

Future of 5G Wireless System

Jayanthkumar A Rathod¹, Anvesh A Shetty², Hithashree³, Rakshitha⁴, Sneha S⁵, Apeksha K⁶

Professor, Department of Computer Science and Design¹

4th Sem, Department of Computer Science and Design^{2,3,4,5,6}

Alva's Institute of Engineering and Technology, Mijar, Moodbidiri, India

(Affiliated to Visvesvaraya Technological University, Belagavi)

jayant1977@aiet.org.in, shettyanvesh86@gmail.com, hithamadival@gmail.com,

rakshithadamodara3@gmail.com, 4a122cg056@gmail.com, 4a122cg005@gmail.com

Abstract: *This research article offers a comprehensive study of 5G wireless networks' future, covering a range of topics from their conception to their anticipated course. The article starts with an introduction and focuses on how 5G technology can revolutionize connection and enable cutting-edge apps and services. The evolution of mobile communication networks from 1G to 5G is then traced, with an emphasis on the societal influences and technological developments that have shaped the current state of the telecom industry. This article examines the present state of 5G networks, highlighting their key features, improvements over earlier generations, and global rollout status. In addition, the article explores the technological developments that are propelling 5G's development, such as network slicing, the use of millimetre wave spectrum, and the deployment of standalone modes, and examines how these can affect network performance. The Internet of Things (IoT), smart cities, remote surgery, and emerging applications like augmented and virtual reality (VR) and AR are some of the applications that are made possible by 5G. Other applications that are explored include security concerns, infrastructure development costs, and regulatory obstacles. The paper concludes with insights into the exciting possibilities and considerations surrounding the future of 5G technology. Finally, the article gives several projections and forecasts regarding the future of 5G, discussing probable dates for wider adoption and the next steps in 5G development.*

Keywords: 5G

I. INTRODUCTION

5G Wireless communication and mobile networks are facing many challenges to meet the unprecedented growing demands for access to wireless services with ultra-low latency and high data rates. 5G network today is the core technology of many cutting-edge technologies such as the internet-of-things (IoT), smart grid, unmanned aerial systems, and self-driving vehicles. 5G wireless networks are required to be characterized by high flexibility in design and resource management and allocation to meet the increasing demands of these heterogeneous networks and users. The integrity and confidentiality of data being transported from a sender to a recipient in a mobile communication device are crucial. For 5G to be credible, a system could be applied to enable the processing of encrypted messages via mobile devices. The message will be encrypted and contain both encryption accessing information and encrypted content. This way, when a mobile device receives a message, it can store the information in its memory for later use. The information obtained from the memory will be retrieved to enable decryption and make the message readable after it has been encrypted. A key component of 5G New Radio, according to the 3GPP's 2017 5G standards, is design flexibility. This is accomplished by combining virtual network function (NRF) and software-defined network (SDN) capabilities. With precise predictions of network behaviours, traffic needs, and user mobility, a flexible 5G system that can adapt in real-time to optimize resource allocation while improving user quality of experience is made possible by this adaptability. Artificial Intelligence (A.I.) is expected to be the next significant "game-changing" technology that will provide 5G the intelligence and flexibility it needs, according to many top wireless research groups. because of this, several academics have looked at how effective this theory is in various 5G wireless applications. The capacity to

send signals wirelessly via electromagnetic waves was first shown more than a century ago, in the 1890s, in the renowned wireless telegraphy experiment carried out by Nobel Laureate G. Marconi [1].

It took over eight decades to develop commercial programs that allow real-time communication between users. Since then, advancements in communication theory, multiplexing techniques, microelectronics and integrated circuits (ICs), microwave circuits and antennas, and other related fields have led to a rapid evolution of mobile communications technologies [2], [3]. A new generation has formed nearly every decade since the 1980s [4]. Frequency-division multiplexing access (FDMA) was used to provide Analog communications in the first generation (1G) of mobile communications.

II. GENERATIONS OF NETWORKS

2.1 First-Generation:

The development of mobile communication is a monument to human resourcefulness and the unwavering quest for connectivity. The advent of 1G networks, the innovative analogue cellular systems that set the stage for the mobile revolution, is central in this investigation, looking at their inception, technological foundations, and lasting influence on the development of the contemporary telecoms industry. The inception of mobile telephony may be traced back to the early 1900s when forward-thinking engineers and innovators imagined a time when communication would not be limited by geographical locations. However, the goal of wireless voice communication did not start to come true until the 1970's and 1980's[5].

