5G network technology
Putting Europe at the leading edge

SUMMARY
5G refers to a future, fifth generation of mobile network telecommunications technologies. While research on the technical characteristics and potential uses of 5G is ongoing, 5G is expected to represent a major leap forward from current telecommunications technologies, including revolutionary changes in radio interfaces and spectrum use. On the basis of current trends and potential uses, 5G networks will be faster, always accessible, highly reliable and efficient in handling a very large number of devices (including smart objects in the Internet of Things).

By supporting a world in which 'anyone and anything will be connected at anytime and anywhere', 5G is expected to enable new applications in various domains, including entertainment, health, transport and industry. However deployment of this new generation of mobile technology in the decade starting in 2020 will also likely give rise to uses (and consequences) that are difficult to foresee at the current time. On the basis of past generations of mobile technology, the increased networking supported by 5G is likely to stimulate economic growth, not just in the information and communication technology sector, but in many areas of the economy.

The EU is providing financial support to 5G research, and has concluded cooperation agreements on 5G development with South Korea, Japan and China. These efforts are intended to contribute to a strong European digital economy, by helping European companies win a significant share of markets related to the new generation of mobile networks. Other sectors of the European economy are also expected to benefit from the increased efficiency, new services and innovative business models that 5G networks should make possible.

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Context

5G is the term used to refer to the next (fifth) generation of ubiquitous mobile telecommunications technology. Progress in mobile telecommunications is measured in ‘generations’ where, roughly every ten years, a new set of technologies represents a radical leap forward in terms of the support needed for new services and applications. Whilst in 2015, fourth generation (4G) mobile technology is still being rolled out in Europe, work is already progressing on defining its successor, 5G, which is expected to be implemented starting in 2020.

As yet, no official definition of 5G exists, but progress has already been made in setting out targets, testing technologies and defining applications for the new generation of connectivity. 5G is expected to integrate new radio access networks seamlessly with network technologies introduced by earlier generations of communications technology. It should allow billions of users and smart objects in the Internet of Things (IoT) to connect with networks; it should transmit vastly increased quantities of data with very little delay; it should provide secure and reliable transmissions anywhere; and it should be more efficient, reducing the per-unit cost of data transported. Not all of the specific goals that experts have set for 5G may be realisable in the short term; however for network operators to continue to meet customer demands effectively in the coming years, a new, radically improved generation of mobile wireless technology is needed.

For many analysts, the development of 5G technology is critical to the growth of the European economy. The information and communications technology (ICT) sector represents about 4% of EU GDP, and investments in ICT are responsible for about half of recent productivity growth in Europe. Moreover, 5G has the potential to create new jobs and stimulate growth in all industries that are able to exploit wireless mobile technology to become more competitive, to create new business models and to offer new services. Whether from incremental improvements or radical new approaches, new generations of mobile technology have been shown to have contributed between 2% and 4% to levels of GDP in six countries at different stages of development. However experts also point out that in the past, truly revolutionary or disruptive applications have only emerged after new mobile technology was widely deployed, so the most important economic and societal benefits of 5G may only become apparent at some point in the future.

Whilst Europe was instrumental in defining the GSM standard that underlies 2G mobile services, it lagged behind in the development of the subsequent two generations of telecommunications technology. With 5G, the EU is seeking to gain a competitive advantage by taking a leading role in the definition and standardisation of 5G technologies. 5G standards are expected to be finalised by 2018 or 2019, with deployments starting after 2020. By active participation in the development of 5G, Europe may capture a significant part of the related markets for intellectual property, network expertise, device manufacture and application development. More importantly, through rapid deployment of 5G, the European economy as a whole could benefit from the new services and greater efficiencies that 5G can make possible.
Trends driving the next generation

The need for a new generation of mobile technology is being driven by a number of major trends. First among these is the rapidly increasing number of internet-connected devices. Forecasts say that by 2019, there will be 24 billion networked devices and connections in the world, up from 14 billion in 2014. Part of this growth will be due to machine-to-machine (M2M) communication in the Internet of Things. Smart objects such as household appliances, industrial robots, cars, and wearables such as watches or clothing need to be connected to networks in order to communicate the information that they collect and have it acted upon in a timely fashion.

