5G

For other uses, see 5G (disambiguation).

5th generation mobile networks or **5th generation wireless systems**, abbreviated **5G**, are the proposed next telecommunications standards beyond the current 4G/IMT-Advanced standards. Rather than faster peak Internet connection speeds, 5G planning aims at higher capacity than current 4G, allowing higher number of mobile broadband users per area unit, and allowing consumption of higher or unlimited data quantities in gigabyte per month and user. This would make it feasible for a large portion of the population to stream high-definition media many hours per day with their mobile devices, when out of reach of Wi-Fi hotspots. 5G research and development also aims at improved support of Device-to-device communication, aiming at lower cost, lower latency than 4G equipment and lower battery consumption, for better implementation of the Internet of things.

5G logo

There is currently no standard for 5G deployments. The Next Generation Mobile Networks Alliance defines the following requirements that a 5G standard should fulfill:[1]

- Data rates of tens of megabits per second for tens of thousands of users
- Data rates of 100 megabits per second for metropolitan areas
- 1 Gb per second simultaneously to many workers on the same office floor
- Several hundreds of thousands of simultaneous connections for massive wireless sensor network
- Spectral efficiency significantly enhanced compared to 4G
- Coverage improved
- Signaling efficiency enhanced
- 1-10 ms latency (limited by speed of light)
- Latency reduced significantly compared to LTE.[2]

The Next Generation Mobile Networks Alliance feels that 5G should be rolled out by 2020 to meet business and consumer demands.[3] In addition to providing simply faster speeds, they predict that 5G networks also will need to meet new use cases,[4] such as the Internet of Things (internet connected devices) as well as broadcast-like services and lifeline communication in times of natural disaster. Carriers, chipmakers, OEMS and OSATs, such as Advanced Semiconductor Engineering (ASE), have been preparing for this next-generation (5G) wireless standard, as mobile systems and base stations will require new and faster application processors, basebands and RF devices.[5]

Although updated standards that define capabilities beyond those defined in the current 4G standards are under consideration, those new capabilities have been grouped under the current ITU-T 4G standards. The U.S. Federal Communications Commission (FCC) approved the spectrum for 5G, including the 28 Gigahertz, 37 GHz and 39 GHz bands, on July 14, 2016.[6][7]

1 Background

A new mobile generation has appeared approximately every 10 years since the first 1G system, Nordic Mobile Telephone, was introduced in 1982. The first '2G' system was commercially deployed in 1992, and the 3G system appeared in 2001. 4G systems fully compliant with IMT Advanced were first standardized in 2012. The development of the 2G (GSM) and 3G (IMT-2000 and UMTS) standards took about 10 years from the official start of the R&D projects, and development of 4G systems began in 2001 or 2002.[8][9] Predecessor technologies have been on the market a few years before the new mobile generation, for example the pre-3G system CdmaOne/IS95 in

the US in 1995, and the pre-4G systems Mobile WiMAX in South-Korea 2006, and first release-LTE in Scandinavia 2009. In April 2008, NASA partnered with Machine-to-Machine Intelligence (M2Mi) Corp to develop 5G communication technology.[10]

Mobile generations typically refer to non–backward-compatible cellular standards following requirements stated by ITU-R, such as IMT-2000 for 3G and IMT-Advanced for 4G. In parallel with the development of the ITU-R mobile generations, IEEE and other standardization bodies also develop wireless communication technologies, often for higher data rates, higher frequencies, shorter transmission ranges, no support for roaming between access points and a relatively limited multiple access scheme. The first gigabit IEEE standard was IEEE 802.11ac, commercially available since 2013, soon to be followed by the multigigabit standard WiGig or IEEE 802.11ad.

2 Debate

Based on the above observations, some sources suggest that a new generation of 5G standards may be introduced in the early 2020s.[11][12] However, significant debate continued, on what 5G is about exactly. Prior to 2012, some industry representatives expressed skepticism toward 5G.[13] 3GPP held a conference in September 2015 to plan development of the new standard.[14]

New mobile generations are typically assigned new frequency bands and wider spectral bandwidth per frequency channel (1G up to 30 kHz, 2G up to 200 kHz, 3G up to 5 MHz, and 4G up to 20 MHz), but skeptics argue that there is little room for larger channel bandwidths and new frequency bands suitable for land-mobile radio.[13] The higher frequencies would overlap with K-band transmissions of communication satellites.[15] From users' point of view, previous mobile generations have implied substantial increase in peak bitrate (i.e. physical layer net bitrates for short-distance communication), up to 1 gigabit per second to be offered by 4G.