Pioneers like Motorola, who led the creation of the first commercially available cellular systems, are credited with helping 1G networks come into being. The Dyna TAC 8000X, introduced by Motorola in 1983, is recognised as the world's initial handheld mobile phone and marked the beginning of the mobile age[5]. Analogue modulation techniques, which made it possible to transmit voice signals over radio waves, were the foundation of 1G networks. 1G technology used continuous wave modulation, in contrast to later digital systems. Voice signals were encoded onto carrier frequencies and sent as analogue signals using this method. Even though this method was novel at the time, it had several drawbacks, such as being susceptible to interference and having comparatively poor call quality.

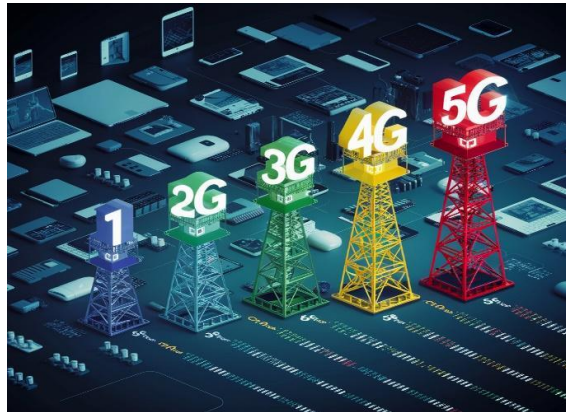
2.2 Second-Generation:

The second generation of cellular technology, or 2G networks, brought digital transmission and a host of additional services beyond simple voice calls, marking a dramatic advancement in mobile communication. The transition from analogue to digital technology during this era was revolutionary and set the stage for the mobile internet revolution that would come in later generations. We examine the salient characteristics, technological developments, and sociological implications of 2G networks in this investigation. Digital modulation, which enables voice sounds to be recorded and sent as digital data, is at the core of 2G technology. Better call quality, more security via encryption, and increased spectral efficiency, which allowed more users to access the network at once, were just a few benefits of switching from analogue modulation. Furthermore, text-based communication between mobile devices was made possible for the first time by 2G networks, which brought new data services like SMS (Short Message Service). This invention transformed communication by offering a practical and affordable substitute for voice calls[5]. The backward compatibility of 2G networks with 1G analogue systems, which for a seamless transfer and broad adoption, was one of its distinguishing characteristics. This commonality made it easier to gradually replace analogue technology with digital, which opened the door for 2G networks to spread over the world. Additionally, 2G networks introduced the idea of worldwide roaming, which allowed users to make and receive calls when travelling overseas. This function would become more and more crucial as mobile communication spread throughout the world.

2.3 Third-Generation:

An important turning point in the development of mobile communication was the introduction of 3G networks, which ushered in the era of mobile broadband and made it possible to use a variety of cutting-edge services beyond simple text messaging and phone calls. When 3G networks were first introduced in the early 2000s, they were a technological quantum leap since they could provide multimedia applications with better capabilities, higher data speeds, and increased network stability. We examine the salient characteristics, technological developments, and sociological

implications of 3G networks in this investigation. The switch to packet-switched networks, which enabled more effective data transmission than earlier circuit-switched systems, was the fundamental development of 3G technology. Video calling, mobile internet browsing, and multimedia messaging are just a few of the multimedia services that have been made possible by this change in network capacity and data speeds. Additionally, 3G networks included support for cutting-edge data protocols like UMTS and CDMA2000, which made it possible to seamlessly integrate data and voice services over a single network architecture. The ability of 3G networks to handle mobile broadband services, which gave consumers access to higher bandwidth and quicker data speeds than previous generations, was one of their most important characteristics. Due to this, customers were able to enjoy a more robust and engaging mobile internet experience, with never-before-seen speeds and dependability for website browsing, video streaming, and file downloads. The way individuals accessed and consumed media was revolutionised by mobile broadband.



