6G Wireless Connectivity: Mission, Prospects, and Researchers

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Abstract

The deployment of the 5G network has begun, and the technology is available for widespread commercial use. Both the development of 5G and the potential of 6G are at the heart of this research. It also summarises the research efforts of various major firms and colleges, as well as the many different industries that could benefit from 6G. NTT Docomo released a white paper about 6G in 2019. Research papers were then released by Samsung, the Finnish 6G Flagship, and Rhode & Schwartz afterward. A number of major companies, including Ericsson, Nokia, Samsung, Qualcomm, Intel, and AT&T, came together to form further research groups, such as Hexa-X and 6G@UT.

Keywords:
6G, 5G. Wireless Connectivity: Mission, Prospects,

1. Introduction

The need to share knowledge with others drove the evolution of numerous forms of electronic communication. With the use of a wired network, information may be transmitted from one place to another. As a result, the PSTN[1]or landline telephone network—came into being. However, as the distance between the transmitter and receiver grew, so did the associated expenses, attenuation, and maintenance requirements. Then somebody had the bright notion of using electromagnetic waves like radio waves, satellites, and so on to send information via the air. First-generation mobile and cellular communication (1G) emerged in the 1980s. As its name implies, 1G[2] was modulated in analogue. In contrast to the Global System for Mobile Communications (GSM), the United States and Australia employ a distinct 1G standard called the Advanced Mobile Phone System (AMPS). The United Kingdom uses a system called Total Access Communications System (TACS). The Nordic countries and parts of Europe and Russia are heavy users of Nordic Mobile Telephone (NMT). The 1G networks were the pioneers in the mobile industry, providing consumers with mobile connectivity and voice services. The second generation, or 2G, was then established in the 1990s. This generation is largely credited with boosting the capacity of phone services and ushering in digital communications. The second-generation mobile communications standard was referred to as the "Global System for Mobile Communications" (GSM). Improvements in 2G technology led to the creation of services such as General Packet Radio Service (GPRS) and Enhanced Data for Global Evolution (EDGE). The backbone of a 2G network was built through circuit switching. Clients of 2G[3] networks can take advantage of digital speech services in addition to the most fundamental data transmission capabilities. In addition, the introduction of third-generation (3G) [4]wireless networks in the 2000s made it possible to offer mobile broadband in addition to traditional telephone services. The third generation (3G) of mobile networks made it possible to send video to mobile devices via a hybrid of circuit and packet core networks. Third-generation mobile networks (3G or UMTS) used a radio frequency of around 2 GHz and had a greater bandwidth (5 MHz) than second-generation networks. (i.e., 200 kHz). When third-generation wireless networks (3G) were introduced, demand for online services increased dramatically among those using mobile devices like smartphones. Increases in capacity and bandwidth were required to accommodate the growing number of users, prompting the development of Long Term Evolution (LTE)[5], commonly referred to as 4G, in the 2010s. 4G[6] made available 20 MHz of bandwidth per channel, and all services were delivered in packet form. With the advent of 4G LTE, users can experience download rates of up to 300 Mbps. A new era of internet and video streaming services was ushered in by these more modern standards. Multiple standards were developed to meet the bandwidth and portability needs.

In order to make a voice call over a 2G network, the user must be in close proximity to the base station. There was no break in service even when I was on the go. Thanks to advancements in 3G technology, mobile phone calls could be kept going even if the user was in a moving car or other vehicle. Now that it's possible to have 4G connectivity, even supersonic transportation networks can take advantage

Manuscript received February 5, 2025
Manuscript revised February 20, 2025
https://doi.org/10.22937/IJCSNS.2025.25.2.8

of it. As a result of the high data transfer rate, the internet packages were not only cheap but also quite reasonable. The demand for inter-device communication has grown alongside the proliferation of IoT-enabled and other forms of smart technology (including autonomous vehicles, robotics, and others).