If 5G appears and reflects these prognoses, then the major difference, from a user point of view, between 4G and 5G must be something other than faster speed (increased peak bit rate). For example, higher number of simultaneously connected devices, higher system spectral efficiency (data volume per area unit), lower battery consumption, lower outage probability (better coverage), high bit rates in larger portions of the coverage area, lower latencies, higher number of supported devices, lower infrastructure deployment costs, higher versatility and scalability, or higher reliability of communication. Those are the objectives in several of the research papers and projects below.

GSMHistory.com[16] has recorded three very distinct 5G network visions that had emerged by 2014:

- **A super-efficient mobile network** that delivers a better performing network for lower investment cost. It addresses the mobile network operators' pressing need to see the unit cost of data transport falling at roughly the same rate as the volume of data demand is rising. It would be a leap forward in efficiency based on the IET Demand Attentive Network (DAN) philosophy.[17]
- **A super-fast mobile network** comprising the next generation of small cells densely clustered to give a contiguous coverage over at least urban areas and getting the world to the final frontier of true "wide-area mobility." It would require access to spectrum under 4 GHz perhaps via the world's first global implementation of Dynamic Spectrum Access.
- **A converged fiber-wireless network** that uses, for the first time for wireless Internet access, the millimeter wave bands (20 – 60 GHz) so as to allow very-wide-bandwidth radio channels able to support data-access speeds of up to 10 Gbit/s. The connection essentially comprises "short" wireless links on the end of local fiber optic cable. It would be more a "nomadic" service (like Wi-Fi) rather than a wide-area "mobile" service.

In its white paper, *5G Empowering Vertical Industries*, 5G PPP, the collaborative research programme organized as part of the European Commission's Horizon 2020 programme, suggests that to support the main vertical sectors in Europe - namely automotive, transportation, healthcare, energy, manufacturing, and media and entertainment - the most important 5G infrastructure performance requirements are a latency below 5 ms, support for device densities of up to 100 devices/m^2 and reliable coverage area, and that a successful 5G deployment will integrate telecommunication technologies including mobile, fixed, optical and satellite (both GEO and MEO).[18]

3 Research and development projects

In 2008, the South Korean IT R&D program of "5G mobile communication systems based on beam-division multiple access and relays with group cooperation" was formed.[19]

In 2012, the UK Government announced the establishment of a 5G Innovation Centre at the University of Surrey – the world's first research center set up specifically for 5G mobile research.[20]

In 2012, NYU WIRELESS was established as a multidisciplinary research center, with a focus on 5G wireless research, as well as its use in the medical and computer-science fields. The center is funded by the National Science Foundation and a board of 10 major wireless

companies (as of July 2014) that serve on the Industrial Affiliates board of the center. NYU WIRELESS has conducted and published channel measurements that show that millimeter wave frequencies will be viable for multigigabit-per-second data rates for future 5G networks.

In 2012, the European Commission, under the lead of Neelie Kroes, committed 50 million euros for research to deliver 5G mobile technology by 2020.[21] In particular, The METIS 2020 Project was the flagship project that allowed reaching a worldwide consensus on the requirements and key technology components of the 5G. Driven by several telecommunication companies, the METIS overall technical goal was to provide a system concept that supports 1,000 times higher mobile system spectral efficiency, compared to current LTE deployments.[4][12] In addition, in 2013, another project has started, called 5GrEEn,[22] linked to project METIS and focusing on the design of green 5G mobile networks. Here the goal is to develop guidelines for the definition of a new-generation network with particular emphasis on energy efficiency, sustainability and affordability.