Data traffic, particularly mobile traffic, is also increasing rapidly. According to projections, global internet protocol (IP) data traffic will grow at a compound annual rate of 23% from 2014 to 2019. By 2020, there will be 30 times as much mobile internet traffic as there was in 2010. This increase is largely due to greater volumes of data-intense video, and the growing use of cloud computing where data and applications are accessed remotely over the internet, as well as the increasing number of connected devices.

Connected devices such as smartphones and tablets are also becoming increasingly ubiquitous: consumers expect to have their personal devices connected at all times wherever they are. Some 90% of 3G and 4G consumers want more coverage, faster data speeds and better battery life, among other improvements. They expect their devices to respond quickly even in dense urban environments where radio spectrum is shared with many thousands of others, or in highly mobile situations, e.g. when they are moving rapidly in a 'connected car', or in a high-speed train.

These increasing demands are driving up costs for network operators who look to 5G as a way to reduce costs per bit transmitted as volumes increase. In particular, energy represents a large cost for network operators, and required increases in network coverage can drive those costs higher (wireless base stations account for almost 60% of mobile network power consumption). Lower energy consumption for personal devices also means longer battery life; this is particularly important for the Internet of Things, since replacing or recharging batteries embedded in devices is very expensive. Energy efficiency is of course also important in terms of mitigating environmental and climate change effects.

5G application scenarios

A more ubiquitous, higher capacity, higher density and more efficient 5G network will enable new kinds of applications and business models. There are many examples of possible applications where 5G connectivity can make a significant contribution.
• **E-health applications** can make use of wearable devices worn by patients in their own home to monitor variables such as blood pressure, pulse and breathing rate. These devices can then securely and reliably transmit the data in near-real-time to a health service which can rapidly intervene (perhaps remotely) in case of need. These applications can reduce health costs by allowing some patients to stay out of hospitals and care facilities and in their own homes.

• Very high data capacity, very rapid response (i.e. low latency) and high reliability of 5G network transmissions would make precision **telesurgery** practical and affordable. Patients who need a specific type of operation could choose the best surgeon regardless of where he or she is located.

• **Road transport** can become safer and more efficient as connected cars share information in real time with other vehicles; information from roadside infrastructure about a problem ahead can allow drivers to change routes quickly. Ultimately, cars may become smart enough and able to respond so quickly and reliably to networked data that they can be autonomous and drive themselves.

• **Train travel** can be more productive or entertaining as passengers travelling at 300 km/h on high-speed trains through the countryside can work with full 5G network connectivity to their cloud computing resources or stream their own choice of high-definition movie.

• **Entertainment** can be enhanced with high-speed, high-capacity networking. In a densely packed crowd at a sporting event, each spectator could use their personal device to view or immediately review events from different angles. Two-way interactive electronic gaming can be enhanced with near immediate, high-capacity information in virtual reality.

• Industry and manufacturing can be revolutionised with 5G connectivity. **Intelligent connected robots** in the Factory of the Future can communicate with each other and parts, to increase manufacturing efficiency, reduce costs and produce individualised ‘one-off’ products. Sensors in **connected products** can alert service centres in a timely fashion to the need for servicing, or can be used to provide new service-based businesses. Workers equipped with **augmented reality glasses**, that superimpose information on a worker’s view of the real world, can function more efficiently.

**Figure 2 - Bandwidth and latency requirements for generic applications**

Source: [GSMA Intelligence](https://www.gsma.com), 2015.
Not all these applications need all the features that can be reasonably expected in 5G networks, and not all applications have the same needs. Future internet network services need to respond to a range of needs, from low data transmission rates (e.g. much sensor and IoT data) to very high rates (e.g. high definition video streaming), and with various latencies (e.g. delays are less well tolerated in video conferencing calls than in video streaming where some buffering can be used). With the exception of autonomous vehicles, augmented reality, and the tactile internet, some observers believe that many of the applications could, at least in theory, be delivered on existing networks. Networks will also need to deal with different Quality of Service requirements for different kinds of applications (e.g. a few seconds delay in a telesurgery application could prove fatal), given that the traditional 'neutral' internet does not provide any guarantee of when, or even if, transmitted data will be delivered.

