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5G PPP

5G Vision

The 5G Infrastructure Public Private Partnership: the next generation of communication networks and services.

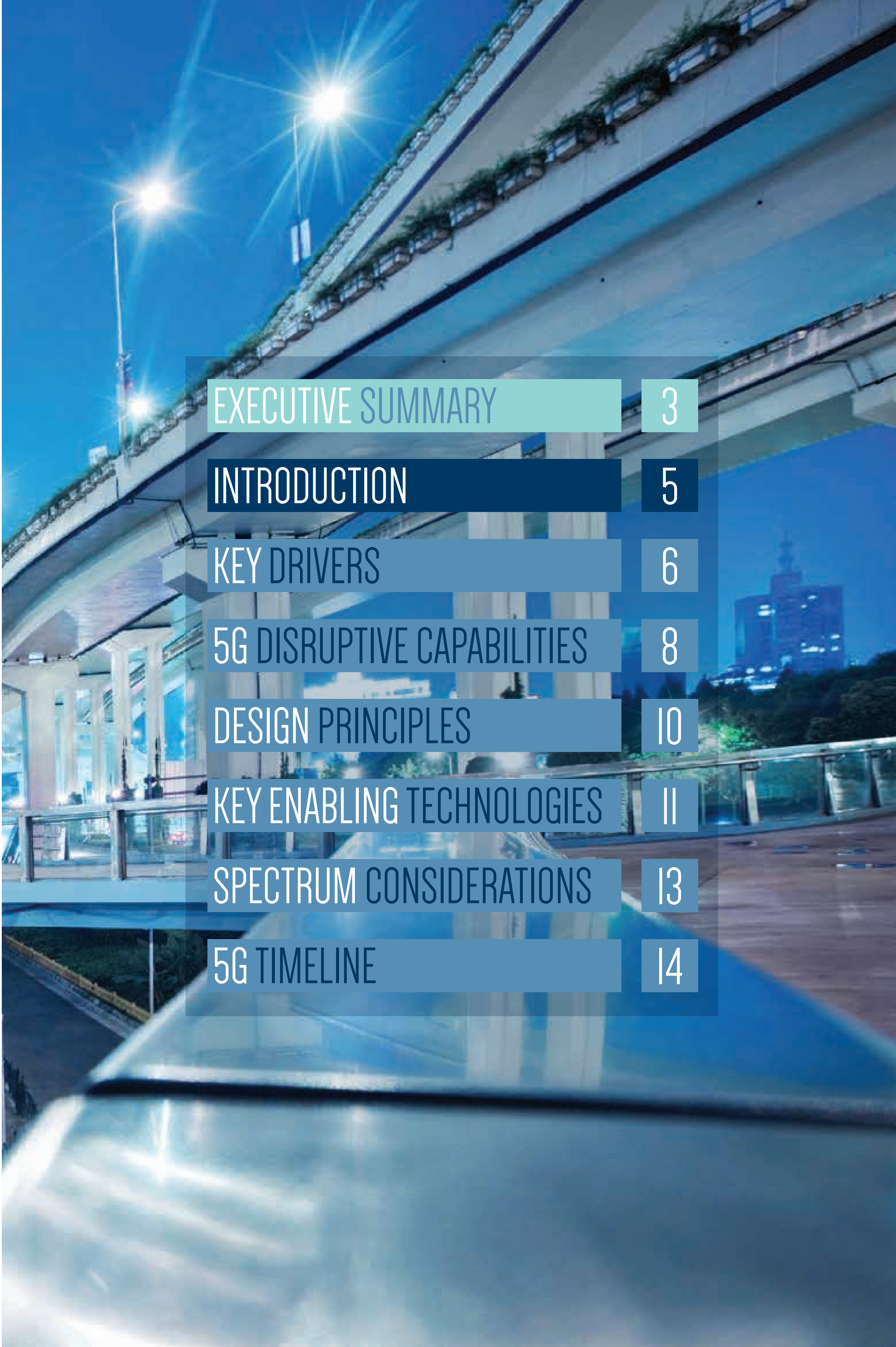
Smart network convergence

Business models based on shared resources

An open ecosystem for innovation

Better sustainability and scalability

New network and service capabilities



EXECUTIVE SUMMARY

Future European society and economy will strongly rely on 5G infrastructure. The impact will go far beyond existing wireless access networks with the aim for communication services, reachable everywhere, all the time, and faster. 5G is an opportunity for the European ICT sector which is already well positioned in the global R&D race. 5G technologies will be adopted and deployed globally in alignment with developed and emerging markets' needs.

Key drivers

5G will not only be an evolution of mobile broadband networks. It will bring new unique network and service capabilities. Firstly, it will ensure user experience continuity in challenging situations such as high mobility (e.g. in trains), very dense or sparsely populated areas, and journeys covered by heterogeneous technologies. In addition, 5G will be a key enabler for the Internet of Things by providing a platform to connect a massive number of sensors, rendering devices and actuators with stringent energy and transmission constraints. Furthermore, mission critical services requiring very high reliability, global coverage and/or very low latency, which are up to now handled by specific networks, typically public safety, will become natively supported by the 5G infrastructure.

5G will integrate networking, computing and storage resources into one programmable and unified infrastructure. This unification will allow for an optimized and more dynamic usage of all distributed resources, and the convergence of fixed, mobile and broadcast services. In addition, 5G will support multi tenancy models, enabling operators and other players to collaborate in new ways.

Leveraging on the characteristic of current cloud computing, 5G will push the single digital market further, paving the way for virtual pan European operators relying on nationwide infrastructures.

5G will be designed to be a sustainable and scalable technology. Firstly, the telecom industry will compensate tremendous usage growth by drastic energy consumption reduction and energy harvesting. In addition, cost reduction through human task automation and hardware optimization will enable sustainable business models for all ICT stakeholders.

Last but not least, 5G will create an ecosystem for technical and business innovation. Since network services will rely more and more on software, the creation and growth of startups in the sector will be encouraged. In addition, the 5G infrastructures will provide network solutions and involve vertical markets such as automotive, energy, food and agriculture, city management, government, healthcare, manufacturing, public transportation, and so forth.

5G disruptive capabilities

5G will provide an order of magnitude Improvement in performance in the areas of more capacity, lower latency, more mobility, more accuracy of terminal location, increased reliability and availability. 5G will allow the connection of many more devices simultaneously and to improve the terminal battery capacity life. Lastly, 5G will help European citizens to manage their personal data, tune their exposure over the Internet and protect their privacy.

