Zhongguo Kuangye Daxue Xuebao

2025 | Vol 30 | Issue 2 | Page 64-76
Journal Homepage: https://zkdx.ch/
DOI: 10.1654/zkdx.2025.30.2-08

Advancing Mobile Wireless Network: The Journey from 1G to 6G and Beyond

Folashade O. Ariba*
Department of Electrical and Information Engineering, College of Engineering Landmark University, Omu-Aran, Nigeria
*Corresponding author

Adebanji Bankole
Department of Electrical and Electronic Engineering, Faculty of Engineering, Ekiti State University, Nigeria

John Onyemenam
Department of Electrical and Information Engineering, College of Engineering Landmark University, Omu-Aran, Nigeria

Oluwaseyi M. Abioye
Department of Agricultural and Biosystem Engineering, College of Engineering, Landmark University, Omu-Aran, Nigeria

Adama J. Enoch
Department of Electrical and Information Engineering, College of Engineering Landmark University, Omu-Aran, Nigeria

Yusuf O. Isaac
Department of Electrical and Information Engineering, College of Engineering Landmark University, Omu-Aran, Nigeria

Adedotun O. Ijagbemi
Department of Electrical and Information Engineering, College of Engineering Landmark University, Omu-Aran, Nigeria

Abstract
The emergence of Fifth Generation (5G) technology has brought a significant change in the mobile wireless communication environment, taking it from First Generation (1G) to Fifth Generation (5G). Integrating diverse communication technologies or adding novel services and capabilities to existing networks are prerequisites for progressing services toward the next generation. Perhaps more than ever, there is a pressing need for increased data transmission rates and transmission efficiency with the introduction of more technologies. This study provides an overview of wireless technologies by analyzing this evolution from 1G to 6G. This review also gave a comparison analysis of the evolution of technology. Finally, this paper concentrates on the future of wireless technology such as 6G enabling technologies, 6G artificial intelligence, and 6G and beyond applications which is expected to be a significant turning point in networking people through a smart network capable of supporting multiple items.

Keywords
Internet of Things, Mobile Wireless Technology, Multi-Input-Multi-Output, 5G, 6G

1. Introduction
Mobile wireless communications have evolved substantially over the past few decades, driven by the growing demands for higher data rates and improved quality of service [1]. This rapid evolution has been enabled by continuous advances in access technologies that form the core of mobile networks. Radio access technologies (RATs) refer to the wireless communication standards used to connect user devices to mobile networks [2]. As new generations of mobile networks have been introduced, the network generation has evolved to provide faster speeds, lower latency, and greater capacity as presented in Fig 1.

In the 1970s, the first generation (1G) appeared, using network standards like Advanced Mobile Phone System (AMPS), Total Access Communication System (TACS), and Nordic Mobile Telephone (NMT) to deliver simple analog Frequency Modulation (FM) for voice services and Frequency Shift Keying (FSK) for digital signaling with the application of Frequency Division Multiple Access (FDMA) [3]. When digital technologies were introduced in 1982 by the European Conference of Postal and Telecommunication Administration (ECPT) for better data services and security, the second generation (2G) emerged. Global System for Mobile (GSM), Code Division Multiple Access (CDMA), and Time Division Multiple Access (TDMA) were the three main 2G standards that dominated 1G standards that provide internet access, multimedia, and simple text messaging [4]. Early in the new millennium, third-generation (3G) networks were created, enabling significantly faster data speeds of up to 2Mbps and supporting multimedia services like mobile TV [5]. Universal Mobile Telecommunication System (UMTS) and CDMA2000 were important 3G standards [6]. Significant improvements were introduced with the fourth generation (4G), which included reduced latency, multi-antenna technology, peak downlink speeds of up to 1Gbps, and an all-IP network architecture [7]. Around 2010, the first Long Term Evolution (LTE)-based 4G systems were introduced. Further developments in LTE, including Multi-Input-Multi-Output (MIMO) and carrier aggregation, expanded its functionality. Intending to achieve exponential gains in data rates up to 20Gbps, extremely low latency, and compatibility for substantial machine-type connections, the most recent Fifth-Generation (5G) technology began to roll out in 2018. Beamforming antennas, network virtualization, network slicing, and Millimeter Wave (mmWave) spectrum are important 5G enablers. Additionally, studies on Sixth-Generation (6G) networks are currently underway, examining novelties such as AI-defined networking, connected drones, terahertz bands, and holographic calling. However, from performance to efficiency to flexibility to supported services, every new generation of wireless network technology has significantly outperformed previous generations. While 5G and beyond promise a hyper-connected society with incredibly rapid and receptive wireless access capabilities to enable the transformational system, 1G only allows basic mobile voice access. The present wireless world has been made possible in large part by the unrelenting evolution of mobile networks. This review article provides an overview of the major generations of radio access technologies and standards that have been developed to meet evolving requirements for mobile connectivity.

The structure of the paper is as follows. An overview of technologies ranging from 1G to 6G is given in Section 2. The comparison analysis of the technologies' evolution is covered in Section 3. The future of wireless technologies is the main topic of Section 4. Section 5 concludes the study.