In November 2012, a research project funded by the European Union under the ICT Programme FP7 was launched under the coordination of IMDEA Networks Institute (Madrid, Spain): i-JOIN (Interworking and JOINt Design of an Open Access and Backhaul Network Architecture for Small Cells based on Cloud Networks). iJOIN introduces the novel concept of the radio access network (RAN) as a service (RANaaS), where RAN functionality is flexibly centralized through an open IT platform based on a cloud infrastructure. iJOIN aims for a joint design and optimization of access and backhaul, operation and management algorithms, and architectural elements, integrating small cells, heterogeneous backhaul and centralized processing. Additionally to the development of technology candidates across PHY, MAC, and the network layer, iJOIN will study the requirements, constraints and implications for existing mobile networks, specifically 3GPP LTE-A.

In January 2013, a new EU project named CROWD (Connectivity management for eneRgy Optimised Wireless Dense networks) was launched under the technical supervision of IMDEA Networks Institute, to design sustainable networking and software solutions for the deployment of very dense, heterogeneous wireless networks. The project targets sustainability targeted in terms of cost effectiveness and energy efficiency. Very high density means 1000x higher than current density (users per square meter). Heterogeneity involves multiple dimensions, from coverage radius to technologies (4G/LTE vs. Wi-Fi), to deployments (planned vs. unplanned distribution of radio base stations and hot spots).

In September 2013, the Cyber-Physical System (CPS) Lab at Rutgers University, NJ, started to work on dynamic provisioning and allocation under the emerging cloud radio-access network (C-RAN). They have shown that the dynamic demand-aware provisioning in the cloud will decrease the energy consumption while increasing the resource utilization.[23] They also have implemented a test bed for feasibility of C-RAN and developed new cloud-based techniques for interference cancellation. Their project is funded by the National Science Foundation.

In November 2013, Chinese telecom equipment vendor Huawei said it will invest $600 million in research for 5G technologies in the next five years.[24] The company's 5G research initiative does not include investment to productize 5G technologies for global telecom operators. Huawei will be testing 5G technology in Malta.[25][26]

In 2015, Huawei and Ericsson are testing 5G-related technologies in rural areas in northern Netherlands.[27]

In July 2015, the METIS-II and 5GNORMA European projects were launched. The METIS-II project [28] builds on the successful METIS project and will develop the overall 5G radio access network design and to provide the technical enablers needed for an efficient integration and use of the various 5G technologies and components currently developed. METIS-II will also provide the 5G collaboration framework within 5G-PPP for a common evaluation of 5G radio access network concepts and prepare concerted action towards regulatory and standardisation bodies. On the other hand, the key objective of 5G NORMA is to develop a conceptually novel, adaptive and future-proof 5G mobile network architecture. The architecture is enabling unprecedented levels of network customisability, ensuring stringent performance, security, cost and energy requirements to be met; as well as providing an API-driven architectural openness, fuelling economic growth through over-the-top innovation. With 5G NORMA, leading players in the mobile ecosystem aim to underpin Europe's leadership position in 5G.[29]

Additionally, in July 2015, the European research project mmMAGIC was launched. The mmMAGIC project will develop new concepts for mobile radio access technology (RAT) for mmwave band deployment. This is a key component in the 5G multi-RAT ecosystem and will be used as a foundation for global standardization. The project will enable ultrafast mobile broadband services for mobile users, supporting UHD/3D streaming, immersive applications and ultra-responsive cloud services. A new radio interface, including novel network management functions and architecture components will be designed taking as guidance 5G PPP's KPI and exploiting the use of novel adaptive and cooperative beam-forming and tracking techniques to address the specific challenges of mm-wave mobile propagation. The ambition of the project is to pave the way for a European head start in 5G standards and to strengthen European competitiveness. The consortium brings together major infrastructure vendors, major European operators, leading research institutes and universities, measurement equipment vendors and one SME.

mmMAGIC is led and coordinated by Samsung. Ericsson acts as technical manager while Intel, Fraunhofer HHI, Nokia, Huawei and Samsung will each lead one of the five technical work packages of the project. [30]

In July 2015, IMDEA Networks launched the Xhaul project, as part of the European H2020 5G Public-Private Partnership (5G PPP). Xhaul will develop an adaptive, sharable, cost-efficient 5G transport network solution integrating the fronthaul and backhaul segments of the network. This transport network will flexibly interconnect distributed 5G radio access and core network functions, hosted on in-network cloud nodes. Xhaul will greatly simplify network operations despite growing technological diversity. It will hence enable system-wide optimisation of Quality of Service (QoS) and energy usage as well as network-aware application development. The Xhaul consortium comprises 21 partners including leading telecom industry vendors, operators, IT companies, small and medium-sized enterprises and academic institutions. [31]

