Chapter

Perspective Chapter: 5G Enabling Technologies – Revolutionizing Transport, Environment, and Health

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Abstract

The latest cellular technology, known as 5G, is anticipated to significantly improve the way systems in the physical and social environment (PSE) interact with technology. 5G technologies allow for the creation of a wide range of novel automation and applications. Recently, the Internet of Things (IoT), virtual and augmented reality (VAR), telemedicine, and autonomous vehicles have increased the growth of applications in the PSEs and can further benefit from 5G's fast data transfer speeds (ranging from 1 to 10 Gbps) and low latency. The introduction of 5G may cause a paradigm shift in the operations of some industries, offer new economic opportunities, and impact our daily lives and relationships with the PSE. In this chapter, we examine how 5G revolutionize transport, the environment, and health. The chapter focuses on recent technologies related to virtual and augmented reality, autonomous vehicles, telemedicine, and edge computing among others.

Keywords: 5G, Internet of things, virtual reality, augmented reality, wireless sensor networks (WSNs), autonomous vehicles, edge computing, environment

1. Introduction

Technological advances in communication have seen a new wave of the fifth generation (5G) networks. 5G networks are predicted to significantly impact areas of health, virtual and augmented reality, transportation, the environment, and edge computing. The healthcare sector is anticipated to be one of the biggest beneficiaries of 5G technology. Healthcare professionals will be able to offer telemedicine and virtual consultations to patients in remote locations with the advent of 5G networks. As a result, patients will not have to travel far to obtain medical attention. Advanced medical gadgets that need fast data transfer rates and low latency will also be able to be used thanks to 5G technology. Healthcare professionals will be able to diagnose and treat patients as a result [1]. Virtual and augmented reality is another area where 5G technology is anticipated to have a big influence. Users will be able to enjoy realistic, high-quality virtual and augmented reality experiences as a result of 5G networks. Virtual and augmented reality will make it possible for people to interact with virtual worlds in real-time, which will have a big influence on a lot of different businesses, like gaming, education, and entertainment. Edge computing, which will assist to lower latency and increasing the overall performance of virtual and augmented reality apps, will also be made possible by 5G technology [2]. 5G technology is also anticipated to have a big influence is transportation. The rollout of 5G networks will make it feasible to give drivers real-time traffic updates, which will lessen congestion and increase road safety. The usage of autonomous cars will also be made possible by 5G technology, which will have a big influence on the transportation sector. The ability of autonomous cars to interact with one another and the infrastructure will assist to improve traffic flow and lower accident rates [1]. 5G technology is anticipated to make a big difference in edge computing. 5G technology offers low latency and high data transfer rates to edge devices with the rollout of 5G networks. This will make it possible to employ cutting-edge edge computing applications, including real-time video analytics, which will have a big influence on a lot of different industries, including manufacturing, shipping, and retail. Local caching will also be possible thanks to 5G technology, which will lessen network traffic and enhance the performance of edge computing apps as a whole [3]. Although 5G technology may have advantages, there are worries about how it could affect people's health. According to research, electromagnetic radiation from 5G networks may cause cancer and reproductive issues, among other harmful health impacts [4]. The World Health Organization (WHO) has argued that there is no evidence to support a link between electromagnetic radiation exposure from 5G networks and adverse health effects in people [1]. Concerns about the possible effects of new technology on different facets of our life arise along with it. This chapter will look at the current studies on how 5G technology will affect things like edge computing, health, virtual and augmented reality, transportation, and the environment. We may better comprehend the opportunities and difficulties that lie ahead as we progress toward a more connected and technologically evolved society by looking at the possible advantages and hazards of 5G in each of these categories. This chapter offers a thorough assessment of the state of research on the effects of 5G on these important domains, as well as highlighting knowledge gaps and recommending topics for further investigation. Ultimately, this chapter will contribute to a more nuanced and knowledgeable conversation about the possible effects of 5G technology, and it will help direct academics, politicians, and the general public toward a more responsible and sustainable use of this formidable new technology.

The remaining parts of the chapter are divided into 10 sections. Section 2 discusses the methodology. In Section 3, recent related works in 5G technology are discussed. In Section 4, we present a discussion on wireless mobile technologies. Section 5 presents an overview of 5G technologies. Section 6 discusses 5G in virtual and augmented reality and Section 7 discusses 5G and transportation (autonomous vehicles). In Section 8, 5G in healthcare (telemedicine) is presented. Sections 9 and 10 present 5G and the environment and edge computing, respectively, and Section 11 concludes the chapter.

2. Methodology

The Prisma systematic review was used to conduct this research. At the identification stage of Prisma, a comprehensive literature review was conducted using various academic databases, including PubMed, Google Scholar, Scopus, Multidisciplinary Digital Publishing Institute (MDPI), ResearchGate, and Institute of Electrical and Electronics Engineers (IEEE). The search terms used included "5G," "health," "transportation," "augmented reality," "virtual reality," "environment," and "edge computing." The search was limited to articles published in English from the year 2017 to 2023. Initially, a total of 120 articles were collected from the various academic databases for this chapter. Upon careful study and review, only 85 of the obtained literature or articles were relevant to the research topic. The literature review was conducted in three stages. The very first stage was the identification of articles or papers that highlighted the general overview of 5G and its architecture. The second stage involved the identification of articles that focused on the potential benefits of 5G to the health sector. Such articles included articles on smart healthcare, remote surgery, and telemedicine. The third stage focused on the potential impact of 5G technology on transportation, augmented and virtual reality, the environment, and edge computing. During the first stage, articles that talked about evolution of cellular networks, and introduction to 5G and 5G architecture were included. Papers that had no direct connection to any of the above were discarded. In the second stage, articles were screened based on their relevance to the topic of health benefits associated with 5G technology. Articles that did not provide original research or data were excluded. In the third stage, articles were screened based on their relevance to the topics of transportation, augmented and virtual reality, the environment, and edge computing. Articles that discussed the potential benefits and drawbacks of 5G technology in these areas were included. Also, Articles that focused on the biological effects of electromagnetic radiation and the potential health risks associated with exposure to such radiation were included. Moreover, articles that discussed the harmful effects of 5G on the environment were also included. Articles that focused solely on the technical aspects of 5G technology or did not provide original research or data were excluded (see **Figure 1**).

Figure 1 illustrates a graphical representation of reviewed papers after going through the identification, screening, eligibility, and inclusion stages of Prisma. The selected articles were then read extensively and various knowledge and findings together with our contributions were synthesized together in this chapter.

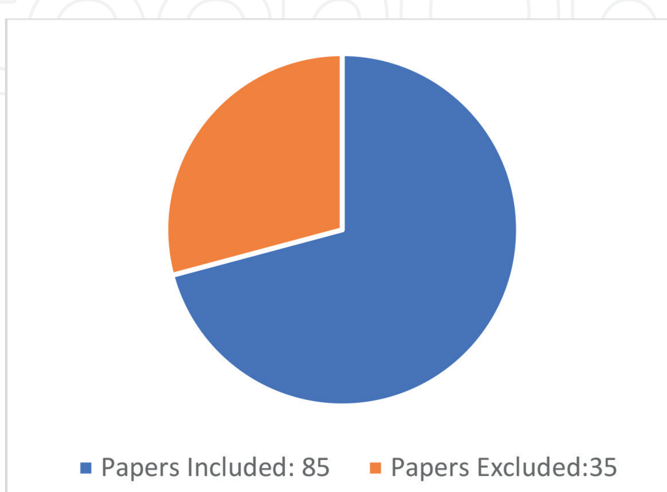

Figure 1.
Outcome of Prisma process.

