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6G

Transforming Global Connectivity Paradigms

SecureITWorld

Abstract

The emergence of wireless communication was observed in the early 1900s after the first radio signal was transmitted. The gradual adoption of such technology gave birth to mobile communication, revolutionizing various facets of human settlements. The evolution has finally contributed to the arrival of 6G technology. It is expected to enhance our wireless connectivity experience from 5g, offering higher frequency with limited latency.

6G, positioned as a more advanced next-generation mobile communication system, extends beyond traditional communication functions. It is envisioned as a distributed neural network, seamlessly integrating communication, sensing, and computing capabilities. This integration aims to unite the physical, biological, and cyber worlds, marking the advent of an era characterized by the Intelligence of Everything. Building upon the foundations laid by 5G, 6G seeks to propel the ongoing shift from connecting people and things to fostering connected intelligence.

Primarily, 6G promises to transcend mere communication, catalyzing a distributed neural network that links seamlessly with integrated communication, sensing, and computing capabilities. This paper presents a comprehensive view of our 6G vision, delving into crucial capabilities, exploring new use cases and requirements, unveiling innovative building blocks, and discussing paradigm shifts in air interface and network architecture designs. Through this holistic exploration, we aim to illuminate the transformative potential that 6G holds for the future of connectivity and intelligence.

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Introduction

The sixth-generation or 6G network is a new advancement in the wireless telecommunication sector. While still in development, industry experts anticipate achieving its full commercial deployment by 2030. For this reason, the network has become a subject of research in the telecom industry and academics. Doubtlessly, 6G aims to offer an enhanced connectivity experience compared to its predecessor, the 5G network, providing the opportunity for one-microsecond latency communications [1].

The next-gen wireless communication facility, the 6G network, intends to combine the real and digital worlds faster. In this regard, the contribution of other technologies, such as AI and ML, will be significant. As AI is known for its approach to achieving complex targets quickly and efficiently with minimal latency, its amalgamation with 6G technology will also help in attaining the chief goal of the latter.

The deployment of 6G technology is under surveillance to ensure its advanced network performance. For this purpose, along with existing performance tracking criteria such as coverage, capacity, bit rates, and minor latency, revised indicators will be implemented to ensure network availability, resilience, trustworthiness, sustainability, etc. Nevertheless, the cost and required time to assess such factors will be considered before the adaptation process [14].

As characteristics, 6G technology will offer advanced features, among which threat identification, health evaluation, facial recognition, toxicity sensing, increased usage of extended reality etc. are significant. Though such features are already in practice with AI's support, users can expect quicker results with a faster network.

Evolution of Wireless Communication Technologies

While tracing the early stones of wireless communication, it is found that the 1880s observed the initial practices in the form of radio waves, resulting in further developments in the following years. The beginning of the 1990s witnessed transatlantic communication between England and Canada. The success inspired the formation of FM frequencies in 1922 following the emergence of Ethernet. in 1970.

Wireless communication technology observed a boost after the invention of mobile phones. In 1983, the 1G network came into the scene alongside handsets. After 17 years, in 2001, 3G technology was introduced that revolutionized the communication process beyond borders. Soon after that, the fourth generation or LTE network was launched in 2007. Wireless communication reached an extra mile with the introduction of the 5G network in 2018. The evolution is ever-progressing as wireless communication is about to achieve another height with the arrival of 6G technology [4].

