International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 05 | May - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

5G- Analysis and Characteristics in Comparison with Previous Generations

Vanshika Saxena

ABSTRACT

This paper explores the architecture and remarkable advantages of 5G technology in the current industry of wireless communication. The paper covers details of the recently developed 5th generation of networks and how its benefits overpower its drawbacks, majorly being its impact on health and environment. This study helps understanding 5G and highlights how this recent advancement has better chances of helping with wide area network connectivity, latency, economic growth, enhanced security features etc.

While advancements in the cellular network technology continue to be one of the most important developments in the economic, telecom and healthcare sector among many others, many common beliefs about 5G which can be listed as its "drawbacks" have been brought to people's attention recently, and with proper facts and studies, it can be easily proved how 5G, till this date, has no significant harm to any area, and simply has a few complexities which are natural with any advancement in technology. The paper covers the characteristics of the 5G network, and addresses common misconceptions and concerns surrounding health, security, and infrastructure.

1. INTRODUCTION

5g is the latest generation of mobile networks after its earlier generations. The 5g network enables one to connect everyone and everything virtually from machines, objects, and devices. This generation of wireless communication is meant to deliver high-speed data speeds in Gbps, very low latency, more reliability, massive network capacity, and high performance.Ever since the third generation of the mobile network was launched, users have been able to send and receive data through it. The Current 4G technology offers a faster data rate than its previous generations but it has limitations due to its bandwidth, scalability, and number of users under individual cells.

Hence, 5G has been designed to scale the network efficiently for the next 10 to 15 years. Any future enhancements will not affect the existing network, but performance improvements are possible. while its drawbacks are comparatively negligent. When implemented within safety guidelines, it does not pose any significant risks to the environment. Hence, while the drawbacks of 5g technology exist, the advancements it brings to wireless communications and connectivity are more significant.

2.INFRASTRUCTURE AND ARCHITECTURE

The deployment and efficiency of 5G technology depends on the underlying infrastructure and architectural innovations. Unlike its predecessors, 5G introduces many new concepts which enhance connectivity, reduce latency, and support a wide range of applications, for rural areas, urban areas, industries and many other sectors. This section covers the key components of 5G infrastructure, including the Radio Access Network, edge computing, service-based architecture, dual connectivity, and multi-access edge computing. These elements contribute to the excellent performance and versatility of 5G networks, laying the groundwork for a communication ecosystem which is sufficient to meet the demands of at least the next decade.

2.1. Radio Access Network (RAN): The Radio Access Network (RAN) is an essential component of a wireless telecommunications system that connects individual devices, such as mobile phones, tablets, and computers, to the core network of a telecommunications service provider. The RAN consists of radio base stations that communicate directly with user devices and the infrastructure that supports these conversations.Edge computing is part of the 5G architecture, bringing computation and data storage closer to the user or device.
This minimises latency and enhances real-time application performance by processing data closer to the source rather than in remote data centres.

2.2. Edge Computing: Edge computing is the method of processing data near to where it is generated rather than using a centralised data centre. This proximity minimises latency and increases application performance, especially for those that require real-time processing and fast response times. It leads to higher dependability and performance. Edge computing is part of the 5G architecture, bringing computation and data storage closer to the user or device.
This minimises latency and enhances real-time application performance by processing data closer to the source rather than in remote data centres.

2.3. Service-Based Architecture (SBA): The design of 5G networks is service-based, with standardized Application Programming Interfaces (APIs) used for communication across various network services. A set of guidelines and procedures known as an API permits communication between various software components. It makes network customisation, service integration, and scalability possible. More effectively developed, deployed, and scaled network services are made possible by this method.

2.4. Dual Connectivity: A characteristic that makes it possible for a device to connect to multiple cells at once is called dual connectivity, and 5G readily supports it. This makes it possible for operators to provide high-speed connectivity and support a variety of services and applications by providing quicker data rates, dependable connectivity, and decreased latency.

Overall, the architecture of 5G networks is designed to provide a foundation for delivering a wide range of services, diverse use cases, and technologies like network slicing, and edge computing, to create a more efficient and responsive network.