Mission-critical services require their own separate bandwidth allocation. All of these needs—and more—inspired the next generation's development (5G). 5G[7] has completed its trial run in the lab and is now available to the public. Several academics have expressed interest in the 6G standard. The concept of 6G is explained, and an outline of current research initiatives is provided. Early on, we compare and contrast 6G with its predecessor, 5G, and examine why it's necessary. The future of 6G[8] and its potential uses will be discussed in Part 2. In what follows, you'll meet the various research teams and learn about the 6G initiatives they're tackling right now.

2. 5G and 6G

The goal of the development of the fifth-generation (5G) wireless communication network is to facilitate the interconnection of diverse machines and intelligent devices. To create the 5G standard, members of the 3rd Generation Partnership Project (3GPP) worked together. 5G NR (New Radio) and New Radio (RAN) are two alternative names for the 5G radio access network. Due to its distributed nature, 5G's design can support a wide range of use cases. The development of 5G networks is driven by the desire to improve machine-to-machine and human-to-human connectivity. The goal of 4G was to make communication faster than 3G, while the goal of 5G is to create an open and unified air interface that can accommodate massive volumes of IoT and critical applications. Increased mobile bandwidth, mission-critical communications, and a massive Internet of Things are just a few of the most prominent uses for 5G. Augmented and virtual reality-related services will require reliable, low-latency data transfers. Remote connections that are both exceptionally stable and have a low latency are required for the proper operation of mission-critical applications, including medical treatments, vehicle operations, and drone services. Various sensors have been set up for monitoring as a result of the increased level of automation in the business, and the data they collect is being stored in the cloud. As technology develops, the density of the Internet of Things' network of sensors and other small battery-operated devices will increase. To a similar extent, this is a crucial use of 5G networks. It is projected that by 2020, consumers would use up to 11 GB of data monthly on their mobile devices and other smart gadgets. In addition to the low bands (those with frequencies below 1 GHz), mid bands (those with frequencies between 1 GHz and 6 GHz), and high bands (also known as millimetre wave bands), 5G can operate in a wide range of other spectrum bands (mmWave). Additionally, the bandwidth for each channel is close to 200 MHz. A 100-fold boost in network and traffic capacity is possible with 5G, which can handle peak data rates of 20 GB/s.

If we're going to spend time and energy creating a benchmark for the next generation, we should start by figuring out what that generation actually needs. This necessitates either the creation of a guiding vision or the identification of target domains for the implementation of the proposed standard. The 3rd Generation Partnership Project (3GPP) will define new radio technologies and new network platforms and test these technologies across a range of use cases to establish the needs following the formation of the vision. Therefore, the needs phase is crucial for any new generation, as it entails the establishment of a foundation and framework, the creation of technical standards, and the introduction of the generation to the market. These are made public as specifications and then eventually become standards that are adhered to by all companies and manufacturers providing the relevant equipment and services. The sixth generation, or 6G, will utilise terahertz frequencies and build its network and core platform around AI and ML.

Major factors	6G	5G
Peak data rate	> 100Gb/s	10[20] Gb/s
User experience data rate	> 10Gb/s	1Gb/s
Traffic density	> 100Tb/s/km^2	10Tb/s/km^2
Connection density	> 10million/km^2	1million/km^2
Delay	< 1ms	ms level
Mobility	> 1000km/h	350km/h
Spectrum efficiency	> 3x relative to 5G	3~5x relative to 4G
Energy efficiency	> 10x relative to 5G	1000x relative to 4G
Coverage percent	> 99%	About 70%
Reliability	> 99.999%	About 99.9%
Positioning precision	Centimeter level	Meter level
Receiver sensitivity	< −130dBm	About −120dBm

Table.1 5G Vs 6G[9]

3. 6G Applications

The key focus of 5G was the interaction between humans and the physical world, whereas the primary focus of 6G will be the maintenance of connectivity between humans, the physical world, and the digital world. The 6G vision asks for synchronisation between the physical and digital worlds, as well as real-time control between the human and digital worlds. If enormous quantities of sensing components and AI/ML are implemented on a broad scale, it is conceivable to establish a digital world that is connected to and governs the real world based on the acquired sensor data.