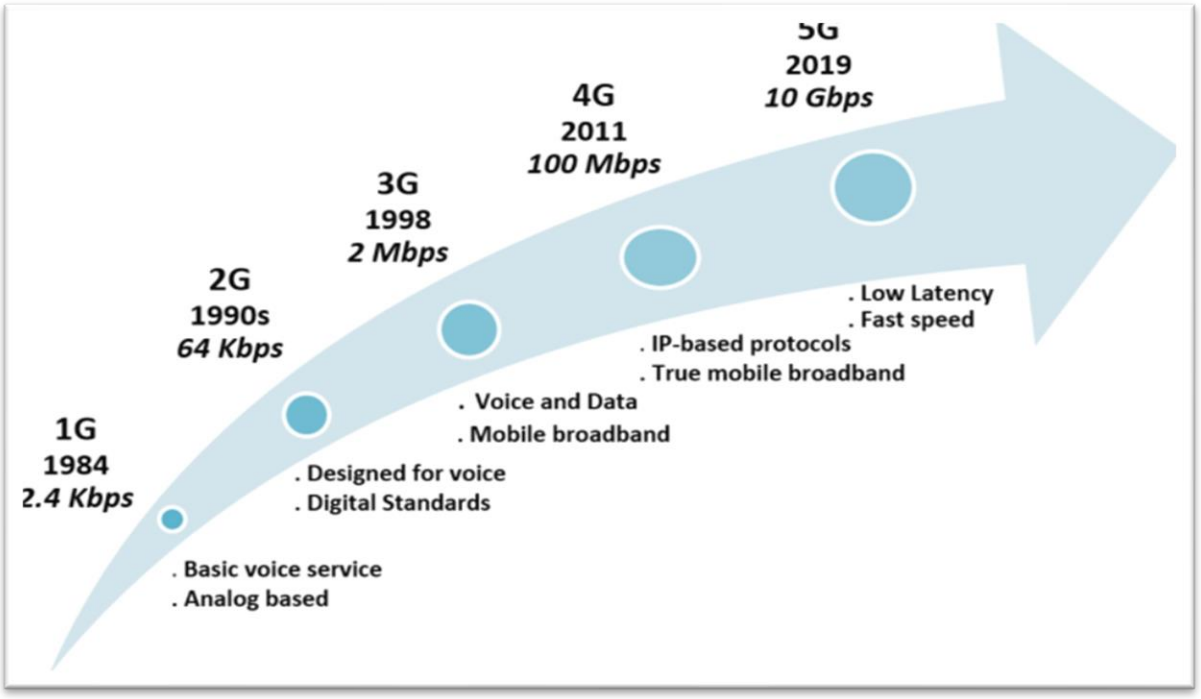


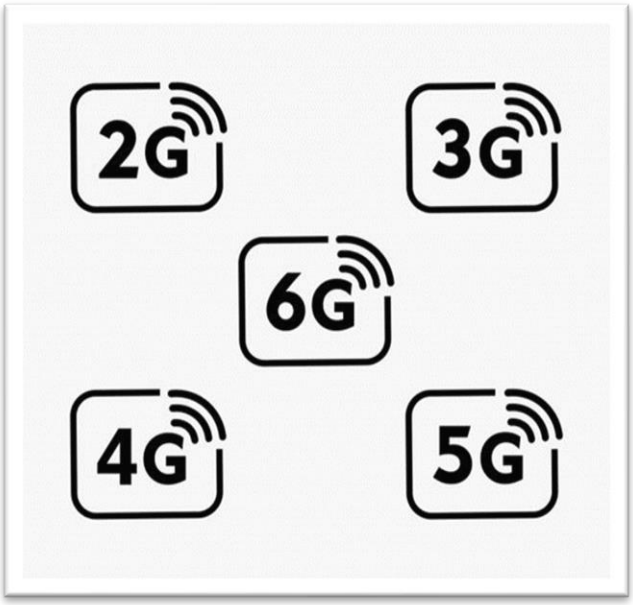
FIGURE 1: WIRELESS COMMUNICATION NETWORKS PROGRESSION

The gradual progression of wireless communication networks can be observed in the above-displayed graphical representation (Figure 1). It shows how the first-generation network laid the early stones of a sustainable mechanism with a 2.4 KB data rate per second that advanced to 10 GB data rate per second with 5G technology.

The evolution of the wireless connectivity mechanism took place strategically, making it easier to understand complex developments. Initially, radio waves were leveraged to exchange short information, which was common for military purposes. Later, the invention of mobile phones redefined wireless connectivity with its feature of connecting people through voice and texts with 1G technology. Soon after that, sharing multimedia became an essential practice over virtual communication networks with the support of multimedia [2].