5G technical requirements

In order to support these types of services and applications, 5G will have to meet a number of technical requirements. Stakeholders have identified a wide range of challenges for 5G including:  
- Increasing wireless capacity by 1 000 times
- Connecting 20 billion people-oriented devices
- Connecting 1 trillion objects in the Internet of Things
- Saving 90% of the energy used
- Supporting ten-year battery life for low power IoT-type devices
- Providing latency of under 5 milliseconds (ms)
- Providing a perceived connection reliability of 99.999%
- Reducing time required to create a network service from 90 hours to 90 minutes.

None of these key performance indicators have yet been formalised by 5G standards bodies (see box). Stakeholders at different times have set more ambitious targets (e.g. 7 trillion connected things; latency under 1 ms, at least for some applications); have added additional goals (e.g. reductions in the capital or operating costs of networks); or even (in the case of the GSM Alliance) pared down the list of targets for 5G to two (latency under 1 ms and download speeds of more than 1 gigabit per second, Gbps) on the grounds that most other goals can be met with 4G technologies.

Whether all these 5G targets are achievable within the same time frame and for all applications remains an open question. Not all the capacity, latency and coverage requirements are needed to support most uses or applications; those that prove most technically difficult or most expensive may be relaxed or reduced when standards are agreed, or may not be supported in the initial deployments of 5G networks.

### Standards organisations

A number of different standards and industry bodies are involved in the process of developing 5G standards. Arguably, the most important of these from a European perspective are the following three organisations.

The International Telecommunications Union (ITU) is a UN specialised agency with responsibility for ICT and radio spectrum that brings together governments along with industry participants. Its work on International Mobile Telecommunications 2020 (IMT-2020) has established a vision and roadmap for 5G development. Important spectrum decisions are taken at World Radio Conference (WRC) meetings that the ITU hosts every few years. In 2015, WRC-15 agreed on additional spectrum for mobile services in the 690-790 megahertz (MHz) band to accommodate...
mobile broadband needs up until 2020. Discussions of higher frequency spectrum bands needed for future 5G communications are on the agenda for the next WRC in 2019.

The 3rd Generation Partnership Project (3GPP) is a consortium of industry associations and standards organisations (including the European Telecommunications Standards Institute). 3GPP 'Releases' appear every year or two and bundle together a range of new or updated specific standards developed by its working groups. The 3GPP has been involved since 2000 in defining Long Term Advanced (LTE) and LTE/Advanced (4G) standards; it will define another LTE upgrade ('Advanced Pro') starting in 2016 with Release 13. Its agreed 5G standards will be published starting with releases in 2018 or 2019.

The 5G Infrastructure Public Private Partnership (5GPPP) brings together industry and telecommunications companies with service providers, small enterprises and academia. Supported by €700 million in EU financing through the Horizon 2020 research programme, mirrored by an equal amount from private partners, it expects to stimulate another five to ten times those sums in outside activities. The 5GPPP aims to rethink next-generation infrastructure and to establish European leadership in 5G developments, including developing and exploiting at least 20% of patents essential for standards.

### 5G technologies

5G will almost certainly introduce a new radio interface, which defines the frequency, channel bandwidth and modulation scheme used to communicate between a mobile device and a wireless base station. However it is also expected to integrate the use of legacy radio access technologies such as those used by 4G and wireless local area networks. Thus 5G represents a convergence of previous generations, the first time that a new generation will incorporate, rather than replace, its predecessors.

5G networks will operate on a range of radio spectrum bands. In addition to the traditional sub-3 gigahertz (GHz) bands (where additional spectrum will be allocated in the 700 megahertz (MHz) band to mobile communications), 5G will exploit higher frequencies of radio spectrum in the millimetre wave range (roughly 20 to 300 GHz) which can provide greater bandwidth, although over shorter distances. (The 2015 World Radio Conference, WRC, decided to place the issue of high-frequency radio spectrum for 5G on the agenda for the next WRC in 2019.) Nevertheless most commentators agree that sharing by different operators of currently authorised and licensed bands, as well as unlicensed bands, will be necessary to make the most efficient use of spectrum. Devices and network base stations will employ multiple antennae (known as multiple input/multiple output or MIMO antennae) that allow multiple simultaneous connections to be set up in order to increase bandwidth, minimise errors and optimise data speed.