3. Related works

This literature review aims to explore the existing research on the impact of 5G technology on health, virtual and augmented reality (VR/AR), transportation, environment, and edge computing. Tiwari and Sharma [5] present components, architecture, and applications of 5G-enabled Internet of Medical Things (IoMT). Butcher et al. [6] seek to ascertain if patient-reported Health-Related Quality of Life (HRQoL), together with or without other factors at baseline, predicts disability in people with kidney failure, aged 65 and older, after a year of follow-up. The aim of [7] is the development and clinical evaluation of a 5G usability test framework enabling preclinical diagnostics with mobile ultrasound using 5G network technology. Also, Nyberg et al. [8] present recent research from the European Union's expert groups, from a large collection of European and other international studies, and previous reviews of the effects of radiofrequency radiation (RFR) on humans and the environment. Balancing risks and rewards is the best strategy forward. Jain and Jain [9] researched the benefits, risks, and diligence of 5G technology for healthcare and its implications on human health. In their approach, the 5G network-connected technology project was split into two phases for proof-of-concept testing: the first phase initially focused on conducting examinations with portable ultrasound equipment at Hospital das Clnicas da Faculdade de Medicina da USP (HCFMUSP), and the second phase concentrated on conducting remote examinations with medical professionals in other states of Brazil who will be working in isolated regions in other states with little access to healthcare. Their outcome suggested that excellent healthcare will be accessible to everyone at all times with 5G technology.

The contribution of de Oliveira [10] is to evaluate the connectivity and capacity of the 5G private network for transmitting a large volume of data remotely with higher speed and lower latency. Lin [11] reviewed the benefits of 5G technologies, which are implemented in healthcare and wearable devices. Some benefits discussed include the use of 5G in patient health monitoring, continuous monitoring of chronic diseases, management of preventing infectious diseases, robotic surgery, and 5G with the future of wearables. A national sample of 5087 Spaniards [12] examines the prevalence of 10 specific misperceptions over five separate science and health domains (climate change, 5G technology, genetically modified foods, vaccines, and homeopathy). Sehrai et al. [13] present the design and analysis of an antenna array for the high gain performance of future mm-wave 5G communication systems. Currently, there is little research exploring how fellowship-trained sports medicine physicians (FTSMPs) address their mental health on a routine basis. Using the theory of secondary trauma stress to help navigate this study, the purpose of this expressive, all-purpose qualitative study is to improve the understanding of FTSMPs' perceptions of their mental health and the kinds of strategies used to manage these issues [14]. An alternate viewpoint to address the demands of the 5G Public Network and the hybrid deployment of 5GS and Wi-Fi on the campus network is provided by DecentRAN, also known as the Decentralized Radio Access Network [15]. Asif Khan et al. [16] presented a comprehensive survey of recent developments in MEC-enabled video streaming bringing unprecedented improvement to enable novel use cases. von Ende et al. [17] described the present and potential future applications of radiogenomics, augmented and virtual reality, and artificial intelligence in interventional radiology, along with the issues and constraints that need to be resolved before these applications can be fully integrated into standard clinical practice.

Hazarika and Rahmati [18] discussed the inclusion of 5G technology in allowing a low-latency environment for AR and VR applications, as well as a thorough examination and in-depth insight into different attractive options from the hardware and software viewpoints. Ali et al. [19] presented a state-of-the-art contribution to the characterization of the outdoor-to-indoor radio channel in the 3.5 GHz band, based on experimental data for commercial, deployed 5G networks, collected during a large-scale measurement campaign carried out in the city of Rome, Italy. In the case of fully grasping the principles of low-carbon tourism development and related policy protection, a suitable low-carbon tourism development model is found. Zhang [20] presented the evaluation of aggregate interference from 5G New Radio (NR) base stations located inside the victim satellites' footprints using Monte-Carlo analysis and calculation of signal-to-noise degradation and bit error rates of the fixed-satellite service (FSS) bent-pipe transponders for each scenario. Assimilating trailblazing technologies such as the Internet of Things (IoT), edge intelligence (EI), 5G, and blockchain into the autonomous vehicle (AV) architecture will unlock the potential of an efficient and sustainable transportation system. Jia et al. [21] propose the application of UAV Based on 5G communication technology, which overcomes the current bottleneck of UAV.

Pastukh et al. [22] provided a comprehensive review of the state-of-the-art literature on the impact and implementation of the aforementioned technologies into AV architectures, along with the challenges faced by each of them. Biswas and Wang [23] proposed a novel framework named Pyramid that unleashes the potential of edge artificial intelligence (AI) by facilitating homogeneous and heterogeneous hierarchical machine learning (ML) inferences. For the ubiquitous Internet of electric power, the application framework of 5G communication technology in over-voltage fault edge computing is proposed, the distribution grid fault identification and response model based on edge computing is built, and He et al. [24] imagine 5G communication application scenarios.

Gao et al. [25] presented a 5G edge computing framework for enabling remote production functions for live holographic Teleportation applications. Qian et al. [26] focused on edge computing, which is one of the cores of beyond 5G, to utilize the virtualization resources (see **Table 1** for a summary of some related works).

Unlike the previous works discussed earlier, Nakazato et al. [27] presented real data for more than one proposed robot working in parallel on-site, exploring hardware processing capabilities and the local Wi-Fi network characteristics. Zhou et al. [28] presented a Secure and lAtency-aware dIgital twin assisted resource scheduliNg algoriThm (SAINT). To provide a high-performance implementation of Module-LWE applications for the edge computing paradigm [29] proposed a domain-specific processor based on a matrix extension of RISC-V architecture. To assure secure and reliable communication in 5G edge computing and D2D-enabled IoMT systems, Yang et al. [30] presented an intelligent trust cloud management method. Mahenge et al. [31] considered task offloading on small cell network (SCN) structures unique to 5G. Jamshidi et al. [32] presented the design, fabrication, and evaluation of a super-efficient GSM triplexer for 5G-enabled IoT in sustainable smart grid edge computing and the metaverse.

4. Wireless mobile technologies

Since the dawn of time, communication has been a vital element in the lives of humans. Like the very food we eat, the air we breathe, and the shelter we seek, communication is now a basic necessity for human survival and development.

Contributions	References
Presenting components, architecture, and applications of 5G enabled Internet of Medical Things (IoMT)	[5]
Development and clinical evaluation of a 5G usability test framework enabling preclinical diagnostics with mobile ultrasound using 5G network technology	[7]
The benefits, risks, and diligence of 5G technology for healthcare and its implications on human health	[9]
Evaluating the connectivity and capacity of the 5G private network for transmitting a large volume of data remotely with higher speed and lower latency	[10]
Reviewing the benefits of 5G technologies, which are implemented in healthcare and wearable devices such as the use of 5G in patient health monitoring, continuous monitoring of chronic diseases, management of preventing infectious diseases, robotic surgery, and 5G with future wearables	[11]
Discussing the inclusion of 5G technology in allowing a low-latency environment for AR and VR applications	[18]
Presenting a 5G edge computing framework for enabling remote production functions for live holographic Teleportation applications	[25]
Focusing on edge computing, which is one of the cores of Beyond 5G, to utilize the virtualization resources	[26]

Table 1.
Summary of related works.

Communication occurs locally or remotely among connecting nodes. Remote communication has contributed enormously to globalization and the advancement of modern technologies. Since the advent of mobile phones in 1983 to facilitate remote communications, the world has already witnessed the full power of four different wireless mobile technologies approximately 10 years apart.

The first-generation (1G) technology was designed for voice communication in the late 1980s. The network speed of 1G was limited to 2.4 kbps. The 1990s witnessed second-generation (2G) technologies, which allowed audio and video files to be shared. 2G technologies had a network speed limitation of 64 kbps, which was not the best but was revolutionary. In the 2000s, the emergence of third-generation (3G) technologies took the network speed to 2 Mbps, which made browsing at high speed possible. Following 3G was the revolutionary Fourth-generation (4G) with a network speed of 100 Mbps, which was developed in 2011.