The advent of smartphones brought higher connectivity activities using 3G and 4G networks. People could access complicated data faster while enhancing their knowledge. 5G technology changed the dynamics of wireless communication. It gave popularity to the usage of artificial intelligence (AI), machine learning (ML), Internet of Things (IoT) with limited latency. However, the increasing adaptation of such technology highlights the requirement for a faster network that is trustworthy, reliable, and can provide security at the same time [3].

The rapid adoption of the 5G network indicates that the global public is heading toward a fast-forward world where latency will not be considered at all in terms of communication and data usage. Such speed is also the outcome of other technological advancements such as AI, ML, and IoT. The usage of multiple mechanisms at a time creates the possibility of latency in accessing information through wireless communication. This ultimately gave rise to the need for an enhanced technology that can eliminate latency to a maximum level, offering reliability and security to the users.



6G is determined to make a network available that can provide one to 10 TB data rate per second while using higher frequency bands. The technology is designed in a way that is sustainable, secure, and fast at the same time. Though the mechanism has yet to enter the commercial setup, research is underway to make it a revolutionary technology. 6G is expected to hit the market by 2023; however, its technological deployment will commence in 2028.

Understanding 6G Technology

The 6G network is about to hit the commercial sector by 2030 to reshape wireless communication methods. It is anticipated to provide enhanced opportunities for connectivity with short latency. Being the successor of the 5G network, it is obvious that 6G will let its users observe a faster technology with much efficiency simultaneously. The technology is projected to be 1,000 times faster than one millisecond, diminishing the concerns about the lengthy response time of the existing methods.

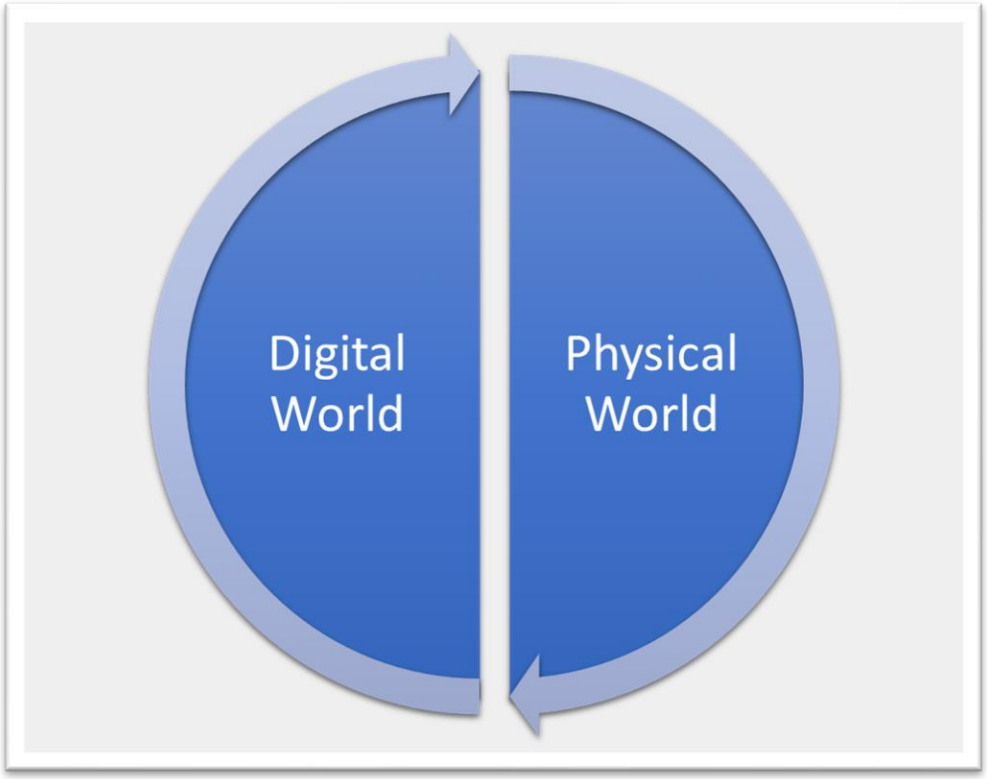


FIGURE 2: 6G NETWORK COMBINES DIGITAL AND PHYSICAL WORLDS

The 6G network will combine human, physical, and digital worlds to offer a connectivity experience among its users like never before. The previous and contemporary networks allowed users to connect with each other vocally, with texts and the Internet, followed by the advent of the Internet of Things (IoT).