3.TECHNICAL DETAILS OF 5G

To fully understand the advancements and capabilities of 5G technology, it is important to understand the technical details of its performance. This section covers critical technical aspects of 5G, including the utilisation of frequency spectrum, the implementation of Massive MIMO technology, and the concept of network slicing. By using a combination of sub-6 GHz and millimetre-wave frequencies, 5G achieves best speeds and capacity. These technological developments collectively serve as the foundation for 5G, allowing it to fulfill the expanding needs of contemporary wireless communications.

3.1. Frequency spectrum

5G networks utilise a combination of sub-6 GHz and mmWave spectrum to provide good coverage and capacity.

1.Sub-6 GHz Spectrum:
This range includes frequencies below 6 GHz. It provides good coverage and penetration through obstacles, making it suitable for broader area coverage. Frequencies in this spectrum include portions of existing cellular bands, such as the ones used by 4G/LTE networks. This spectrum is crucial for supporting enhanced mobile broadband (eMBB) and IoT applications

Millimetre-Wave (mmWave) Spectrum:
Millimetre-wave frequencies are in the range of 30 GHz to 300 GHz. Because they have more available bandwidth than lower frequency bands, these provide noticeably better data speeds and capacity. These frequencies enable the "ultra-high frequency" characteristics of 5G and can offer multi-gigabit speeds. mmWave technology is primarily used in densely populated urban areas and specific high-data-rate applications.

The challenges associated with mmWave propagation have led to the development of advanced technologies like massive MIMO and beamforming to overcome signal limitations

3.2. The MIMO technology:

Multiple-Input, Multiple-Output, or MIMO, is a technology that increases the quality and efficiency of wireless data transmission by utilising a large number of antennas at both the transmitter (base station) and the receiver (user device). Because we use MIMO on a much greater scale for the 5G network, it is also known as huge MIMO technology.
The utilisation of beamforming by Massive MIMO is one of its main benefits. By focusing signal transmission toward certain user devices, beamforming reduces interference and boosts signal strength. Better coverage, higher-quality signals, and more capacity result from this.
This also is helpful for interference reduction, increased capacity of the network, and energy efficiency.

3.3. Network slicing

Multiple separate networks can be created inside a same physical network architecture thanks to network slicing.Every virtual network is referred to as a "slice," and every slice is made to meet particular service needs. Through the allocation of distinct resources and configurations for each slice, network slicing enables the customisation of services while guaranteeing that all requirements are satisfied effectively and without interfering with one another.

4. BENEFITS OF 5G

By the year 2030, 5g is believed to shoot up the gdp to 1.3 trillion usd. It won't just be improving the voice and data services but also support the business to business uses, where a wide range of services can be provided.

4.1**. Faster speeds and reduced latency**:
5g network provides ultra low latency to all real time applications, which includes faster downloads, better and smoother video streamings, efficient video and audio calls over the internet etc to enhance user experience and support new applications like AR, VR and 4k/8k video streaming.

4.2. **IOT support**:
5g technology can support multiple simultaneous connections with efficiency and no latency. 5G can efficiently connect a vast array of IoT sensors, actuators, and devices deployed across diverse environments

4.3. **Economic growth**:
with high data speeds and a quicker and better access to the internet for a large number of users, 5g can support new upcoming industries, business models and innovations, hence helping bring out more ideas, startups, business and job opportunities in the market and online for everyone across the globe.

4.4. **Healthcare**:
Faster communication can be helpful in developing technologies like telemedicine and remote patient monitoring. 5g can help build a very strong communication system for all healthcare workers, patients and hospitals hence increasing the basic functionalities and efficiency of hospitals and healthcare sector around the world.

4.5. **Smart cities**:
developing teletraffic management, energy efficiency and in general providing a better quality of life and connectivity throughout large areas, 5g can be used to build smart cities. This connectivity backbone supports real-time data exchange, enabling smart city systems to monitor and respond to changing conditions efficiently.