In July 2015, the European 5G research project Flex5Gware was launched. The objective of Flex5Gware is to deliver highly reconfigurable hardware (HW) platforms together with HW-agnostic software (SW) platforms targeting both network elements and devices and taking into account increased capacity, reduced energy footprint, as well as scalability and modularity, to enable a smooth transition from 4G mobile wireless systems to 5G. This will enable that 5G HW/SW platforms can meet the requirements imposed by the anticipated exponential growth in mobile data traffic (1000 fold increase) together with the large diversity of applications (from low bit-rate/power for M2M to interactive and high resolution applications).[32]

In July 2015, the SUPERFLUIDITY project, part of the European H2020 Public-Private Partnership (5G PPP) and led by CNIT, an Italian inter-university consortium, was started. The SUPERFLUIDITY consortium comprises telcos and IT players for a total of 18 partners. In physics, superfluidity is a state in which matter behaves like a fluid with zero viscosity. The SUPERFLUIDITY project aims at achieving superfluidity in the Internet: the ability to instantiate services on-the-fly, run them anywhere in the network (core, aggregation, edge) and shift them transparently to different locations. The project tackles crucial shortcomings in today's networks: long provisioning times, with wasteful over-provisioning used to meet variable demand; reliance on rigid and cost-ineffective hardware devices; daunting complexity emerging from three forms of heterogeneity: heterogeneous traffic and sources; heterogeneous services and needs; and heterogeneous access technologies, with multi-vendor network components. SUPERFLUIDITY will provide a converged cloud-based 5G concept that will enable innovative use cases in the mobile edge, empower new business models, and reduce investment and operational costs. [33]

In September 2016, China's Ministry of Industry and Information Technology announced that the government-led 5G Phase-1 tests of key wireless technologies for future 5G networks were completed with satisfactory results.[34] The tests were carried out in 100 cities and involved seven companies – Datang Telecom, Ericsson, Huawei, Intel, Nokia Shanghai Bell, Samsung and ZTE. The next step in 5G technology development involving trials is under way, with planned commercial deployment in 2022 or 2023.

4 Research

The first widely cited proposal for the use of millimeter wave spectrum for cellular/mobile communications appeared in the IEEE Communications Magazine in June 2011.[35] The first reports of radio channel measurements that validated the ability to use millimeter wave frequencies for urban mobile communication were published in April and May 2013 in the *IEEE Access Journal* and *IEEE Transactions on Antennas and Propagation*, respectively.[36][37]

The *IEEE Journal on Selected Areas in Communications* published a special issue on 5G in June 2014, including, a comprehensive survey of 5G enabling technologies and solutions.[38] *IEEE Spectrum* has a story about millimeter-wave wireless communications as a viable means to support 5G in its September 2014 issue.[39]

- Radio propagation measurements and channel models for millimeter-wave wireless communication in both outdoor and indoor scenarioes in the 28, 38, 60 and 72–73 GHz bands were published in 2014.[40][41]

- Massive MIMO: This is a transmission point equipped with a very large number of antennas that simultaneously serve multiple users. With massive MIMO multiple messages for several terminals can be transmitted on the same time-frequency resource, maximizing beamforming gain while minimizing interference.[42][43][44][45][46][47]

- Three Dimensional Beamforming (3DBF): utilizing hundreds of antennas at base station which performs in millimeter wave spectrum results in a highly directional antenna beam that can be steered to a desired direction which optimizes some performance metric of the network.[48]

- Proactive content caching at the edge: While network densification (i.e., adding more cells) is one way to achieve higher capacity and coverage, it becomes evident that the cost of this operation might not be sustainable as the dense deployment of base stations also requires high-speed expensive backhauls. In this regard, assuming that the backhaul is

capacity-limited, caching users' contents at the edge of the network (namely at the base stations and user terminals) holds as a solution to offload the backhaul and reduce the access delays to the contents.[49][50] In any case, caching contents at the edge aim to solve the problem of reducing the end-to-end delay, which is one of the requirements of 5G. Caching can be particularly enabled by leveraging user context information from sources such as mobility and social metrics.[51][52][53] The upcoming special issue of IEEE Communications Magazine aims to argue massive content delivery techniques in cache-enabled 5G wireless networks.[54][55]