The changing requirements of individuals and organizations contributed to the need for faster problem-solving methods. Moreover, global communication is at its peak due to the knowledge-transferring process across nations. With the help of wireless communication, every event is known to the global public. Instead, people are also allowed to put their viewpoints over anything with the availability of cellular technologies. However, everyone expects quick responses while communicating beyond boundaries [4].

4G and 5G networks have supported users in breaking the barrier of latency in a network to an extent. Nevertheless, the arrival of 6G technology sets high expectations for higher frequencies while using wireless networks that provide worldwide coverage. To meet this goal, the 6G technology will implement multiple satellites that will be operated from different countries

The chief goal of the 6G network is to make 'intelligence and connection available everywhere.'

Along with that, the technology will possess certain features. Among the influential features are high speed, enhanced efficiency, lower latency, usage of revised spectrum bands, concentration on energy efficiency, M2M connection support, and data reliability [5].

Fundamental Technology Pillars of 6G

While discussing the next advancement in the wireless communication sector, the 6G network, it is crucial to shed light on the fundamental technological factors that help shape it. There are six fundamental technological pillars of 6G that are required to be solidified for its better performance.

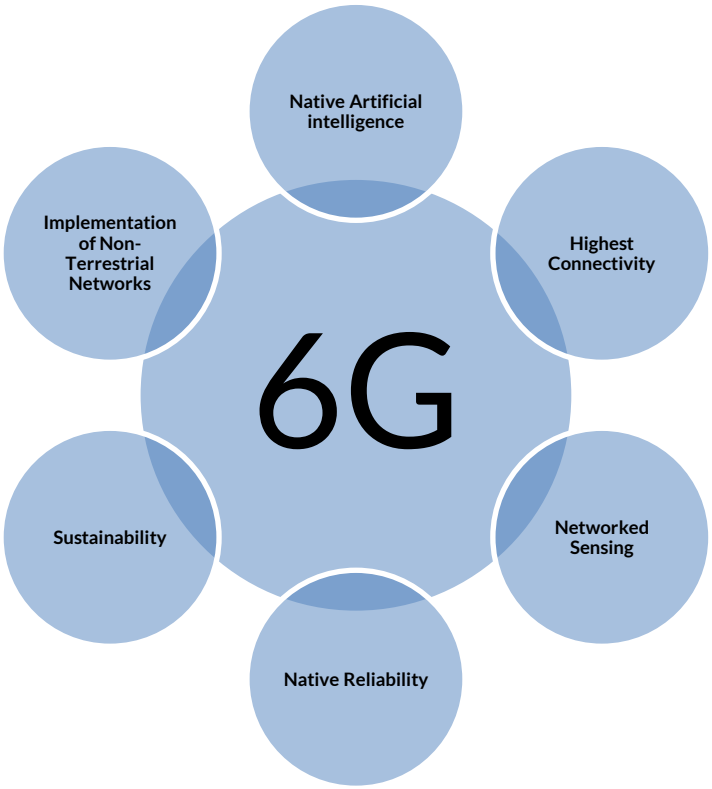


FIGURE 3: FUNDAMENTAL TECHNOLOGY PILLARS OF 6G

Native Artificial intelligence

It is quite evident that 6G will possess major significance in the standard practice of AI. Furthermore, one of the chief motives of the latest wireless communication advancement is to support AI while combining digital and physical worlds. Therefore, AI will be a primary technological aspect of 6G that will be available as a service and native characteristic. Automation, personalization, management, administration, etc., are a few of the features of the 6G network for which end-to-end AI and ML adoption will be required [10].