5G infrastructures will be also much more efficient. The enhanced spectrial efficiency will enable 5G systems to consume a fraction of the energy that a 4G mobile networks consumes today for delivering the same amount of transmitted data. 5G will reduce service creation time and facilitate the integration of various players delivering parts of a service. Lastly, 5G systems will be built on more efficient hardware. The ultra-efficient 5G hardware will be energy aware, very flexible and interworking in very heterogeneous environments. The increased efficiency of the 5G infrastructure will allow costs to be dramatically reduced.

Design principles

5G design will ensure high flexibility and be driven by a service approach. The network shall flexibly and rapidly adapt to a broad range of usage requirements and deliver converged services preserving security and privacy across a versatile architecture with unified control of any type of ICT resources.

Since 5G will enable new business models in a programmable manner, Application Programming Interfaces (APIs) should be available at different levels (resources, connectivity and service enablers) to support a variety of network and service application developers.

Key technological components

5G wireless will support a heterogeneous set of integrated air interfaces: from evolutions of current access schemes to brand new technologies. 5G networks will encompass cellular and satellite solutions. Seamless handover between heterogeneous wireless access technologies will be a native feature of 5G, as well as use of simultaneous radio access technologies to increase reliability and availability. The deployment of ultra-dense networks with numerous small cells will require new interference mitigation, backhauling and installation techniques.

5G will be driven by software. Network functions are expected to run over a unified operating system in a number of points of presence, especially at the edge of the network for meeting performance targets. As a result, it will heavily rely on emerging technologies such as Software Defined Networking (SDN), Network Functions Virtualization (NFV), Mobile Edge Computing (MEC) and Fog Computing (FC) to achieve the required performance, scalability and agility.

5G will ease and optimize network management operations. The development of cognitive features as well as the advanced automation of operation through proper algorithms will allow optimizing complex business objectives, such as end-to-end energy consumption. In addition, the exploitation of Data Analytics and Big Data techniques will pave the way to monitor the users Quality of Experience through new metrics combining network and behavioral data while guaranteeing privacy.

Spectrum considerations

It is expected that 5G access networks for some services will require very wide contiguous carrier bandwidths (e.g. hundreds of MHz up to several GHz) to be provided at a very high overall system capacity. To support the requirements for wide contiguous bandwidths, higher carrier frequencies above 6 GHz need to be considered. The consideration of any new bands for such services will require careful assessment and recognition of other services using, or planning to use, these bands. Maintaining a stable and predictable regulatory and spectrum management environment is critical for the long term investments. Research on this spectrum has to take into account long-term investments so that they can be preserved. The exclusive mobile licensed spectrum assignment methods will remain important even if new techniques may be envisaged to improve spectrum utilization under some circumstances.

Timeline

The start of commercial deployment of 5G systems is expected in years 2020+. The exploratory phase to understand detailed requirements on future 5G systems and to identify the most promising technical options has already started. Although several standardization bodies will potentially be involved in the 5G definition, 3GPP will be most probably the focal point for technical specifications, with 5G study items starting from 2015.

INTRODUCTION

I

This paper gives an overview of the 5G vision of the European ICT sector. It addresses the key drivers and disruptive capabilities for 5G as well as the design principles, key technological components, spectrum and timeline considerations.

The strategic nature of the communication 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 € 660 billion, is generated today by the ICT sector itself. Additional investment in ICT in Europe could contribute to a rebirth of GDP growth in Europe up to 1.21% points in high-income economies and 1.38% points in low and middle-income economies, as suggested by a report from the World Bank[1]. The overall employment level of the ICT sector in Europe has been rather stable between 7.2 to 7.5 million employees since 2002 (Source: Digital Agenda Scoreboard[2]).

European industry has been historically strong in research, development and integration of complex systems like communication networks as well as manufacturing critical systems. A wide spread and well-established research community in R&D centres and universities is cooperating with industry and SMEs for knowledge and IPR generation. The novel 5G network requirements, technologies and architectures will introduce a wide range of industrial opportunities for both established and new actors among which SMEs. The 5G Infrastructure PPP is a unique opportunity for the European ICT industry to compete on the global market for 5G infrastructure deployment, operation and services.

1 Worldbank: Information and Communication for Development: Extending Reach and Increasing Impact – Economic impacts of broadband, 2009, http://siteresources.worldbank.org/EXTIC4D/Resources/IC4D_Broadband_35_50.pdf.

2 EU Commission: Digital Agenda Scoreboard – The ICT Sector and R&D&I. 2012. https://ec.europa.eu/digital-agenda/en/scoreboard.

KEY DRIVERS

2

4G was designed for improving capacity, user data-rates, spectrum usage and latency with respect to 3G. 5G is more than an evolution of mobile broadband. It will be a key enabler of the future digital world, the next generation of ubiquitous ultra-high broadband infrastructure that will support the transformation of processes in all economic sectors and the growing consumer market demand. The following paragraph intends to give an insight on what makes 5G so special.

An opportunity to launch brand new services

5G will bring new unique service capabilities for consumers but also for new industrial stakeholders (e.g. vertical industries, novel forms of service providers or infrastructure owners and providers).

Firstly, it will ensure user experience continuity in challenging situations. HD video or teleworking will be commonplace and available anywhere, regardless of if the user is in a dense area like a stadium or a city centre, or in a village or in a high speed train or an airplane. 5G Systems will provide user access anywhere and will select transparently for the user the best performing 5G access among heterogeneous technologies like WiFi, 4G and new radio interfaces. The choice of the best performing access will not only be based on throughput but on the most relevant metrics depending on the nature of the service e.g. latency may be more important than throughput for an online game.

In addition, 5G will be a key enabler for the Internet of Things by providing the platform to connect a massive number of objects to the Internet. Sensors and actuators will spread everywhere. Since they require very low energy consumption to save battery lifetime, the network will have to support this effectively. Objects, users and their personal network, whether body worn or in a household, will be producer and consumer of data. Future smart phones, drones, robots, wearable devices and other smart objects will create local networks, using a multitude of different access methods. 5G will allow all these objects to connect independently from a specific available network infrastructure.

Furthermore, some mission critical services will become feasible natively on the 5G infrastructure thanks to the unprecedented performance achievable on demand. It will cover services which were handled by specific networks for reliability reasons such as public safety. It will also cover new services requiring a real time reactivity such as Vehicle-to-Vehicle or Vehicle-to-Road services paving the way towards the self-driving car, factory automation or remote health services.