- Advanced interference and mobility management, achieved with the cooperation of different transmission points with overlapped coverage, and encompassing the option of a flexible use of resources for uplink and downlink transmission in each cell, the option of direct device-to-device[55] transmission and advanced interference cancellation techniques.[56][57][58][59]

- Efficient support of machine-type devices to enable the Internet of Things with potentially higher numbers of connected devices, as well as novel applications, such as mission-critical control or traffic safety, requiring reduced latency and enhanced reliability.[4]

- Use of millimeter-wave frequencies (e.g. up to 90 GHz) for wireless backhaul and/or access (IEEE rather than ITU generations).[4]

- Pervasive networks providing Internet of things, wireless sensor networks and *ubiquitous computing*: The user can be connected simultaneously to several wireless access technologies and can move seamlessly between them (See Media independent handover or vertical handover, IEEE 802.21, also expected to be provided by future 4G releases. See also multihoming.). These access technologies can be 2.5G, 3G, 4G, or 5G mobile networks, Wi-Fi, WPAN, or any other future access technology. In 5G, the concept may be further developed into multiple concurrent data-transfer paths.[60]

- Multiple-hop networks: A major issue in systems beyond 4G is to make the high bit rates available in a larger portion of the cell, especially to users in an exposed position in between several base stations. In current research, this issue is addressed by cellular repeaters and macro-diversity techniques, also known as group cooperative relay, where users also could be potential cooperative nodes, thanks to the use of direct device-to-device (D2D) communication.[55]

- Wireless network virtualization: Virtualization will be extended to 5G mobile wireless networks. With wireless network virtualization, network infrastructure can be decoupled from the services that it provides, where differentiated services can coexist on the same infrastructure, maximizing its utilization. Consequently, multiple wireless virtual networks operated by different service providers (SPs) can dynamically share the physical substrate wireless networks operated by mobile network operators (MNOs). Since wireless network virtualization enables the sharing of infrastructure and radio spectrum resources, the capital expenses (CapEx) and operation expenses (OpEx) of wireless (radio) access networks (RANs), as well as core networks (CNs), can be reduced significantly. Moreover, mobile virtual network operators (MVNOs) who may provide some specific telecom services (e.g., VoIP, video call, over-the-top services) can help MNOs attract more users, while MNOs can produce more revenue by leasing the isolated virtualized networks to them and evaluating some new services.[61]

- Cognitive radio technology, also known as smart radio. This allows different radio technologies to share the same spectrum efficiently by adaptively finding unused spectrum and adapting the transmission scheme to the requirements of the technologies currently sharing the spectrum. This dynamic radio resource management is achieved in a distributed fashion and relies on software-defined radio.[62][63] See also the IEEE 802.22 standard for Wireless Regional Area Networks.

- Dynamic Adhoc Wireless Networks (DAWN),[8] essentially identical to Mobile ad hoc network (MANET), Wireless mesh network (WMN) or wireless grids, combined with smart antennas, cooperative diversity and flexible modulation.

- Vandermonde-subspace frequency division multiplexing (VFDM): a modulation scheme to allow the co-existence of macro cells and cognitive radio small cells in a two-tiered LTE/4G network.[64]

- IPv6, where a visiting mobile IP care-of address is assigned according to location and connected network.[60]

- Wearable devices with AI capabilities.[8] such as smartwatches and optical head-mounted displays for augmented reality

- One unified global standard.[8]

- *Real wireless world* with no more limitation with access and zone issues.[60]

- *User centric* (or *cell phone developer initiated*) network concept instead of operator-initiated (as in 1G) or system developer initiated (as in 2G, 3G and 4G) standards[65]