2.4 Fourth-Generation:

In terms of mobile communication, the advent of 4G networks was a turning point that ushered in a new era of fast connectivity, low latency, and fluid multimedia experiences. 4G networks, which were first introduced in the late 2000s and early 2010s, expanded upon the infrastructure of their predecessors by offering more network dependability, higher data rates, and more capabilities for a greater variety of applications. We examine the salient characteristics, technological developments, and societal implications of 4G networks in this investigation. Long-Term Evolution (LTE), a packet-switched network technology that provided noticeably faster data rates and more bandwidth than earlier generations, was at the core of 4G technology. Data rates of several hundred megabits per second were made possible by LTE technology, which made it possible to play online games in real-time, stream HD video without lag, and download big files quickly[5]. Additionally, LTE networks had lower latency, which allowed for more rapid communication for uses like voice over IP (VoIP) and video chatting by cutting down on the time it took for data packets to be sent and received. The ability of 4G networks to offer a large variety of multimedia services and applications was one of their distinguishing characteristics[5]. Users could stream high-definition video, access cloud-based services, and participate in bandwidth-intensive activities like virtual reality (VR) and augmented reality (AR) applications thanks to 4G networks' faster data speeds and increased network capacity.

2.5 Fifth-Generation:

With the potential to completely change mobile communication, unleash new avenues for innovation, and completely transform entire industries, 5G networks are a game-changer. 5G networks, which represent the fifth generation of cellular technology, offer previously unheard-of levels of speed, capacity, and dependability by building on the foundation set by previous generations. We examine the salient characteristics, technological developments, and societal implications of 5G networks in this investigation. 5G technology's key feature is its capacity to provide noticeably greater data speeds and reduced latency than earlier generations[5]. 5G networks promise customers an incredibly smooth and immersive connectivity experience, with latency reduced to milliseconds and data throughput possibly reaching multiple gigabits per second.

III. CURRENT STATE OF 5G

3.1 Increased Capacity and Speed: Compared to 4G and 3G networks, 5G networks offer far quicker data rates and more capacity. 5G promises to offer many gigabits per second at its peak data rates, which will allow for lightning-fast downloads, smooth HD video streaming, and low-latency gaming. Numerous bandwidth-intensive services and applications, such as virtual reality (VR), augmented reality (AR), and real-time cloud gaming, are supported by this enhanced speed and capacity.

3.2 Low Latency and High Dependability: Compared to earlier generations, 5G networks have reduced latency and higher dependability, which makes them appropriate for mission-critical applications like industrial automation, remote surgery, and autonomous cars. 5G allows real-time communication and responsiveness, supporting applications that require instantaneous input and minimal delay. Latency is decreased to only milliseconds[7].

3.3 Enormous Connectivity and IoT Support: 5G's capacity to facilitate enormous connectivity, which allows for the simultaneous connection of a large number of devices within a certain area, is another important benefit. The enormous deployment of IoT devices and sensors—from linked cars and smart cities to industrial automation and healthcare monitoring—requires this capacity.



3.4 Flexibility and Network Slicing: 5G networks bring new technologies like virtualization and network slicing that let operators divide their network infrastructure into virtualized slices tailored for particular applications or use cases. Because of this adaptability, network operators can customize their systems to match the various requirements of various sectors and applications, boosting resource efficiency and enhancing performance.

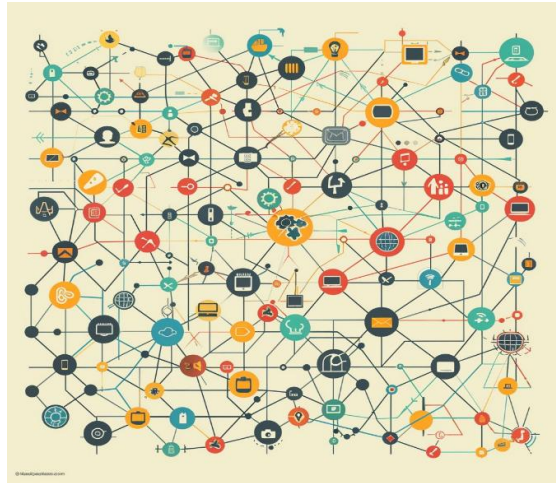
IV. TECHNOLOGICAL ADVANCEMENT

There is a lot of enthusiasm and expectation surrounding the future of 5G technology, as academic institutes and industry experts are predicting and forecasting many aspects of its progress and influence. Here, we examine a few of these forecasts, talk about possible release dates, and explore the next developments in 5G technology, such as 5G Advanced and possibly 6G investigation.