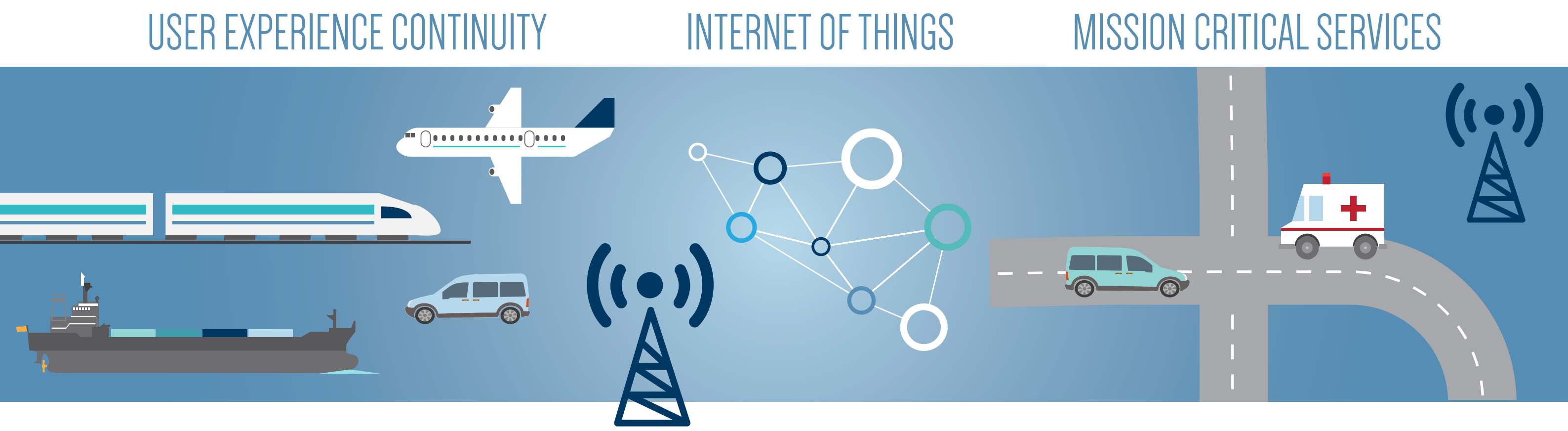


FIGURE I. 5G new service capabilities

As a conclusion, 5G needs to support in an efficient way three different type of traffic profiles, namely high throughput for e.g. video services, low energy for eg. long –lived sensors and low latency for mission critical services. In addition, 5G infrastructure will cover the network needs and contribute to the digitalization of vertical markets such as automotive, banking, education, city management, energy, utilities, finance, food and agriculture, media, government, healthcare, insurance, manufacturing, real estate, transportation and retail.

A unified telecom and IT infrastructure ready for multi-tenancy

Our vision is that in ten years from now, telecom and IT will be integrated towards a common very high capacity ubiquitous infrastructure. In order to assure the required scalability and flexibility, the network functions will be more and more "virtualised" on general purpose, programmable and specific high performance hardware that will offer resources for data transport, routing, storage and execution. 5G will integrate telecom, compute and storage resources into one programmable and unified infrastructure which will allow for an optimized usage of all distributed resources.

The wireless part of global network connectivity will grow from 45% in 2012 to 75% in 2020 (UMTS Forum[3]), with Wi-Fi covering close to 50% of total connectivity. Consumers as well as vertical business segments will want to use a unified wireless and wireline telecommunication network for an extreme variety of services. Being unified, 5G infrastructure will offer natively converging capabilities for fixed and mobile accesses, as well as for broadcast and broadband networks.

In addition, this infrastructure will be ready for multi-tenancy. Operators will add to their services portfolio the possibility to be asset providers (infrastructure, network functions, platform offered as a service) for other operators or other players like integrators. Leveraging on this fundamental design principle will push the single digital market further, paving the way for virtual pan European operators relying on nationally deployed infrastructures.

A sustainable and scalable technology

5G systems have to resolve the fundamental challenge of handling the anticipated dramatic growth in the number of terminal devices, the continuous growth of traffic (at a 50-60% CAGR), and heterogeneous network layouts without causing a dramatic increase of power consumption and management complexity within networks. In addition, users and the civil society will be much more sensitive to the sustainability of telecom services. As a result, 5G will have to be designed to be a sustainable and scalable technology.

Firstly, 5G will bring drastic energy efficiency improvement and develop energy harvesting everywhere. This energy chase will cover terminal devices, network elements, and the network as a whole including data centres. For example, it will enable a 10 years lifetime of a battery powered sensor. It will also contribute to Europe's objectives to improve our energy sources mix with more renewables installed e.g. on base stations.

In addition, costs reduction through human tasks automation and hardware usage optimization will feed the development of sustainable business models for all ICT stakeholders. 5G will embed advanced automation towards autonomics and cognitive management features which will improve operators efficiency. It will also improve the competitiveness of the European ICT industry. Furthermore, to sustain ubiquitous access in developing countries (the next 2 Billions of people) or in low-density areas, ultra-low cost network options will be developed. Lower cost technologies at all levels of networks (access, backhaul, core, IT, energy), as well as new types of deployments such as high altitude platforms (balloon, drones…), will be explored by relaxing target objectives on availability, peak rate, and latency.

A larger ecosystem, more open to new players, start-ups and other sectors

Last but not least, 5G will open the ecosystem for technical and business innovation. Business models will involve more and more partners delivering a part of the value. The extension of the cloud computing model to the telecom industry will unleash innovation and allow new players to access the ecosystem.

With 5G, network services will rely massively on software. It will strengthen Europe's software industry, including SME developers and solutions providers that can better compete in an increasingly hardware-agnostic market. Larger IT providers have already penetrated this market recently, relying on their expertise in cloud computing and virtualization to provide the same value proposition towards the telecom sector. It will cause a disruptive impact to network manufacturers which will re-position themselves, with a rollout of software solutions from their in-house development labs, or strategic partnerships with IT providers.

With 5G, the trend will be to dynamically adjust resources to demands. Infrastructure resources, connectivity and all network functions will be delivered as a service. It will foster partnership-based business models. Operators will tap into the opportunity to enhance the value of third party services. Partnerships will be established on multiple layers ranging from sharing the infrastructure, to exposing network capabilities as a service end-to-end, and integrating partners' services into the 5G system through a rich and software oriented capability set.

In addition, we will see some specific network platforms for each vertical sector with dedicated features and performance requirements (e.g. high reliability for health or automobile verticals or high density of terminals for smart cities). The use of COTS (Commercial of the Shelf) instead of current proprietary technologies, will change the market with these industries having a much greater influence on the development of network services and their SMEs will be able to innovate and launch new applications leveraging the new capabilities of 5G.

