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5G and up to 6G

V. Basil Hans*

Abstract

The 5th generation of mobile networks is called 5G, and the next generation, 6G is expected to arrive soon. With the promise of faster speeds, less latency, and increased connectivity, 5G technology has revolutionized mobile communications. However, the 6G vision is already taking shape as the need for high-performance networks keeps increasing. By offering ultra-high-speed communication, smooth artificial intelligence (AI) integration, extensive Internet of Things (IoT) connectivity, and support for holographic communications and immersive technologies like augmented and virtual reality (AR/VR), this next-generation network is anticipated to surpass the capabilities of 5G. Terahertz (THz) frequency bands are expected to be used by 6G, allowing for previously unheard-of data throughput and decreased latency. These features are essential for applications like remote healthcare, smart cities, autonomous systems, and next-generation industrial automation. The developments in 5G technology, the expected transition to 6G, and the obstacles to its implementation, such as spectrum management, network security, energy efficiency, and international interoperability, are all covered in this study. There have been notable turning points in the development of mobile communication technologies, with each generation bringing notable advancements in functionality, speed, and capacity. Unprecedented connection has already been made possible by the 4G to 5G shift, enabling a new generation of innovations including smart cities, driverless cars, and improved augmented reality experiences. But as we move forward, it is becoming clearer that even quicker, more effective, and scalable networks are required. The next wave of wireless communication technology, 6G, is here. In order to meet the constantly increasing need for more data, faster speeds, and pervasive connection, 6G is anticipated to expand on the capabilities of 5G. 6G proposes a fully integrated and intelligent network environment that smoothly supports a wide range of future technologies, including as edge computing, artificial intelligence, and the Internet of Things (IoT), in contrast to 5G, which is solely focused on improving mobile broadband. 6G seeks to provide near-instantaneous data transfer and near-zero latency by utilizing higher frequency bands, such as the terahertz (THz) spectrum, opening up applications that were previously thought to be far off. This study looks at the expected characteristics and developments of 6G, the obstacles that need to be removed to make it a reality, and its possible uses in a world that is getting more digital and linked by the day. Understanding 6G's potential to transform industries, enhance lives, and open up completely new avenues for global connectivity is crucial as we set out on this path.

Keywords: Communication, technologies, worldwide connectedness, Internet of Things (IoT), 5G & 6G network, faster speeds

***Author for Correspondence**
V. Basil Hans
E-mail: vhans2011@gmail.com

Research Professor, Department of Management and Commerce, Srinivas University, Mangaluru, Karnataka, India

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INTRODUCTION

Overview of 5G Technology

The earliest wireless communication technology, known as the analog cellular network, operated in the 1980s. Voice calling between mobile users was this technology's sole function. The Nordic Mobile Radio System was the first-generation network in use at that time in a few European nations. This system's primary benefit was its ability to scan passive channels and switch the FM audio channels.

This system was incompatible with German technology overall. Additionally, the Advanced Mobile Phone System was the primary service offered by this network. Second-generation wireless communication, or 2G, was a more sophisticated form of first-generation technology. High-quality, secure mobile voice and basic data services like voicemail and fax were the objectives of this second-generation technology. Using the 900-MHz band, the Global System for Mobile Communications standard was implemented in the early 1990s as the second generation of wireless communication technology worldwide. Switching and cellular networks, such as narrowband TB, formed the foundation of GSM. 2G divided radio frequency channels using frequency division multiple access.

Additionally, 2G split the time frame into distinct time slots using Time Division Multiple Access. Many users could communicate at once thanks to the FDMA and TDMA method. GSM introduced a digital system network to support basic SMS. Compression, proto buffering, and increased capacity for long-distance internet-based traffic were implemented to enable further GSM features like always-on. These factors led to the development of GPRS, and the Enhanced Data GSM Environment, an upgraded version of GSM, which was implemented using GPRS. GSM-enabled services like continuous mobile phone calls to consumers were made possible via DSC and EDGE. Poor voice quality was less than an exhilarating landline due to the 1G network's transparency failure. The 1G network was unpopular. Other features that were introduced in 2G included privacy, security, voice messaging, P2P SMS text messages, and HD nonsense sound grades. These additional features were ultimately essential to the 2G network's success. Without a doubt, the rollout of the 2G network around the globe was a tremendous success for GSM technology [1].