- Li-Fi (a portmanteau of *light* and *Wi-Fi*) is a massive MIMO visible light communication network to advance 5G. Li-Fi uses light-emitting diodes to transmit data, rather than radio waves like Wi-Fi.[66]
- *Worldwide wireless web* (WWWW), i.e. comprehensive wireless-based web applications that include full multimedia capability beyond 4G speeds.[8]

5 History

- In April 2008, NASA partnered with Geoff Brown and Machine-to-Machine Intelligence (M2Mi) Corp to develop 5G communication technology[10]
- In 2008, the South Korean IbjngT R&D program of "5G mobile communication systems based on beam-division multiple access and relays with group cooperation" was formed.[19]
- In August 2012, New York University founded NYU WIRELESS, a multi-disciplinary academic research center that has conducted pioneering work in 5G wireless communications.[67][68][69]
- On October 8, 2012, the UK's University of Surrey secured £35M for a new 5G research center, jointly funded by the British government's UK Research Partnership Investment Fund (UKRPIF) and a consortium of key international mobile operators and infrastructure providers, including Huawei, Samsung, Telefonica Europe, Fujitsu Laboratories Europe, Rohde & Schwarz, and Aircom International. It will offer testing facilities to mobile operators keen to develop a mobile standard that uses less energy and less radio spectrum while delivering speeds faster than current 4G with aspirations for the new technology to be ready within a decade.[70][71][72][73]
- On November 1, 2012, the EU project "Mobile and wireless communications Enablers for the Twenty-twenty Information Society" (METIS) starts its activity towards the definition of 5G. METIS achieved an early global consensus on these systems. In this sense, METIS played an important role of building consensus among other external major stakeholders prior to global standardization activities. This was done by initiating and addressing work in relevant global fora (e.g. ITU-R), as well as in national and regional regulatory bodies.[74]
- Also in November 2012, the iJOIN EU project was launched, focusing on "small cell" technology, which is of key importance for taking advantage of limited and strategic resources, such as the radio wave spectrum. According to Günther Oettinger, the European Commissioner for Digital Economy and Society (2014–19), "an innovative utilization of spectrum" is one of the key factors at the heart of 5G success. Oettinger further described it as "the essential resource for the wireless connectivity of which 5G will be the main driver".[75] iJOIN was selected by the European Commission as one of the pioneering 5G research projects to showcase early results on this technology at the Mobile World Congress 2015 (Barcelona, Spain).
- In February 2013, ITU-R Working Party 5D (WP 5D) started two study items: (1) Study on IMT Vision for 2020 and beyond, and; (2) Study on future technology trends for terrestrial IMT systems. Both aiming at having a better understanding of future technical aspects of mobile communications towards the definition of the next generation mobile.
- On May 12, 2013, Samsung Electronics stated that they have developed a "5G" system. The core technology has a maximum speed of tens of Gbit/s (gigabits per second). In testing, the transfer speeds for the "5G" network sent data at 1.056 Gbit/s to a distance of up to 2 kilometres.with the use of an 8*8 MIMO.[76][77]
- In July 2013, India and Israel have agreed to work jointly on development of fifth generation (5G) telecom technologies.[78]
- On October 1, 2013, NTT (Nippon Telegraph and Telephone), the same company to launch world's first 5G network in Japan, wins Minister of Internal Affairs and Communications Award at CEATEC for 5G R&D efforts[79]
- On November 6, 2013, Huawei announced plans to invest a minimum of $600 million into R&D for next generation 5G networks capable of speeds 100 times faster than modern LTE networks.[80]
- On May 8, 2014, NTT DoCoMo start testing 5G mobile networks with Alcatel Lucent, Ericsson, Fujitsu, NEC, Nokia and Samsung.[81]
- In June 2014, the EU research project CROWD was selected by the European Commission to join the group of "early 5G precursor projects". These projects contribute to the early showcasing of potential technologies for the future ubiquitous, ultra-high bandwidth "5G" infrastructure. CROWD was included in the list of demonstrations at the European Conference on Networks and Communications (EuCNC) organized by the EC in June 2014 (Italy).
- In October 2014, the research project TIGRE5-CM (Integrated technologies for management and operation of 5G networks) is launched with the aim to design an architecture for future generation mobile networks, based on the SDN (Software Defined Networking) paradigm. IMDEA Networks Institute is the project coordinator.