[3] UMTS Forum Report 44 "Mobile traffic forecasts 2010-2020© UMTS Forum January 2011",
http://www.umts-forum.org/component/option,com_docman/task,doc_download/gid,2537/Itemid,213/

5G DISRUPTIVE CAPABILITIES

3

5G will provide disruptive capabilities as described below, which will be an economy booster by fostering new ways to organize the business sector of service providers, as well as fostering new business models supported by advanced ICT. In addition, 5G should pave the way for a larger number of partnerships and Business to Business to Customers (B2B2C) business models through APIs deployed at different levels (assets, connectivity, enablers). The 5G architecture and technology will allow using only the necessary network functions and resources for each specific service (e.g. some M2M devices may not need mobility), as well as sharing infrastructure and spectrum costs in a flexible way between a rich ecosystem of service providers.

At the societal level, the 5G disruptive capabilities will provide ubiquitous access to a wide range of applications and services. These will be provided with increased resilience, continuity, and much higher resource efficiency including a significant decrease of energy consumption. At the same time security and privacy will be protected. In addition, 5G should provide enormous improvements in capacity and boost user data rates. In particular, peak data rates in the order of 10 Gb/s will be required to support services such as 3D telepresence on mobile devices. In addition, a capacity of 10 Tb/s/km² will be required to cover e.g. a stadium with 30.000 devices relaying the event in social networks at 50 Mb/s. Moreover, reduced end-to-end latencies of the order of 5 ms are needed to support interactive applications and ensure ultra-responsive mobile cloud-services. Future 5G infrastructure is expected to cope with 30-50 Mb/s for a single video transmission (before channel coding) and perform most of the light-field and sound-field processing in the network, in order to adapt the data stream with (close to) "zero latency".

Besides human-centric applications outlined above it is expected that a wide variety of Internet of Things (IoT), Massive Machine-Type Communication (M-MTC), and Ultra-reliable Machine-Type communication (U-MTC) will be prevalent by 2020. Supporting the diverse requirements coming from IoT verticals may require restructuring key architecture components of mobile systems.

The highly demanding disruptive capabilities of 5G require an enormous research effort for industry and academia, because it requires orders of magnitude of improvement over the current technology and infrastructure. The following numbers, which are currently under discussion in various fora such as NGMN or ITU-R, indicate the advances required by 5G systems:

1,000 X in mobile data volume per geographical area reaching a target ≥ 10 Tb/s/km2

1,000 X in number of connected devices reaching a density ≥ 1M terminals/km2

100 X in user data rate reaching a peak terminal data rate ≥ 10Gb/s

1/10 X in energy consumption compared to 2010

1/5 X in end-to-end latency[4] reaching 5 ms for e.g. tactile Internet and radio link latency reaching a target ≤ 1 ms for e.g. Vehicle to Vehicle communication

1/5 X in network management OPEX

1/1,000 X in service deployment time reaching a complete deployment in ≤ 90 minutes

[4] End-to-End latency should be understood as limited for the case of terminals physically close, as nearby vehicles, a swarm of robots in an automated factory, or a terminal connecting to advanced services provided by a cloud located within its backhaul.

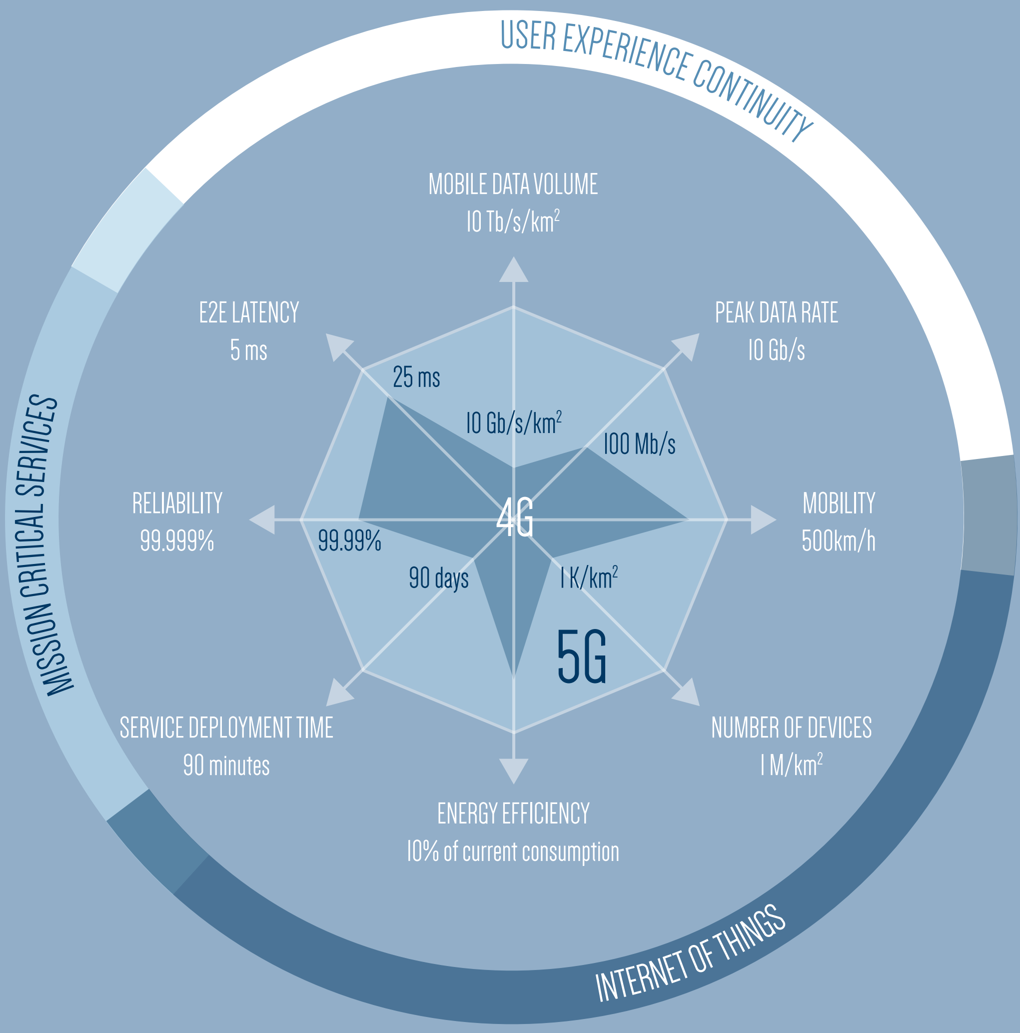


FIGURE 2. Radar diagram of 5G disruptive capabilities

In addition, 5G services will complement and largely outperform the current operational capabilities for wide-area systems, reaching the following high-performance indicators:

Guaranteed user data rate ≥ 50Mb/s	Capable of human-oriented terminals ≥ 20 billion
Capable of IoT terminals ≥ 1 trillion	Aggregate service reliability ≥ 99.999%
Mobility support at speed ≥ 500km/h for ground transportation	Accuracy of outdoor terminal location ≤ 1 meter

Non-quantitative capabilities of the technology include a software-based system architecture, simplified authentication, support for shared infrastructure, multi-tenancy and multi-RAT (with seamless handover), support for terrestrial and/or satellite communication, robust security, privacy, and lawful interception capacity.