4G technologies brought about super-high-speed browsing, making digital streaming, online gaming, and downloading and uploading video calling, faster and more convenient. With the rapid increase of mobile phones, the demand to share files at an even faster rate with little to no delay is high. Despite the performance of 4G, there was a need for a flexible network with a shared infrastructure, hence fifth-generation (5G). With the new generation of mobile networking emerging, 5G will be a visionary innovation platform for the next 10 years and beyond due to its amazing speed of about 20Gbps. Most importantly, 5G will open up fresh opportunities and efficiencies that are not even imaginable with the networks in use presently [33]. **Table 2** presents a summary of the evaluation of cellular technologies from 1G to 5G technologies.

In comparison to 4G, 5G offers faster download and upload speeds, lower latency, with more dependable connections. The expected system latency for 5G is 2–5 ms.

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Generation	Access techniques	Data rate	Frequency bands	Applications	Key parameters	Transmission techniques	Error correction mechanism
5G	NOMA, FBMC	10–50 Gbps	1.8 GHz, 2.4 GHz, 30–300 GHz	Voice, data, video calling, ultra HD video, virtual reality applications	Ultra-low latency, ultra-high availability, ultra-speed, and ultra-reliability	Packet switching	LDPC
4G	LTEA, OFDMA, SCFDMA, WIMAX	100–200 Mbps	2.3 GHz, 2.5 GHz, 3.5 GHz	Voice, data, video calling, HD television, and online gaming	Faster broadband internet and lower latency	Packet switching	Turbo codes
3G	WCDMA, UMTS, CDMA	384 Kbps to 5 Mbps	800 MHz, 850 MHz, 900 MHz, 1800 MHz, 1900 MHz, 2100 MHz	Voice, data, and video calling	Broadband internet and smart phones	Circuit and packet switching	Turbo codes
2G	GSM, TDMA, CDMA	10 Kbps	800 MHz, 900 MHz, 1800 MHz, 1900 MHz	Voice and data	Digital	Circuit switching	N/A
1G	FDMA, AMPS	2.4 Kbps	800 MHz	Voice	Mobility	Circuit switching	N/A

Table 2.
Evaluation of technology generations from 1G to 5G.

The current long-term evolution (LTE) network has a round-trip delay of roughly 15 ms, compared to dedicated short-range communication (DSRC), which has a latency of about 10 ms. Some of the options that can help in providing this latency include device-to-device (D2D), software-defined networks (SDNs), and cloud radio access networks (C-RAN) [33].

5G is the newest and fastest generation of cellular technology. 5G technology is the replacement for 4G LTE technology. The Internet of Things (IoTs), linked cars, smart homes, virtual and augmented reality, and other innovative use cases that were not viable with 4G are all supported by 5G technology. Many facets of our everyday life, including entertainment, communication, healthcare, and transportation, are anticipated to change as a result of 5G technology [34].

5. Overview of 5G technology

5G technology is built to use a variety of frequencies, including low, middle, and high-band spectrum, to provide faster speeds and greater coverage. Low-band 5G is frequently used to improve existing 4G networks and provides greater coverage (see **Table 3** for a comparison of 4G and 5G's key features). Mid-band 5G, which strikes a balance between speed and coverage, is used to support most 5G services. Although its range is limited, high-band 5G, also known as millimeter-wave 5G, provides the fastest speeds. In addition to beamforming and massive MIMO (multiple-input multiple-output) technology, 5G technology combines multiple frequencies to improve signal quality and reduce interference. Beamforming utilizes canny receiving wires to think the remote transmission in a specific region, upgrading signal quality and bringing down obstruction. Numerous antennas are used in massive MIMO to increase data transport efficiency and increase network capacity.

5.1 5G architecture

To meet the ever-increasing demand for faster data rates, lower latency, and more dependable connectivity, the fifth generation (5G) of mobile communication networks was developed. This subsection gives an outline of the 5G design, its key parts, and the fundamental innovations that empower its high-level abilities. The 5G architecture can be divided into three main components: the radio access network (RAN), the core network (CN), and the user equipment (UE) as illustrated in **Figure 2** [36].

Feature	5G	4G
Speed	Fast, up to 20 Gbps	Fast, up to 1 Gbps
Latency	Low, 1 ms or less	High, 20 ms or more
Bandwidth	A high, wider range of frequencies	Limited, primarily below 6 GHz
Capacity	High, supports more devices	Limited, congestion in densely populated areas
Reliability	High, improved network architecture	Moderate, prone to network congestion

Table 3.
5G versus 4G key features.

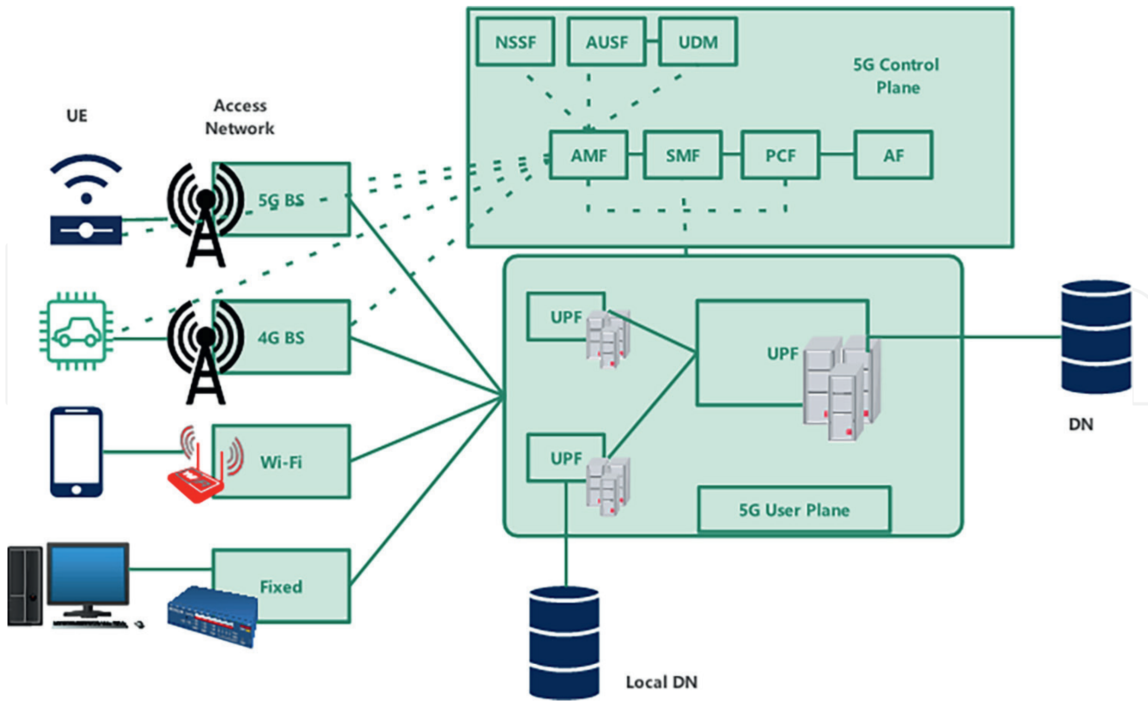

Figure 2.
5G architecture based on the control plane and user separation showing the UE, RAN, and CN [35].

The wireless communication between the UE and the CN is the responsibility of the RAN. Beamforming and massive multiple-input multiple-output (mMIMO) are two advanced technologies that have been incorporated into 5G's RAN [37]. The RAN can support higher data rates and more simultaneous connections thanks to beamforming and mMIMO, which also reduce latency. 5G's core network (CN) is in charge of data routing and connection management among various network components. Utilizing techniques of network slicing and virtualization, the 5G CN is designed to be more adaptable and scalable than previous generations [38]. It creates customized network configurations for various use cases. The smartphones, tablets, and IoT devices that are connected to the 5G network are referred to as the UE. To fully utilize the capabilities of the network, these devices must support the advanced features of 5G, such as new waveform designs and higher frequency bands [36].

5.2 Key technologies in 5G

Several key technologies enable the advanced capabilities of 5G networks. Some of these technologies include:

- Network Slicing: On a single physical infrastructure, multiple virtual networks can be created using network slicing, with each slice tailored to specific use cases [38]. Operators can optimize resources and provide individualized services to various user groups as a result of this.