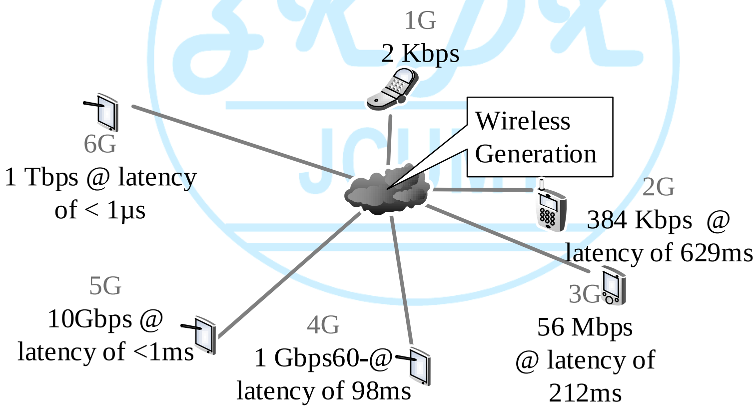

Fig. 1 Mobile wireless network generations

2. Overview of 1G and 6G Technologies

This section discusses different RAT generations, standards, and requirements in wireless communication realization.

2.1 First Generation (1G)

The first generation of cellular systems, or 1G systems, are the early cellular phone systems that made their debut in the late 1960s and were only widely deployed in the early 1970s because of regulatory hurdles. These systems were built on the enabling analog Frequency Modulation (FM) for voice services and FSK for digital service. 1G made use of several network protocols in different regions, such as Total Access Communication System (TACS) in the United Kingdom, Nordic Mobile Telephone (NMT) in Portugal and South Africa, C-Netz in Germany, and Advanced Mobile Phone Service (AMPS) in America.

The 1G system was originally tested for use in Chicago in 1978. The AMPS presented in Fig 2, as it was then called, was first used for commercial purposes in 1982, but it was limited to speech transmission. Several nations worldwide have adopted variations of this AMPS under various designations and characteristics. The phone had a conversation time of about thirty minutes and weighed 2.5 pounds.

Fig. 2 1G advanced mobile phone system

Many nations have put in place mobile communication systems to suit their unique requirements. Several nations have implemented as shown in Fig 3 the Total Access Communication System (TACS), including Austria, Ireland, Italy, Spain, and Britain, among others. Conversely, several nations have used Nordic Mobile Telephony (NMT) in Fig 4, whereas apan has chosen to use Mobile Communication System-L1 (MCS-L1). The C-Netz referred to as radio telephone C in Fig 5 was used in Germany by applying Phase Modulation (PM) for voice services. It was primarily used in Germany's rail service with an internet connection.

Fig. 3 1G total access communication system

Fig. 4 1G Nordic mobile telephony

Fig. 5 1G C-Netz car phone

This variety of mobile communication systems emphasizes how crucial it is to match technology to particular needs to increase effectiveness and efficiency. Even if analog systems are becoming less us overseas, AMPS is still widely used in the US. AMPS standards use Frequency Division Multiple Access (FDMA) to provide basic voice services with limited capacity and security. Handover decisions for a mobile at the BSs are made based on the power received at the nearby BSs [8]. It is noteworthy that in the context of cellular communication, a particular pair of channels from the spectrum that is accessible within each cell are allocated to each call. In this sense, the spectrum is split up into multiple channels, each of which has its own speed, capacity, and usefulness limitations. Because of this restriction, each call must be assigned a certain set of channels to prevent the cell's total capacity from being exceeded. To ensure the successful and efficient functioning of the cellular network, it is crucial to optimize the allocation of the limited number of available channels [9].

2.2 Second Generation (2G)

In the early 1990s, the advent of Second-Generation (2G) wireless networks marked the transition from analog to digital technology. These 2G networks offered enhanced capabilities such as higher bandwidth, enhanced security, and the ability to support data services, setting them apart from the preceding 1G systems. 2G technologies presented in Figure 6 that emerged during the evolution of mobile communication networks include Code Division Multiple Access (CDMA), and the Global System for Mobile Communications (GSM) a hybrid of Time Division Multiple Access (TDMA) and FDMA. These technologies greatly aided the growth of mobile communication networks; while CDMA was more common in North America, GSM had a major impact on the European market. These technologies' development opened the door for the creation of 3G and 4G networks, which significantly transformed the realm of mobile communication [2]. Advanced digital modulation was utilized in deploying 2G CDMA and TDMA in North America to strengthen the quality and capacity of the voice. Narrowband TDMA and GSM became the most widely used 2G networks worldwide operating a range of frequency bands such as 900 MHz -1800 MHz in some parts of the world and 850MHz- 1900 MHz in America. It was further improved to handle circuit-switched data and SMS data services. However, 2G provided text messaging, and digital voice, and restricted mobile internet access, laying the groundwork for upcoming networks.