To support a high density of connections and large bandwidth, 5G wireless networks will be heterogeneous, being made up of both large and small cells (so called depending on how much area they cover) using different technologies. Small cells are needed to provide coverage in very dense urban areas; using high frequency spectrum, they can provide much higher capacity transmissions and increased energy efficiency (beams can be directed, though high frequency waves can have problems penetrating vegetation and buildings). Small-cell base stations can be designed to configure themselves automatically in relation to nearby cells to reduce interference and simplify installation. Coordination of traffic and spectrum will be more complex as users move between small-cell coverage areas, with communications reverting back to the main 'macro' cell if they move out of the small cell's range. In a 5G network, transmissions may also eventually pass from one user device to another, or one cell to another, before being transmitted on to the network.
With 5G, the time and cost of network service deployment for network operators should be reduced. Virtualisation techniques,\(^7\) which separate the services and capabilities offered by a system from its underlying infrastructure, should make it faster, easier and cheaper for operators to put in place new network services using cloud-based servers. Energy efficiency is also a major requirement, both for operators deploying many more stations in small cells, and for users with increasingly sophisticated devices and power-hungry applications. As a result, 5G should help network providers and users to reduce their carbon footprints, bring down costs and increase battery life.

**EU research support**

In the Seventh Framework Programme (FP7) that ran from 2007 to 2013, the EU supported 5G-relevant research topics such as ultra-high speed broadband and energy-efficient connected objects. FP7 sponsored a number of projects that dealt with issues critical to 5G functionality and architecture, such as small cells, virtualisation, millimetre wave transmissions, and machine-to-machine communication.\(^8\) In the successor Horizon 2020 research programme, running from 2014 to 2020, the EU created a public-private partnership with industry participation (5GPPP) as a flagship initiative to focus on research developments in 5G technology. 5GPPP will receive a total of €700 million from Horizon 2020, as well as the same amount of private funding (not counting perhaps as much as €3.5 billion by 2020 in industry investments outside the 5GPPP).

**International cooperation**

Harmonised global standards for 5G are needed in order to avoid fragmented markets, promote cross-border use and realise economies of scale. In the early stages of standards development, companies must cooperate in agreeing targets and technologies even if they will eventually compete with each other in providing 5G products and services. Similarly countries or regions that wish to influence the development of that standard need to cooperate in order to reach a consensus that does not side-line their work and investments. To that end, the EU has signed research and development agreements with countries in Asia where 5G services are likely to be first deployed. These agreements provide joint funding for research programmes, encourage joint development projects on applications and systems, and promise cooperation in arriving at global agreements on standards and on spectrum assignment.

In June 2014, the EU signed an agreement with South Korea, where the manufacturer Samsung has performed tests using millimetre wave frequencies that allow users to download a movie in less than one second, and mobile operator SK Telecom has pursued joint 5G research projects with Alcatel-Lucent. 5G may be showcased at the 2018 PyeongChang Winter Olympics, a challenging environment where thousands of people within a small perimeter would be interested in watching near-instantaneous video on their personal devices. In May 2015, the EU reached a similar agreement with Japan where NTT DoCoMo has done extensive research and tests, particularly using high radio frequencies (10 GHz or above), small cells and large numbers of antennae (i.e. 'massive MIMO'); they may also launch their 5G services for the 2020 Tokyo Olympics. Finally, the EU signed an agreement with China in September 2015. The Chinese Ministry of Science and Technology (MOST) has provided support to the IMT-2020 (5G) Promotion Group that fosters partnerships between academia and companies such as Huawei (a network equipment manufacturer participating in EU
research projects) and China Mobile (the world’s largest mobile operator, which has been particularly interested in cloud-based management of Radio Access Networks).

In October 2015, Commissioner Günther Oettinger expressed confidence that a similar agreement would be reached with the US government, although in that country, there is no public funding aimed at coordinating research and no major, inclusive group has been formed specifically to push development of 5G technologies.

The EU institutions

In a 2014 Communication, the European Commission underlined the importance of the technological underpinnings of the mobile internet and the evolution of large-capacity networks for a data-driven economy. Oettinger has highlighted the importance of 5G as an infrastructure for industrial and societal transformation, and an innovation platform providing opportunities to service-developers and third-party providers. In 2015, the Commission launched a study to identify the social and economic impacts of 5G in various industries and environments.