4.5. **Industrial Automation**:
By facilitating real-time monitoring and control of production lines and machines, 5G has the potential to completely transform industrial automation. This results in better productivity, less downtime, and the capacity to use more advanced manufacturing techniques.

4.6. **Education and Remote Learning**:
5G's high-speed, low-latency features can improve distance learning opportunities. By utilising interactive, real-time virtual classrooms, accessing superior educational materials, and improving their collaborative skills, students can effectively bridge the divide between education systems in urban and rural areas.

Overall, 5G technology delivers benefits across various sectors, driving innovation, improving efficiency, and fostering economic growth. Its wide-ranging applications and superior performance capabilities position it as a cornerstone of future technological advancements.

	1G	2G	3G	4G	5G
Deployment date	1980	1990	2000	2010	2020
speed	2kbps	384kbps	42Mbps	1Gbps	20Gbps
latency	>1000ms	600ms	200ms	100ms	1ms
Services	Analog voice	Digital voice, text, GPRS	Mobile broadband, Voice multimedia	Fast mobile broadband, NB-IOT, VoLTE	Enhanced mobile broadband, massive IoT, ultra low latency

Table 1: comparison of 5G and previous generations

5.DRAWBACKS OF 5G

In a survey conducted in 2018, 67% of Nordic consumers confirmed that they wanted to switch to 5G. This number decreased to 61% by 2020, due to the continuous widespread misinformation about the 5G

technology. There have been several false beliefs on the impact of 5G on other nations' environments, health, and other aspects, even though they are not very prevalent in India.
Here are some commonly quoted drawbacks of 5G and, based on facts and figures, why they don't seem to be a threat to the people or the environment in the long run:

5.1. Health concerns

"The radiations from 5G cause cancer"/ "radiations from 5G harm the environment"

The 5G signal still uses the RF wave of frequencies less than 10MHz. These radiations emitted are non ionising radiations, which are not believed to have any major defects in the DNA.Unlike ionising radiations, non-ionizing radiation cannot remove electrons from atoms. Any noticeable changes that these radiations may have are on a very microscopic level and hence do not have any strong harmful effects on our bodies in the long run. According to experts the millimetre waves used in 5G are safer than lower frequency microwaves because they cannot penetrate the skin and reach internal organs. Extensive research has been conducted on the safety of RF radiations being used in 5G. Organisations like the World Health Organization (WHO) state that, based on current studies, there is no sign of negative effects of these radiations on health at levels below the internationally set guidelines, while ongoing monitoring and research continue to ensure the safety of 5G technology.

5.2. Interference and Signal Range:

Higher-frequency bands used in 5G have shorter wavelengths, leading to reduced signal range and potential interference from physical obstacles like buildings or trees. To eliminate this, 5G networks use a combination of frequency bands, including mid-band and low-band frequencies, which have a better coverage. Additionally, advancements in technology, such as beamforming and small cell deployment, have enhanced signal strength and overcome obstacles, providing a more reliable connection.

5.3. Limited Coverage and Infrastructure Challenges:

The deployment of 5G requires significant infrastructure upgrades, and initial coverage may be limited to urban areas, leaving rural or remote areas underserved.
But with time, as the technology develops, infrastructure is likely to expand. Governments and telecommunication companies may invest in extending 5G coverage to more areas, ensuring a more inclusive and widespread network.

5.4. Increased Energy Consumption:

"The deployment of 5G networks, particularly with the increased density of small cells and additional infrastructure, may lead to higher energy consumption, raising concerns about the environmental impact."

The current studies on 5G focus on optimising the energy efficiency of 5G networks. Technologies like network slicing and dynamic network management can be used to allocate resources more efficiently,

reducing overall energy consumption. Additionally, advancements in hardware and network architecture may contribute to more energy-efficient 5G deployments over time.

5.5.Security concerns

" The increased connectivity and the massive number of devices connected to 5G networks raise concerns about potential security vulnerabilities and privacy issues, including the risk of cyberattacks and unauthorised access."