The evolution of 2G led to the deployment of 2.5G and 2.75G. 2.5G provides a packet-switched data service known as GPRS, for continuous data transmission and better internet access. GPRS is an extension that was integrated into the GSM switching network subsystem to form what is known as 2.5 G. This prevented spectrum wastage by enabling the sharing of network capacity among network users, unlike circuit switching. The 2.75G standard Enhanced General Packet Radio Service (EGPRS) involves the addition of higher order modulation and coding schemes to GPRS offering higher data transmission, and improved mobile internet and multimedia services.

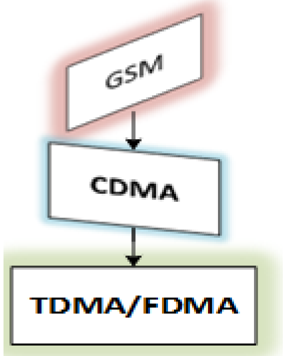

Fig. 6 2G technology standards

2.3 Third Generation (3G)

The late 1990s saw an unparalleled demand for sophisticated services and quicker data speeds due to the widespread use of mobile phones. The development of 3G technologies was initiated in response to these requests. These systems made mobile broadband connectivity a reality by fusing high-speed packet-switched data delivery with digital voice services. With peak downlink rates of up to 14 Mbps, the three main 3G technologies are High-Speed Downlink Packet Access (HSDPA), High-Speed Uplink Packet Access (HSUPA), Universal Mobile Telecommunication System (UMTS) and CDMA2000 as presented in Fig. 7 [10]. Up to 2 megabits per second (Mbps) can be produced by 3G mobile technology based on ideal circumstances. The UMTS increases packet data transmission and capacity with a Wide Code Division Multiple Access (WCDMA) air interface, operating at a frequency band of 2100 MHz. Internet-style applications are made possible by UMTS. Moreover, UMTS maintains circuit data transmission and offer a worldwide standard or protocol to encourage interoperability among various mobile devices. In essence, UMTS is the first option for internet access and worldwide roaming, independent of location.

To enhance the downlink and uplink data packet speed up to 14.4Mbps downlink and 5.76 Mbps uplink, HSDPA and HSUDP are 3G standards. These two standard are jointly referring to as High-Speed Packet Access (HSPA) to increase data rate and reduce latency. A series of 3G mobile technology standards called CDMA2000 developed from 2G CDMA technology and is compatible with it, enabling 2G devices already in use to continue functioning. It was created by the Third Generation Partnership Project 2 (3GPP2) and standardized by the Telecommunications Industry Association (TIA). Compared to 2G, CDMA2000 delivers considerable gains in capacity, customer service, and data speed ranging from 144 kbps through several Mbps. It is utilized extensively in North America and portions of Asia. The simultaneous use of data as well as voice call services by mobile customers is made possible by CDMA2000, which enhances user experience. However, applications that were not possible on earlier networks, such as multimedia streaming, video calling, GPS navigation, and mobile web surfing, were made possible by 3G networks. The upgrade from 2G to 3G signified a significant advancement in terms of services and user experience.

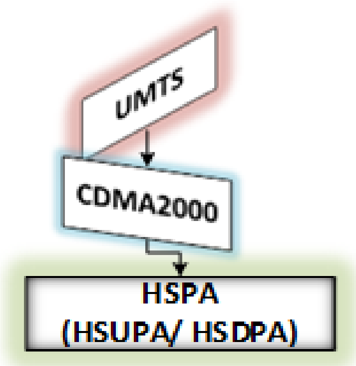

Fig. 7 3G technology standards

2.4 Fourth Generation (4G)

The progression to 4G has been driven by the persistent trend towards smarter devices and bandwidth-hungry gadgets. According to [10] the two main 4G standards as shown in Fig. 8 are WiMAX and Long Term Evolution (LTE), which promise data rates of up to 1 Gbps and smooth mobility at fast vehicle speeds. With far higher speeds and reduced latency than 3G previous generations, LTE has become the dominant 4G system worldwide. It offers a faster and more seamless handoff, a high data rate, and wider bandwidth. Sending and receiving enormous amounts of data from a desktop or laptop computer to a wireless device has gotten relatively simple these days. Contacts, Messages, and Emails can all be readily synchronized, giving users more power [7]. To address anticipated needs for faster, higher capacity networks and to enable new applications like the Internet of Things and mission-critical services, research is currently concentrated on 5G systems and technologies. The development of radio access technologies has played a crucial role in making mobile connectivity possible, which is now commonplace globally [11].

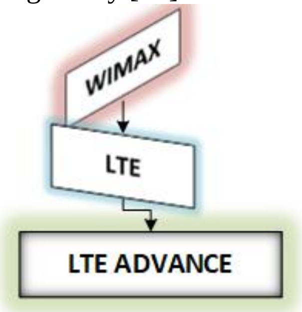

Fig. 8 4G technology standards

2.5 Fifth Generation (5G)

The 5G standard is a suffix given to the current generation of mobile communication protocols. In terms of speed, latency, and capacity, this protocol performs better than 4G/IMT-Advanced. The 5G standard makes use of cutting-edge technology like massive MIMO, beamforming, and millimeter-wave frequencies to provide customers with faster and more dependable connectivity as presented in Fig. 9 [12]. 5G's widespread adoption is predicted to completely transform several industries, including manufacturing, transportation, and healthcare, by offering massive Machine-Type Communication (mMTC) and Ultra-Reliable Low-Latency Communication (URLLC). The World-Wide Wireless Web (WWWW), a perfect wireless web in the actual world, is possible with 5G's unlimited wireless access that provides breakneck speeds up to 20 Gbps, ultralow latency, and support for massive device connectivity [11]. 5G is classified with millimeter wave spectrum, advanced beamforming, and small cell deployment. Also, it has enabled emerging technologies like autonomous vehicles, virtual reality, and the Internet of Things [13].