The fifth generation of wireless technology, or 5G, seeks to offer mobile services that are quicker, more dependable, and more adaptable. It is made to link more machines, gadgets, and people simultaneously.

How does 5G operate?

- *Speed:* Compared to 4G, 5G offers quicker upload and download rates.
- *Latency:* 5G is closer to real-time since it has lower latency.
- *Capacity:* 5G allows for the simultaneous connection of additional devices.
- *Connectivity:* 5G can offer smooth communication between cellular networks and Wi-Fi.

What advantages does 5G offer?

- Numerous applications, like as online gaming, videoconferencing, and self-driving cars, would perform better with 5G.
- 5G will benefit companies by establishing a network of interconnected machines and devices.
- 5G will increase connection in both urban and rural locations.

India's 5G

- In October 2022, 5G services were introduced in India. In India, there were more than 100 million 5G customers as of October 2023.

Security and 5G

- Concerns over security and its ties with Chinese vendors have been brought up by 5G technology.

The fifth generation of wireless cellular technology, or 5G, offers better capacity than earlier networks, more reliable connections, and faster upload and download rates. 5G has the potential to completely change how we use the internet to access information, social networks, and applications because it is far quicker and more dependable than the already widely used 4G networks. For instance, 5G connectivity is expected to significantly enhance technologies that need extremely dependable, fast data connections, like as self-driving cars, sophisticated gaming apps, and live streaming media [2].

Important Attributes and Capabilities

The technological capabilities, service requirements, and usage scenario of the fifth-generation (5G) technology are thoroughly examined and discussed in this study. The fourth-generation (4G) systems are greatly improved by the new features that the 5G system offers. Increasing the system's capacity is largely dependent on the use of overlapping network deployments of various wireless access technologies. The capacity of OFDMA-based heterogeneous underlay networks is examined in this study with reference to the interactions between various network types. The system's capacity is analyzed using both a simulation-based approach and mathematical modelling [1–4]. Additionally, an algorithmic approach to the analysis, design, and management of heterogeneous underlay networks that addresses issues of quality of service, fairness, and capacity is described. The arrival of a fifth-generation (5G) mobile communication technology is imminent. With the potential to surpass fourth-generation (4G) technology in every facet of wireless communication, 5G has the potential to become the dominant technology of the future. The adoption of orthogonal frequency-division multiplexing-based air interfaces and the strict requirement of nearly doubling the spectrum efficiency over 4G technology have been agreed upon by the global standardization, in conjunction with the development of digital signal processing and error control coding [5–9]. The 5G network, sometimes referred to as International Mobile Telecommunications 2020, is intended to offer high mobility consumers a data throughput of 100 Mbit/s, which is a threefold speedup over 4G communication systems. Unmanned drone infrastructures and a number of intriguing intelligent transportation systems are made possible by multilane and millisecond communications. In some situations, certain operating modes that have been added to the RAN may be viewed as high-performance modes created to meet the performance needs of a particular group of UEs and services. These modes of operation are activated adaptively by the UE and/or network, rather than being introduced at the start of a connection [10].

5G's Drawbacks and Limitations

Research on what will happen after 5G and the move towards 6G are the results of current wireless communication breakthroughs [1]. Evaluating the improvements of each generation is vital, but it is also critical to draw attention to the difficulties that restrict 5G's potential. In order to shape a route for future generations, it is imperative to have a deeper understanding of the restrictions imposed by 5G. Notable obstacles in the 5G race are delaying the necessary momentum for 5G to reach its full potential. Adoption of this new technology has presented a number of technological, administrative, and social issues for cities and communities around the world. 5G requires both infrastructure upgrades and installations in order to realize its full potential. Data centers and optical fiber are necessary to provide 5G services' desired low-latency gigabit speed. Even though these implementations are less expensive than satellite-based backhauls fueled by nuclear power, their successful deployment necessitates a significant amount of manual labor and patience with bureaucratic procedures [11–14]. Spectrum allotment is a further topic of concern. Services that need wireless communication technologies can only consume a certain amount of bandwidth. IoT, V2X, and even a single industry-level private network rollout cannot be accommodated by the current bands. To exacerbate the situation, it is difficult to guarantee equitable bandwidth allocation across a wide range of applications or compliances. ISPs, device users, industries, Wi Fi networks, and even rival 5G networks will all compete for a piece of the bandwidth pie in 5G. If not for the fact that these various actors function in radically different ways and under radically different circumstances, everything would be OK. Creating a thorough plan that demonstrates that all of these applications can coexist without interfering with one another will be challenging.