- Massive MIMO: To boost capacity and spectral efficiency, Massive MIMO uses a lot of antennas at the base station [37]. Higher data rates and a greater number of simultaneous connections are made possible by this technology in 5G networks.

- Beamforming: Beamforming is a method that directs the radio signal in a particular direction to increase signal strength and decrease interference [37]. Beamforming also supports higher frequency bands and increases network capacity in 5G networks.

The goal of the 5G architecture is to meet the growing need for faster data rates, lower latency, and more stable connectivity. 5G networks have the potential to support a wide range of use cases and deliver improved performance by incorporating cutting-edge technologies like beamforming, massive MIMO, and network slicing.

5.3 Benefits of 5G

The fifth-generation (5G) wireless technology is a ground-breaking innovation in the telecommunications industry that offers numerous advantages over its predecessors. The benefits of 5G technology, such as increased data rates, decreased latency, increased network capacity, improved energy efficiency, and the facilitation of new applications and services [39]. The benefits of 5G include:

- Enhanced data rates: With peak data rates reaching 20 Gbps, 5G networks can deliver data speeds up to 100 times faster than 4G networks [40]. Users will be able to quickly download and stream high-quality content thanks to this increased speed [39].

- Reduced latency: The amount of time it takes for a signal to travel from the sender to the receiver is referred to as latency. When compared to 4G networks, which have a latency of approximately 50 ms, 5G networks have a significantly lower latency of as little as 1 ms [39]. In applications like gaming, virtual reality, and remote surgery [40], the reduction in latency makes it possible to communicate in real-time and enhances the user experience.

- Increased capacity of the network: 5G networks are essential for the expanding IoT ecosystem because they can simultaneously support a greater number of devices than 4G networks [39]. This increased capacity makes it possible to have better connectivity and less network congestion, making the network more reliable and effective [40].

- Improved energy efficiency: 5G technology is more environmentally friendly than previous generations because it uses advanced network architectures and techniques to save energy [39]. This improved energy productivity diminishes functional expenses for network suppliers as well as adds to worldwide maintainability endeavors [40].

- New applications and services: New applications and services that were not possible with previous wireless technology generations are made possible by 5G technology. Innovations in a variety of industries, including Industry 4.0, smart cities, telemedicine, and autonomous vehicles, are made possible by the convergence of high data rates, low latency, and increased network capacity [39].

5G technology offers numerous benefits, including enhanced data rates, reduced latency, increased network capacity, improved energy efficiency, and the facilitation of new applications and services. It also has the potential to transform the way we live, work, and communicate [40]. Because of these benefits, 5G will play a crucial role in the future of telecommunications and could have an impact on a variety of industries and aspects of daily life.

5.4 Challenges and limitations

- Implementing 5G technology comes with many drawbacks and difficulties that must be resolved. The use of millimeter wavelengths, which are smaller and do not travel as far as those used in 3G and 4G networks, is one of the primary limitations. As a result, 5G's coverage profile is smaller than that of previous generations. Carriers are deploying a larger array of antennas to provide sufficient coverage to overcome this limitation.

- The use of energy is another obstacle to 5G technology implementation. Due to the increased number of antennas required for coverage, 5G networks consume more energy than previous generations [41]. Businesses may face increased costs as a result, and additional infrastructure may be required to support the network.

- Implementing 5G technology poses another obstacle in the form of latency. Although 5G promises to have lower latency than previous generations, achieving this requires significant infrastructure and technology investments [42]. In addition, interference from other wireless signals can affect latency and slow down the network.

- 5G technology also presents a challenge in terms of spectral efficiency. Although 5G can transmit more information than earlier cellular networks, it needs a larger area to achieve higher spectral efficiency [42]. The need for higher spectral efficiency may require more infrastructure investment and reduce the amount of spectrum available for other uses.

Implementing 5G technology has several advantages in virtual and argument reality, transportation, healthcare, the environment, and edge computing. Some several drawbacks and difficulties must be resolved. These include difficulties with spectral efficiency, a small coverage area, high energy consumption, latency, and other issues. Tending to these difficulties will require a critical interest in foundation and innovation via transporters and organizations the same.

6. 5G in virtual and augmented reality

The way we interact with digital content has been transformed by transformative technologies like VR and AR. They enable users to interact with digital content in ways that were previously only possible in science fiction by providing immersive experiences that combine the real and virtual worlds. This chapter discusses the history, applications, and potential developments of virtual reality and augmented reality concerning 5G.

VR is a computer-created climate that recreates actual presence in genuine or envisioned universes, permitting clients to cooperate with the climate reasonably [43].

Figure 3.
A person in a head-mounted display (HMD).

Head-mounted displays (HMDs) as illustrated in **Figure 3** are used to create a VR experience which gives users a 360-degree view of the virtual environment. The system can adjust the view based on the user's head movements, giving the impression of presence.

AR enhances the user's perception of reality by overlaying digital content on their view of the real world. AR can be experienced with a variety of devices, including AR glasses (See **Figure 4**), smartphones, and tablets. This innovation can change how we access data and associate it with our general surroundings. Dissimilar to VR, AR does not supplant the client's current circumstance yet rather upgrades it with logically pertinent computerized content [44].

6.1 Brief history of VR and AR

The creation of the first head-mounted display (HMD), which Ivan Sutherland dubbed the "Sword of Damocles," in the 1960s is the beginning of the history of virtual reality and augmented reality. Since then, the market for consumer VR devices like the Oculus Rift, HTC Vive, and PlayStation VR has grown significantly. In a similar vein, advances in AR can be seen in the development of AR headsets like Microsoft's HoloLens and Magic Leap One and smartphone-based augmented reality experiences like Pokémon Go [45].

6.2 Applications of VR and AR

Various sectors, including manufacturing, education, healthcare, and entertainment, have utilized VR and AR. VR gaming and 360-degree videos have gained popularity in the entertainment industry, while AR has been used to enhance live events and create interactive experiences [46]. In education, VR and AR can provide immersive learning experiences that allow students to explore historical sites, visualize complex concepts, and practice skills in a secure setting [47]. VR is used for pain

Figure 4.
A lady in AR glasses.

management, rehabilitation, and surgical training, and AR is used to assist surgeons during procedures [48]. Healthcare has also benefited from these technologies. VR and AR have the potential to simplify procedures, enhance instruction, and support product design and prototyping in manufacturing [49].

As developments in software, hardware, and content creation continue, the future of VR and augmented reality holds a lot of promise. The development of new display technologies and input devices may further enhance immersion, and the integration of artificial intelligence and machine learning may result in experiences that are more realistic and personalized. The impact of these technologies on society and our interactions with the outside world will continue to expand as they become more affordable and accessible.

6.3 Benefits of 5G for VR and AR

The development of 5G technology has the potential to completely alter our relationship with the digital world. 5G is expected to significantly benefit AR and VR applications due to its extremely low latency, increased capacity, and high-speed connectivity.

- Providing an immersive and seamless experience is one of the primary advantages of 5G for AR and VR. Real-time interaction and instantaneous response in AR and VR applications are made possible by the extremely low latency of 5G, which can be as low as one millisecond [50]. Low latency is essential for applications like remote surgery, where a delay in response time could be detrimental [51]. In addition, the high-speed connectivity of 5G, with the potential to reach speeds of up to 20 Gbps makes it possible to stream content of high quality that uses a lot of data. 5G in AR and VR provides an experience that is both smooth and uninterrupted [50].

- 5G for augmented reality and virtual reality supports a large number of connected devices. 5G networks can accommodate the growing number of AR and VR devices because they can handle up to a million devices per square kilometer [51]. For large-scale deployments in smart cities, industrial applications, and entertainment venues, this increased capacity is necessary.