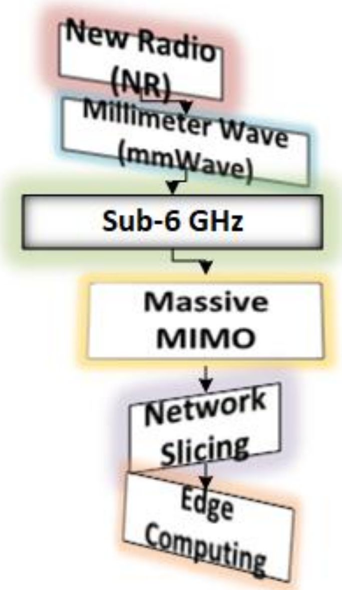

Fig. 9 5G technology standards

2.6 Sixth Generation (6G)

Owing to the explosive growth in the diversity of devices connected to the World Wide Web, which is anticipated to be around 2030, wireless data traffic may increase by one thousand times. Statistics clearly show the exponential growth in demand for machine-type applications and data traffic, including self-driving cars, smart cities, industries, and healthcare monitoring, in addition to traditional individualized communications. Future wireless networks will likely become more complex and diversified due to the cohabitation of such machine-type and individualized services. Thus, the development of alternative technology, or 6G and beyond, is required. Technologies that fall beyond 5G's purview may be included in

6G, particularly regarding how data is gathered, handled, and transferred within wireless networks [8]. 6G is expected to have low error rate and support for various applications, to bring about the same level of reliability as wired networks. It will enable performance mobility of up to 1000 km/h, less than 1 ms U-plane latency, less than 1 ms C-plane, terabit greater than 1 data rate, and spectral efficiency of 100bps/Hz. The 6G spectrum will be quite broad, having frequency bands of 73GHz, 140GHz, and 1-10THz [2].

3. Related Works

In this session, some past literature that is centered on the evolution of mobile wireless technologies is presented. Due to the advancement in mobile networks, many researchers have studied this evolution. In [14], the comparative analysis of cellular technologies from 1G to 5G was presented. The authors discussed the data rates, technology standards, frequencies, and development of the cellular wireless evolution in recent years. [15] presented a review of the evolution of mobile generation, which is based on the contrasting the type, challenges, features, data speed rate, techniques, and their application till 5G evolution. The paper also shows 5G innovative ideas, services, features necessities, advantages, and applications. To solve the problem of high data rates, user coverage in hot spots and overcrowded areas at lower latency, cost, and energy consumption [16] presented 5G multi-tier cellular wireless for interference management. The paper surveyed and quantitatively compared the problems of cell association and power control techniques in the interference management of 5G networks.

The authors in [18] thoroughly reviewed the history of mobile cellular networks, from 1G to the upcoming 6G and beyond. The transformation of digital systems and smart production with cloud computing and AI in 5G networks has led to the vision that B5G will transform wireless cellular communication globally. The author in [19] studied B5G and issues that will occur in the transition to 6G. The paper discussed the vision, challenges, research, and technology infrastructures in the 6G network. [20] discussed the overview of cellular technology evolution from 3G to 4G. The authors also explained the cellular technology of 4G, referred to as LTE. Authors in [21] reviewed emerging wireless technologies that increase the channel capacity and spectral efficiency that users need. The advantages and recent research problems related to the usage of these technologies were studied. Also, 5G and B5G solutions techniques such as mMIMO advantages and functions were described. [22] presented the development and idea of cellular networks from 1G to 5G. The paper studied all the individual generations parameters. The detailed development of wireless communication networks from 1G to 6G was presented in [23]. The paper discussed the novelty of upcoming 6G networks with offered services such as: machine learning, free connection with optical in the space, charging using wireless system, and energy harvesting. Also, the benefits and issues faced from 1G to 5G in terms of innovations, applications and strategies were described.

4. Comparison Analysis of the Technologies Evolution

This session compares the evolution of access technologies from 1G to 6G in Table (1) in terms of development, features, technology, benefits, and limitations. The evolution of access technologies has led to an improvement from one generation to the next generation. 1G is best for circuit switching technology for analogue voice calls while 2G is used for digital voice and SMS.