It is important to highlight that not all of the above performance indicators will be required by every terminal everywhere and all the time. Each connected device will typically have its mix of latency, bandwidth and traffic intensity characteristics. Also, each connected area will have its specific characteristics: the network will not provide the same coverage for a business district, a stadium, a residential area, or on board of a vehicle (bus, train, boat, airplane...). This is why the infrastructure has to be adapted to the characteristics of the service demand expected at each area. In particular, ultra-low cost infrastructure options will satisfy the demands of low ARPU terminals/users, as they will be commonplace in developing regions and as part of IoT services.

DESIGN PRINCIPLES

4

Operators of ICT infrastructures need more network and services flexibility, scalability and business sustainability. The future 5G infrastructure shall flexibly and rapidly adapt to a broad range of requirements. Indeed, it will be required to host new types of services , new types of devices (vehicles, machines, connected objects, things) and different technologies (for access, fronthaul and backhaul).

In order to meet the expected high throughput targets, small cells will be pushed further leading to Ultra Dense Networks (UDN). As already pointed out, 5G will cover human-to-human, human-to-machine and machine-to-machine communications and this will drive the future infrastructure towards all-encompassing smart connectivity: smart cars, smart grids, smart cities, smart factories and so forth. It will foster new Radio Area Network paradigms such as Device to Device (D2D) and Moving Networks (MN).

The architecture of 5G will change dramatically compared to previous generations, in order to meet the expected business and performance requirements, especially in terms of latency and reliability, and to support new business models and scenarios, beyond what is currently foreseeable. In order to realize such a radical view on what the 5G infrastructure is to become, the various 5G subsystems and interfaces, as well as their integration into the overall 5G substrate need to be inspired by modern operating system architectures.

While today's mobile networks are an overlay on top of transport network infrastructures, the foundational principles of software and computing architectures suggest designing 5G as a set of native service/network applications, and unifying all fundamental procedures of the access stratum (AS) and non access stratum (NAS) protocols, such as connection, security, mobility and, especially, routing management. It means convergence between fixed and mobile networking services with the associated evolution of core and transport networks. This will dramatically reduce latency due to protocol simplification and optimal locations of network/service applications and corresponding states; improve reliability through the possibility of establishing simultaneously multiple connections, not limited to a single dimensional communication chain; enable new business models through open interfaces (APIs for resources, connectivity and services enablers); and support legacy services and communication systems running applications fully compatible to them and their future enhancements. A vision of 5G networks and services is illustrated in Figure 3.

While the diversity of services and the complexity of the infrastructure will apparently increase, 5G is expected to radically cut total cost of ownership (TCO) of the infrastructure, on the one hand, and the service creation and deployment times, on the other. Hence, service/network management that classically rely on the Operation Administration and Management (OA&M) tools and the Business and Operations Support Systems (BSS and OSS) will evolve accordingly with advanced automation including cognitive operations for handling trillions of actuators, sensors, and exploiting Big Data for better QoS and QoE, whatever the prosumer will be (human, machine or thing). Energy consumption will be also dramatically reduced in the terminal and infrastructures and harvesting energy systems will power ICT equipment.

