth in recent years. There is a dramatic and still ongoing increase in data traffic on converged mobile and fixed communications networks generated by smart city, smart energy, environmental monitoring and eHealth applications etc.

The European success story resulting from the investment in collaborative research projects is certain to continue for many years to come, if Europe continues to invest in collaborative research!

Many of the basic concepts and technologies used in the 3G UMTS standards, the LTE standard and 5G had their origin in Framework Programme collaborative research projects, which are co-funded by the European Union. The investment of Framework Programme funds in mobile communications research has contributed strongly to job creation in Europe and improvements in living standards and economic growth on a global scale. The level of return

on investment achieved by the key collaborative research projects has few, if any, parallels in other sectors and contributes to the export power of European industry. Major milestones are:

- **GSM first commercially introduced in 1991:** The development of the **GSM** standard was part of the early formation of the European Union at the level of technology and mobile communications. For the first time, a solution was developed for Europe and the world enabling users to roam internationally using only one phone. Europe pooled its R&D, industrial base and services to provide the user with a mobile world without national borders. This initiative and the further collaborative R&D created a new generation of technologists focused on European and global needs. The GSM group was formed in 1982. GSM networks are accessible basically all over the world.
- **3G-UMTS first introduced in 2001:** European research projects developed the key contributions to the **3G UMTS** standard in the '90's. 3G systems provide users with broadband multi-media mobile communications, including voice and video services, mobile Internet access, mobile TV services and machine-to-machine communications services. One of the key Framework Programme co-funded project was FRAMES in the FP4 ACTS Programme.
- **LTE / IMT-Advanced first introduced in 2010:** European research projects developed key contributions to the **LTE system** in the '00's. LTE provides high speed mobile broadband connectivity to laptops, smart phones, tablet PC's and other mobile devices. On-line gaming services, streamed video and cloud computing services are brought to life by LTE. The LTE service has been progressively introduced in Europe since 2011. Key Framework Programme co-funded projects were WINNER and WINNER II in the FP6 Programme.
- **5G first commercial deployment in the 2019/20-time frame:**
    - The technical basis for ultra-high-speed broadband and M2M communication using energy efficient techniques were research challenges being addressed in Framework Programme 7 projects. These were preparatory research activities towards the global research on 5G, which was accelerated during the Horizon 2020 Programme. 5G is a paradigm shift by the direct cooperation between vertical sectors and the ICT domain for the three pillars eMBB (Enhanced Mobile Broadband), mMTC (Massive Machine Type Communication) and URLLC (Ultra Reliable Low Latency Communication) with challenging requirements. Major co-funded projects were METIS and 5G Now in the FP7 Programme.
    - Partnerships like **5G PPP** in the Horizon 2020 Programme are contributing significantly to the research, development and global standardisation of 5G mobile communication systems, supporting international consensus building on the 5G vision, standards, frequency spectrum and the global promotion of the cooperation of vertical sectors and ICT globally. Major successes are:
        - In December 2017 the first 5G standard was frozen as 3GPP Release 15.
        - Europe identified 5G pioneer frequency bands for early deployment.
        - 5G PPP introduced a set of innovations in mobile and wireless communications [34].
        - The PPP mobilised a huge additional investment in 5G research and development with a leveraging factor of 14 in 2016 compared to the allocated public funding.
        - 5G PPP Phase 1 projects submitted 96 contributions to the international 5G standardisation to create impact.
        - The involvement of SMEs and industry was increased compared to former programmes, which helps to exploit research results economically.

9. Conclusions

It is intended that Framework Programme 9 should be based on Global Challenges, Open Science and Open Innovation. For the time being, the area of communication systems and networks (Smart Networks) is currently not clearly visible in the Areas of Intervention as in former research programmes including Horizon 2020. With respect to the importance of this domain as key enabler of the Human Centric Internet and the digital transformation as well as for all the other domains and the upcoming challenges it should be part of the overall ICT agenda in a prominently visible form with sufficient budget allocation.

Communication systems and networks and the economic impact in terms of GDP contribution across variuos domains and industry show the strong relevance of this domain for secure, highly available and reliable networks.

5G is just the beginning of a new paradigm after the successful development of digital communication systems such as GSM, UMTS and LTE. The further development is leading towards new challenges and requirements from many different sectors in society and industry. Future communication systems and networks (Smart Networks) will increasingly be based on Artificial Intelligence, Machine Learning and software technologies in addition to classical communication technologies. Therefore, these different domains have to be researched in future close cooperation from an overall system perspective. The communication infrastructure will form the nervous system of the future Internet. It will amalgamate distributed network, compute and storage ressources to facilitate an agile composition of new services in a variety of markets and industry sectors.

The UN 2030 goals (Section 2.1) are a good starting point to identify needs on future systems and where and how communication technology can support such goals by the digitalisation of society and economy in developing and developed countries. Several studies have shown that economic growth can be increased by the availability of broadband access (Section 2.2). This has also positive impacts on employment in the overall economy (Section 3.1). The ICT domain is rather diverse with different sectors, which are closely related to each other. In the domain of communication systems and networks employment is slightly decreasing in the last years due to technology changes and the impact of globalisation, where in the service sector employment is increasing. However, the infrastructure side represents a strong contribution to the European economy with

- about 28 % of ICT employment,
- 40 % of ICT market size and
- 49 % of R&D expenditure in Europe.