Table 1 comparison analysis of the technlogies from 1g to 6g

Generation	Development	Technologies	Features	Benefits	limitation	Ref.
1G	1980‘s,	circuit switching	Analogue systems, Frequency Modulation (FM), Frequency Division Multiple Access (FDMA), and voice calls.	Allow mobile communication, use allocated frequency to each caller, it is cheap.	Only voice service no data service, poor voice call quality, poor handoff reliability, limited capacity, enormous mobile device.	[1]
2G	1999‘s	Global System for Mobile (GSM) communications, General Packet Radio Services (GPRS), Enhanced Data Rate for Global Evolution (EDGE)	Digital system,Time Division Multiple Access (TDMA), Multiple Access Code Division (CDMA), Short Message Service (SMS)	Makes use of electronic information services like emailing and text messages, it has lower power.	Weak signal strength.	[2]
3G	2002’s	High-speed packet Access (HSPA), wideband wireless network	Broadband wireless data, teleconferencing calling through video, and large-area wireless telephone service Multiple Access Code	Higher data speed than 1G and 2G, provides better audio and video call services, offers	Higher power consumption Problem of roaming for improved services, base	[3]

			Division (CDMA),	services based on location to users, such as the Global Positioning System (GPS), greater network capacity through improved spectral efficiency, supports video conferencing, more effective and safe method of communicating via wireless, allows interoperability	stations are placed close to the user	
4G	2010	All- Internet Protocol (IP) based, All packet switching	ultra-fast downlink and uplink speeds, Multiple Access Code Division (CDMA),	Faster data transfer and less expensive, Broader bandwidth than 3G smooth and quicker handoff, global mobility, it allows interoperability with other technologies, it improves voice quality	Higher data service cost to user. Requires new hardware components lack of device compatibility with 3G device	[4]
5G	2020	Uses technologies that offer more bandwidth, such as mmWave as well as sub-6 GHz. All packet switching	Orthogonal Frequency-Division Multiplexing (OFDM), Signal unified standard	Give the speed of the data in gigabytes per second (Gbps). Not affected by overcrowdi. The capacity to unify all networks into one system	The implementation is costly process. Lack of device compatibility with another generation device	[5]
6G	Early stage of development	Proposed holographic communication and seamless integration of AI with machine learning	Beamforming and significant multiple-input multiple-output (MIMO)	Anticipated to be able to handle a large number of linked devices at once.Will have a substantial decrease in latency over earlier generations.Will have uninterrupted worldwide connections	High cost of implementation Might have an impact on the environment by increasing greenhouse gas emissions, energy consumption, and technology discards. Might have issues with Connectivity and Simplicity	[6]

On the other hand, 3G and 4G are best for mobile internet access but 4G gives broadband internet access when compared with 3G technology. Additionally, 5G offers enhanced mobile broadband and 6G is expected to use tactile internet.

5. Future of Mobile Wireless Technology

This section discusses the vision of 6G and beyond in cellular wireless networks that will fulfill global connectivity with the increase in smart applications and equipment. The evolution of mobile wireless technology has presented unprecedented opportunities and redefined communication. The imminent sixth-generation (6G), and beyond networks represent the next phase of this progression, heralding the potential to revolutionize society and elevate connectivity to unparalleled levels [25]. While 6G system design is poised to enhance the capabilities of 5G by delivering enabling technological solutions, better Key Performance Indicators (KPIs) values in terms of accelerated speeds, location load capacity diminished latency, larger bandwidth usage, reliability, mobility, increased autonomous and intelligent network, energy efficiency, improved coverage and novel applications, beyond 6G is geared towards pushing boundaries further by assimilating cutting-edge applications and technologies that amalgamate digital, biological, and physical systems, thereby extending connectivity beyond terrestrial confines.

5.1 6G Enabling Technological Solutions

Different solutions to wireless communication technologies have been developed in the past decade due to increased bit data rates required by mobile users. However, this technology paradigm such as mm Wave within 5G will not satisfactorily cater to evolving applications and industrial automation. This will lead to a more robust enabling technological solution as shown in Fig. 10 in 6G networks such as networks working at frequencies in the band range of Terahertz for faster data speed, Artificial Intelligent networks for decision-making, optimization, and resource allocation, Space-based Internet of Things for global connection and coverage, Millimeter-wave massive MIMO antenna communications for increased capacity and coverage, Intelligent Reflecting Surface (IRS) communication environment, Lite-Fidelity (Li-Fi) based communication, ambient backscatter communication for harvesting energy from the environment, network automation in large quantity and front end all-spectrum reconfigurable [25]. Also, technologies that might surface for the emerging beyond 6G as present in Fig. 11 are quantum computing for ultra-secure communication, Immersive Technologies for holographic networks, Artificial General Intelligence for sensing automation and control, BioNanoThings technology that involves the integration of communication systems with biological systems, Space Base Quantum Network (SBQN), Energy harvesting networks and Advance privacy and security protocol [7].