Cybersecurity measures are continuously evolving to counter the challenges posed by new technologies. 5G networks incorporate enhanced security features, such as improved encryption standards and network segmentation. Industry stakeholders, governments, and regulatory bodies working together can establish frameworks to address security concerns and enforce privacy regulations, ensuring that the benefits of 5G technology are not compromised by potential risks.

6. Characteristics of 5G in comparison with previous generations

The differences in characteristics between 5G and previous generations arise from the fundamental shifts in technological requirements and infrastructure deployment strategies. While older generations of networks, such as 4G, have had more time to establish a dense infrastructure footprint over the past decade, 5G prioritises high-speed data transmission and low-latency communication, which needs a different approach to coverage and compatibility. The evolution of wireless technologies requires hardware upgrades, meaning some older devices may not support 5G technology without the users having to upgrade their hardware. Despite these differences, ongoing advancements in infrastructure and technology aim to address coverage gaps and compatibility issues, ensuring that the benefits of 5G technology are accessible to a wider range of users and applications over time.

6.1. High speeds and low latency

5G offers significantly faster data speeds compared to previous generations like 4G. This enables quicker downloads, smoother streaming, and better real-time communication, which was not observed in the previous generations which provided latency of greater than a thousand milliseconds. One of the key features of 5G is its low latency, which means reduced delays in data transmission. This is crucial for applications where real-time responsiveness is essential.

6.2. Coverage

While 5G networks are expanding rapidly, coverage is still not as widespread as older generations like 4G. In remote or rural areas, older generations provide more reliable coverage. Older generations of networks were deployed over the past decade and have had more time to establish a dense infrastructure footprint. This means that there are more cell towers and base stations covering a wider geographic area, including remote and rural regions. 4G networks typically operate in lower frequency bands (e.g., 700 MHz, 800 MHz, 1800 MHz) that offer better coverage over long distances and better penetration through obstacles like buildings and foliage. These lower frequencies are well-suited for rural areas where population density

is low. On the other hand, initial 5G deployments need higher frequency bands (e.g., mmWave spectrum), which offer higher data speeds but poorer penetration characteristics. Deploying network infrastructure in remote or rural areas might also be economically challenging. While 4G networks have already been deployed in many of these areas, the cost of extending 5G coverage to such regions may be higher, particularly in the early stages.

6.3. Greater Capacity

5G networks have the capability to support a massive number of connected devices simultaneously. This is essential for the proliferation of Internet of Things (IoT) devices and smart city initiatives. The capacity of 5G networks to support a massive number of connected devices simultaneously enables a wide range of innovative use cases beyond traditional IoT applications, facilitating the rapidly increasing ioT applications and smart city connections.

6.4. Compatibility:

Some older devices may not support 5G technology and require users to upgrade their hardware to be able to take advantage of the new network. Previous generations ensure connectivity for a wider range of devices and have been in deployment for longer periods and are thus more mature in terms of infrastructure and ecosystem support. This maturity also means more stable and reliable service in certain regions.

6.5. Network Slicing:

5G introduces the concept of network slicing, allowing network operators to create multiple virtual networks within a single physical infrastructure. This enables customization and optimization of network resources for specific applications or user groups. Network slicing enables customization and optimization of network resources. By partitioning the network into virtual slices, operators can allocate dedicated resources to each slice based on the needs of the users. This ensures performance and reliability while maximising efficiency and flexibility across the network. Network slicing hence facilitates the coexistence of a wide range of use cases and services on a single infrastructure.

7.RESULT AND DISCUSSION

In conclusion, while concerns exist regarding the deployment of 5G technology, its numerous benefits far outweigh its drawbacks. From significantly faster data speeds and reduced latency to enabling transformative innovations across various sectors such as healthcare, transportation, and manufacturing, 5G offers immense potential for economic growth and societal advancement. Moreover, advancements in infrastructure and technology continue to address challenges related to signal range, energy consumption, and security, ensuring a more reliable and sustainable network. As the global deployment of 5G progresses,

it is evident that its positive impact on connectivity, efficiency, and innovation will shape the future of technology and empower societies worldwide.

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