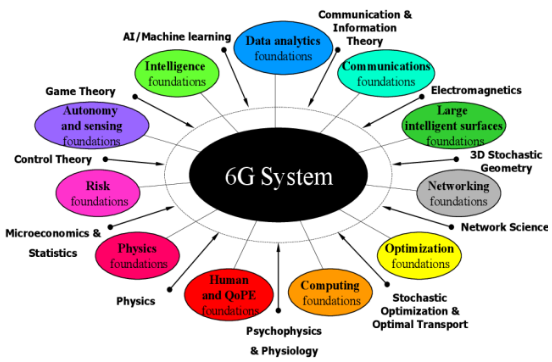

Fig.1 6G[10]

The advent of artificial intelligence and machine learning makes this possible. The ability of a person to manipulate machines in real time is another aspect that is continually advancing. The new application sector for 6G technology is synchronisation between the physical and digital worlds. This is illustrated by virtual avatars and healthcare facilities, for instance.

• Extreme Reality (XR) applications combine augmented reality (AR), virtual reality (VR), and mixed reality (MR) experiences into one.

• Creating digital reproductions of all physical objects for the purpose of examination and modifying the physical objects using artificial intelligence.

• Enhanced communication services that utilise both terrestrial and non-terrestrial networks, such as satellites.

• Applications based on the Internet of Everything (IoE);

• Network Services with advanced safety characteristics.

• Artificial intelligence (AI) and machine learning (ML)-based solutions that, in addition to offering more effective and efficient services, may also predict potential problems and propose solutions in advance.

4. 6G Research

In 2019, NTT Docomo released the first 6G white paper, and in 2020, Rohde & Schwarz did the same. The Finnish 6G Flagship has just released the following set of white papers on 6G: Researchers and developers at Finland's University of Oulu have begun work on 6G technology under the auspices of the 6G Flagship project. In addition, Samsung published a white paper on 6G in July of 2020. Several major companies, including Ericsson, Nokia, Samsung, NTT Docomo, Huawei, LG, and ZTE, are making strides towards realising the 6G goal.

i. **NTT Docomo (2019):** In this study report, the evolution of 5G and 6G are both discussed. It shows the difficulties that are currently being experienced in 5G as well as the future research directions for the improvement of 5G and the creation of 6G[11]. It describes the various fields of application. The limitations of location and time will be eliminated thanks to the real-time solutions that users of 6G networks will be able to access using these solutions. Users will be able to do so from any location. Another potential field would be human-machine interactions, which present an almost infinite number of opportunities. It wouldn't matter if you were in the air, on the ground, or in the air above the earth; communication services would be accessible everywhere. In addition, artificial intelligence and the digital replication of the physical world will require low latency and a high level of reliability. In the report, the requirements for 6G are broken down into the following six categories: extremely high data rate and capacity; extremely broad coverage; extremely low energy consumption and cost; extremely low latency; extremely high dependability; and extremely enormous interconnectedness. The paper also suggests technological areas for further research, such as glass antennas, antennas integrated with sensors and communications, distributed network topology, satellites for providing super coverage, high frequency range, terahertz frequency, spectrum utilisation, massive MIMO, faster-than-Nyquist (FTN) signalling, artificial intelligence and machine learning platforms, and so on.

ii. **Samsung (2020):**A white paper from Samsung titled "The Next Hyper-Connected Experience for All" describes the company's plans for 6G wireless networks. This paper discusses the estimated timeline for the standardisation of 6G, as well as consumption trends, the desire for new services, the requirements, and the identification of candidate technologies. This research analyses the megatrends that will pave the way for the advent of 6G networks. Several of them are networked machines that will soon dominate 6G traffic. Improved tools for optimising networks and foreseeing solutions can be developed with the aid of platforms powered by AI and ML. Three main types of 6G services are outlined in the study article: fully immersive extended reality, high-fidelity mobile holograms, and digital reproductions. Applications with XR capabilities support all three types of augmented reality (AR), virtual reality (VR), and mixed reality (MR). This application necessitates a lot of speed and bandwidth on the network. The next possible field of use is in wearable displays, which can give the user holograms in three dimensions.