NEW IDEAS AND TECHNOLOGIES FOR 6G

There have been notable advancements in wireless communication technology in recent years. With a complete commercial timetable by 2021, the fifth-generation (5G) technology is being progressively deployed throughout the world [3]. Even though the 5G system's standard formalization was recently finished, the sixth generation (6G) has begun to garner more interest from both academia and industry. A 6G network design is most likely to be deployed between 2027 and 2030 [5]. Future 6G wireless communication and network designs are the main focus of this study, which also discusses a number of

cutting-edge ideas and technologies that may serve as the basis for future 6G system implementations. The main topic of interest here is a detailed examination of 6G network applications, together with the requirements that have been determined for the next-generation system. Presenting a forward-looking viewpoint on the networks and connectivity that will shape the future digital world is the overall goal.

One noteworthy fact is that, as wireless communication serves as the foundation for connecting a large number of intelligent devices that have been produced, it will emerge as a key technology to support future digital systems. Future developments and changes are expected to be accompanied by a comprehensive synergy between the digital and physical worlds through an enhanced wireless communication system. In order to effectively utilize the centimeter and millimeter wave bands in 5G systems, certain developments in devices, circuits, antennas, infrastructures, materials, and millimeter-wave communication are probably going to be crucial. Nevertheless, significant obstacles related to 5G communication technologies could not be sufficiently addressed. With a focus on the 300 GHz communication system, which may be a game-changer for upcoming developments, restrictions on enriched bandwidth are anticipated. Conversely, the incorporation of artificial intelligence into the various management and optimization processes of the core, radio, and outer networks is thought to be extremely revolutionary and might guarantee the efficiency and viability that the future 6G vision purports to address. Reconfigurable intelligent surfaces, wireless information and energy transfer on demand, immersive terabyte network access, and intelligent PN are a few examples of what may be accomplished.

Communication at Terahertz

Every element of human daily life, from entertainment and social services to healthcare and security, has been profoundly altered by the development of terrestrial high-speed wireless communication in recent years. These developments promise new opportunities and revolutionary breakthroughs in fields like Big-Data, Machine Learning, and the Internet of Things. Following the successful rollout of 4G, research and industry are now examining the fifth generation of mobile networks (5G), with various implementations already in use in cities across numerous nations. In comparison to the present 4G technology, 5G promises to offer faster transmission data rates, specifically, 20 Gbps downstream and 10 Gbps upstream, as well as consistently low latency and extensive coverage. Potential future scenarios are analyzed, taking into account more developments in wireless communication, from now until 2030. Future networks are expected to rely on a number of technologies, such as network slicing, massive multiple-input multiple-output, cloud radio access networks for terahertz, communication with cloud and edge computing and networks, millimeter-wave communications with 5G, and Terahertz communication with 6G. In general, 6G wireless communication makes it possible for infrastructure and service providers to collaborate effectively in order to guarantee that the network quickly focuses on the evolving needs of its clients. In the context of the 6G era, a number of relevant research have examined potential scenarios and compiled findings for Terahertz communication, which can be advantageous to markets and industries.

Integration of Artificial Intelligence

With the present rollout of 5G networks and the arrival of the next generation, wireless communications are experiencing significant breakthroughs. Diverse technologies and approaches are investigating distinctions from the existing operational 5G by leveraging both technical and social viewpoints. The need for quick and effective connectivity has increased in our digitally linked world. Preparation for future technologies has intensified due to the telecommunications industry's change during uncertain times following the rough rollout of 5G. A wide range of enlarged horizons has been further studied in recent studies evaluating the important components of future communication networks, leading to a revolutionary transformation brought about by beyond 6G.