4.1 Forecasts and Predictions: In the upcoming years, 5G technology is expected to increase significantly, according to research organizations and industry executives. Market research companies like GSMA Intelligence and IDC predict that by the end of this decade, there will be hundreds of millions of 5G connections worldwide, and by 2030, there will be billions of devices linked to 5G networks. These projections are fueled by the expanding need for fast internet, the expansion of IoT devices, and the introduction of new services and applications made possible by 5G technology.

4.2 Date of Widespread Adoption: The pace at which 5G technology will be widely adopted will vary by market and location and will be influenced by things like customer demand, regulatory frameworks, spectrum availability, and infrastructure.

4.3 Future Development Steps for 5G: With the development of 5G Advanced and the investigation of 6G, it is anticipated that the technology will continue to progress in the future. Release 16 and beyond, also referred to as 5G Advanced, is a release that expands on the capabilities and performance gains of current 5G standards. Massive machine type communication (MTC), network slicing, and ultra-reliable low-latency communication (URLLC) are a few of the major areas of study for 5G Advanced. Furthermore, studies are also being conducted to investigate the possibilities of 6G technology, which is anticipated to push connection further with even higher data rates, reduced latency, and more sophisticated features and services[7].



4.4 Messenger Lessons: Exciting opportunities exist for 5G technology to change connections and open up new services and applications for a range of sectors and facets of society in the future. With the potential to propel digital transformation and open up new avenues for sustainable innovation, social progress, and economic prosperity, 5G has the ability to alter everything from remote healthcare and immersive entertainment to smart cities and linked infrastructure. But in order to fully utilize 5G technology, issues including public perception, infrastructure development costs, security concerns, and regulatory barriers must be resolved. Stakeholders can fully realize the benefits of 5G technology and capitalize on its future potential by working together and innovating throughout the ecosystem. In conclusion, 5G has a bright future ahead of it with countless possibilities that will change the way we work, live, and interact with technology[7].

V. CONS OF THE NETWORK

Although 5G technology has many advantages and has the potential to completely transform communication, it also has a number of problems that need to be resolved. Comprehending these limitations is important to guarantee that the implementation of 5G networks is efficient and long-lasting. We examine a few of the main disadvantages of 5G technology below:

5.1 Infrastructure Requirements: The substantial infrastructure investment needed for the 5G rollout is one of the technology's main disadvantages. In order to offer coverage and sustain high data speeds, 5G networks rely on a dense network of tiny cells and infrastructure, such as antennas and base stations. The construction of this infrastructure can be expensive and time-consuming, particularly in underserved and rural areas with low population densities and possibly little return on investment.

5.2 Restricted Coverage: Although 5G is expected to offer lower latency and better throughput than previous generations, its initial coverage area is more constrained. 5G signals have a limited range and are more readily obstructed by objects like trees and buildings because of the higher frequency bands that they use. Therefore, 5G service might initially only be available in metropolitan and heavily populated areas, leaving rural and isolated locations with insufficient connectivity[7].

5.3 Interference and Signal Penetration: 5G's vulnerability to interference and signal penetration problems is another disadvantage. The millimetre wave (mm-Wave) spectrum, one of the higher frequency bands used by 5G, is more vulnerable to atmospheric attenuation and obstruction by physical barriers. This can result in poor performance and unstable connectivity, particularly in settings with a lot of urban infrastructure or bad weather[7].

5.4 Health Concerns: The potential health effects of 5G radiation have raised concerns among some segments of the population. While extensive research has been conducted on the safety of radiofrequency (RF) radiation, including that used by previous generations of cellular technology, some individuals fear that the higher frequencies and denser network deployments associated with 5G could pose health risks. However, the scientific consensus is that 5G radiation

exposure is within established safety limits set by regulatory bodies such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP)[7].