In May 2015, the Council in its conclusions on the digital transformation of European industry recognised the importance of standardisation, including for 5G wireless communications, the Internet of Things and cloud computing.

In a 2013 own-initiative resolution on electronic communications, the European Parliament stated that innovation, economic growth and job creation could only be stimulated through a competitive market in high-speed broadband services; it also called for pan-European auctioning of spectrum for 5G so as to enable Europe-wide wireless services. In adopting the Horizon 2020 programme, the EP emphasised that development and deployment of e-infrastructure was needed to ensure world-leading capability in networking and computing.

Stakeholders

The European Telecommunications Network Operators’ Association (ETNO) feels that the EU should devote substantial funding to 5G R&D so as to ensure comprehensive development of the components of 5G infrastructure. In particular, the EU should avoid rigid and prescriptive rules that would hamper the development of 5G services. The 5G-Infrastructure Association (the industry part of the 5GPPP) also recommends avoiding over-prescriptive regulation of network traffic management practices that would interfere with the development of specialised 5G services guaranteeing low latency or high quality of service. DigitalEurope, an advocacy organisation for the ICT sector in Europe, believes that Europe should be a centre of excellence for 5G R&D and supports studies of high frequency bands, European harmonisation of spectrum allocations to permit economies of scale and a European Common Proposal to the WRC-19 for allocation of additional spectrum for 5G. According to the Boston Consulting Group (BCG), the EU’s policy-makers should set clear goals for 5G, based on benefits such as low latency and high security for IoT devices; they should coordinate spectrum assignment on an international, not country-by-country, basis. They should also allow specialised services that can guarantee security, availability, and latency for applications such as eHealth, driver-assisting cars or smart grids. Finally they should avoid weakening patent protection, curtailing licensing or influencing industry-driven standards-setting.

Certainly not all stakeholders and observers are entirely convinced of the value of 5G at the current time. Some point to the still limited rollout of 4G on a global basis, and the often confused descriptions of what 5G will really be. Others question the immediate need for a superfast network, arguing that more time is needed to ensure users are really taking advantage of the faster download speeds offered by 4G and the possibility of improving device capabilities before the network is upgraded. Even after 5G is
finalised, the economic costs involved in moving to 5G are substantial: significant capital investment will be necessary to provide the network infrastructure, leverage digitalisation and transform traditional environments and industries in order to realise the benefits of 5G networks. (BCG estimates that globally mobile stakeholders will need to invest about US$4 trillion between 2015 and 2020.) Given the complexity of the proposed 5G solutions, and the diversity of current proposals, it may be difficult to keep 5G developments on track and on time. On the application side, some in the transport industry are sceptical of the benefits of 5G because less-than-universal coverage may prove to be the same barrier as it was for previous 3G and 4G services.

Main references
European Commission, *Why the EU is betting big on 5G*, research*eu Focus, No 15, 2015.

Endnotes
1 At the end of 2014, Long Term Evolution (LTE) mobile technology was available to almost 80% of the population of the EU, up from just under 60% a year earlier.
2 The Internet of Things (IoT) is a distributed network connecting physical objects that are capable of sensing or acting on their environment and communicating with each other.
3 Latency is the delay with which a signal is transmitted from one end of the connection to the other. Users perceive low latencies as very fast responses.
4 This list is based largely on challenges identified by the 5GPPP, though these appear somewhat differently in different 5GPPP publications.
5 Indeed the GSM Alliance (GSMA) believes that the common lists of 5G technical features are not entirely coherent and that the main feature of 5G is a new radio technology.
6 For example, see Alcatel-Lucent, *5G is coming: are you prepared?*, 2015, pp. 6-7 for a description of how 5G low and high band carriers deployed in macro and small cells could be combined with 4G and WLAN.
7 For example, *Software-Defined Networking* (SDN) and *Network Function Virtualisation* (NFV).
8 For a brief summary of FP7 research projects, see Pirinen, P. *A brief overview of 5G research activities*, International Conference on 5G for Ubiquitous Connectivity, 2014.

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