To establish this pillar, 6G technology has to collect big data so that AI and ML stay equipped with the information to operate as a service as well as a native feature.

Highest Connectivity

6G network is about to provide the highest experience among wireless communication technologies. Therefore, connectivity will be the basic factor where the technology has to excel. 6G will use higher frequencies than the existing networks alongside different spectrums

for better performance. Furthermore, 6G will not only use millimeter waves but also utilize terahertz or THz frequency. Such units can create difficulties in terms of connectivity. To tackle such challenges, THz transceivers, high-power devices, new materials for antennas, radio frequency power transistors, etc., need to be employed.

Networked Sensing

One of the attributes of the 6G network will be its network sensing abilities. This will help in sensing the radio transmission waves and gathering data to understand the physical world better while combining it with the digital world. Though network sensing is already enabled in 5G technology, due to higher frequency, 6G technology will require the employment of strong frequency bands, huge antenna arrays, broader bandwidth, and others.

Native Reliability

6G technology is supposed to revamp the network architecture with advanced communication, computing, and sensing to meet its goal of offering one to 10 TB data range per second. To excel in this sector, 6G is about to leverage AI components to collect and analyse data. Under such circumstances, reliability, which consists of privacy, resilience, security, trustworthiness, and safety in the network, is essential. The knowledge or data attained from such components needs to be end-to-end encrypted, enhancing native reliability.

Sustainability

The 6G network will be more energy-efficient than other wireless communication technologies. Moreover, every tech advancement in the contemporary period complies with the sustainability measures for positive energy consumption. 6G technology is determined to reduce energy consumption than 5G to become an energy-efficient wireless communication mechanism. For this purpose, the 6G aims to formulate a green design with AI support while contributing to sustainable development [7].

Implementation of Non-Terrestrial Networks

6G network is determined to provide high-speed connectivity with global coverage. The motive behind this approach is simply knowing the unknowns. Non-terrestrial and terrestrial networks (NTNs) will be integrated to attain this aim. In this situation, the cost of production and implementation of the satellites can be a barrier. To tackle this challenge, there is a possibility for implementation of low- or very low-earth orbit (LEO/VLEO). Along with worldwide network coverage, it will abolish issues like communication latency.

6G Network vs 5G Network

The 6G network is the latest addition to wireless communication methods and the successor of 5G, indicating that the former is an upgraded version of the latter that will improve virtual communication. The main distinction between the two is its data rate. 5G networks offer a data rate at a maximum of 20 GB per second, whereas 6G technology can provide one to 10 TB data rate per second.

Such speed contributes to the procedure of decreasing latency in the network; hence, 6G is supposed to provide shorter latency than 5G. Moreover, 6G will use higher spectrums to provide efficiency in network usage. Its frequency band is determined to be 95 GHz to 3 THz (Terahertz), but the 5G network deals with 6 GHz to 24.25 GHz (Gigahertz) frequency band.

5G has doubtlessly given emergence to IoT technology. However, it will achieve extra heights with 6G [7]. From the perspective of sustainability, 6G will offer a more sustainable and efficient approach than 5G. It will support energy efficiency by keeping energy consumption much lower than 5G technology. Additionally, users will trust and rely on 6G technology more than 5G due to its high-frequency levels [8].

Trends and Growth Drivers of 6G Network

6G is a developing mechanism that has not made its industrial entry. Therefore, its trends have not been identified yet. Nevertheless, the expectations are high with the network for providing experiences of high speed, extreme connectivity, low latency, enhanced sustainability, and others. The introduction of the 6G network will surely contribute to technological convergence [13].

Progressive societies seek faster resolutions to their problems. However, such resolutions can sometimes be complex, requiring thorough research, which may consume more than considerable time [6]. On such grounds, technological integration can play a vital role. Its capabilities of deep learning and data analytics in no time are a specimen of how complicated tasks can be simplified with technology. Below can be the probable growth drivers for 6G networks after its advent.