5.5 Risks to Privacy and Security: 5G networks bring new privacy and security issues that need to be addressed, just like any other linked technology. There are growing worries regarding data privacy, cybersecurity, and possible weaknesses in network architecture due to the growth of connected devices and the enormous volumes of data being transferred across 5G networks. Strong encryption, authentication, and cybersecurity procedures are necessary to ensure the security and integrity of 5G networks in order to guard against cyberattacks and illegal access[7].

5.6 Widening of the Digital Divide: Although 5G has the potential to close the digital divide by giving underprivileged populations access to high-speed internet, there is a chance that it may make already-existing disparities worse. Rural and low-income communities may be left behind as 5G networks are deployed, giving preference to urban areas with high population density and significant economic potential. Vulnerable groups run the risk of becoming even more marginalized as a result of the digital divide expanding in the absence of concerted steps to provide fair access to 5G technology[7].

5.7 Impact on the Environment: The installation of 5G infrastructure, such as base stations, antennas, and tiny cells, may have an impact on the environment through increased energy use, visual pollution, and disturbance of natural habitats. Significant resources are needed for the production, setup, and upkeep of 5G equipment, which also has the potential to increase carbon emissions and electronic waste. Concerns have also been expressed over the possible harm that electromagnetic radiation from 5G infrastructure could do to ecosystems and wildlife, while further study is required to fully comprehend these consequences[7].

VI. CHALLENGES

Although 5G provides exciting new developments, a number of issues must be resolved before it can be widely used. Here is a summary of some significant obstacles:

6.1 Infrastructure Development: Expanding coverage and capacity requires deploying a dense network of tiny cells, particularly for high-frequency mm-wave bands. This necessitates a large expenditure on permitting procedures and infrastructural upgrades.

6.2 Standardization: For smooth roaming and widespread acceptance, equipment from many vendors must be compatible with one another. Consistency and preventing fragmentation within the 5G ecosystem require ongoing efforts.

6.3 Security Issues: With so many devices linked, 5G networks are more complicated, which creates new security holes. Implementing strong cybersecurity measures is necessary to reduce potential threats such as data breaches and hacking.



Digital Divide: There is a chance that the unequal deployment of 5G infrastructure could widen the gap in digital access between industrialized and developing countries. Concerns about accessibility and price must be addressed in order to close this gap and guarantee that everyone can take advantage of 5G's promise.

6.4 Energy Efficiency: With the requirement for denser installations, there is rising worry about the power consumption of 5G networks. The development of network management techniques and energy-saving technology will be essential for the long-term deployment of 5G.

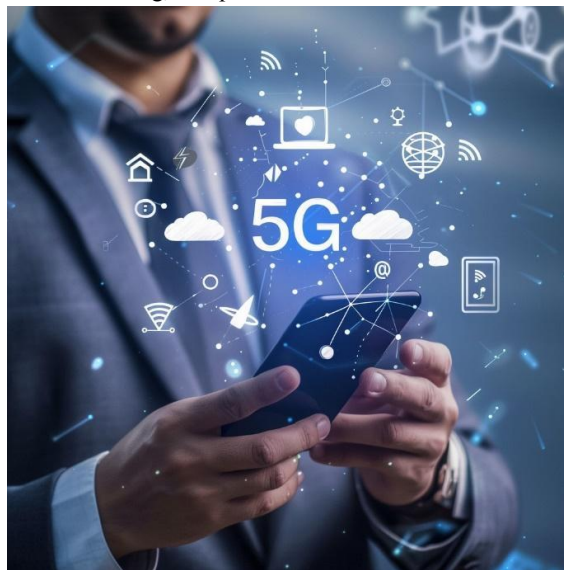
6.5 Cost-Effectiveness: It's still difficult to strike a balance between user adoption and the hefty expenses of infrastructure upgrades while maintaining affordability for both consumers and companies. It may take creative pricing strategies and government assistance to promote broad adoption.

Governments, telecom companies, equipment manufacturers, and research organizations must work together to address these issues. We can create a future where everyone can benefit from 5G technology by successfully resolving them[11].