- Edge computing, made possible by 5G, enables data processing to occur closer to the data's source [51]. 5G technology makes it less necessary to send data between devices and data centers, which reduces latency and boosts AR and VR applications' performance. Edge registering likewise upgrades the protection and security of information by keeping it nearer to the client [51].

- New use cases and applications will also be made possible by combining 5G with AR and VR technologies. 5G-powered AR and VR can, for instance, provide users with immersive learning experiences that allow them to explore virtual environments and interact with digital content in real-time [52]. 5G can make telemedicine, remote patient monitoring, and VR-based therapies for mental health and rehabilitation possible in the healthcare industry [51].

Applications in AR and VR stand to gain significantly from 5G technology's ultra-low latency, high-speed connectivity, increased capacity, and edge computing. These advantages will make it possible to have an immersive and seamless experience, support a large number of connected devices, and open up new applications and use cases in a variety of industries.

7. 5G and transportation

New opportunities for innovation, efficiency, and safety are presented by 5G technology, which has had and will have a significant impact on the transportation industry. The development of new technologies, such as high-speed networks, decentralized storage systems, edge computing, and others, has made it possible to operate a car with little to no human involvement. The use of 5G means that the way cars connect and the infrastructure around cars could be completely altered by 5G. Vehicles that operate without the direct input of the driver are referred to as autonomous vehicles (AV). AVs do not require the driver to continuously monitor the road. AVs are also referred to as driverless automobiles or autonomous cars. With enhanced safety measures and enhanced energy efficiency, the AVs appear to be a promising technology with reduced environmental impact. Due to the impact of 5G, major automakers are adding more AVs to their fleets. For instance, Mercedes-Benz has implemented autonomous driving (AD) in its S-class automobile. Similarly, Tesla has already developed cutting-edge software and hardware to enable completely driverless driving (level 5 automated vehicle).

Figure 5 illustrates the levels of vehicle automation from conventional vehicles (CVs) to connected autonomous vehicles (CAVs) whereas **Figure 6** shows the levels of automation in autonomous vehicles. However, to enable fully autonomous driving and high-speed networks, fifth-generation (5G) or beyond 5G (B5G) technologies, is the key to a successful implementation of the levels of autonomy required by such vehicles [36]. The switch from conventional vehicles to fully autonomous vehicles is a slow but sure process that 5G will spearhead as illustrated in **Figure 6**.

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	Features															Technologies			
	Data Transmission	Data Analysis	Safety	Energy Consumption	Comfort for Driver	Comfort for Passenger	Independent Decisions	Sensors	Computer Vision	Wireless Communication	Tracking	Environment Awareness	Resource Consumption	Process Optimization	Self- Protection	Co-operative Driving	Physical Layer Security	Cloud/Edge/Fog/Roof Computing	mmWave
Conventional Vehicles	N	N	L	H	L	M	N	N	N	N	N	N	H	N	N	NA	NA	NA	NA
Connected Vehicles	M	N	L	M	L	M	N	L	N	M	M	L	H	N	N	A	NA	A	NA
Advanced Connected Vehicles	M	L	M	L	L	M	N	L	L	M	M	M	H	N	N	A	NA	A	NA
Self-driving Vehicles	L	L	M	M	M	H	N	M	M	M	L	M	H	N	L	NA	NA	A	A
Autonomous Vehicles	M	M	H	L	H	H	M	H	H	M	M	M	M	M	M	A	A	A	A
Connected Autonomous Vehicles	H	H	H	L	H	H	H	H	H	H	H	H	L	M	H	A	A	A	A

L Lower Level: This feature does not play a vital role and is not given importance while manufacturing.
M Medium Level: This feature is taken into account while manufacturing but not wide coverage.
H High Level: This feature plays a vital role and is given higher importance while manufacturing.
N Not Available. NA Not Applicable. A Applicable.

Figure 5.
Conventional Vehicles to Connected Autonomous Vehicles (CV-CAV) [53].

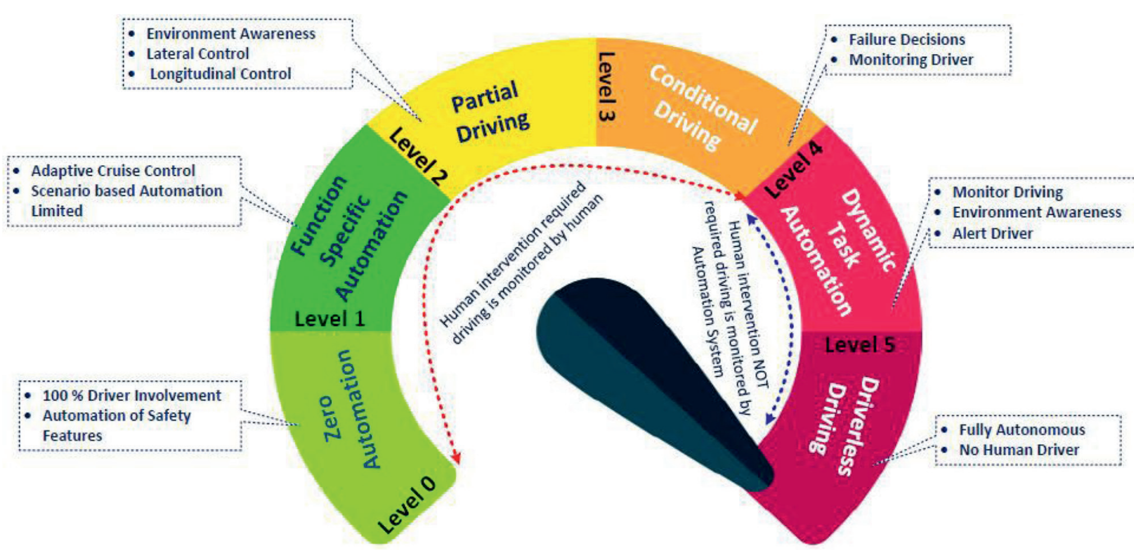


Figure 6.
Levels of automation in autonomous vehicles [53].

7.1 Evolution of autonomous vehicles

The idea of AVs has been around for decades. In recent years have seen significant technological advancements and the pursuit of more effective transportation systems accelerate their development [54]. The development of autonomous vehicles, from their infancy to the present, and the significant milestones achieved along the way will be briefly discussed in this subsection. AVs have been around since the 1920s when experiments with radio-controlled automobiles were carried out [55]. The first truly autonomous vehicle, the VaMoRs, was created in the 1980s by Ernst Dickmanns and his group at the Bundeswehr University Munich [56]. The VaMoRs paved the way for subsequent research in the field by utilizing cameras and computer algorithms to navigate and avoid obstacles.

The Autonomous Land Vehicle (ALV) program was started in the 1990s by the Defense Advanced Research Projects Agency (DARPA) of the US Department of

Defense. Its goal was to create vehicles that could operate independently in off-road environments. ALV program prompted the improvement of the NavLab series via Carnegie Mellon College, which exhibited the capability of independent driving in different circumstances. The DARPA Grand Challenge, a series of competitions in which teams were challenged to create autonomous vehicles capable of traversing desert terrains, spurred significant advancements in AV technology in the 2000s [57].

New algorithms and sensor technologies were developed as a result of these competitions, as were government, business, and academic partnerships. Google's self-driving car project, which is now known as Waymo, was the pioneer in the field of AV development in the 2010s [58]. In 2014, Tesla released its Autopilot feature, which enabled semi-autonomous highway driving [59]. In the interim, Uber and Lyft started investigating independent ride-hailing administrations, flagging the potential for AVs to upset conventional transportation frameworks [60]. Companies like Waymo, Cruise, and Argo AI are leading the charge in testing AVs in a variety of settings worldwide today [61]. Countries like Germany, China, and the United States have enacted policies and invested in infrastructure to support, regulate, and regulate the development and deployment of AVs [62]. The widespread use of AVs is anticipated to have a significant impact on transportation, urban planning, and society as a whole as the technology develops further [63].

7.2 Benefits of 5G for transportation

Increased safety, better efficiency, and new chances for innovation are some of the primary advantages of 5G for the transportation sector.