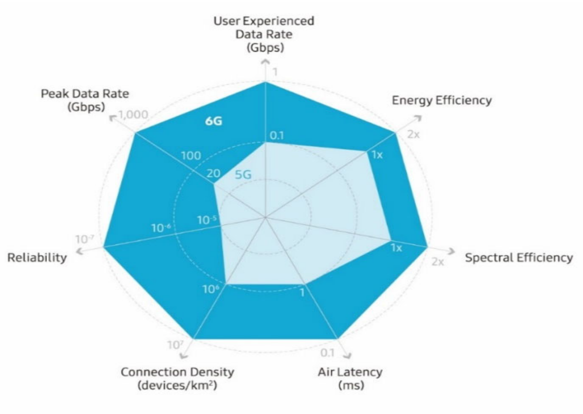

Fig.2 6G Samsung Research[12]

Intelligent data management, which is essential for keeping bandwidth usage low, will be greatly aided by artificial intelligence. Users will have access to a suite of services under the umbrella term "Digital Replica," allowing them to see and interact virtually with digital twins of people, things, and equipment. This will work in tandem with a suite of sensors and artificial intelligence (AI) platforms; should the AI detect a fault with the digital twin of the object, it will analyse the issue and update the physical version accordingly. The requirements for 6G are also discussed in the paper, and these include very low latency, very wide network coverage, and very smooth high-end services. The processing requirements of augmented reality and virtual reality applications must be factored into the 6G design. The multi-access edge computing server (MEC) is proposed for incorporation into the 5G core to bring ultra-low-latency networks closer to mobile phones. The 6G network's nodes should contain AI functionality.

Similarly important is the system's ability to be trusted, which necessitates the incorporation of security features into the underlying platform in order to protect users' private information in an otherwise open 6G network. In other words, confidence in the system is essential. The paper discusses two potential technologies: one that operates at terahertz frequencies and the difficulties that come with it. Novel antenna technologies, the improvement of duplex technology, the development of network topology, spectrum sharing, complete artificial intelligence, partitioned computing, and high-precision networks are all other viable options. Many different tunable elements, such as varactor diodes and PIN diodes, are arranged in a repeating pattern to create a metamaterial at scales lower than the wavelengths. These components form a pattern that is repeated over and over. This can be used to create advanced antenna technologies like intelligent surfaces that can be reshaped and reprogrammed and metamaterial antennas that can calculate propagation paths. Another potentially fruitful area of study is orbital angular momentum. Coverage in the highlands, which is unachievable with a terrestrial network, may require a network topology that includes base stations in addition to satellites and HAPS. The scheduling, traffic, and UE data can be fed into the AI platform to foresee potential collisions and make spectrum allocation decisions. AI can be used in three different ways: locally, collaboratively, and end-to-end. Artificial intelligence (AI) at each network node can help optimise that node's needs, and AI shared between two nodes can improve the performance of the network as a whole.

Through E2E AI, the entire network is optimised, and any corrective measures that are required are implemented. Processing can be split between a mobile phone, a base station, and MEC servers due to the limitations of mobile computing for use in extreme reality applications. It's because of this that mobile devices may achieve top performance without wasting too much juice. Data synchronisation, low-latency wireless connectivity, and efficient use of battery life will make distributed computing much more practical. The 6G is now in the exploratory and requirements-defining stage of development. In 2022, the ITU-R is expected to start developing 6G specifications, and a commercial rollout could happen as late as the 2030s.

iii. **Hexa-X (January 2021):**Twenty-five researchers from Europe's top companies and universities make up Hexa-X, the continent's 6G Flagship Research Group. Nokia is in charge of this research team, while Ericsson is in charge of technical matters. Companies like Intel and Orange are also part of the group[13]. The agenda's stated goal is to lay the groundwork for the development of future digital technologies and outline the conditions for a study of 6G. Using 6G technology, they hope to unify the virtual and real realms.