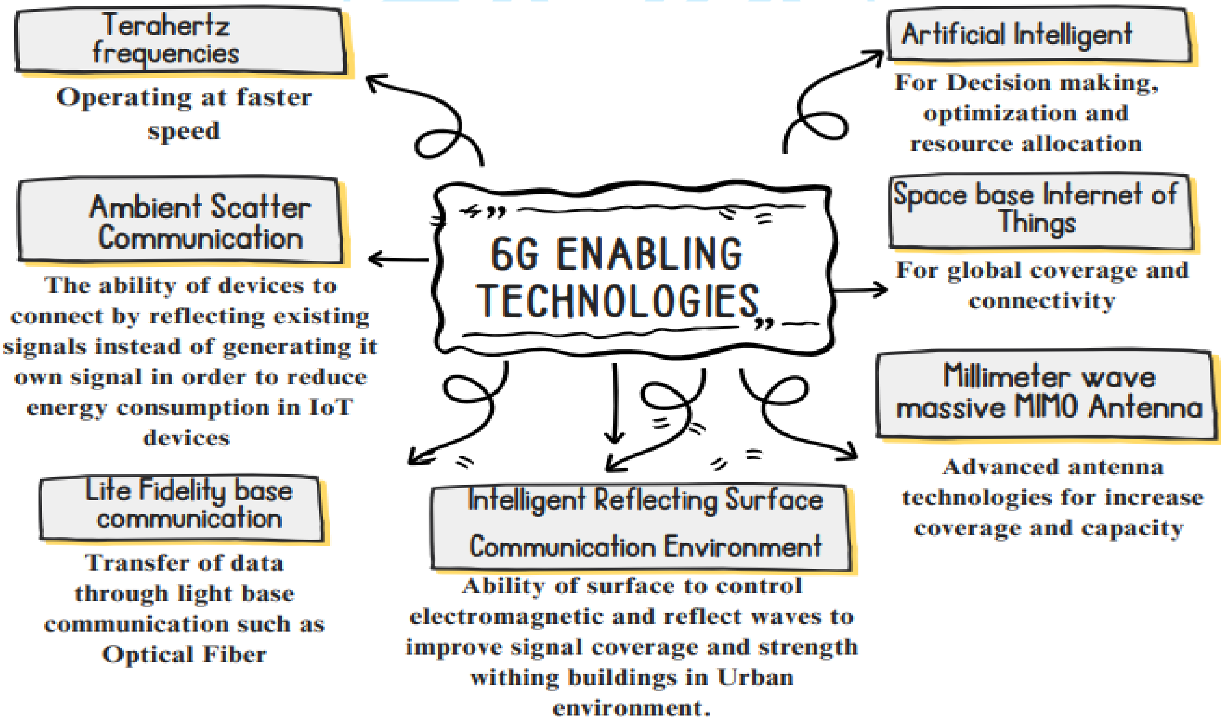

Fig. 10 6G Enabling Technologies

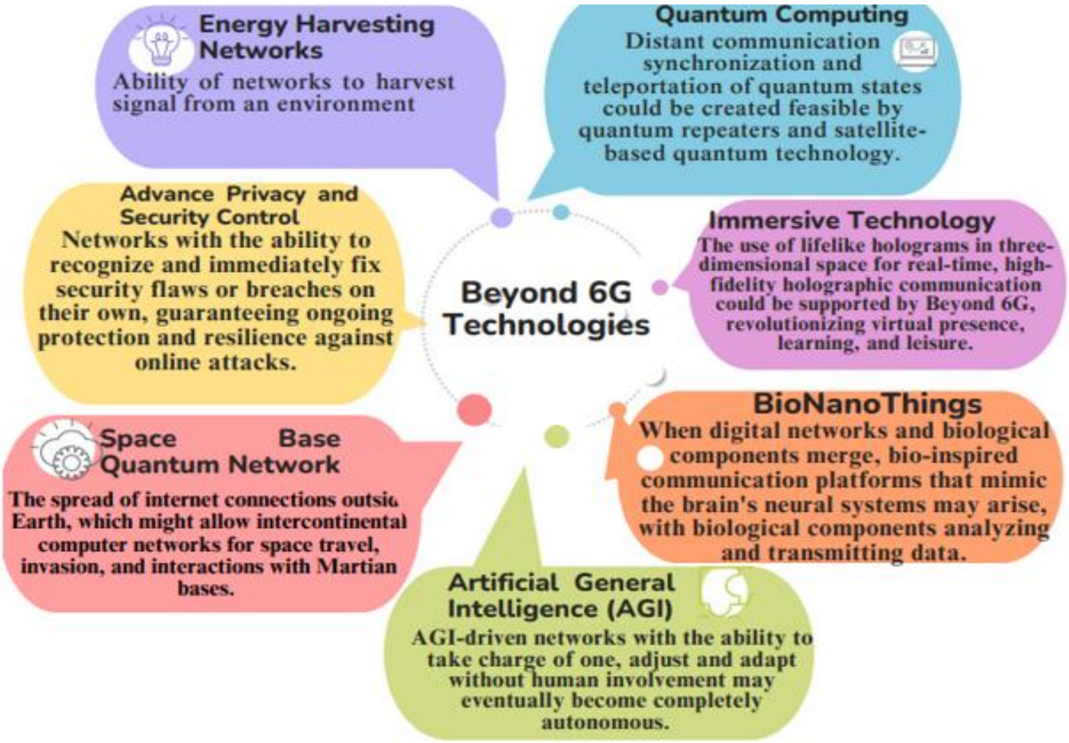

Fig. 11 Beyond 6G enabling technologies

5.2 6G Artificial Intelligent

Artificial Intelligence (AL)-driven networks mainly Machine Learning (ML) schemes will perform an enabling role in the design of a 6G network. The integration of ML in the 6G network is expected to provide intelligent services and autonomous network management, real-time analysis, threat detection, intelligent access control, network orchestration of resources, predictive maintenance, lower latency, increased efficiency, and improved reliability. ML is divided into three categories: Federated learning, Meta-learning, and Quantum Machine Learning in 6G. To overcome the challenges of the original ML processes, recently federated learning is being adopted. Federated learning applies ML via a distributed means by allowing on-device ML without drifting data through end devices to the cloud. Meta-learning helps the models to learn with complex designs. Quantum ML is the combination of ML and quantum physics, which ultimately results in the fast-ranging speed of models [11].