- Increased safety**:** Cars can interact with one another and the infrastructure around them with the help of 5G, which will improve traffic flow and reduce the likelihood of accidents. 5G-enabled automobiles, for instance, have the potential to make better decisions and steer clear of potential dangers thanks to real-time traffic and road condition updates.

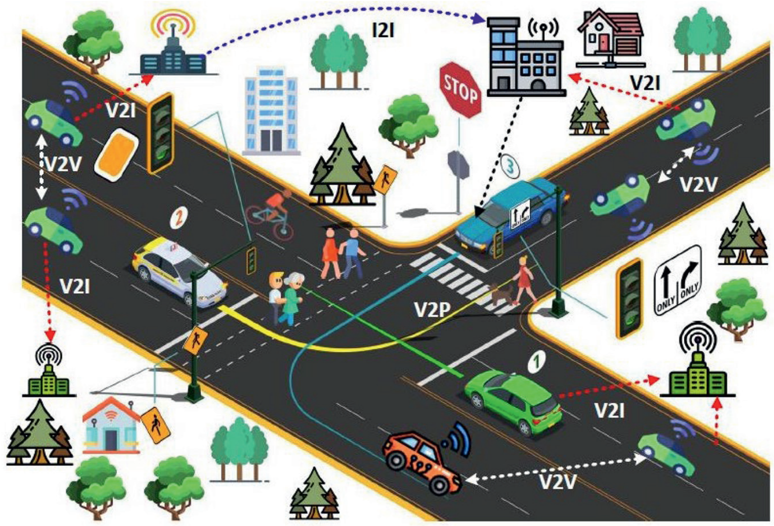
- Improved efficiency**:** The transportation industry's productivity could rise as a result of 5G. 5G-enabled automobiles, for instance, may communicate with traffic control systems and with one another to enhance traffic flow and routing. This may result in less traffic and shorter travel times, which will reduce emissions and fuel consumption.

- More opportunities for creativity: Ultimately, 5G presents new opportunities for mechanical progression in the transportation area. For instance, 5G can enable previously impractical new services and applications by supporting emerging modes of mobility like connected drones and driverless cars.

7.3 Applications of 5G in transportation

There are several possible uses for 5G in the transportation sector, including:

- Vehicle connectivity: Real-time communication, improved efficiency, and increased safety can all be achieved through the use of 5G, which can connect cars to nearby infrastructure and one another as illustrated in **Figure 7**. For example, 5G can be used to make vehicle-to-vehicle (V2V) communication



V2V – Vehicle to vehicle | I2I – Infrastructure to Infrastructure | V2I – Vehicle to Infrastructure | V2P – Vehicle to People

Figure 7.
Connected autonomous vehicles, infrastructure, environment, and communication [53].

easier. This lets cars share information in real-time about traffic conditions, potential road hazards, and other important information.

- Autonomous vehicles: Driverless vehicles can be built and used with the help of 5G, expanding mobility options and improving road safety. Due to its low latency and high speed, 5G can provide the real-time communication and data transfer that autonomous cars need to navigate their environment and make educated decisions.

- Intelligent transportation systems: 5G has the potential to facilitate the development of these systems, opening up new services and applications that improve traffic safety and efficiency. 5G could, for instance, support real-time traffic management and routing, which would improve traffic flow and reduce congestion.

- Drones: New transportation-related applications and services are now possible thanks to the use of 5G to connect drones to ground-based control systems and each other. 5G facilitates the use of connected drones for delivery, inspection, and surveillance.

8. 5G in healthcare

The introduction of 5G technology has the potential to have a significant impact on the healthcare industry because it presents new opportunities for innovation, efficiency, and improved patient outcomes. 5G has the potential to completely alter the way healthcare is provided and consumed because it can enable previously unimaginable new services and applications. Digital 5G technology has the potential to enhance healthcare services for patients and healthcare professionals at any time and from any location [64]. It can also contribute to more efficient medical research, diagnosis, and treatment. AI will support a variety of novel applications, including virtual and augmented reality [65, 66] and 5G technology will offer significantly faster data speeds. Deep learning technology has also been the subject of studies involving the application of technology to the secondary diagnosis of breast cancer [67]. However, in other fields, such as telerobotic surgery [68] and remote surgical procedures supported by the 5G network [69], significant progress has been made in recent years regarding its contribution.

8.1 Benefits of 5G for healthcare

Patient outcomes are better, efficiency is higher, and there are more prospects for innovation with the advent of 5G. One of the most significant advantages of 5G for the medical industry is the improvement of patient outcomes. With minimal latency, 5G can provide novel telemedicine and remote care models that enable physicians to diagnose and treat patients at a distance as illustrated in **Figure 8**. This may be very helpful to people who live in rural or isolated areas and may not have access to local healthcare facilities. Besides, 5G can give constant observing and following of patient information, empowering medical services professionals to go with better-taught choices and answer quickly to changes in a patient's condition. 5G in healthcare also provides proficiency gain and offers more opportunities for creativity among medical personnel.

- Proficiency gain: 5G can also boost the efficiency of the healthcare industry by making it easier for doctors and patients to communicate and send data in real-time. Medical professionals may be able to make decisions more quickly and thoroughly as a result of 5G's efficiency, which may reduce wait times and improve information flow. In addition, 5G can facilitate the automation of several procedures, decreasing the likelihood of human error and enhancing overall healthcare delivery efficiency.

- More opportunities for creativity: Last but not least, 5G opens up new opportunities for healthcare innovation. For instance, telemedicine platforms, remote

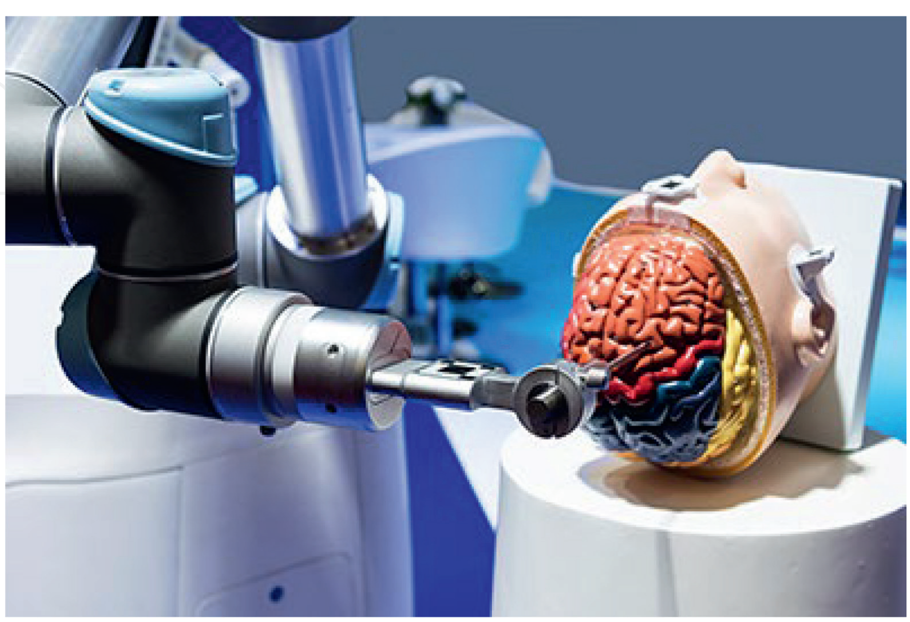


Figure 8.
5G-powered medical robot performs remote brain surgery [70].

patient monitoring systems, and wearable health monitors can all benefit from 5G's assistance in the creation and implementation of new medical technology and equipment. In addition, new services and apps like AR and VR in healthcare can be developed with 5G's assistance, opening up new opportunities for patient training, education, and treatment [71].