VII. APPLICATIONS

The advent of 5G technology is expected to transform how we live, work, and interact with technology by enabling or greatly enhancing a wide range of applications and use cases across multiple industries. The following are a few possible uses and applications made possible by 5G:

7.1 Internet of Things (IoT): By enabling widespread connection and facilitating extensive IoT installations, 5G technology is anticipated to fully realize the potential of the Internet of Things. 5G facilitates smooth communication between IoT devices, sensors, and systems by connecting a large number of devices at once. This makes it easier to implement industrial IoT solutions, smart cities, and smart homes. 5G-enabled IoT applications can boost productivity, sustainability, and efficiency in a variety of industries. Examples of these applications include asset tracking, smart energy management, environmental monitoring, and predictive maintenance.



The growth of smart cities and connected infrastructure is greatly aided by 5G technology, which makes it possible to integrate digital technologies to improve resource management, public safety, and urban transportation. 5G makes it possible to monitor and manage vital infrastructure—like public services, utilities, and transportation networks—in real time because of its fast connectivity and low latency. Applications for smart cities made possible by 5G include emergency response systems, intelligent traffic management, smart grid optimization, and remote surveillance. These systems can raise urban resilience, improve quality of life, and lessen their negative effects on the environment.

The integration of digital technologies to improve urban transportation, public safety, and resource management is made possible by 5G technology, which is essential to the development of smart cities and connected infrastructure. 5G provides real-time monitoring and control of essential infrastructure, including public services, utilities, and

transportation networks. It does this by providing high-speed connectivity and low-latency communication. 5G-enabled smart city applications can improve quality of life, lessen environmental impact, and increase urban resilience. Examples of these applications include intelligent traffic management, smart grid optimization, remote surveillance, and emergency response systems.

7.2 Remote Surgery and Healthcare: By enabling telemedicine, remote patient monitoring, and remote surgery, 5G technology has the ability to completely transform the way that healthcare is delivered. 5G offers real-time collaboration amongst healthcare experts, independent of their physical location, permitting virtual consultations, surgical procedures, and diagnostic imaging. Its low-latency connectivity and excellent reliability make this possible. Telesurgery, robotic-assisted surgery, and remote patient monitoring are examples of remote surgery applications made possible by 5G, which can save lives, increase access to healthcare services, and lower costs—particularly in underserved and distant places.

7.3 Advanced Virtual Reality (VR) and Augmented Reality (AR) Experiences: 5G technology opens up new avenues for immersive and interactive VR and AR apps that provide immersive and engaging experiences. 5G improves gaming, entertainment, and training experiences by enabling seamless streaming of high-definition material and real-time interaction with virtual worlds through high-speed data transmission and low-latency communication. Immersion gaming, virtual travel, remote training, and virtual conferences are just a few of the AR and VR uses made possible by 5G that have the potential to revolutionize entertainment, education, and teamwork across a range of sectors.

7.4 Enhanced Mobile Broadband Experiences: Providing superior mobile broadband experiences over previous generations with faster data speeds, more capacity, and increased network dependability is one of the main applications of 5G technology. 5G provides smooth streaming of HD video, cloud gaming, and real-time communication on mobile devices thanks to its incredibly fast connectivity and low latency communication. 5G-enabled enhanced mobile broadband experiences can improve productivity, enjoyment, and connectivity for people globally. These experiences include seamless multimedia streaming, immersive live events, and high-speed internet access[16].

VIII. FUTURE OUTLOOK PREDICTIONS

- **Industry Growth:** It is anticipated that by 2029, there will be 5.3 billion 5G subscribers worldwide, or almost 58% of all mobile subscriptions worldwide. This represents a substantial growth in the industry.
- **Stand-alone 5G:** As these networks proliferate, they will allow for the complete application of 5G features, including ultra-low latency and network slicing.
- **Artificial Intelligence:** AI will be essential to 5G networks, helping to save costs, increase revenue, and enhance performance.
- **Internet of Things (IoT):** 5G will facilitate the expansion of IoT by allowing the creation of new applications and the connectivity of a huge number of devices.
- **Cybersecurity:** With the necessity for strong security measures to fend off attacks and guarantee data integrity, cybersecurity will be a key problem with 5G.
- **Worldwide Deployment:** China, the US, South Korea, Japan, and other nations will be at the forefront of the worldwide rollout of 5G.
- **Novel Use Cases:** 5G will make it possible for novel use cases like 3D robotic control, digital twins, and more, which will have a big influence on a lot of different businesses.
- **6G:** 6G is currently undergoing research and is anticipated to deliver even higher speeds, reduced latency, and new capabilities including widespread connection and large human-to-machine communication[9].