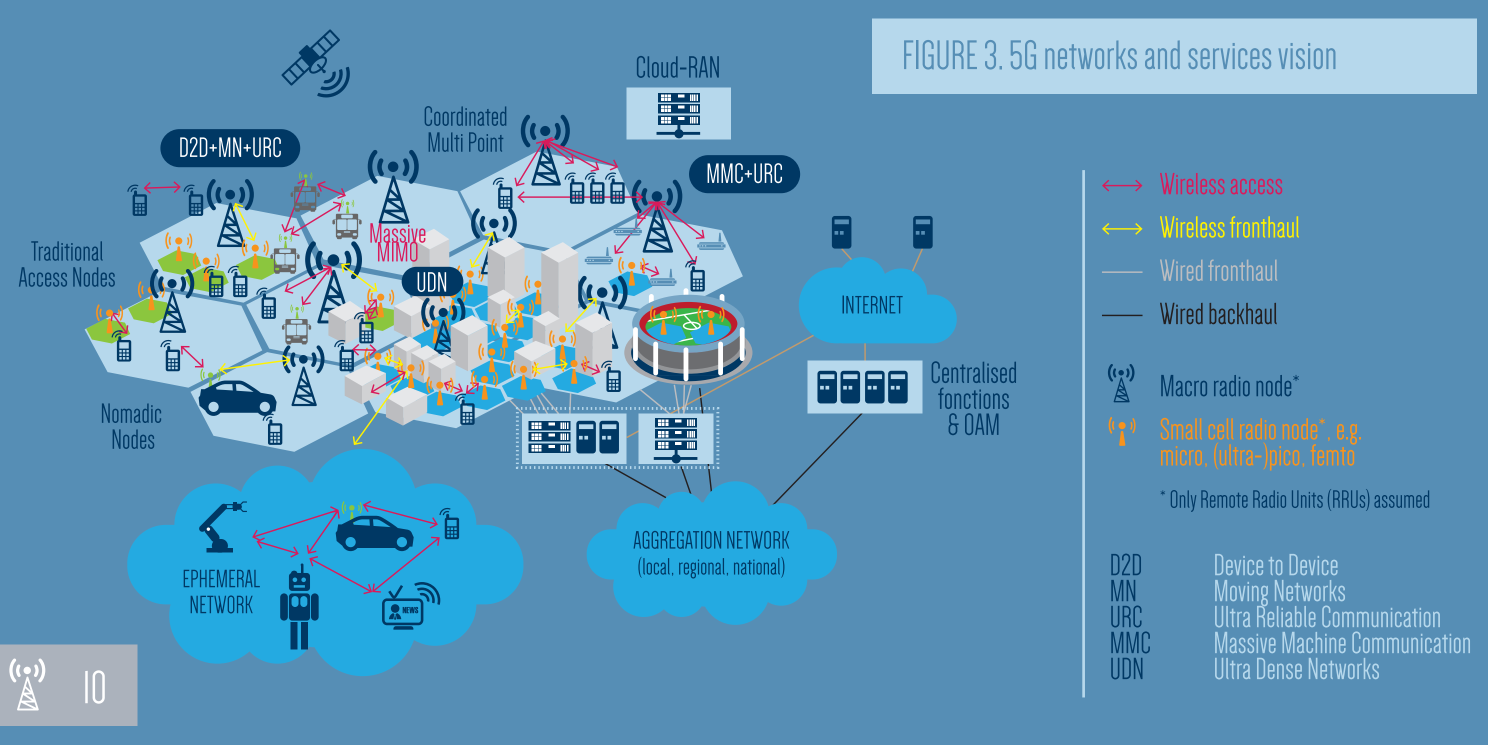


FIGURE 3. 5G networks and services vision

KEY ENABLING TECHNOLOGIES

5

Wireless technologies will be the starting point

Designing a wireless access network that simultaneously satisfies future demands for both human-centric and machine-centric services calls for technologies capable of using contiguous and wide spectrum bandwidth; flexible resource allocation and sharing schemes; flexible air interfaces; new waveforms; agile access techniques; advanced multi-antenna beam-forming and beam-tracking and MIMO techniques; new radio resource management algorithms, to name just a few.

5G wireless will support a heterogeneous set of integrated air interfaces. 5G network deployments are expected in the “low” band, i.e. frequencies below 6GHz on macro and small cells, coexisting with legacy (2-3G) and LTE (4G) technologies; and in the “high” band, i.e. frequencies above 6GHz, on small cells, together with WiFi and previous releases of 3GPP technologies.

The 5G network architecture will enable the integration of small cells and ultra-dense networks (UDN) which will require new operational models for access networks like crowd networking (relying partly on non-operators to deploy and maintain the cells) which will call for new standard interfaces.

5G will leverage on the strengths of both optical and wireless technologies

The novel 5G architecture is also expected to integrate both fronthaul and backhaul into a common transport network. The technologies, which have been already identified span from fiber optics with software-defined optical transmission to novel CPRI-over-packet technologies, also considering wireless links such as mmWave. On top of them a general processing plane is expected to carry out bulk operations in shared transmission media, and provide carrier grade services in terms of re-configurability, energy efficiency and multi-tenant operations.

Furthermore, to achieve the expected capacity, coverage, reliability, latency and improvements in energy consumption, the 5G architecture is expected to i) run over a converged optical-wireless-satellite infrastructure for network access, backhauling and fronthauling with the possibility of transmitting digital and modulated signals over the physical connections; ii) leverage flexible intra-system spectrum usage; iii) make optimal utilization of the specific strengths of the different underlying infrastructures (e.g. leverage multicast for satellite or flexible spectrum for optical).

5G will be driven by software

Network functions virtualization (NFV) and software-defined networking (SDN) provide examples for possible new design principles to allow more flexibility and tighter integration with infrastructure layers, although performance and scalability need further investigation. Both approaches stem from the IT realm: NFV leverages recent advances in server virtualization and enterprise IT virtualization; SDN proposes logical centralization of control functions and relies on advances in server scale out and cloud technologies. However, none of those is essentially a networking technology, as the network is assumed to be there, before NFV or SDN can be even used. Hence, 5G will provide a unified control for multi-tenant networks and services through functional architectures deployment across many operators’ frameworks, giving service providers, and ultimately prosumers, the perception of a convergence across many underlying wireless, optical, network and media technologies. 5G will make possible the fundamental shift in paradigm from the current “service provisioning through controlled ownership of infrastructures” to a “unified control framework through virtualization and programmability of multi-tenant networks and services”.

Efficiency and security will be of paramount importance

Energy efficiency is also in circuit design, such as power amplifiers and analog front-ends in microwave and millimeter frequency ranges, DSP-enabled optical transceivers for access and backhaul networks, and ultra-low power wireless sensors harvesting ambient energy, such as solar, thermal, vibration and electromagnetic energy. In addition, wireless power transfer technologies and optimization of sleep mode switching present another exciting alternative to battery-less sensor operation for M2M and D2D communications.

It is of course intended that such a revolution in the network infrastructure cannot happen without parallel evolution of the connected objects (terminals, machines, robots, drones, etc.) in terms of wireless connectivity, computational power, memory capacity, battery lifetime and, cost.

In 5G, security issues are radically amplified by the expected multiplication of both types of stakeholders and numbers of tenants. To resolve the potential increased complexity within the system associated with this, it will become necessary to work under different contexts and to always consider security realms. It will require new access control models, as we have seen them emerge in the domain of online social networks and, generally, online services. Beyond confidentiality, integrity and availability, cyber-physical system (CPS) security, and new security concepts in this area, need to address trustworthiness of information, integrity of remote platforms, contextual correctness, proof of possession and similar topics. The existence of and support for highly limited devices such as sensors will require probabilistic security mechanisms deployed in parallel to the high-security solutions mentioned before. Also, tailored security at the service and device level should be envisioned: 5G might consider dynamic control and data plane support for different security system instantiations to be able to provide differentiated security services on request. The dynamic composition of the 5G infrastructure needs security guarantees within the system: beyond the mutual authentication and secure communication channel establishment, we will need to delve into topics of infrastructure/system integrity and operational security assurance. The key here is to go beyond the currently prevailing operational security models like prevention and protection, which tend to limit degrees of freedom. If the system dynamics is key to achieve the agility of stakeholders (as recent NFV and SDN initiatives suggest), then the survivability must be increasingly understood as the major operational security model.

Research & innovation collaborative projects will play a key role in 5G development

It is essential that large-scale, multi-layered collaboration projects are available to achieve this transformation. The ICT sector in Europe is leading the way to drive this process, which is supported by the 5G Public-Private-Partnership (5G PPP) in Horizon 2020 of the EU. The initiative can remove obstacles that may hamper the 5G development by achieving an early consensus among key global stakeholders, e.g. on a common 5G vision, architecture, spectrum utilization, pre-standardization and international collaboration between Europe and the relevant bodies in China, Japan, Korea and USA, to start from. In addition to the private continuous effort, it is of vital importance that public authorities and the private sector develop effective policies with regard to spectrum, pre-standardization and international collaboration. What we need is an evolving regulatory framework that provides a true level playing field for current and new players coming into the picture, thanks to the novel sustainable business models that 5G will enable.