The service sector is based on the availability of a high-performance communication infrastructure – the future Smart Networks. Therefore, the different sectors should be seen together. The existing employment in the communications sector is of strategic importance to enable the huge number of services and applications, to ensure the development of secure systems, a stable and secure operation of all critical infrastructures and to maintain and increase the know-how base in Europe.

The ICT market size in Europe is in the order of € 600 billion for the different sectors, which corresponds to about 4 to 5 % of GDP in Europe depending on definition (Section 3.2). The domains of manufacturing including communication equipment and telecommunications services (connectivity) correspond to 40 % of that market, where the service domain represents 60 % of the market. Research, development on infrastructure and telecommunications services (connectivity) is an essential precondition to enable the huge market success and growth in the services domain. Therefore, the 60 % of value added by the service sector depend on the 40 % value added by the other sectors. Compared to other regions the adoption rate of new technologies in Europe is much lower, which may also have negative impacts on economic growth and jobs in Europe. Further significant growth in the ICT market is expected by the digitalisation of industry, society and the Internet of Things.

The R&D intensity of business enterprises in Europe is lagging behind the US and Japan and is in a similar order like in China (Section 3.3). The slower adoption rate of new technologies in Europe and the faster market take up in other regions plays a role here. The 40 % of value added from the infrastructure including communication equipment and telecommunications services (connectivity) domains require 49 % of business expenditures, where the 60 % of value added for the service domain require 51 % of business expenditures. Therefore, R&D in the infrastructure domain including communication equipment and telecommunications services (connectivity) is much more expensive than in the service domain. It is essential to include Smart Networks with a significant budget and highly visible in the Framework 9 research programme to maintain and improve the position of Europe in global competition with industry from North America and Asia.

Traffic in communication networks is still growing exponentially (Section 4.1). Technical requirements are becoming more challenging with respect to the limited amount of available frequency spectrum. Video, augmented and virtual reality applications are driving the traffic growth. Vertical sectors are increasingly using communication systems and networks. Many of these vertical sectors are critical infrastructures like energy, water and gas, smart city applications, traffic including autonomous vehicles, health etc. Therefore, network security, high availability and reliability are essential for such application domains. Smart Networks are critical infrastructures in itself.

Such infrastructures require a high level of security, availability and reliability (Section 4.2). Security solutions must be part of the overall system design of Smart Networks from the start. Investment in research and development of solutions to mitigate cyber-attacks must keep pace with the increasing number of attacks to maintain a reliable overall infrastructure in the EU. This requires the necessary know-how and access to secure network infrastructure and devices products in Europe. It will not be sufficient to rely on access to products on the world market, where it is difficult to assess the security level.

With respect to requirements of a secure, highly available and reliable infrastructure Europe should ensure technology sovereignty with own know-how, research and development on communication networks (Section 5).

The NetWorld2020 ETP is proposing to establish a key area in Framework Programme 9, on

Smart Networks as key enabler of the Human Centric Internet and the digital transformation,

to support overall objectives like technology sovereignty and a secure European infrastructure as well in the communication infrastructure as in critical infrastructures of the society and economy (Section 6). This is critically important in order to stay in the forefront of the technology evolution, development and deployment, enabling subsequent innovation across the sectors beyond ICT. Such a leadership position is fundamental to keep or even improve the strong and effective societal impact from ICT, communcation systems and networks in order to maintain the economic growth as documented in this report. This area is providing the links between the other different Global Challenges in the programme

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About NetWorld2020

NetWorld2020 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 NetWorld2020 European Technology Platform gathers 1000 players of the communications networks sector: industry leaders, innovative SMEs, and leading academic institutions. NetWorld2020 has as mission developing position papers on technological, research-oriented and societal issues, in order to strengthen Europe's leadership in networking technology and services so that it best serves Europe's citizens and the European economy.

5G Infrastructure Association (5G-IA)

The 5G Public Private Partnership (5G PPP) is the 5G collaborative research program that is organised as part of the European Commission's Horizon 2020 program – The European Union Program for Research and Innovation. It is aimed at fostering industry-driven research, monitored by business-related, technological performance and societal KPIs. The 5G-PPP will deliver solutions, architectures, technologies and standards for ubiquitous next-generation communication infrastructure over the coming decade.

In the 5G PPP, the 5G Infrastructure Association (5G-IA) represents the private side and the European Commission the public side. The 5G-IA is committed to the advancement of 5G in Europe and to building global consensus on 5G. To this aim, the Association brings together a global industry community of telecoms & digital actors, such as operators, manufacturers, research institutes, universities, verticals and SMEs. The 5G-IA carries out a wide range of activities in strategic areas including standardisation, frequency spectrum, R&D projects, technology skills, collaboration with key vertical industry sectors, notably for the development of trials, and international cooperation.