Unprecedented growth of intelligence:

With each upgrade of gadgets, new methods of intelligence make space among human practices. This has contributed to the growth of gadgets and intelligent practices such as AI, ML, and IoT. It is also known that the popularity of such technologies will remain the same; rather, the usage will increase with elevated adoption to address critical tasks in the upcoming years.

Faster networks are required to ensure smooth operations of these. 6G, in this regard, can attract much attention as it integrates higher frequencies for quicker functioning and decreased delays.

The emergence of new technologies:

The rise of the 6G technology will result in the formulation of new mechanisms integrating AI and IoT that will only run on faster networks. Moreover, the concept of Extended Reality (XR) is also gaining significance in cross-domains, significantly boosting faster network usage. Such factors will attain prominence by 2030 when 6G is commercially available. Thus, it will contribute as a major growth driver for the 6G network.

While discussing the key drivers of 6G technology, it is vital to mention that since the mechanism is not available at the moment, several other drivers may contribute to its prominence as per the ongoing application measurements [9].

Use Cases of 6G Network in Cross-Domains

6G technology will assuredly reform the connectivity paradigms across borders, supporting digitalization in multiple sectors. Below are a few specimens in the form of use cases with actual problems and hypothetical outcomes to better understand the 6G mechanism's impact.

6G in Extended Reality

Overview:

Extended reality (XR) became popular among the public after the arrival of the 5G network. It gave the audience an extraordinary experience combining real and virtual worlds.

Problem statement:

Extended reality is a growing technology that is venturing into multiple industries, including education, entertainment, healthcare, automotive, manufacturing, and others. The integration is getting higher continuously, giving XR new methods of usage. The data-heavy methods or applications can create data latency in functioning multi-media content alongside XR. Such mechanisms require one TB data rate per second, and a 5G network only provides a maximum of 20 GB data frequency per second [12].

Solution:

6G mechanism will have a data rate of one to 10 TB/s. Moreover, it is determined to support other technological aspects such as AI, ML, XR, etc. Therefore, integrating 6G for XR will also help handle applications with heavy data requirements.

Probable outcomes:

The inability of 5G functioning data-heavy applications of XR will be eliminated. It will further provide a smooth experience to the users while operating with AR and VR devices and applications without interruption and latency.

6G and eHealth

Overview:

eHealth defines healthcare facilities on digital platforms. Recent events like the COVID-19 outbreak emphasized digital operations in many sectors, including healthcare. People seek assistance with everything from scheduling appointments with doctors to ordering medicines on digital platforms in contemporary times.

Problem statement:

Though eHealth is a developing process, it will soon include every healthcare facility, including remote surgery. Such tasks are critical and sensitive. Latency or interruption in the network can be a huge barrier to the process of smooth operation. Moreover, the quality of service due to higher costs over digital platforms can also be a matter of concern.

Solution:

6G network aims to provide global network coverage to bridge the gap between unknowns and the public around the world. The more people will use the technology, the more its cost will decrease. Moreover, the frequency band of 6G will be higher from 95 GHz up to 3 THz (Terahertz), lessening the possibility of network interruption.

Probable outcome:

Future eHealth facilities like remote surgery can be carried out with ease on a network with a high-frequency band, 6G, eliminating probable interruption. The concerns regarding high costs will also be limited as network costs will be considerable.

6G in Robotics and Industry 4.0

Overview:

The manufacturing and production industries adopted digitalization and gave birth to Industry 4.0, which practices robotics at a high level. Such functions require IoT support to a larger

extent. Automation is another component of Industry 4.0 that bears great significance and reduces over-time consumption and resource allocation.

Problem statement:

Industry 4.0 requires IoT and automation to function. Such elements need heavy data to operate with. Networks with latency may fail to support heavy data and to provide instant response to many technical aspects.