Funding for promising projects will speed up progress. The EU can play an important role in consolidating and building on the most important research and innovation results attained in previous research programs, gathering resources for 5G tests, proof of concept and large-scale trials, and bringing the right stakeholders even beyond the ICT sector on board, notably vertical industries. The METIS project, among others – e.g., MiWeba, MiWaves, 5GNow, iJoin and CREW/EVARILOS – are very good examples of successful European initiatives. These pan-European projects aim at contributing to the foundation of 5G and have been developing and evaluating key technology component candidates for 5G systems.

Nevertheless, let us not forget that 5G is still in its early research stages. As presented above, a number of issues must be resolved before it can become a reality: we need to join forces – across countries, continents, industries and sectors. Europe has a key role to play in creating the right synergies, paving the way for a hyper-networked future and building a better connected world.

5 Analysys Mason, "Wireless network traffic worldwide: forecasts and analysis 2014–2019," October 2014
6 Cisco, "The Zettabyte Era: Trends and Analysis," White Paper, June 2014
7 NGMN Alliance, "5G White Paper – Executive Version," 22 December 2014
8 METIS, "Deliverable D5.3. Description of the spectrum needs and usage principles," 1 September 2014
9 Ofcom call for input, "Spectrum above 6 GHz for future mobile communications," 16 January 2014
10 FCC notice of inquiry, "Use of spectrum above 24 GHz for mobile radio services," GN Docket No. 14-177, FCC 14-154, 17 Oct 17 2014

SPECTRUM CONSIDERATIONS

6

Radio based services rely on appropriate access to electromagnetic spectrum at suitable frequencies. To meet the expected growth in traffic and requirements associated with new applications as discussed in Section I, the success of 5G systems and services depends inter-alia on i) a more efficient use of spectrum already assigned to terrestrial mobile services; and ii) the timely ability to utilise certain new bands in order to support new capabilities for which demand exists. Research on this spectrum has to take into account long-term investments so that they can be preserved.

The following three topics are considered concerning spectrum for 5G:

- Trends in the spectrum requirements for mobile broadband access and backhaul
- Considerations for new wireless broadband spectrum above 6 GHz
- Spectrum management methods

Trends in the spectrum requirements for wireless broadband access and backhaul

Driven in particular by video applications and the ever-increasing use of smartphones, tablets and machine communication, mobile data traffic is expected to grow dramatically according to several reports, such as Analysys Mason[5] and Cisco[6]. These indicate about 50 to 60 % annual growth over the five year period 2013 to 2018, a trend which may well continue beyond 2020. It is also expected that 5G access networks for some services will require wide contiguous carrier bandwidth (e.g., hundreds of MHz up to a few GHz) to be provided at a very high overall system capacity. These will need to be supported by appropriately scaled backhaul links that themselves will require adequate spectrum resources.

Considerations for new wireless broadband spectrum above 6 GHz

To support the requirements for wide contiguous bandwidths, higher carrier frequencies above 6 GHz need to be considered. For instance, the NGMN Alliance has identified that wide bandwidths may be required to "support very high data rates and shorter-range connectivity"[7].

Higher carrier frequencies can provide wide contiguous bandwidth for very high overall system capacity, as the effective user range will be relatively short, enabling very efficient frequency reuse over a given geography. With increasing carrier frequency the propagation conditions become more demanding than at the lower frequencies traditionally used for wireless services. In particular both path loss and diffraction loss become more severe, atmospheric effects must be accounted for, and the use of directional antennas becomes necessary. The result will be comparatively short links which to some degree basically rely on line-of-sight paths. In fact, this can be considered an advantage rather than a drawback, as in dense urban settings cell sizes are becoming smaller anyway (e.g. of the order of hundreds of meters) in order to provide high capacity. Furthermore, advances in technology development such as 3D beam-forming and massive MIMO techniques will realize their full potential when taking advantage of the short wave-lengths, which come with high frequency bands.

The consideration of any new bands above 6 GHz for wireless networks will require careful assessment and recognition of other services using, or planning to use, these bands. This will require the application of several methods and criteria, including, but not limited to, e.g. the minimum required bandwidth and the level of spectrum utilization, including existing and planned other services.

There is considerable work in the literature that provides useful information on the most relevant spectrum bands, e.g., the outcome of the EU METIS[8] studies, the Ofcom consultation[9], and FCC[10]. These views are given without prejudice to the normal regulatory processes at ITU, European and national levels, including sharing studies as usual and appropriate.

Spectrum management methods

Maintaining a stable and predictable regulatory and spectrum management environment is critical for the long-term investments of terrestrial and satellite operators and service providers into networks, services, and spectrum. The exclusive mobile licensed spectrum assignment methods will remain important for ensuring stability for long-term investments into networks and the underlying spectrum. In the interest of improving spectrum utilisation, new techniques and technologies may be envisaged to facilitate long-term co-existence between services and applications. New technologies for the use of higher frequency bands and innovative regulatory tools could provide new spectrum coexistence opportunities for 5G systems.

Methods have been suggested and are investigated involving a more dynamic sharing of spectrum than is currently used. In addition, cognitive radio solutions may gain traction in the market in coming years.

5G TIMELINE

7

This section describes the most important milestones of research, development and innovation and standardization activities on 5G.

Research, Development and Innovation Phases

The start of commercial deployment of 5G systems is expected in years 2020+, following the R&D phase and the standardization and regulatory phases (e.g. spectrum in World Radiocommunications Conference - WRC). Japan has committed to have a commercial system for the 2020 Olympics. It is too early for the European operators to commit to network rollouts but many are predicting the 5G commercial availability in 2020 – 2025. The exploratory phase to understand detailed requirements on 5G future systems and identify most promising technical and technological options has already started before 2014. The path from 5G exploration to early deployment from the today's perspective in 5G PPP is summarized in the following table.

TABLE I : FROM 5G EXPLORATION TO 5G DEPLOYMENT

MILESTONES	
2014-2015	Exploratory phase to understand detailed requirements on 5G future systems and 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.
2015-2017	Detailed system research and development for all access means, backbone and core networks (including SDN, NFV, cloud systems, undedicated programmable hardware...) by taking into account economic conditions for future deployment.
2016-2018	Detailed system optimisation by taking into account all identified requirements and constraints. Identification and analysis of frequency bands envisaged for all 5G communications (also taking into account the result of WRC15) and final system definition and optimisation by means of simulations, validation of concepts and early trials. Contributions to initial global standardisation activities e.g. in 3GPP. Preparation of WRC19. 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 2020.
2017-2018	Investigation, prototypes, technology demos and pilots of network management and operation, cloud-based distributed computing and big data for network operation. Extension of pilots and trials to non ICT stakeholders to evaluate the technical solutions and the impact in the real economy. Detailed standardisation process based on validated system concepts by means of simulations and close to real world trials.
2018-2020	Demonstrations, trials and scalability testing of different complexity depending on standard readiness and component availability.
2020	New frequency bands available for trial network deployment and initial commercial deployment of new systems. Close to commercial systems deployment under real world conditions with selected customers to prepare economic exploitation on global basis.