8.2 Applications of 5G in healthcare

There are many potential applications of 5G in healthcare, including:

- Telemedicine: With the backing of 5G, telemedicine services may be delivered, allowing medical professionals to diagnose and treat patients remotely. 5G can provide real-time video conferencing and data transmission with low latency and high-speed connectivity, allowing healthcare practitioners to make educated choices and react swiftly to changes in a patient's condition.

- Remote patient monitoring (RPM): RPM is possible with 5G, allowing healthcare professionals to gather and evaluate patient data in real-time. The adoption of wearable health monitors, for instance, can be supported by 5G, allowing patients to communicate data on their vital signs to their healthcare practitioners for immediate analysis and action [69].

- Virtual and augmented reality: 5G can facilitate the usage of VR and AR in healthcare, opening up new avenues for patient training, education, and treatment. For example, 5G can facilitate the use of VR simulations for surgical training, enabling healthcare personnel to perform complicated procedures in a safe, virtual environment.

- Medical equipment: 5G can help the creation and introduction of new medical devices, including telemedicine systems and wearable health monitoring. 5G can offer real-time data transfer and analysis with low latency and high-speed connection, allowing healthcare practitioners to make educated decisions and react swiftly to changes in a patient's condition. **Figure 9** presents a summary of the applications of 5G in healthcare.

9. 5G and the environment

The introduction of 5G technology has a significant impact on the environment. 5G has the potential to exacerbate environmental issues like rising energy consumption and technological waste.

9.1 Benefits of 5G for the environment

Given that the long-term effects of this new technology are unknown, the environmental impact of 5G is cause for concern. However, there may also be environmental advantages to 5G. The reduction of emissions and energy consumption is one of the most significant advantages. According to international standards, 5G should use much less power to operate than 4G, thereby transmitting more data while using less power. In 4G, for instance, 300 high-definition movies can only be downloaded with

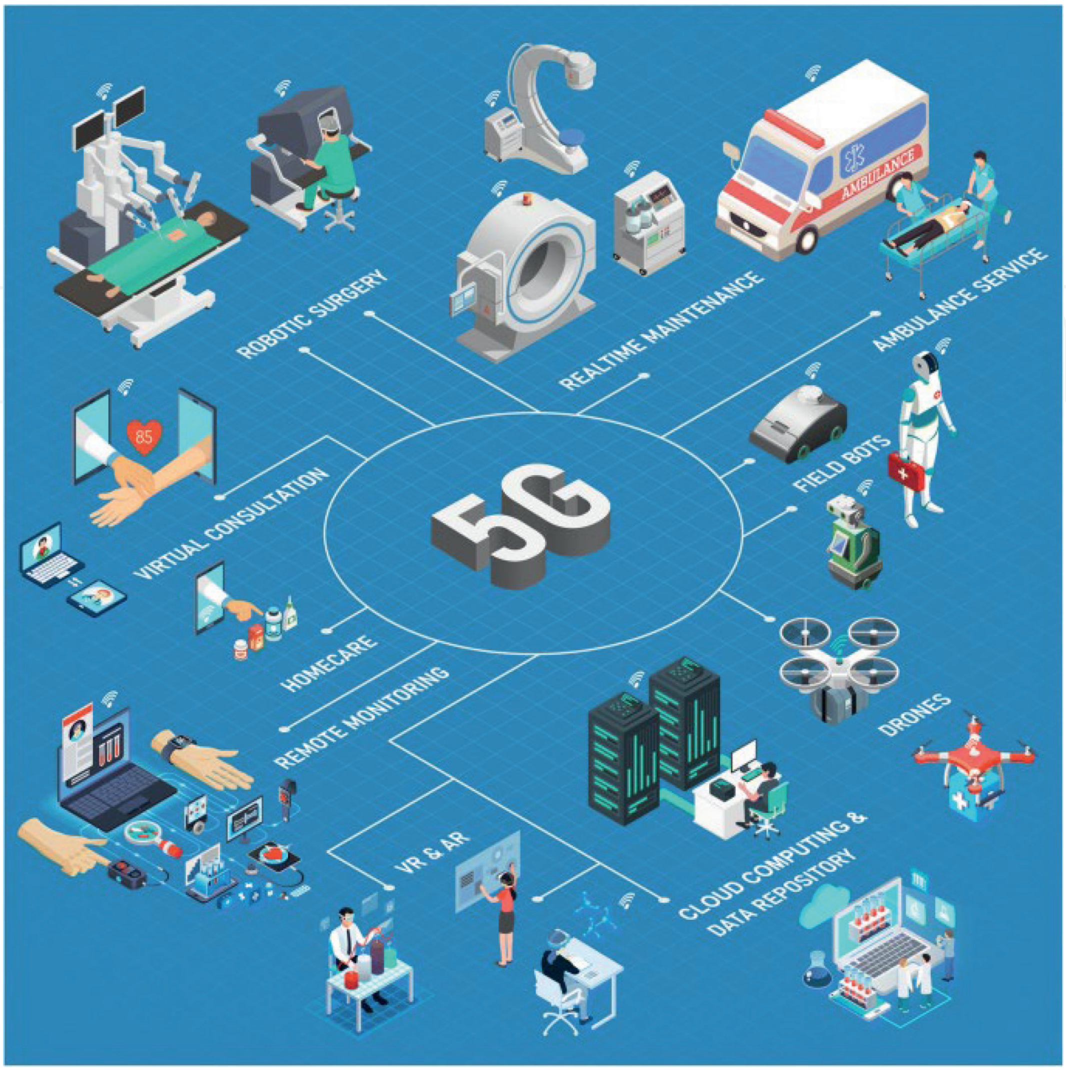


Figure 9.
5G technology revolutionizing healthcare [72].

one kWh of electricity; One kWh of 5G capacity can download 5000 HD movies. Data centers in 2020 were using 73 billion kWh of energy due to the increased efficiency of 5G technology [73].

5G is significantly more energy-efficient than previous generations of mobile networks, according to research conducted by the University of Zurich and Empa [74]. The study also concluded that applications like flexible working and smart grid technology that uses 5G have a lot of potentials to save energy and protect the environment [74]. Together with the increased use of environmentally friendly energy sources, real-time monitoring of the built environment has the potential to cut carbon emissions by 67.9 million metric tons [75]. This reduction will be made possible by energy grids, smart meters, and energy management systems that are enabled by 5G [75].

With IoT and 5G, we can fully comprehend the impact on the environment and respond accordingly [76]. Stakeholders will be able to forecast, optimize, and measure the impact of the environment using real-time data as 5G is implemented globally [76]. Once the right infrastructure is in place, 5G may also enable a new phase of the green revolution. Experts are hopeful that the increased speed of data sensors will result in a more efficient than ever real-time energy conservation system [76].

Although the long-term environmental effects of 5G are unknown, there may be advantages to using this new technology. Real-time monitoring of the built environment, as well as the facilitation of the green revolution, are some of the potential benefits of 5G. But it is critical to keep an eye on how 5G affects the environment and take steps to minimize any negative effects.

9.2 Challenges and limitations

Notwithstanding the advantages, there are several challenges and restrictions related to 5G and its effects on the environment. The challenges include but are not limited to:

- Increasing the amount of energy used: The extent to which 5G will impact energy consumption is a major issue. To support 5G, additional equipment and cell towers must be installed, which may raise energy costs and increase emissions of greenhouse gases. In addition, laptops and smartphones that are 5G-capable are anticipated to consume more energy than their 4G counterparts.

- Waste electronics: It is anticipated that 5G technology will increase the amount of electronic waste as older, 5G-enabled devices are replaced with newer ones. If electronic trash contains toxic substances that harm wildlife and the ecosystem, this could be bad for the environment.

- Human health and the environment: There are worries about 5G affecting human health and the environment. Although the scientific evidence is still murky, several studies have demonstrated that 5G radio frequency (RF) emissions may have negative effects on animal and human health, including decreased fertility, increased risk of cancer, and altered migratory patterns [4] Additionally, it is anticipated that the full rollout of the 5G infrastructure will have a significant impact on the environment due to the need for new cell towers and other equipment. This could lead to deforestation, habitat destruction, and other problems with the environment.