A machine learning overview of 6G wireless networks was presented by [26], covering techniques such as supervised and unsupervised learning, deep learning, reinforcement learning, and federated learning. It discusses the implementation of machine learning algorithms in various network categories and summarizes the use of machine learning to address technical challenges and improve energy efficiency in 6G networks. These advancements are anticipated not only to revolutionize entire industries and enhance living standards but also to engender unprecedented opportunities that were hitherto inconceivable.

5.3 6G And Beyond Applications

Fundamentals in 5G systems' ongoing evolution will provide the framework for applications that 6G will be most suited for as presented in Figure 12. To support a broad range of applications, 5G initially introduced the targeted use cases of massive Machine Type Communications (mMTC), Ultra-Reliable Low-Latency Communication (URLLC), and improved Mobile Broadband (eMBB). There are several applications for which the 5G KPIs are insufficiently stringent. We can more clearly identify the applications that will profit most from 6G as we become aware of the performance trade-offs related to throughput, latency, coverage, energy efficiency, and dependability associated with 5G systems. Human-centric services, holographic communication-based services, Nano-Internet of Things (N-IoT), Bio-Internet of Things (B-IoT), massive URLLC (mURLLC), haptics communications, and autonomous mobility are some of the applications of 6G [24].

5.3.1 Human-Centric Services

5G applications such as virtual and real services with great benefits, there is a need to develop a more robust application in 6G that is human-centric. The human-centric nature involves the quality of user experience satisfaction metrics [27]. It is anticipated that the 6G age will bring forth new gadgets that combine our inherent human senses to produce a completely new paradigm for human-machine interactions. By fusing the real and virtual worlds into one creative continuum, eXtended Reality (XR) based wearables are certain to enhance our ability to work with contemporary technologies and increase our opportunities for using and interacting with various modern or well-known IT services. The development of various adaptable quality evaluation metrics, targets, and assessments that incorporate human perceptions and physiological bodily aspects is, in this context, an essential topic of 6G research [27].

5.3.2 Holographic Communication-Based Services

Present communication paradigms are about to undergo a radical change owing to holographic-communication-base. It will use an immersive experience that appeals to all five senses sight, perception, sense of smell, touch, and taste to effortlessly connect people who are in different places. Several authors have given different names to it, namely: holographic-type communication, holographic teleportation, holographic technology and communication, holographic telepresence, multisensory XR experience, multisensory XR applications and multisensory holographic teleportation [28]. Furthermore, the next developments in multimedia experiences are holographic displays, which give users a fully-fledged 3-D experience by sending 3-D pictures from one or more sources to one or more destinations. A blend of extremely fast data rates and ultralow latency will be needed for the network to support interactive holographic capabilities. The first results from the fact that a hologram is made up of several three-dimensional images, whilst the latter is caused by the addition of parallax, which allows the user to control the image while it also varies according to the viewer's position. This is essential to giving the user a fully vivid 3-D experience [28].

5.3.3 Nano-Internet of Thing

The growing popularity of the Internet of Things (IoT), which connects hundreds of thousands of tangible assets to the Internet through pervasive sensing and processing abilities has been aided by recent advancements in wireless connectivity and gadget technology.

IoT is now a crucial component of the Internet of the future and has drawn a lot of interest from academia as well as industry because of its enormous ability to provide customer support in many facets of contemporary life [29]. IoT is predicted in the upcoming years to see remarkable development. As opposed to just 26 billion internet users in 2020, there could be over 500 billion IoT devices online by 2030 Cisco projects [30]. In addition, the development of linked worldwide IoT devices is expected to progress at an astounding rate of 12 percent annually, from almost 27 billion in 2017 to 125 billion in 2030, according to a new report by IHS Markit, a global leader in vital information, analytics, and solutions. According to a recent projection by Globe Newswire, the global market for 5G-IoT is expected to expand from USD 694.0 million in 2020 to USD 6,285.5 million by 2025 [30]. To build the future for an improved IoT environment there is a need for the application of devices with nanotechnology to communicate through the internet link referred to as the Nano-Internet of Things (N-IoT). N-IoT mostly relies on chemical communication which 5G may have trouble enabling [29].