The six objectives of 6G are as follows: connecting intelligence; building a network of networks; being sustainable; delivering service coverage on a global scale; giving a truly remarkable user experience; and being trustworthy. The project's major focus is on the interplay between the three realms. There are three distinct realms of existence: the human or biological realm, which includes mental faculties, physical structures, and moral principles; the material realm, which includes objects and machinery; and the digital realm, which includes information, computation, and data. Real-time interaction between humans and their physical surroundings requires great reliability and extremely low latency, as in the management of robots, autos, medical operations, and similar activities.

Connectivity between the digital and physical realms is achieved by the transfer of information gathered by various sensing elements from the physical world to the digital one. Platforms for artificial intelligence and machine learning take this information and output it as a sort of feedback to the physical world. An additional choice is the use of applications that function as a human-machine interface and that allow for the synchronisation of the real and virtual worlds. Several augmented and virtual reality applications could be valuable in this industry, such as performing surgery on an avatar and then analysing the results. The network requirements of many application domains are being researched.

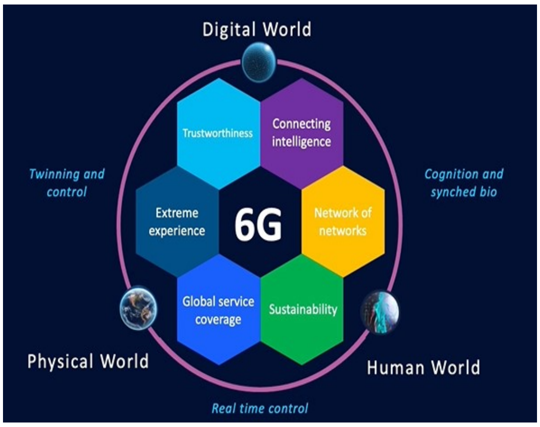

Fig.3 Hexa-X 6G Vision

iv. **6G@UT (July 2021):** A research centre for 6G technology was formed at the University of Texas at Austin in 2021 by AT&T, Samsung, Qualcomm, nVIDIA, and Interdigital. Aside from Honda R&D America Inc., our other industry partners include names like Intel and Western Digital. The mission of this study group is twofold: to advance 6G technology through research and development and to train and instruct the next generation of wireless experts. Some of the areas being investigated include deeply integrated machine learning, pervasive sensing, new spectrum, and network slicing or spectrum sharing. Data from sensors distributed across the physical space will be transmitted to the machine learning platform.

v. **Others:** LG Electronics is another significant manufacturer that has started looking into the 6G network. Here's an example: Through a partnership with the Fraunhofer Gesellschaft (European research lab), LG demonstrated THz-band signal transmission and reception over a distance of 100 metres in June 2021. In addition, LG collaborated with the Korea Advanced Institute of Science and Technology to establish the LG-KAIST 6G Research Center. A road map for 6G technology is also something Huawei is working on. A 5.5-gigabit upgrade to 5G is now in development, and a 6G standard is expected to be established sometime around 2030. In 2020, ZTE's R&D division will work with academic institutions and international partners on 6G initiatives, the company announced.

5. Conclusion

This page summarises the numerous studies conducted to advance the state of the art in 6G technology. It takes a look at how 5G networks have evolved and where they differ from the next generation of networks, 6G. Multiple additional uses for 6G are also discussed in the report. After that, it discusses in depth the various studies being conducted by universities and organisations today. It also includes research into the reasons behind 6G, the features needed in 6G networks, and potential solutions. 6G wireless communication development has entered the research phase. Topologies and network architectures are being proposed in abundance at this time. The development of 6G specs is the next step. It is expected that by 2023, the 6G standard's exploratory phase will be complete. Scientists predict that by the 2030s, 6G networks will be available to the public.

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