10. 5G and edge computing

Edge computing aims to move decision-making operations as close as possible to data by extending cloud computing services to the network's edge [77]. Edge computing is turning out to be progressively famous because of the developing interest in constant information handling and the need to diminish dormancy [78]. The architecture of edge computing consists of three layers: a cloud layer, an edge layer, and a device layer [78] as illustrated in **Figure 10**. Sensors, actuators, and other devices that gather data make up the device layer. Edge servers, gateways, and other data-processing devices make up the edge layer. Cloud servers, which store data and provide cloud services, make up the cloud layer [78].

10.1 Benefits of edge computing

There are several benefits to edge computing, including:

- Reduced latency: Edge computing can significantly shorten the time it takes for data to travel from the source to the processing unit by processing it locally,

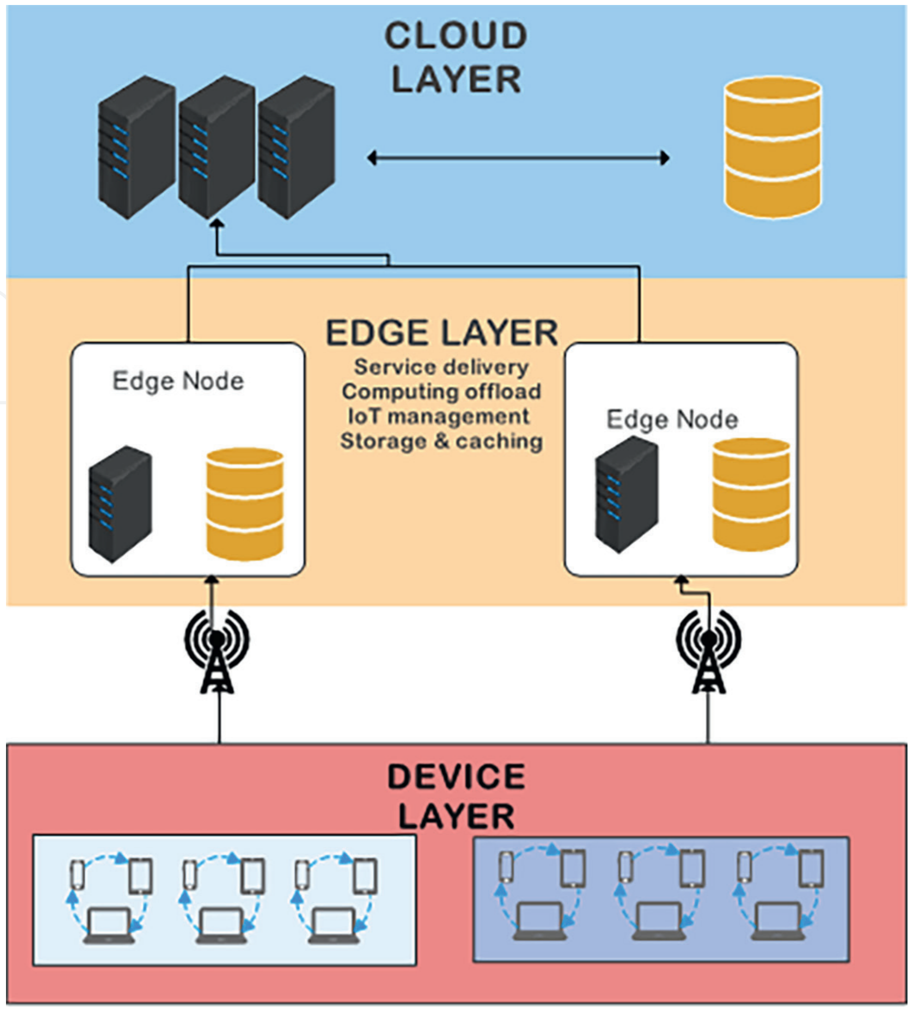


Figure 10.
Edge computing architecture.

resulting in faster response times [79]. This is especially important for applications like telemedicine, autonomous vehicles, and smart cities that require processing in real-time or near real-time [80].

- Bandwidth usage reduction: Sending a lot of data to a centralized cloud can use up a lot of network resources, which can cause congestion and increase costs [79]. By processing data locally, edge computing alleviates congestion and reduces the amount of data that must be transmitted over the network [81]. This can save a lot of monetary resources, especially in applications that collect a lot of data, like IoT devices and industrial automation [80].

- Improved data security and privacy: Organizations may ensure compliance with data protection regulations and reduce the risk of data breaches by storing sensitive data on the edge device [81]. Furthermore, by enabling localized encryption and decentralized authentication, edge computing can provide additional security layers [82].

- Adaptability: By dispersing computing resources across the network, edge computing can assist businesses in scaling their infrastructure more effectively as the number of connected devices and data volumes continue to rise [81]. Because a single-edge device's failure is less likely to have an impact on the entire network, this decentralized approach can also improve system resilience.

Edge computing offers advantages which include decreased latency, reduced bandwidth consumption, enhanced data privacy and security, and increased scalability. Edge computing is an appealing option for a wide range of applications, particularly those that involve large-scale data collection and real-time processing.

10.2 The benefits of 5G and edge computing

The combination of 5G and edge computing offers several key benefits, including:

- Low latency: The low latency of 5G connectivity enables real-time data processing and transfer. Edge computing significantly reduces latency by processing and storing data closer to the source rather than relying on centralized data centers. This combination of low-latency communication and local data processing is suitable for applications that require real-time data processing, such as driverless cars and virtual and augmented reality.

- Better connectivity: Numerous connected devices may be supported by 5G's improved connection. By processing and storing data closer to the source, edge computing may improve connection even further, reducing the need for centralized data centers and boosting productivity.

- Enhanced Privacy: Edge computing can improve privacy by reducing the need to send sensitive data to centralized data centers by processing and storing it locally. One of 5G's improved security features, network slicing, can further enhance privacy and security.

- Increased Adaptability: Edge computing may be easier to scale than centralized data centers because the number of devices can be increased as needed. Because it can handle the increasing number of connected devices, 5G is the best option for the Internet of Things.

11. Conclusion

Virtual and augmented reality (VR/AR), transportation, healthcare, the environment, and edge computing are just a few of the areas that have seen significant shifts since the introduction of 5G technology. The main effects of 5G on these industries are outlined in this concluding chapter, along with the potential benefits and challenges that lie ahead. 5G's ultra-low latency and high bandwidth capabilities have made it possible to create immersive and seamless VR/AR experiences [83]. Real-time applications like remote collaboration, gaming, and training have been made possible by these enhancements, paving the way for the widespread adoption of VR/AR technologies across various industries. Enhanced connectivity has fueled the growth of autonomous vehicles, smart traffic management systems, and vehicle-to-everything (V2X) communication, resulting in safer and more efficient transportation networks [84]. The transportation sector has also witnessed significant advancements as a result of 5G. The expansion of telemedicine, remote monitoring, and robotic surgery in the healthcare industry has been made easier by 5G, improving both access to medical services and the overall quality of care. In addition, the integration of 5G with IoT devices has sped up the creation of smart healthcare systems, resulting in better outcomes for patients and lower costs [85]. There are both benefits and drawbacks to the environment from 5G. Through increased efficiency across a variety of industries, 5G has the potential to, on the one hand, cut down on emissions and energy consumption. However, additional research is necessary due to concerns about the potential health risks posed by higher-frequency radio waves and the increased energy requirements for 5G infrastructure. Last but not least, real-time data processing and analytics at the network's edge have been made possible by 5G, which has revolutionized edge computing by lowering latency and increasing system efficiency. Innovative applications have emerged in a variety of fields, including smart cities, agriculture, and manufacturing [82]. 5G will have profound and far-reaching effects on VR/AR, transportation, healthcare, the environment, and edge computing. Stakeholders need to address the obstacles and take full advantage of this revolutionary technology as 5G networks continue to grow.

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