Solution:

6G integration can help achieve Industry 4.0 goals easily with its higher network frequency usage and minimal latency. Industrialists can operate with applications and software with high data requirements, limiting interruptions. The mechanism will provide flexibility, instant resolution, and the capability to leverage multiple methods simultaneously to the fourth industrial revolution.

Probable outcome:

The activities of Industry 4.0 can function appropriately without significant delay and inconvenience. The big data required for such operations can be analysed and utilized by a network with a high data rate in no time.

Global Initiatives for 6G Technology

In the development phase, the telecom industry and renowned educational institutions worldwide are conducting significant research on 6G technology to understand its abilities and explore its growth opportunities.

The Electronics and Telecommunications Research Institute of South Korea is studying the terahertz frequency band that will be added to the 6G network. As per the organization, the mechanism will be five times faster than 5G and 100 times faster than 4G networks. Similarly, the Ministry of Industry and Information Technology of China is conducting research on the implementation of the 6G network in the country. The USA is also advancing in 6G research by spectrum testing for the network [2].

The University of Oulu, situated in Finland, is studying the wireless communication mechanism by introducing the 6Genesis research to accomplish the goal of full-fledged initiation of 6G by 2030. Likewise, other global governmental and non-governmental bodies are actively researching and developing 6G technology.

Challenges and Future of 6G Network

Though the 6G network reflects promising resolution to many technological and non-technological barriers, many social and technological challenges can interrupt its complete deployment.

Lack of Spectrum:

6G network will function with terahertz (THz), one of the extremely high-frequency bands, to fix network latency concerns. However, such high frequencies can be dangerous as they can cause a high atmospheric absorption spectrum. Such spectrums can hamper the smooth deployment of 6G technology.

Privacy and Security:

The 6G mechanism is supposed to combine the physical and digital worlds, raising great concerns for user data privacy. Extreme connectivity signifies the availability of private data on multiple platforms. In case of any unauthorized data breaches, the users may encounter major problems in terms of security and privacy [14].

Regulation:

Multiple governmental and non-governmental organizations are researching 6G technology, contributing to its development. This indicates that the mechanism must comply with several regulations proposed by each developer and researcher. This can further delay the deployment of the wireless communication network.

Energy consumption and efficiency:

6G technology will operate on higher frequencies and will be available to the global public. Such remarks simplify that the network will require big data and energy to function smoothly. This raises significant energy efficiency concerns to meet sustainable goals.

Undoubtedly, the introduction of the 6G network will revolutionize wireless communication methods. Nevertheless, its success can be hindered by specified barriers. Keeping challenges in mind, developers are willing to explore many ways to make the technology more reliable so that the global public can easily leverage it

A green model has been formulated for the 6G network that will assist it in becoming more sustainable and energy-efficient. Furthermore, special attention has been given to the privacy and security concerns of the high-connectivity providing technology with gradual security advancement. The continuous research and development process indicates that the mechanism can put its probable challenges back and become a sustainable technological advancement by 2030 [11].

Conclusion

The deployment of the 6G network can transform the global connectivity and economic atmosphere. It is determined to offer its users an extraordinary experience, bridging the gaps between the known and the unknown. In this regard, supporting other technological aspects, such as AI, ML, and IoT, will also be significant. The 6G network can benefit multiple domains simultaneously, providing extremely high-speed data rates of up to 10 TB per second. Moreover, it will utilize the terahertz (THz) frequency band to eliminate the probability of network latency.

With this technological advancement, attaining knowledge and data transferring will become easier than ever. Its usage of unique spectrum bands will enhance the machine-to-machine connections to fulfill the intention of providing high-connectivity. Experts assert that it will be 100 times faster than the 4G network abolishing the 5G network latency rate. The deployment of the 6G network will also boost the formation of new technological advancements such as gadgets, applications, and software. However, its social acceptance can be an issue considering the factors of energy efficiency.

To make it a trustworthy and sustainable network, a green infrastructure is being developed. The researchers of the 6G technology ensure compliance with the energy efficiency guidelines so that its users can head toward a sustainably developed society.

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