Standardization Activities

Industry will play the major role in the 5G Infrastructure PPP with respect to the necessary long-term investment in global standardization and the integration of technological contributions into complex interoperable systems. Results of the 5G Infrastructure PPP projects will be suitable for global standardization in bodies like 3GPP, IEEE, IETF and other standards and specification bodies in the IT domain, which can be contributed via established channels of 5G PPP partner organizations to respective standards bodies. These channels will be used to exploit research results in international standardization.

It is clearly expected that the core of the 5G standardization related to mobile technologies will happen in the context of 3GPP, e.g. 3GPP RAN, CT and SA groups. However the 5G Infrastructure PPP members will also contribute to a wide range of other standardization bodies (IETF, ETSI, ONF, Open Daylight, OPNFV, Open Stack, ...). A high-level overview of the 5G roadmap, as seen from 5G Infrastructure PPP, is depicted in Figure 4.

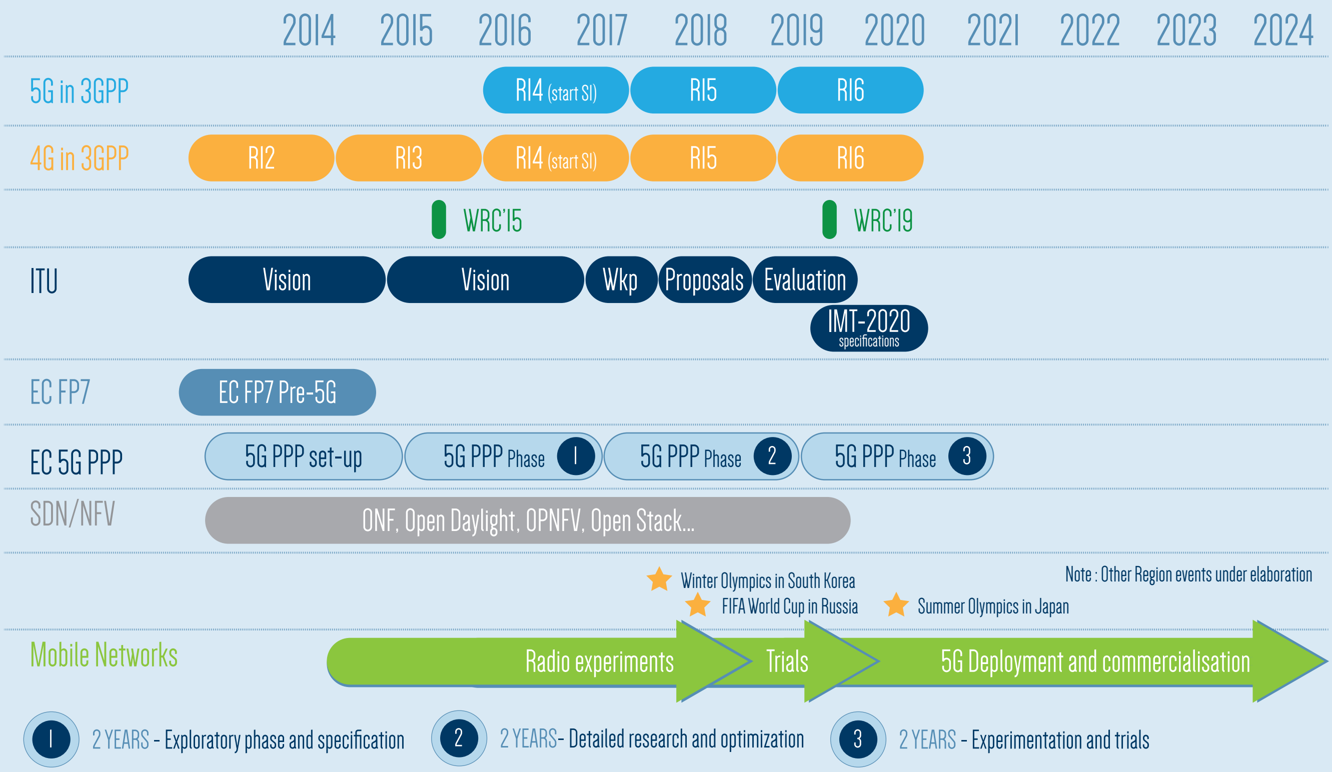


FIGURE 4. 5G ROADMAP

ANNEX 5G PPP

The 5G Public-Private-Partnership (5G PPP) is within the EU Horizon 2020 – The EU Framework Programme for Research and Innovation – under one of the most important EU Industrial Leadership challenges: ICT-14 Advanced 5G Network Infrastructure. Within this research and innovation framework, the European Commission (EC), under the approval of the European Parliament (EP), has already committed 700M€ of Public funds over 6 years (2015-2021). From two to ten times higher is expected to be the investment from Private Party: Industry, SME, and Research Institutes.

General objectives of 5G PPP are to

- Conduct research and innovation work that will form the basis of the 5G infrastructure for the Future Internet for a wide range of applications from IoT (Internet of Things) to very high throughput services;
- Develop the next generation of network technologies taking into account key societal challenges and their networking requirements;
- Reinforce the European industrial capability in communication network technologies;
- Serve as a consensus-based platform for effective collaboration of players from industry, academia, research organizations and SMEs from both the terrestrial and the satellite communities
- Pave the way towards successful introduction of innovative business models based on more powerful and open networks;
- Support the emergence of global standards;
- Help addressing non-technological barriers such as regulatory issues and spectrum availability;
- Validate technologies from a technical and business perspective through early trials and reference deployments;
- Develop skilled personnel, which is needed to research, develop and operate advanced communication networks as well as use of new systems in vertical markets;
- Provide a reliable and trustworthy communications infrastructure, which secures critical infrastructures.

5G PPP is a consensus-oriented organization aimed at fostering roadmap-driven research, which is controlled by business-related, performance and societal KPIs. The program has a lifetime from 2014 to 2020 and is open for international cooperation and participation.

This document has been written by experts from members of the 5G Infrastructure Association. It represents the best of their expert knowledge to date and aims to provide a perspective on the development of 5G in Europe. This document is released in February 2015.

Updates will be made regularly and are available for download at www.5g-ppp.eu/roadmaps .

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More information at
www.5g-ppp.eu

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