In this regard, full-dimensional wireless coverage, integration of all functionalities from sensing, communication, and computing to intelligence and fully autonomous control and 6G's remarkable features and powerful capabilities will make 6G a crucial enabler for future IoT networks and applications. Unlike [50] the 5G mobile network, the next generation 6G mobile networks are expected to offer more scalability and extensive coverage to support IoT connectivity and service delivery [30]. Nano-communication can all be used to track an intelligent plant's water quality, humidity, carbon emissions, and gaseous fumes [29].

5.3.4 Bio-Internet of Things

In the future, there is a vision of integrating biological systems into the Internet of Things (IoT) and 6G next-generation wireless technologies to establish the Bio-Internet of Things (B-IoT). This convergence of 6G and IoT has the potential to usher in a new era of connectivity and data exchange, providing the capability for seamless communication between biological entities such as plants, humans, animals, and computer systems [30].

5.3.5 Massive Ultrareliable Low-Latency Communication

Improved mobile broadband (eMBB) has made it possible for new uses in Ultra-Reliable Low-Latency Communications (URLLCs) and massive machine-type communications (mMTCs), which have propelled the development of international mobile telecommunications 2020 (IMT-2020), also known as Fifth-Generation (5G) wireless systems. However, to improve the functionality of URLLC to a higher percentile in the future, massive Ultra-Reliable Low-Latency Communication (mURLLC) will be implemented in 6G.

Tenth times swifter than 5G URLLC's target of 1 millisecond, 6G aims for latency as little as 0.1 milliseconds. For services where actual time adaptability is essential, such as haptic communications for surgery from afar or tactile internet applications, this extremely low latency is essential. It is anticipated that 6G will achieve incredibly high levels of reliability, with transmission loss rates decreasing to as little as a single in a billion (10^-9). For applications with vital functions, where even a little communication breakdown could have fatal repercussions, this degree of dependability is crucial. Although latency and reliability have always been the main priorities of URLLC, 6G will also seek to enable high data rates in addition to these characteristics. As a result, data-intensive applications will be able to run without sacrificing connection speed or dependability [31].

5.3.6 Haptics Communications

The concept of "haptics" describes touch-based interactions between people and real-world objects, such as flicking the screen of a mobile device. The term "haptics" has been widened to include all touch-based interactions, such as those between people and tele-operated machines in the real world or virtual objects in the virtual world, due to the advancements in teleoperation technologies over the past few decades. Haptic information is the information that in these kinds of encounters conveys the sense of touch. The human skin and muscles include many mechanoreceptor types that are related to the sensation of touch. The haptic information is generally divided into visceral and physiological categories. However, haptic communications in 6G have the potential to change how we engage with the virtual world completely. By enabling greater depth, collaborative, and realistic experiences, this technology has the potential to completely transform industries including medical treatment, production, schooling, and recreation [32].

5.3.7 Autonomous System

In contrast to traditional cellular connections, future-oriented wireless networks, also called 6G or beyond, are anticipated to use Artificial Intelligence (AI) to universally supply a low-latency, highly reliable tandem for automotive networks. Automated driving systems have been developed by closely collaborating with promising technologies, such as surround detection, object recognition and surveillance, control selection, and wireless offloading via multi-access edge computing (MEC), to prevent accidents caused by human driving errors and reduce emissions. With its myriad demanding service qualities, connected autonomous vehicles (CAVs) emerge as a pivotal vertical business domain in the context of 6G. Under the umbrella of CAVs, two distinct definitions exist. Firstly, autonomous vehicles (AV) that are interconnected with other vehicles and/or infrastructure fall within the purview of CAVs. These automatic vehicles (AVs) possess the capability to perceive their surroundings and navigate safely with minimal human intervention. Secondly, at a more intricate level, connected autonomous vehicles (CAVs) encompass the technology and applications that collaborate with infrastructure to heighten road safety and efficiency in comparison to stand-alone AVs. Initially, autonomous vehicles and connected vehicles, identified as two of the most promising technologies for future transportation systems, were developed contemporaneously [33].

6. Conclusions

In a few short decades, mobile networks have rapidly evolved from limited analog voice systems to sophisticated digital networks providing high-speed mobile broadband. Progressive generations of radio access technologies have enabled this transformation through innovations in radio transmission, digital modulation, packet-based data networking and more. As user needs continue advancing, researchers envision systems beyond 5G that could achieve data rates up to 10 Gbps through techniques like higher frequency bands, advanced antenna technologies, and dense heterogeneous networks. The incredible evolution of wireless networking will likely continue for decades, bringing ever faster and more capable mobile broadband.

Acknowledgement

The authors are thankful to the Management of Landmark University for their continuous encouragement. The authors are thankful to the Department of Electrical and Information Engineering, College of Engineering, Landmark University, Omu-Aran, Nigeria for providing facilities. We extend our sincere thanks to anonymous who provided language help, writing assistance and proof reading the article.

Author's Contributions

Folashade O. Ariba wrote the original draft preparation. Folashade O. Ariba, Adebanji Bankole, and Enoch J. Adama did the first review and editing. Folashade O. Ariba and Adebanji Bankole wrote the first version of the manuscript. All authors reviewed and approved the final version of the manuscript.

Funding

The author(s) received no financial support for the research or authorship

Conflicts of Interest

The authors declare no conflict of interest.

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