IX. CONCLUSION

5G wireless networks are poised to revolutionize connectivity by providing unprecedented speed, low latency, and extensive device connectivity. These features will drive innovation and efficiency across various industries, fostering the development of smart cities, advanced healthcare solutions, automated transportation systems, and much more. The deployment of 5G networks marks a critical step towards a more connected and intelligent future[7]. 5G networks are

set to transform various sectors by providing ultra-fast, low-latency, and highly reliable connectivity. This will enable the proliferation of smart devices, enhance real-time communication, and support the growing demand for data and connected services, paving the way for innovative applications and smarter, more efficient systems.

REFERENCES

- [1]. Vouyioukas, D. (2023). Study and Investigation on 5G Technology: A Systematic Review. Retrieved from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8747744/>
- [2]. .Al-Imari, et al. (2022). A Review Paper on 5G Wireless Networks. Retrieved from <https://www.ijert.org/a-review-paper-on-5g-wireless-networks>
- [3]. Beck, M. T., et al. (2020). 5G Wireless Communication Systems: A Survey. Retrieved from https://www.researchgate.net/publication/343351134_5G_Wireless_Communication_Systems_A_Survey
- [4]. Wang, S., et al. (2020). 5G Wireless Networks: A Survey. Retrieved from https://www.researchgate.net/publication/343351135_5G_Wireless_Networks_A_Survey
- [5]. Gupta, A., & Jha, R. (2020). 5G Wireless Communication Systems: A Survey. Retrieved from https://www.researchgate.net/publication/343351136_5G_Wireless_Communication_Systems_A_Survey
- [6]. Kour, K., & Ali, K. (2022). A Review Paper on 5G Wireless Networks. Retrieved from <https://www.ijert.org/a-review-paper-on-5g-wireless-networks>
- [7]. Gupta, A. (2021). A Survey of 5G Network. Retrieved from <https://www.wikipedia.org/wiki/5G>
- [8]. Demosthenes Vouyioukas, "A Survey on 5G Network Technologies: Key Drivers, Enabling Technologies, and Open Challenges", <https://www.mdpi.com/2079-9292/9/3/407>
- [9]. l-Imari, M., Xiao, P., Imran, M.A. and Tafazolli, R., "Uplink non-orthogonal multiple access for 5G wireless networks", <https://ieeexplore.ieee.org/abstract/document/6815890>
- [10]. Akhil Gupta and Rakesh Kumar Jha, "A Survey of 5G Network: Architecture and Emerging Technologies", <https://ieeexplore.ieee.org/abstract/document/7416836>
- [11]. Giordani, M., Polese, M., Mezzavilla, M., Rangan, S. and Zorzi, M., "Toward 5G networks: Use cases and technologies", <https://ieeexplore.ieee.org/abstract/document/8736986>
- [12]. Letaief, K.B., Chen, W., Shi, Y., Zhang, J. and Zhang, Y.A., "The roadmap to 5G: AI empowered wireless networks", <https://ieeexplore.ieee.org/abstract/document/8736890>
- [13]. Kato, N., Mao, B., Tang, F., Kawamoto, Y. and Liu, J., "Ten challenges in advancing machine learning technologies toward 5G", <https://ieeexplore.ieee.org/abstract/document/8736901>
- [14]. Alsharif, M.H., Kelechi, A.H., Albreem, M.A., Chaudhry, S.A., Zia, M.S. and Kim, S., "Fifth generation (5G) wireless networks: Vision, research activities, challenges and potential solutions", <https://ieeexplore.ieee.org/abstract/document/8736902>
- [15]. Letaief, K.B., Chen, W., Shi, Y., Zhang, J. and Zhang, Y.A., "The roadmap to 5G: AI empowered wireless networks", <https://ieeexplore.ieee.org/abstract/document/8736890>
- [16]. Rappaport, T.S., Xing, Y., Kanhere, O., Ju, S., Madanayake, A., Mandal, S., Alkhateeb, A. and Trichopoulos, G.C., "Wireless communications and applications above 100 GHz: Opportunities and challenges for 5G and beyond", <https://ieeexplore.ieee.org/abstract/document/8736897>