- In November 2014, it was announced that Megafon and Huawei will be developing a 5G network in Russia. A trial network will be available by the end of 2017, just in time for the 2018 World Cup.[82][83]
- On November 19, 2014, Huawei and SingTel announced the signing of a MoU to launch a joint 5G innovation program.[84]
- On June 22, 2015, Greek government announced to Euro-group council talks that potential licensing 5G and 4G technology would offer 350 million euros earnings, as a result they were criticized for misleading European leaders in producing potential earnings from a technology that is supposed to roll-out after 2020.[85]
- On July 1, 2015, METIS-II project was launched. This project aims at designing the 5G radio access network, building the basis for the multi-service allocation on an holistic cross-layer and cross-air interface framework.[28]
- On September 8, 2015, Verizon announced a roadmap to begin testing 5G in field trials in the United States in 2016.[86]
- On October 1, 2015, the French Operator Orange announced to be about to deploy 5G technologies to begin the first trial in January 2016 in Belfort, a City of Eastern France.[87]
- On January 22, 2016, the Swedish mobile network equipment maker Ericsson said it had partnered with TeliaSonera to develop 5G services based on TeliaSonera's network and Ericsson's 5G technology. The partnership aims to provide 5G services to TeliaSonera customers in Stockholm, Sweden and Tallinn, Estonia in 2018. Sweden has long been a pioneer ICT nation and notably Ericsson and TeliaSonera launched the world's first commercial 4G network in Sweden in 2009.[88]
- On February 22, 2016, NTT DoCoMo and Ericsson succeed in World's first trial to achieve a cumulative 20Gbit/s with two simultaneously connected mobile devices in 5G outdoor trial.[89]
- Also on February 22, 2016, Samsung and Verizon joined to begin trial for 5G.[90]
- On January 29, 2016, Google revealed that they are developing a 5G network called SkyBender. They planned to distribute this connection through sun-powered drones.[91]
- In mid-March 2016, the UK government confirmed plans to make the UK a world leader in 5G. Plans for 5G are little more than a footnote in the country's 2016 budget, but it seems the UK government wants it to be a big focus going forward.[92]
- On June 2, 2016, the first comprehensive book on 5G was launched. The book "5G Mobile and Wireless Communications Technology" by Cambridge University Press is edited by Afif Osseiran (Ericsson), Jose F. Monserrat (UPV) and Patrick Marsch (Nokia Bell Labs) and covers everything from the most likely use cases, spectrum aspects, and a wide range of technology options to potential 5G system architectures.[4]
- On October 17, 2016, Qualcomm announced the first 5G modem, the Snapdragon X50, as the first commercial 5G mobile chipset.[93][94]

6 See also

- List of mobile phone generations
- Femtocell
- IEEE 802.11u authentication
- IEEE P1905 hybrid networking
- Ka band
- OpenFlow/OpenRadio for sharing backhaul.
- Picocell
- Ultra-wideband (UWB)
- 3GPP (Mobile standards for 5G will start in 3GPP Release 15 of the standard)

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8 Further reading

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- Osseiran, Afif; Monserrat, Jose F., Marsch, Patrick (2 June 2016). *5G Mobile and Wireless Communications Technology* (1 ed.). Cambridge University Press. p 410. ISBN 9781107130098. Written by leading experts in 5G research, this book is a comprehensive overview of the current state of 5G.
- Madhusanka Liyanage, Mika Ylianttila, Andrei Gurtov (August 2016), Software Defined Mobile Networks (SDMN) : Beyond LTE Network Architecture, Wiley Publishers, p 438. ISBN 978-1-118-90028-4. This book describes the concept of a Software Defined Mobile Network (SDMN), which provide the baseline for 5G networks. The reader will be introduced to cutting-edge knowledge in areas such as network virtualization, as well as SDN concepts relevant to next generation mobile networks. [Liyanage, Madhusanka (2015). *Software Defined Mobile Networks (SDMN): Beyond LTE Network Architecture*. UK: Wiley Publishers. pp. 1–438. ISBN 978-1-118-90028-4.]

9 External links

- 5G Technology Technical Paper
- Information About Generation 5G
- Applications of 5G
- 2016 -- the year testing of 5G wireless really took off

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