The most obvious and revolutionary change among all the developments is the incorporation of artificial intelligence into cutting-edge telecommunications technologies. This agreement serves as the

impetus for this special part, which attempts to present the state of research and new findings that successfully connect AI and the wireless domain. A new age of intelligent wireless communication networks powered by AI is ushered in by the arrival of 6G. Due to the intricate interactions between various AI hardware, software, and services, AI will be an essential part of the basic architecture of future 6G networks. Particular attention will be paid to enabling AI-infused module designs and the possible practical application of AI with 6G networks. Next, methodologies for designing cross-layer networks for AI services coupled with 6G cellular networks are developed. Future wireless network platforms powered by 6G technology will undoubtedly be built on top of ready AI fusion, enabling a variety of services and applications and generating value ecosystems in the process. The studies in this special section, taken as a whole, make great progress in utilizing AI-enabled innovations to propel the ongoing disruptions surrounding 6G networks.

POSSIBLE USE CASES AND APPLICATIONS FOR 6G

Wireless communication has emerged as a vital means of interaction and information sharing between humans and machines worldwide [7]. As a result, the goal of connectivity solutions has changed. Wireless technology generation over the last few decades has sought to provide more than just better speech and data transfer capabilities [1]. 5G is seen as more than merely an advancement of existing systems to offer faster speeds, lower latency, and more energy efficiency, since it scales far beyond expectations, even when it was still very young. Predictions that 6G will set the bar even higher have grown commonplace. As a result, scholars and organizations across the globe have started investigating and attempting to gather the possible technological advantages and difficulties related to the implementation of these future solutions. Healthcare, industry, energy, entertainment, education, and smart cities are just a few of the internet of everything applications that are part of the 2020 vision for possible 6G uses. Future connection solutions are anticipated to be created and implemented globally during the course of the next 10 years, allowing for revolutionary changes in the processing and sharing of information. Furthermore, satellite communication systems are regarded as a fundamental prerequisite for supporting a wide range of complex applications, including distance learning across difficult geographic regions. However, six all-inclusive applications for the upcoming generation of connection solutions are offered to work together. To create an internet of space objects, one of them entails giving CubeSats and tiny unmanned aerial vehicles (UAVs) the ability to wirelessly transfer electricity simultaneously. Drones and CubeSats might provide other mobile networks with tiny, much-needed energy resources thanks to SWPT, which would also increase service availability and coverage. For instance, a network of solar-powered small-horizon UAVs might offer Wi-Fi coverage throughout isolated rural or hilly regions.

CONCLUSION AND PROSPECTS FOR THE FUTURE

Finally, a brief overview of wireless communication's history, beginning with the 1G era, was given, along with a discussion of the latest developments in 5G technology, its drawbacks, and its difficulties. Potential future study as well as a form of exploratory research were presented. Looking back on the investigation, the advancements in wireless communication from the first 1G mobile phones to 5G and newer technologies leading to 6G have shown overlapping trajectories propelled by a mutually reinforcing mix of societal demands and economic opportunities. Cellular networks have had a revolutionary social impact due to their shared need for seamless and ubiquitous connectedness. Unexpected insights into the technological difficulties and constraints of 5G are revealed by the conversation about current developments in the short- and long-term evolutions of wireless communication technology. This information is essential to advancing the question to 6G and beyond. Assuming that 5G restrictions are overcome, capabilities like terahertz transmission and integrated network technologies, which are now mostly untapped, will have enormous promise for future wireless systems. Thus, combining it with network analytics powered by artificial intelligence will be the next crucial area of study for a world that is genuinely effective, safe, and wirelessly ideal. This opens up a whole new world of broadband and intelligent services that may be provided to society, especially when combined with a universe of smart and varied devices that are enabled by network-of-everything

architecture. But there are still problems that have been anticipated but have not been brought up yet. There is probably more to discover about the advancements for 6G wireless networks. An interesting period of additional research on the technological, policy, and globalizing 6G communication ecosystem is ahead, as the economy has expanded beyond cellular and wireless communication as a result of acceptance and suitable reactions to new technological and market settings. Furthermore, preventive measures could potentially ensure future prosperity and global connectedness, even though the future well-being of both wealthy and developing nations in the context of 6G wireless communication remains uncertain. "A lot of times, people don't know what they want until you show it to them", is the last quote offered. How intriguing will the development of that wireless horizon glance be! Beyond the radio waves, what is there? Together, let us find out.

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